NEBRASKA

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DEPARTMENT OF TRANSPORTATION

ELECTRIC VEHICLES & DC FAST CHARGING INFRASTRUCTURE

Needs & Feasibility in Nebraska

SUBMITTED BY

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16. Abstract

A key factor to increase market penetration of battery electric vehicles (EVs) and support the electrification of transportation at scale is to increase the number and output capabilities of Electric Vehicle Charging Stations (EVSE) deployed in public spaces. In other words, an adequate public charging infrastructure is needed to effectively extend EVs' battery ranges when it is away from home charging access. As technology advances to make EVs more convenient, as technology such as DC fast charging becomes more available, and as production costs continue to decrease, the improved economic and environmental benefits will make it more practical for consumers to purchase electric vehicles. As of December 2016, a total of 14,750 cars (320 EVs and 14,430 electric/gasoline hybrid) were registered in Nebraska. Following national-level trends, this number is expected to grow in Nebraska; the market share of electrified vehicle sales is expected to reach eight percent nationwide by 2020. Nationwide, 159,139 EVs were sold in 2016.

This project investigates the elements that make electrified transportations economically and environmentally beneficial and develops an algorithm to determine the best locations for Fast DC charging infrastructure throughout the state of Nebraska. The specific goal of this project is to lay the informational foundation necessary for a comprehensive understanding of current EV needs in Nebraska and the planning, analysis, and execution of a robust networked DC fast charging infrastructure for Nebraska and its citizens.

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Executive Summary

The mission of the Nebraska Community Energy Alliance (NCEA) is to build and promote advanced technologies for housing and transportation that save energy, reduce CO2 pollution and cut costs. (http://www.necommunity.energy/mission/). NCEA believes that demonstrating these technical advances at the local level is the best way to accelerate the market in Nebraska. Establishing the economic and environmental benefits of advanced technologies, such as electric vehicles and smart charging stations, at this level will serve the mission of the NCEA.

In collaboration with the University of Nebraska-Lincoln, and funding from the Nebraska Department of Transportation (NDOT), this Battery Electric Vehicles and DC Fast Charging Infrastructure: Needs and Feasibility in Nebraska project, set out to lay the informational foundation necessary for a comprehensive understanding of current EV needs in Nebraska and the planning, analysis, and execution of a robust networked DC fast charging infrastructure for Nebraska and its citizens. DC fast charging most closely approximates the gasoline refueling experience and Nebraskans buying EVs will increasingly expect public access to a refueling infrastructure that can deliver any of the charging technologies on the market.

The project investigates Nebraska's interstates and highways, divides the state into three zones and develops an algorithm to calculate the number of charging infrastructures required and their location in each zone when driving a specific model of an electric car. The algorithm takes into consideration parameters that include electric vehicle battery status, range anxiety, population of cities along the interstate and highways, and other parameters. After the locations are identified, a prioritization method is applied to each zone. Prioritizing is used to assist Nebraska's policymakers, city and state agencies, utility companies and EV associated agencies among others to develop plans to incorporate charging infrastructures as the deployment and penetration of EVs increases.

The project investigates Long Range Transportation Plan (LRTP) for each state in the U.S. with respect to EVs and charging infrastructure. Comparison study is conducted between U.S. states similar to that of the state of Nebraska. Degree of similarity is based on region, population density and the number of vehicles in each state.

The project studies the benefits and needs of electrified transportations and charging infrastructure and determines the environmental and economic benefits of electrified transportations in Nebraska. A survey is conducted on a focused age group to determine their attitudes and behavior toward electrified transportation in Nebraska.

The outcomes of this research project are:

- For Nissan Leaf 2016 S24 model:
  - Number of charging infrastructure locations:101
  - Number of charging infrastructure in Zone 1: 28 (Highways benefitted: 9)
  - Number of charging infrastructure in Zone 2: 49 (Highways benefitted: 13)
  - Number of charging infrastructure in Zone 3: 24 (Highways benefitted: 7)

- For Chevrolet Bolt 2017 model:
  - Number of charging infrastructure locations: 44
  - Number of charging infrastructure in Zone 1: 10 (Highways benefitted: 9)
  - Number of charging infrastructure in Zone 2: 23 (Highways benefitted: 13)
  - Number of charging infrastructure in Zone 3: 11 (Highways benefitted: 7)

- 32 States discuss EVs or charging infrastructures in their LRTPs.

- U.S. States discussed EVs in their LRTPs for:
  - Reduction of Green House Gases (GHG)
  - Concern for Motor Fuel Tax- Proposal of Vehicle Miles Traveled (VMT) tax to mitigate this problem
  - Emerging technologies and the necessary charging infrastructures to support them

- Environmental impact of electrified transportation in Nebraska is dependent on the energy mix used to generate electricity from each utility provider. The reduction in GHG, when driving an EV compared to a conventional vehicle, ranges from 40-80% reduction.

- Economic impact of electrified transportation in Nebraska is dependent on gasoline and electricity fuel cost. The economic savings range from 4-14 cents per mile when driving an EV compared to a conventional vehicle.

- The survey analysis revealed that there is a trend towards the greater importance and awareness towards electric vehicle use in the state of Nebraska, as well as towards the needs for certain aspects related to the use of such EV's that include charging infrastructure.

Details of each outcome as well as other analysis is discussed in the main report.

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1. **Project Summary**

a. Introduction

A key factor to increase market penetration of battery electric vehicles (EVs) and support the electrification of transportation at scale is to increase the number and output capabilities of Electric Vehicle Charging Stations (EVSE) deployed in public spaces; in other words, an adequate public charging infrastructure is needed to effectively extend EVs' battery ranges when it is away from home charging access. Currently, there are three types of EVSE stations: Level 1 (110 V) for home charging, Level 2 (240 V) for workplace and commercial charging, and Level 3 (480 V) DC fast charging for commercial and highway travel. DC fast charging can recharge a dead battery to 80% of its full capacity in 30 minutes or less. In contrast, Level 2 charging can take between four and six hours, depending on the size of the vehicle's onboard charger and Level 1 takes 8-12 hours. As technology advances to make EVs more convenient, as technology such as DC fast charging becomes more available, and as production costs continue to decrease, the improved economic and environmental benefits will make it more practical for consumers to purchase electric vehicles. As of December 2016, a total of 14,750 battery electric vehicles (320 EVs and 14,430 electric/ gasoline hybrid) were registered in Nebraska [1]. Following national-level trends, this number is expected to grow in Nebraska; the market share of electrified vehicle sales is expected to reach eight percent nationwide by 2020. Nationwide, 159,139 EVs were sold in 2016.

This project investigates the elements that make electrified transportations economically and environmentally beneficial and determines the best locations for these systems throughout Nebraska. The project builds on on-going work of the Nebraska Community Energy Alliance (NCEA) to demonstrate the economic and air quality benefits of EVs, and to a smaller extent, compressed natural gas (CNG) vehicles. Of available electronic charging technology, DC fast charging most closely approximates the gasoline refueling experience and Nebraskans buying EVs will increasingly expect public access to a refueling infrastructure that can deliver any of the charging technologies on the market. With the support of NET, NCEA deployed 34 Level 2 charging stations with 68 charging ports and one DC fast charger in Nebraska. This makes the total number of charging stations in Nebraska 48, 57 when the Tesla chargers are included in the count. In order for Nebraskans to realize the full benefit of EVs, the refueling infrastructure for EVs must be as robust and ubiquitous as that in existence for gasoline-powered vehicles.

There are a number of global, national, and local market signals that indicate this is an ideal time to conduct this project in Nebraska, including:

- Every major auto manufacturer has introduced or is bringing to market an electric vehicle. This trend is indicative of the need to develop a modern and forward-thinking EV recharging infrastructure in Nebraska, particularly when considering that electricity is the best substitute or supplement to gasoline as a transportation fuel. The feedstock for electrical generation is derived locally and not subject to global pricing or the price volatility of national or world economies. Furthermore, the distribution system for electricity as a transportation fuel is already in place, operating with abundant excess capacity to service electric vehicles.

- Nebraska municipalities are demonstrating interest for a statewide EV refueling infrastructure that promotes electric travel between and among communities. As a strong show of support for EV infrastructure, out of the 29 NCEA member cities, 21 have contributed/committed to a 50/50 local matching funds in support of projects related to electrified transportations.
- Existing quantifiable data supporting the economic and environmental benefits of a public charging infrastructure in Nebraska. Data is continuously collected from existing charging stations throughout Nebraska. Detailed results can be viewed here: www.engineering.unl.edu/e-vehicle/.

b. Goal and Objectives

The goal of this research proposal is to lay the informational foundation necessary for a comprehensive understanding of current EV needs in Nebraska and the planning, analysis, and execution of a robust networked DC fast charging infrastructure for Nebraska and its citizens. This proposed work is part of a larger build out effort that is taking place at multiple coordinated entities within Nebraska agencies. Using literature research, interviews, and surveys, as well as data collection from existing charging stations, this project will achieve its goal through the following five objectives:

1. Determine the needs for a DC fast charging infrastructure in Nebraska.

2. Determine the benefits of a DC fast charging infrastructure to Nebraska's Department of Transportation (DOT) and Nebraska communities and citizens.

3. Develop a vision and deployment strategy for Nebraska's policy makers based on research on what other federal, state, and local agencies – including DOTs and MPOs – are planning, doing, or have done with respect EVs and their charging infrastructures.

4. Determine the necessary elements for successful DC fast charging installation across Nebraska by collecting and documenting data from the charging station at Gretna.

5. Implement a high impact public education campaign in order to promote and advertise the new charging station's availability and to build interest, usage, and acceptance.

c. Report layout

Following this introduction section, Section 2 will provide detail information on the research that took place to determine the optimal location for the charging infrastructure in Nebraska. Section 3 provides detail information on the status of Long Range Transportation Plan (LRTP) across all the states in the U.S. The section also investigates states that are comparable to Nebraska. Section 4 provides detailed information on the environmental impact of electrified transportation in Nebraska. The Section looks into the energy make of the utilities in Nebraska and use this information to compare the GHG emission of various vehicle types. Section 5 provides detailed information on the economic benefits of electrified transportation in Nebraska. The section looks into the fuel cost and use that information for a case study to the impact electrified transportations will have on Nebraska and its citizens. Section 6 looks into Electrified transportation needs and feasibility across the U.S. The section provides detailed information on surveys conducted to determine attitudes and behaviors with respect to needs and feasibility of electrified transportations and infrastructure in Nebraska. Section 7 provides detailed usage of the DC fast charging station available in Ashland, Nebraska. Section 8 Discuss promotion and educational activities that took place to promote and provide public awareness regarding electrified transportations. Finally, Section Nine provide a summary of the project and future work. Section 10 is the appendix with detailed data, publication papers and other relevant information to the sections in the main report.

References

[1] "The Number of Registered Vehicles in Nebraska by the Fuel Consumed" [Online] http://www.neo.ne.gov/statshtml/196.htm, [Accessed: 22- Dec- 2017].

2. Optimal Locations for Charging Infrastructure

a. Background

Electric vehicles has been around since the early 19th century. In the U.S., the first successful electric vehicle was made around 1890 by William Morrison, a chemist from Des Moines, Iowa. He made a six-passenger vehicle capable of a top speed of 14 miles per hour. This helped in motivating and triggering interest in electric vehicles. Over the next few years, different automakers made electric vehicles and they were seen all across the U.S. New York City which even had a fleet of more than 60 electric taxis. By 1900, electric vehicles accounted for around a third of all vehicles on the road [1]. However, electric vehicles in the market were short-lived with shortcomings in their technology and also, with the advent of gasoline-powered vehicles. With the advancement of battery-life technologies and with the concern for the environment, electric vehicles came in to the market again in the late 20th century.

Electric vehicles have a lot of advantages over the conventional vehicles like lesser negative impact on the environment, reduced maintenance due to lesser number of moving parts, does not make a lot of noise as well as it can be fast and also less dependent on oil economy. With all these advantages it is seen that the sales record in the past few years in the U.S. has gone high. Figure 2.1 shows the monthly sales of electric vehicles in the U.S. [2].

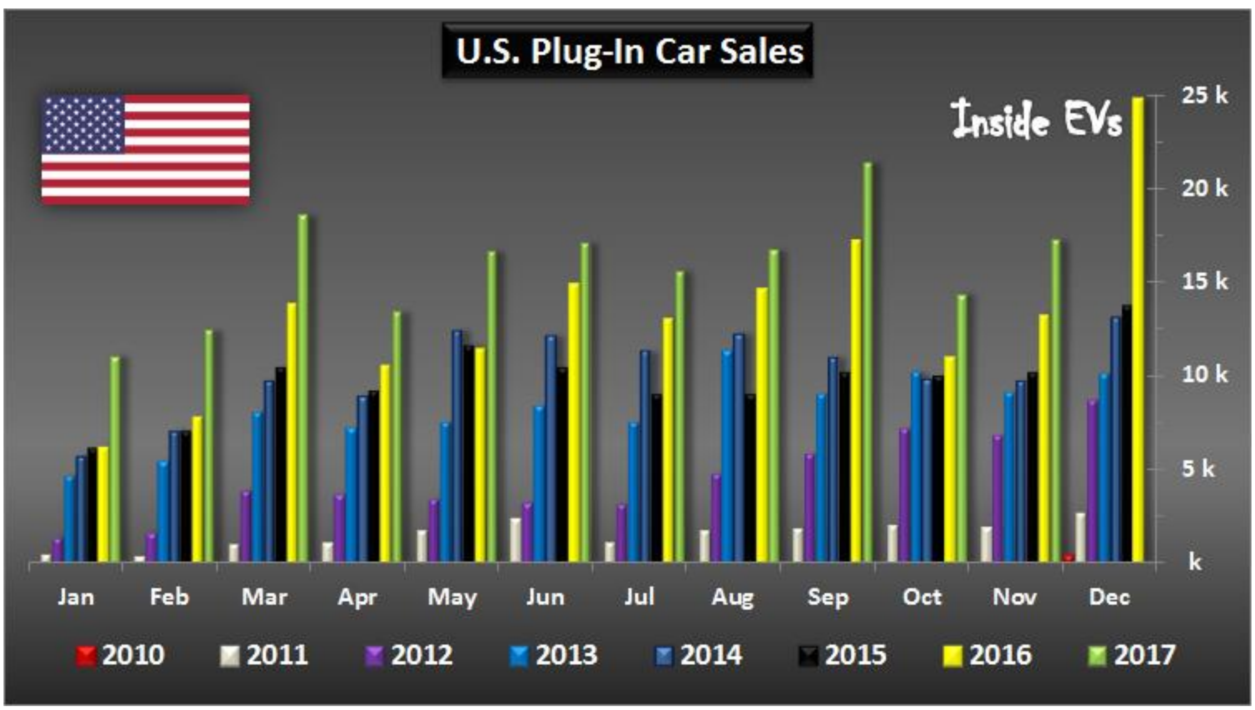

Figure 2.1: Monthly sales of EVs in the U.S. from 2010

Though Electric Vehicles have a lot of advantages, however, one of the limiting factors to the Electric Vehicles growth in the market is the lack of a proper charging infrastructure network. To understand this problem, the charging infrastructure is discussed briefly. Charging of an Electric Vehicle can be done at homes, workplaces and at public charging stations. Electric Vehicle charging equipment is classified by the rate at which the batteries are charged. Time required for charging will vary based on various factors like how depleted the battery is, the type of battery, and the type of Electric Vehicle Supply Equipment [3]. There are three levels of charging and is explained in Table 2.1.

Table 2.1: Classification of Charging Levels

	LEVEL I	LEVEL II	LEVEL III
Type of power supply	AC	AC	DC Fast charging
Voltage level	120V	240V (residential application) 208V (commercial application)	480V DC
EVSE	J1772 charge port	J1772 charge port	J1772 combo, CHAdeMO, TESLA combo
Type of charging	Residential charging	Residential, workplace and public charging	Public charging

An average U.S. driver drives around 29 miles per day [4]. This daily commute is mainly for work purposes. With the range in the Electric Vehicles nowadays, daily commute is not that much of a problem. A person can charge their EVs in their workplace or once they are back at their homes. However, the problem magnifies during inter-city or inter-state travel. If there is no charging stations in the right locations, people are discouraged to take their Electric Vehicles for long distance travels. This restricts potential EV buyers, as they cannot make their EV as their primary car. From a financial perspective, at this moment many people are not willing to have two cars, an electric one for city driving and a conventional car for long distance travel due to lack of public charging infrastructure. This is a major problem for potential electric vehicle owners in many states in the country as they are demotivated by the lack of charging infrastructure network. From recent data, in the U.S. there are 16,269 electric vehicle charging stations and 44,528 charging outlets [5]. Figure 2.2 shows the locations of these charging stations. It is observed that the locations of these charging stations are unevenly distributed concentrating mainly in the east coast and the west coast. In Nebraska, there are 48 electric vehicle charging stations, 57 with the Tesla chargers, and 153 charging outlets [5]. Figure 2.3 shows the locations of these charging stations in Nebraska. It is observed that the locations of these charging stations are again unevenly distributed such that an EV owner cannot move about freely without range anxiety.

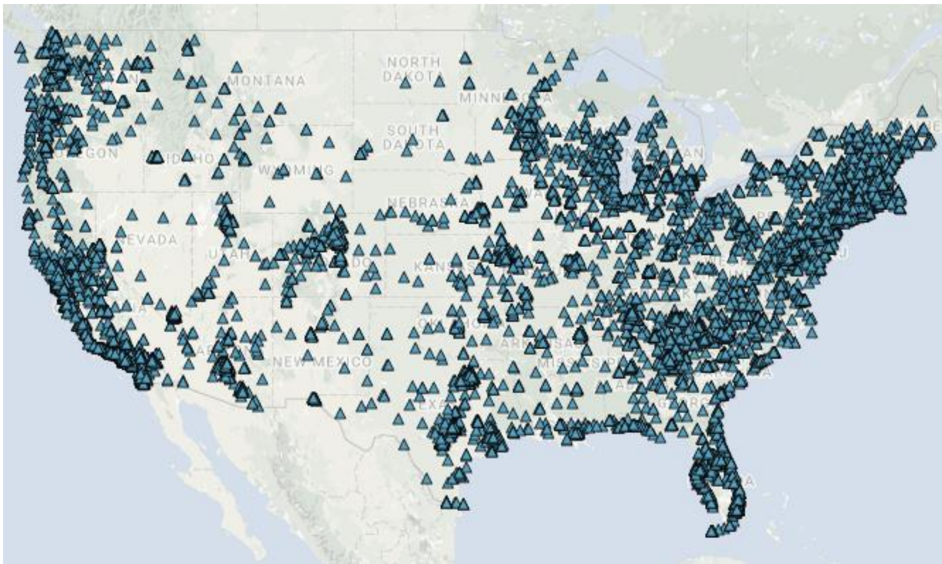

Figure 2.2: Locations of charging stations in the U.S.

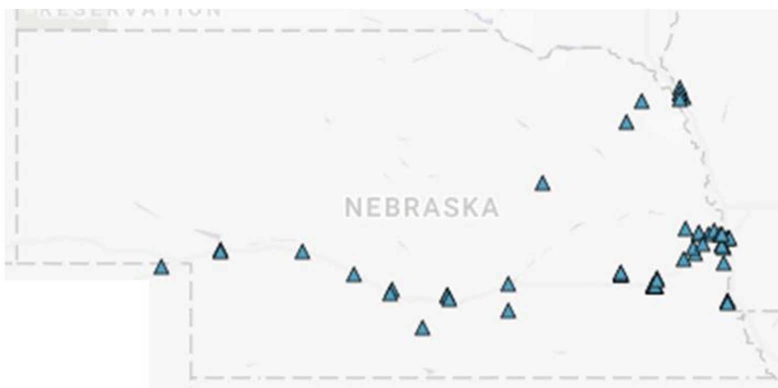

Figure 2.3: Locations of charging stations in the state of Nebraska

b. Algorithm For Interstate & US-Highways

Determining the location for electric vehicles charging stations within a particular area of interest can be a key factor for a successful deployment. In our work, an algorithm has been proposed to calculate the number of charging infrastructures and their location for a particular model of an electric vehicle when traveling between two points in a particular Interstate or US- Highway in the state of Nebraska. The algorithm developed is essentially a search algorithm, incorporating many constraints in its formulation, including: range anxiety, rated mileage of the electric vehicle, population of the cities near or on the Interstate or US-Highway, and distance between origin city and destination city. With few assumptions, a mathematical formula is modeled which calculates the real mileage of the electric vehicle which in turn is used in the search algorithm to determine the number of charging infrastructures to be installed. This information will not only help the users to check the maximum number of times they must stop to charge, but also help the manufacturing car companies to estimate the position of the placement of the charging stations for their model of the car.

The first assumption being that the charging infrastructures considered are the DC fast chargers because charging time in an Interstate or US-Highway will be a major concern for the electric vehicle user. In addition, if a fast charger infrastructure is used then the battery capacity that an electric vehicle user is able to utilize is different than charging the electric car in Level I and Level II infrastructure. This will give us a different numerical value for battery utilization percentage used for the calculation of real mileage. Another assumption has been made that when the electric vehicle leaving the city to its destination will be fully charged. As the algorithm is used to determine the number of charging infrastructures required to travel from one particular point to another and to locate them, it is very important that this assumption is made so to ensure the electric car does not run out of charge in any unexpected location. This assumption allow us to locate an electric charging station in the origin city.

The algorithm is so modeled that when the city of origin of the travel and the destination is specified, the algorithm calculates the number of charging stations required in between for the electric vehicle to complete the trip. The total number of charging stations calculated in this paper gives the maximum value, and the user may boost the range of their cars, depending on their driving style.

For calculation purposes of the algorithm, two databases are created for this process. The first database contains the required information for a specific U.S. state, including the Interstates/ US-highways in it, the cities on the interstate/ US-Highway with their population, and the distance between each city based on a reference city for a specific U.S. state. This reference city is generally the origin city of travel. The second database lists all the electric vehicle manufacturers, with the model and rated mileage of the vehicle (m_a). Based on the value of m_a, a mathematical formula is formulated to calculate the real mileage of the electric vehicle m_r. The constraints and calculations in each database are defined to describe the process of the search algorithm.

Two factors has been introduced in the model developed to find the best charging infrastructure location between two cities are discussed as follows. The first factor is the 'x' factor. The search algorithm looks in the database for cities in a state whose population is greater than x. The database would contain all the cities in or near the Interstate/ US-Highway. The x parameter will decide how the database will be checked by the algorithm for cities in an Interstate/ US-Highway. The value of x is so chosen that it exclude very small cities along the Interstate/ US-Highway, the reason being the utility company supplying these cities will have limited generation and sufficient infrastructure to provide for the electrical needs of the DC fast charging. This value of x will differ in different states, depending on the population per city of the state. For the state of Nebraska, USA the value of x is chosen as 1,000. It can be seen from the consensus report of Nebraska [6] for the year 2015/2016 that out of the 451 cities nearly 117 cities (about 25.94%) have a population that is greater than 1,000. The cities having population greater than 1,000 in Nebraska is well distributed along the Interstate or US-Highway and the utility companies supplying these cities have enough generation as of now as well as in the near future to cope up with the additional consumption of energy due to charging of the electric cars.

The second assumption has been made, that the cities with population greater than *y* will be installed with charging stations. This assumption is made because cities with population above *y* will have utility companies, which will have the potential to generate more power for the charging infrastructure. Also, cities having a population greater than *y*, will be installed with charging station in order to promote the growth of electric vehicle market and encouraging more and more people to drive electric cars. The value of *y* will also be different in different states. Both the values of *x* and *y* will depend on the state and utility companies of the cities, and it is to be determined before running the algorithm for each state.

The electric vehicle model is selected first and the information is given as an input to the algorithm. The calculated mileage m_c, is then calculated using rated mileage m_a of the electric vehicle with added assumptions of the battery life, heating, ventilation and air conditioning (HVAC) system usage, and range anxiety. A critical component to an electric vehicle is the durability of the battery, which is greatly affected by how it is charged over time. A battery should not be depleted past 20% of its charge to maintain a good battery life. Also, for DC fast charging, 80% of the battery is recharged very quickly and the remaining 20% takes a very long time [7]. Therefore, it can be calculated that we will be able to utilize 60% of the battery where the battery constraint accounts for 40% of m_a. The ambient temperature outside would also affect the battery and hence the mileage of the car. This is included in the 40% battery constraint, in our model.

Next, we consider that the electric vehicle uses the heating or air-conditioning when driving. If the windows are rolled down when driving on an interstate or U.S. highway, the drag force due to the speed will decrease the mileage of the electric vehicle to a greater extent. The usage of HVAC in the car will account for 10% of the calculated mileage m_c.

In addition, the range anxiety of the driver will also affect the mileage of the electric car. The range anxiety [8] is the concern of the Electric Vehicle user of not having enough charge in the car to make it to the nearest charging station or destination. The range anxiety factor varies from individual to individual. In our model, we have considered that the range anxiety will account for 10% of the calculated mileage m_c.

First step will be to find the calculated mileage of the car m_c and is defined as,

$$m_c = m_a - 0.4m_a = 0.6m_a \qquad (1)$$

The second step will be to find the real mileage m_r of the car. The HVAC constraint and the range anxiety together account for 20% of the calculated mileage m_c. The real mileage of the car m_r becomes,

$$m_r = m_c - 0.2m_c = 0.8m_c \qquad (2)$$

The third step will be to substitute the calculated mileage m_c from Equation 1 into Equation 2, and we get

$$m_r = 0.8*(0.6m_a) = 0.48m_a \qquad (3)$$

The real mileage of the electric vehicle m_r is calculated using Equation 3. The distance d_i is defined as the distance between two cities on the Interstate or the US Highway whose population is greater than x. The total number of charging stations S_t, is calculated using the database created when origin city of travel and destination is specified. S_t is calculated using the two components S_i and S_d. The values of S_i and S_d are explained as follows. S_i is defined as,

$$S_i = \lfloor d_i/m_r \rfloor \qquad (4)$$

where $\lfloor \ \rfloor$ returns the integer value of d_i/m_r which gives us the value of the number of charging stations between two cities that needs to be implemented along the way. S_d is defined as,

$$S_d = d_i/m_r - S_i \qquad (5)$$

The value of S_d returns a decimal number and this value is used to decide whether there needs to be a charging station in the next city. In this paper, it has been considered that if the decimal part S_d is more than 0.45, a charging station needs to be installed in the next city. If the decimal part is less than 0.45 then a charging station is not required in the next city. This assumption has been made because if the electric vehicle user decides to return from the next city, one will have enough charge to the nearest charging station. 0.45 signifies the percentage of miles utilized by the electric car.

The search algorithm checks whether the next city is the destination city or not. If the next is the destination city, then the algorithm stops, and the final number of charging stations are calculated. If the next city is not the destination city, then two cases can be studied.

CASE I: The next city does not require a charging infrastructure to be installed. In this scenario, the last city where a charging station has been assigned by the algorithm, is marked as the source city and the next city on the database, whose population is greater than *x* is used to calculate the distance (d_i) between these two cities. The calculations are repeated to check the number of charging infrastructures in between the two cities.

CASE II: The next city do require a charging infrastructure to be installed. In this case, the next city is marked as the source city and the next city on the database, whose population is greater than *x* is used to calculate the distance (d_i) between these two cities. The calculations are repeated to calculate the number of charging infrastructures in between these two cities.

The algorithm continues until the destination city specified is reached on the database. The charging infrastructures are then added to find the total number of charging infrastructures in between the source city and destination city for a specific model of the electric vehicle. A flowchart of the search algorithm is shown in Figure 2.4.

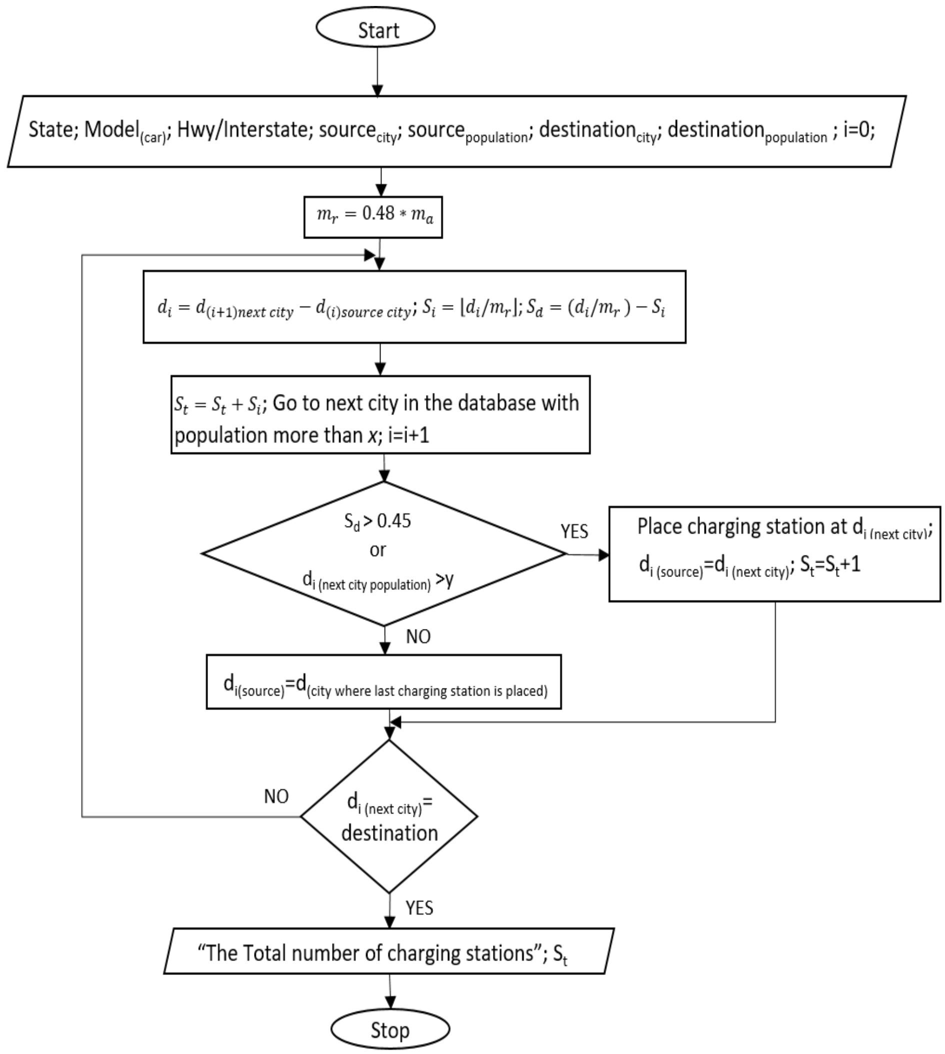

Figure 2.4: Flow chart of the search algorithm to determine best charging infrastructure location on a given Interstate or US-Highway

In the state of Nebraska, all the prominent US-Highways and the Interstates are documented. Table 2.2 shows the list of names of the Interstates and the US-Highways in Nebraska with their extreme points and the distance they cover. Figure 2.5 gives the visual presentation of the Interstates and the US-Highways in Nebraska.

Table 2.2: List of US-Highways and Interstates in Nebraska

INTERSTATE or US-HIGHWAYS	START CITY	END CITY	DISTANCE (miles)
INTERSTATE-80	OMAHA	KIMBALL	**432**
US-HIGHWAY-30	BLAIR	KIMBALL	**440**
US-HIGHWAY-34	PLATTSMOUTH	HAIGLER	**355**
US-HIGHWAY-6	OMAHA	IMPERIAL	**341**
US-HIGHWAY-75	SOUTH SIOUX CITY	DAWSON	**180**
US-HIGHWAY-77	WINNEBAGO	WYMORE	**163**
US-HIGHWAY-20	SOUTH SIOUX CITY	HARRISON	**421**
US-HIGHWAY-275	OMAHA	O'NEILL	**185**
US-HIGHWAY-81	HARTINGTON	HEBRON	**196**
US-HIGHWAY-83	VALENTINE	MCCOOK	**199**
US-HIGHWAY-136	AUBURN	OXFORD	**220**
US-HIGHWAY-183	SPRINGVIEW	ALMA	**202**
US-HIGHWAY-281	SPENCER	RED CLOUD	**207**
US-HIGHWAY-283	LEXINGTON	BEAVER CITY	**50**
US-HIGHWAY-385	CHADRON	SIDNEY	**130**
US-HIGHWAY-26	OGALLALA	SCOTTSBLUFF	**124**

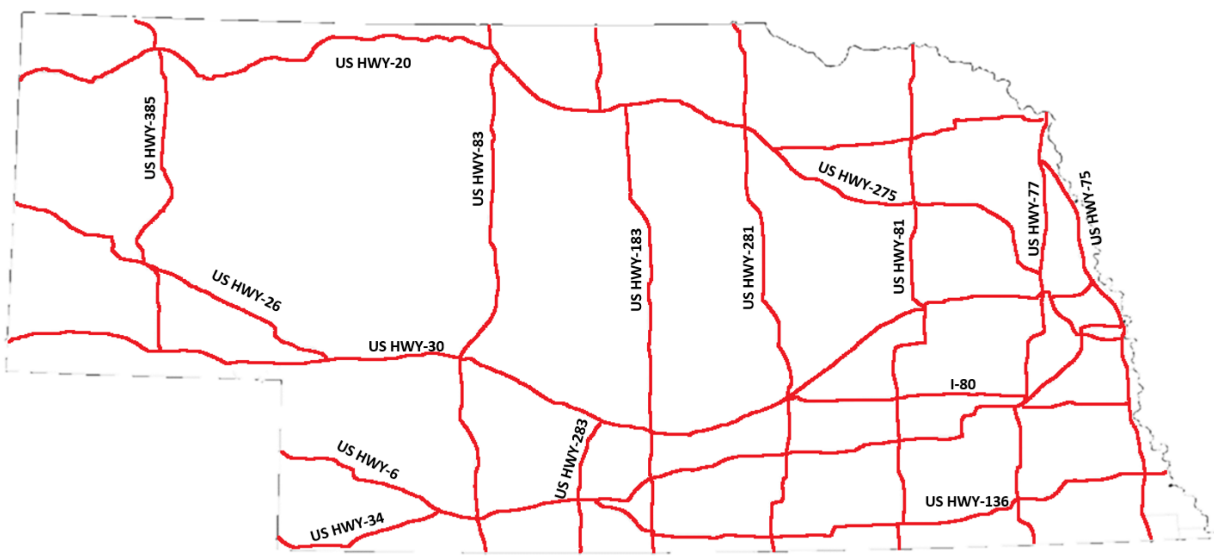

Figure 2.5: State map of Nebraska showing the Interstates and the US-Highways

After identifying the Interstates and the US-Highways in the state, databases needed to be created. The databases included cities name on the Interstate or the US-Highway, their population and the distance between them. A sample database for the Interstate-80 in Nebraska is shown in Table 2.3. The city names in bold format in Table 2.3 indicate the origin city and the destination city. Figure 2.6 shows the map of Nebraska showing Interstate-80 with cities which has population greater than 1,000 as indicated by the *x* parameter.

Table 2.3: Database I containing all the city names on Interstate-80 in Nebraska, USA with their population and the distance from the reference city which is Omaha

City Names	Population [8]	Distance (cumulative) (in miles)	City Names	Population [8]	Distance (cumulative) (in miles)
Omaha	408,958	0	Cozad	3,977	230
Gretna	4,441	19.6	Gothenburg	3,574	240
Ashland	2,453	26.5	Brady	428	253
Greenwood	568	31.6	Maxwell	312	262
Waverly	3,277	40.1	North	24,733	275
Lincoln	258,379	51.4	Hershey	665	287
Seward	6,964	73.3	Sutherland	1,286	294
York	7,766	99.2	Paxton	523	306
Henderson	991	110	Ogallala	4,737	325
Aurora	4,479	120	Brule	326	335
Doniphan	829	140	Big Springs	400	344
Wood	1,325	152	Chappell	929	366
Shelton	1,059	161	Lodgepole	318	382
Gibbon	1,833	167	Sidney	6,757	392
Kearney	30,787	180	Potter	337	413
Elm Creek	901	195	Dix	255	422
Overton	594	204	**Kimball**	2,496	431
Lexington	10,230	215			

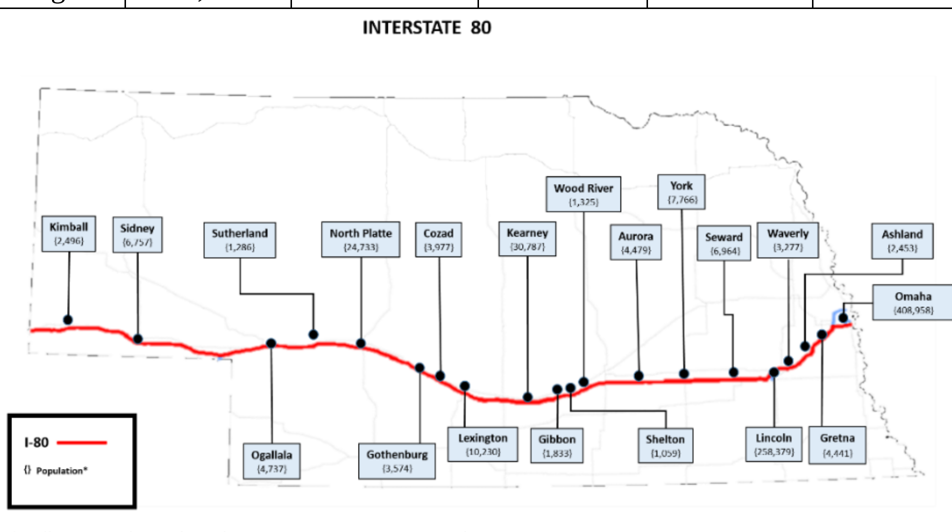

Figure 2.6: A map of Nebraska, USA showing Interstate-80 with cities having a population greater than 1,000

Next, the model of the electric car was chosen, which in this case was Nissan Leaf 2016 model. The rated mileage of the car (m_a) was found out to be 84 miles [9] and the actual mileage (m_r) was calculated to be 40.32 miles. The search algorithm was applied to the databases and simulations were run. Table 2.4 shows the steps for each iteration step for the Interstate-80 in Nebraska when driving a Nissan Leaf 2016 model.

Table 2.4: Simulations for Interstate-80 in Nebraska

i^{th} iteration	Distance (in miles) $d_i = d_{i+1(next\ city)} - d_{i(source)}$	m_r	$S_t=d_i/m_r$	S_{ti}=Integer part of S_t	Decimal part of S_t	S_{td} (cumulative)
1	19.6-0=19.6	40.32	0.486	0	>0.45	1
2	26.5-19.6=6.9	40.32	0.171	0	<0.45	1
3	40.1-19.6=20.5	40.32	0.508	0	>0.45	2
4	51.4-40.1=11.3	40.32	0.280	0	<0.45 but y>10,000	3
5	73.3-51.4=21.9	40.32	0.543	0	>0.45	4
6	99.2-73.3=25.9	40.32	0.642	0	>0.45	5
7	120-99.2=20.8	40.32	0.516	0	>0.45	6
8	152-120=32	40.32	0.794	0	>0.45	7
9	161-152=9	40.32	0.223	0	<0.45	7
10	167-152=15	40.32	0.372	0	<0.45	7
11	180-152=28	40.32	0.694	0	>0.45 also y>10,000	8
12	215-180=35	40.32	0.868	0	>0.45 also y>10,000	9
13	230-215=15	40.32	0.372	0	<0.45	9
14	240-215=25	40.32	0.620	0	>0.45	10
15	275-240=35	40.32	0.868	0	>0.45 also y>10,000	11
16	294-275=19	40.32	0.471	0	>0.45	12
17	325-294=31	40.32	0.769	0	>0.45	13
18	392-325=67	40.32	1.662	1	>0.45	14
19	431-392=39	40.32	0.967	0	>0.45	15
				$\sum S_{ti}=1$		$\sum S_{td}=15$

Calculations show that while driving a Nissan leaf 2016 S24, from Omaha to Kimball using Interstate-80, Nebraska, USA, a total number of 16 charging stations will be needed. The locations were also identified and is shown in Figure 2.7.

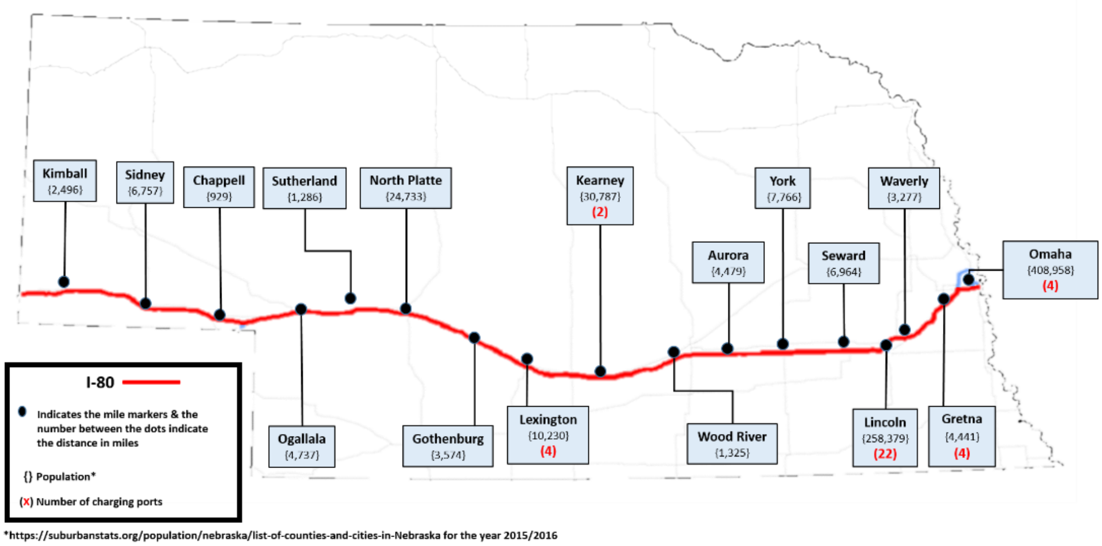

Figure 2.7: Charging station location for Nissan Leaf 2016 S24 in I-80

For the sake of simplicity, the whole state of Nebraska was divided into three zones. Zone 1 is the area east of US-Highway 81. Zone 2 is the area between US-Highway 81 and US-Highway 83. And, finally Zone 3 is the area west of US-Highway 83. Then the databases containing the information of all Interstate and the US-Highways were created and shown in Appendix-2.1. Then they were subjected to the algorithm and simulated to find out the total number of charging stations required along with their locations for each zone. Figure 2.8 shows the state of Nebraska divided into three zones. Figure 2.9, Figure 2.10 and Figure 2.11 shows the three zones separately will all the Interstates and US-Highways in it with some cities on them. Results are plotted on the state map of Nebraska and shown in Appendix 2.2.

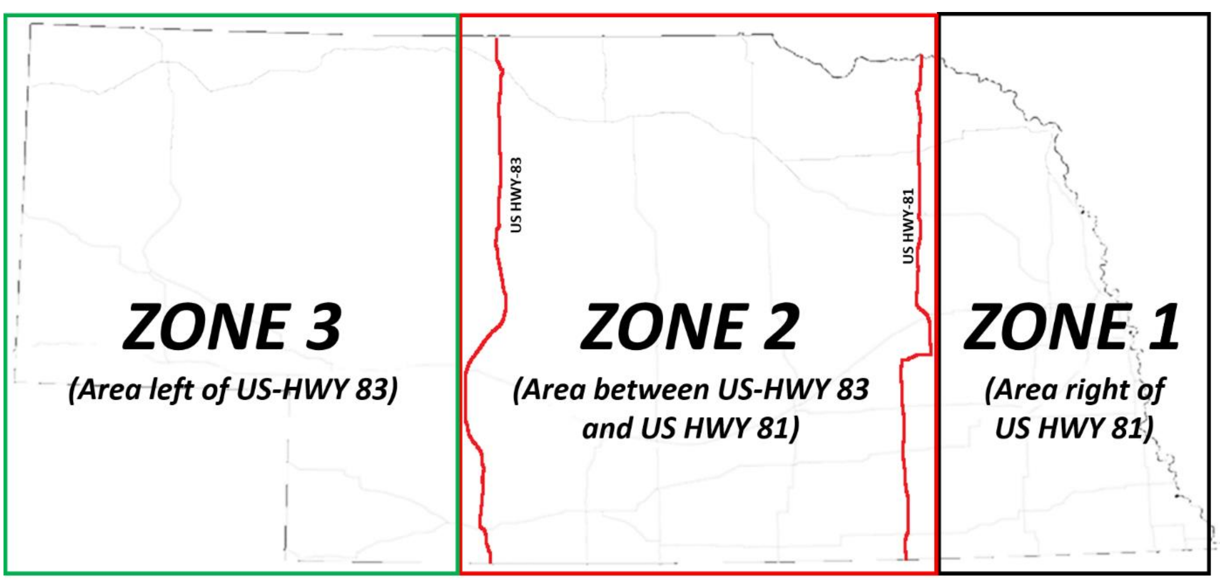

Figure 2.8: State of Nebraska divided into 3 zones

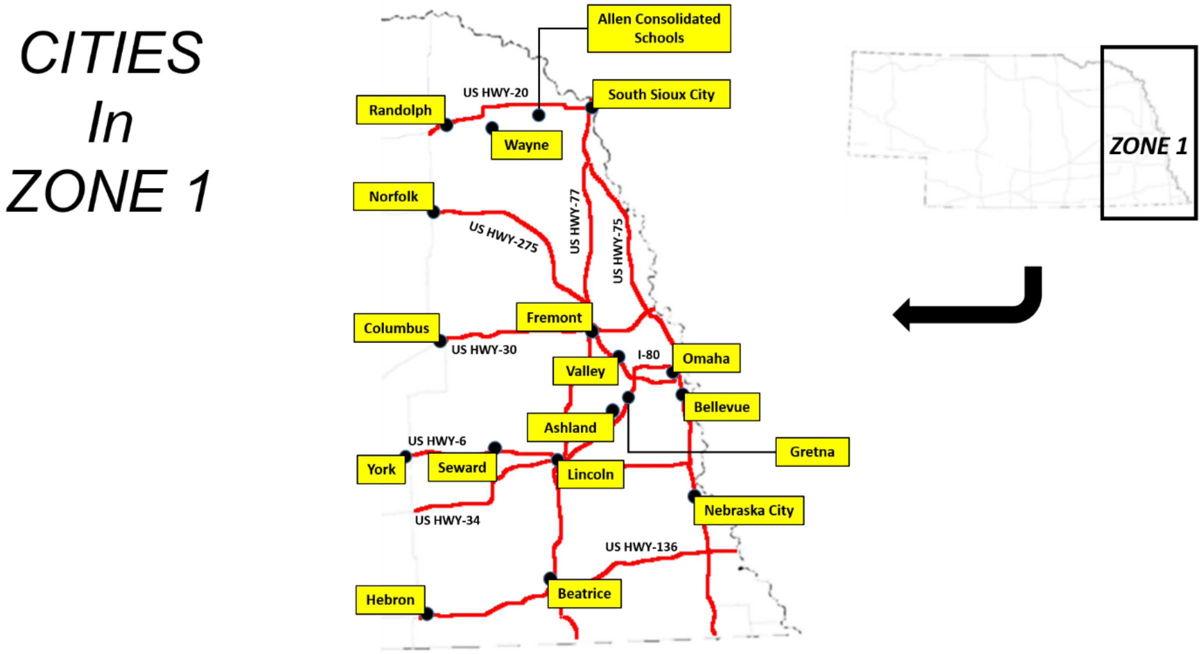

Figure 2.9: State map of Nebraska showing Zone 1 with all the Interstates and US-Highways with few cities on them

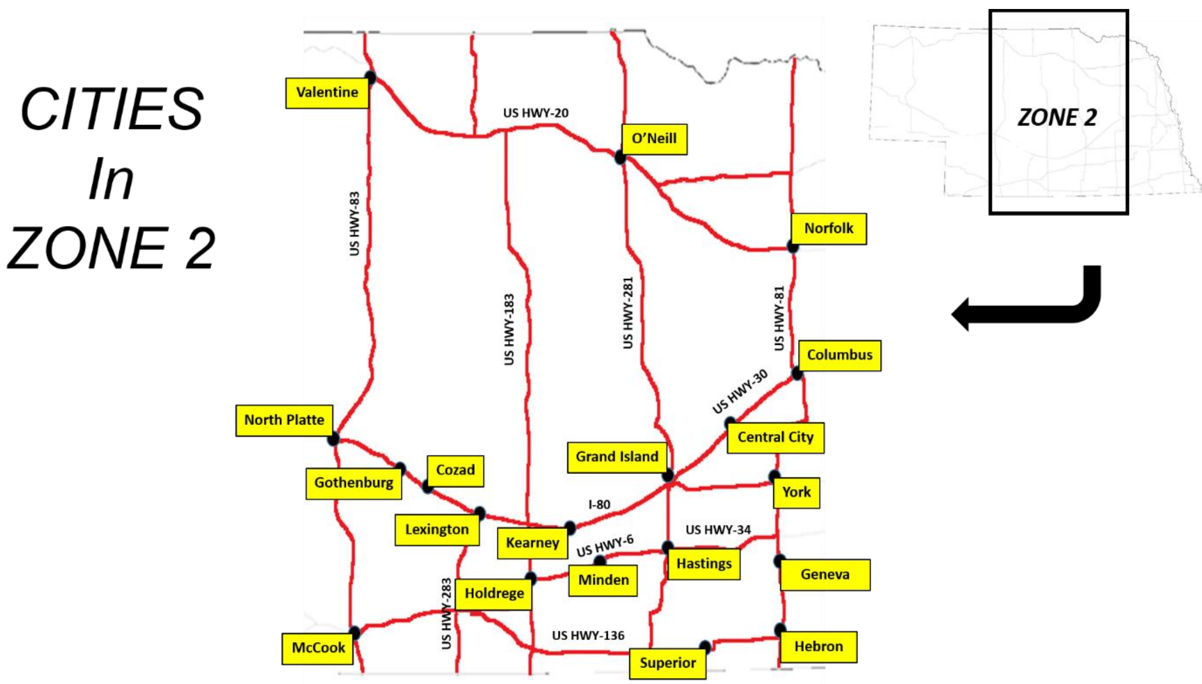

Figure 2.10: State map of Nebraska showing Zone 2 with all the Interstates and US-Highways with few cities on them

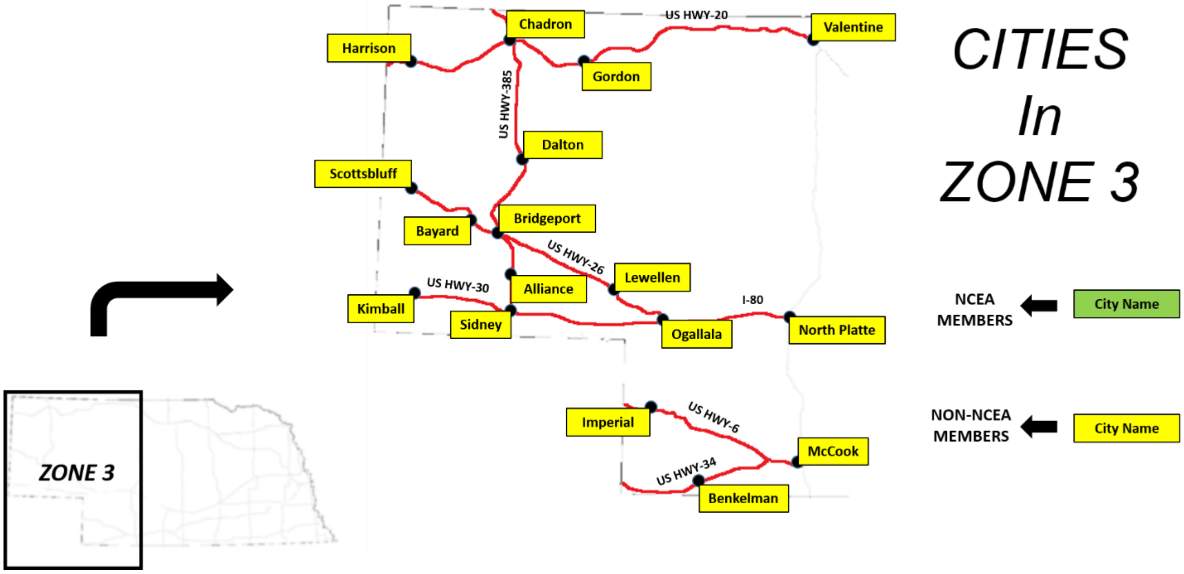

Figure 2.11: State map of Nebraska showing Zone 3 with all the Interstates and US-Highways with few cities on them

Calculations show that a total of 101 charging stations were required (three zones combined) in the state of Nebraska for the Electric Vehicle owners and the potential EV buyers to move in and about the state without any range anxiety. Out of these 101 locations there are 15 locations that are already installed with charging infrastructures. Figure 2.12 shows the locations where charging infrastructures need to be installed in the state map of Nebraska. Also, Figure 2.13, Figure 2.14 and Figure 2.15 shows the locations in each of the zones in the state map of Nebraska. Table 2.5 gives a summary of the number of locations and number of Interstates and US-Highways in each of the zones.

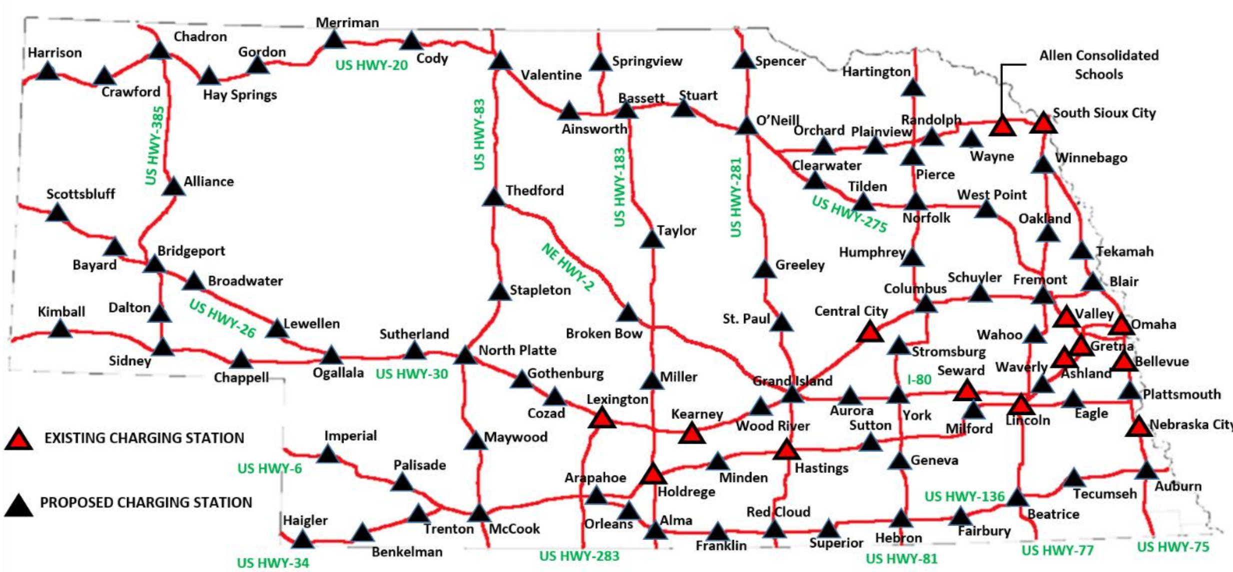

Figure 2.12: State map of Nebraska showing the possible locations for EV charging infrastructures driving Nissan leaf 2016 S24 model

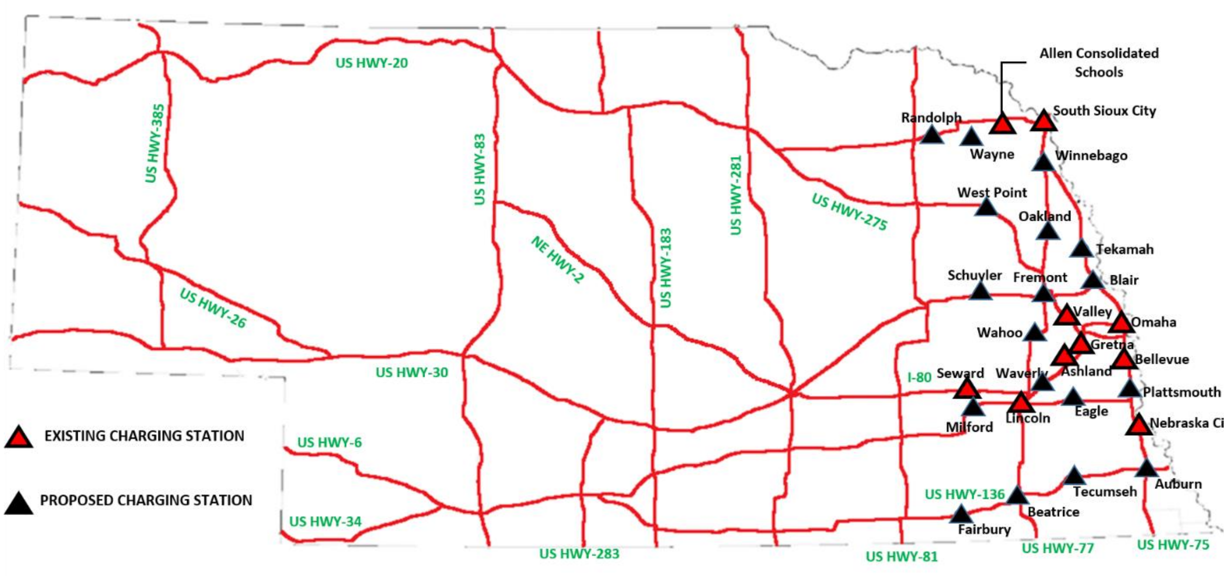

Figure 2.13: Possible locations for EV charging infrastructures in Zone 1 driving Nissan leaf 2016 S24 model

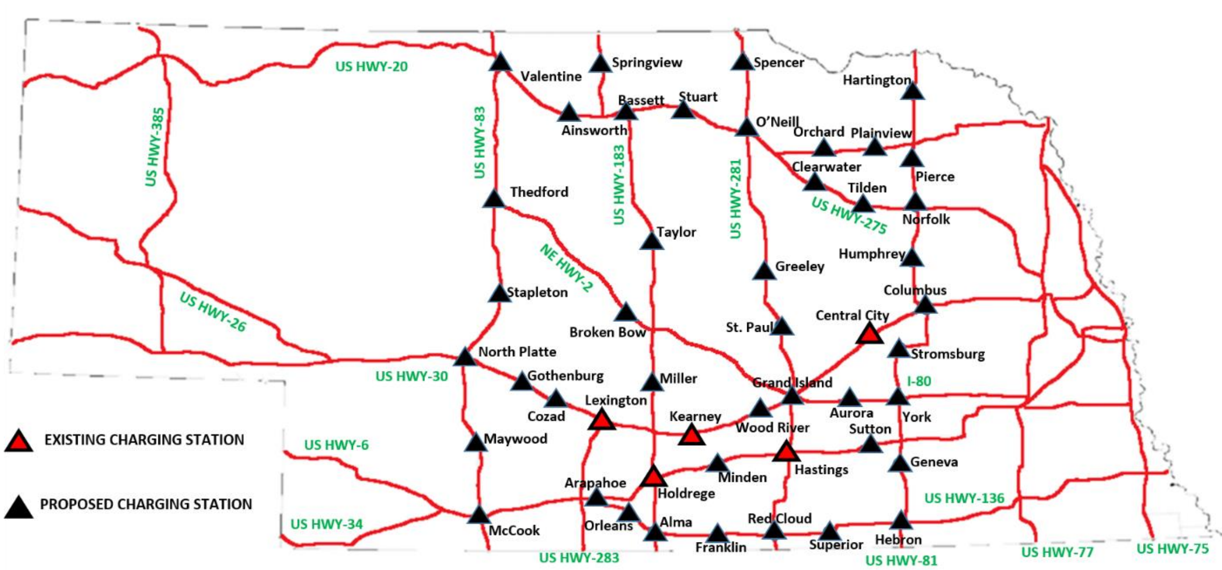

Figure 2.14: Possible locations for EV charging infrastructures in Zone 2 driving Nissan leaf 2016 S24 model

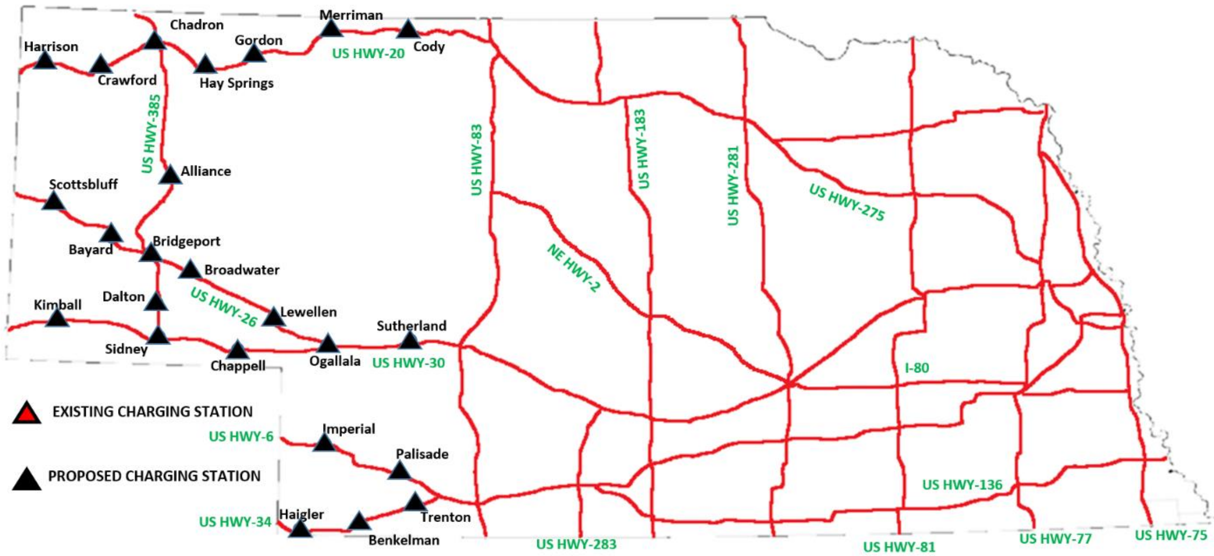

Figure 2.15: Possible locations for EV charging infrastructures in Zone 3 driving Nissan leaf 2016 S24 model

Table 2.5: Summary of all three zones in Nebraska driving Nissan leaf 2016 S24 model

ZONE	NUMBER OF CITIES	NUMBER OF HIGHWAYS	INTERSTATE/HIGHWAY NAMES
1	28	9	INTERSTATE: 80; US-HIGHWAY: 75, 77, 20, 30, 6, 34, 136, 275
2	49	13	INTERSTATE: 80; US-HIGHWAY: 20, 30, 6, 34, 136, 275, 81, 83, 183, 281, 283; HIGHWAY 2
3	24	7	INTERSTATE: 80; US-HIGHWAY: 20, 30, 6, 34, 26, 385

Once the charging stations are in place in the particular locations, not only the Interstate and the US-Highways will be benefitted but also the places in and around the locations will be benefitting from these charging stations. To get an idea, the coverage area of the electric vehicle which in this case is Nissan Leaf 2016 S24 is estimated when the charging station is placed on Omaha and Lincoln in Nebraska. Appendix 2.3 shows the round trip coverage area of Nissan Leaf 2016 S24 in the three zones. It shows the distance the car can travel starting from the charging infrastructure location and can travel to the end of the red line and then can travel back to the location, without having to charge their electric cars in-between. Appendix 2.4 shows the one way coverage area of Nissan Leaf 2016 S24 in the three zones. It shows the distance the car can travel along the red line from the charging infrastructure location, however will not have sufficient charge to come back to the origin city. Appendix 2.3 and 2.4 shows the coverage area from the individual locations as well as on the Interstate and the US-Highways in the three zones. The individual locations were chosen on the basis of their membership with Nebraska Community Energy Alliance as of when the research was conducted.

Using the results obtained from the simulations all the locations were documented with the number of Interstates and the US-Highways that can be accessed from that location. Table 2.6 documents all the 101 locations in Nebraska stating whether they have already existing charging stations and the Interstates and the US-Highways that can be accessed from that location. The higher the number of Interstates and US-Highways that can be accessed from the location indicate that the location is of prior geographic importance in terms of placing a charging infrastructure. Also, Interstate-80 is the most important corridor serving as a main pathway for cross-country drive. So any location on Interstate-80 is of utmost significance. These 101 locations could be analyzed based on their priority of their position and planning of placement of charging infrastructures can be determined.

Table 2.6: Locations for the placement of the Electric Vehicle Charging Infrastructures

CITY NAME	PROPOSED	EXISTING	INTERSTATE AND US-HIGHWAYS THE CITY CAN ACCESS	CITY NAME	PROPOSED	EXISTING	INTERSTATE AND US-HIGHWAYS THE CITY CAN ACCESS
AINSWORTH	✓		US-HWY-20	GOTHENBURG	✓		I-80 and US-HWY-30
ALLEN CONSOLIDATED SCHOOLS		✓	US-HWY-20	GRAND ISLAND	✓		I-80 and US-HWY-30, 34, 281
ALLIANCE	✓		US-HWY-385	GREELEY	✓		US-HWY-281
ALMA	✓		US-HWY-136, 183	GRETNA		✓	I-80 and US-HWY-6
ARAPAHOE	✓		US-HWY-34, 6, 283	HAIGLER	✓		US-HWY-34
ASHLAND		✓	I-80 and US-HWY-6	HARRISON	✓		US-HWY-20
AUBURN	✓		US-HWY-136, 75	HARTINGTON	✓		US-HWY-81
AURORA	✓		I-80 and US-HWY-34	HASTINGS		✓	US-HWY-6, 34, 281
BASSETT	✓		US-HWY-20, 183	HAY SPRINGS	✓		US-HWY-20
BAYARD	✓		US-HWY-26	HEBRON	✓		US-HWY-81, 136
BEATRICE	✓		US-HWY-77, 136	HOLDREGE		✓	US-HWY-6, 34, 183
BELLEVUE		✓	US-HWY-75	HUMPHREY	✓		US-HWY-81
BENKELMAN	✓		US-HWY-34	IMPERIAL	✓		US-HWY-6
BLAIR	✓		US-HWY-30, 75	KEARNEY		✓	I-80 and US-HWY-30
BRIDGEPORT	✓		US-HWY-26, 385	KIMBALL	✓		I-80 and US-HWY-30
BROADWATER	✓		US-HWY-26	LEWELLEN	✓		US-HWY-26
CENTRAL CITY		✓	US-HWY-30	LEXINGTON		✓	I-80 and US-HWY-30, 283
CHADRON	✓		US-HWY-20, 385	LINCOLN		✓	I-80 and US-HWY-6, 34, 77
CHAPPELL	✓		I-80 and US-HWY-30	LONG PINE	✓		US-HWY-20, 183
CLEARWATER	✓		US-HWY-275	MAYWOOD	✓		US-HWY-83
CODY	✓		US-HWY-20	MCCOOK	✓		US-HWY-6, 34, 83
COLUMBUS	✓		US-HWY-30, 81	MERRIMAN	✓		US-HWY-20
COZAD	✓		I-80 and US-HWY-30	MILFORD	✓		US-HWY-6
CRAWFORD	✓		US-HWY-20	MILLER	✓		US-HWY-183
DALTON	✓		US-HWY-385	MINDEN	✓		US-HWY-6, 34
O'NEILL	✓		US-HWY-20, 281	STROMSBURG	✓		US-HWY-81

ORCHARD	✓		US-HWY-20	STUART	✓		US-HWY-20
ORLEANS	✓		US-HWY-136	SUPERIOR	✓		US-HWY-136
PALISADE	✓		US-HWY-6	SUTHERLAND	✓		I-80 and US-HWY-30
PIERCE	✓		US-HWY-81	SUTTON	✓		US-HWY-6
PLAINVIEW	✓		US-HWY-20	TAYLOR	✓		US-HWY-183
PLATTSMOUTH	✓		US-HWY-34, 75	TECUMSEH	✓		US-HWY-136
RADOLPH	✓		US-HWY-20	TEKAMAH	✓		US-HWY-75
RED CLOUD	✓		US-HWY-136, 281	THEDFORD	✓		US-HWY-83
SCHUYLER	✓		US-HWY-30	TILDEN	✓		US-HWY-275
SCOTTSBLUFF	✓		US-HWY-26	TRENTON	✓		US-HWY-34
SEWARD		✓	I-80 and US-HWY-34	VALENTINE	✓		US-HWY-20, 83
SHELTON	✓		I-80 and US-HWY-30	VALLEY		✓	US-HWY-275
SIDNEY	✓		I-80 and US-HWY-30, 385	WAHOO	✓		US-HWY-77
SOUTH SIOUX CITY		✓	US-HWY-20, 75	WAVERLY	✓		I-80 and US-HWY-6
SPENCER	✓		US-HWY-281	WAYNE	✓		US-HWY-20
SPRINGVIEW	✓		US-HWY-183	WEST POINT	✓		US-HWY-275
ST. PAUL	✓		US-HWY-281	WINNEBAGO	✓		US-HWY-75, 77
STAPLETON	✓		US-HWY-83	WOOD RIVER	✓		I-80 and US-HWY-30
EAGLE	✓		US-HWY-34	NEBRASKA CITY		✓	US-HWY-75
FAIRBURY	✓		US-HWY-136	NORFOLK	✓		US-HWY-81, 275
FRANKLIN	✓		US-HWY-136	NORTH PLATTE	✓		I-80 and US-HWY-30, 83
FREMONT	✓		US-HWY-30, 75, 275	OAKLAND	✓		US-HWY-77
GENEVA	✓		US-HWY-81	OGALLALA	✓		I-80 and US-HWY-30, 26
GORDON	✓		US-HWY-20	OMAHA		✓	I-80 and US-HWY-6, 34, 75, 275
YORK	✓		I-80 and US-HWY-34, 81				

Another model of the electric car was chosen, which was Chevrolet Bolt EV 2017 model. The rated mileage of the car (m_a) was found out to be 238 miles [10] and the actual mileage (m_r) was calculated to be 114.24 miles. The search algorithm was applied to the databases and simulations were run. It was seen that 44 total locations are required to be installed with charging infrastructures so that the EV user can move in and about the whole state of Nebraska without any range anxiety. Figure 2.16 shows the locations of the charging infrastructures in the state map of Nebraska when driving Chevrolet Bolt EV 2017 model. Also Figure 2.17, 2.18 and 2.19 shows the locations in each of the zones in the state map of Nebraska. Table 2.7 gives a summary of the number of locations and number of Interstates and US-Highways in each of the zones.

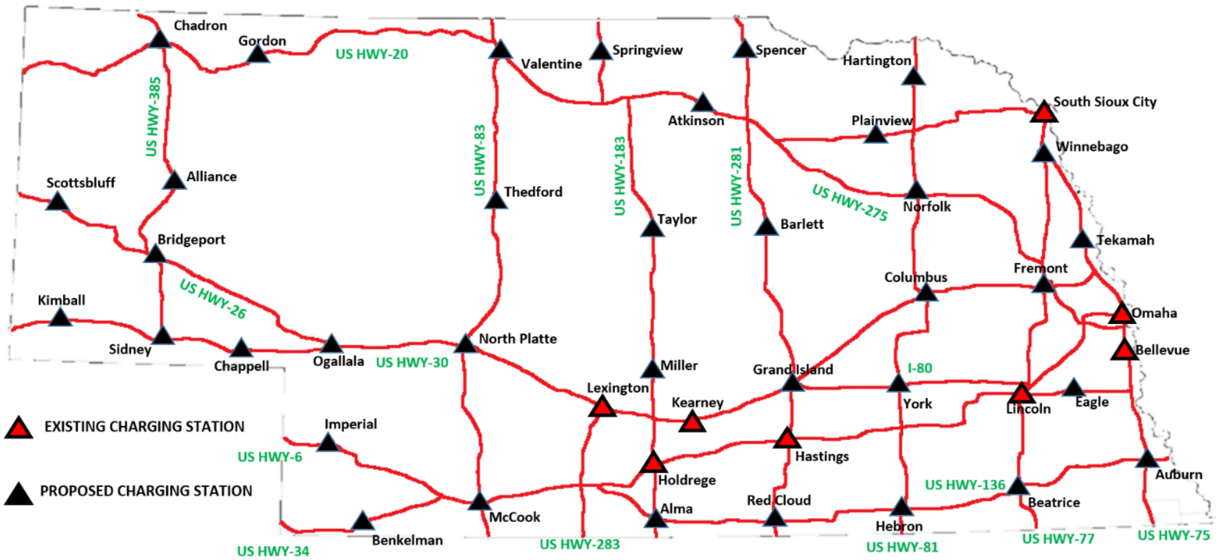

Figure 2.16: State map of Nebraska showing the possible locations for EV charging infrastructures driving Chevrolet Bolt EV 2017 model

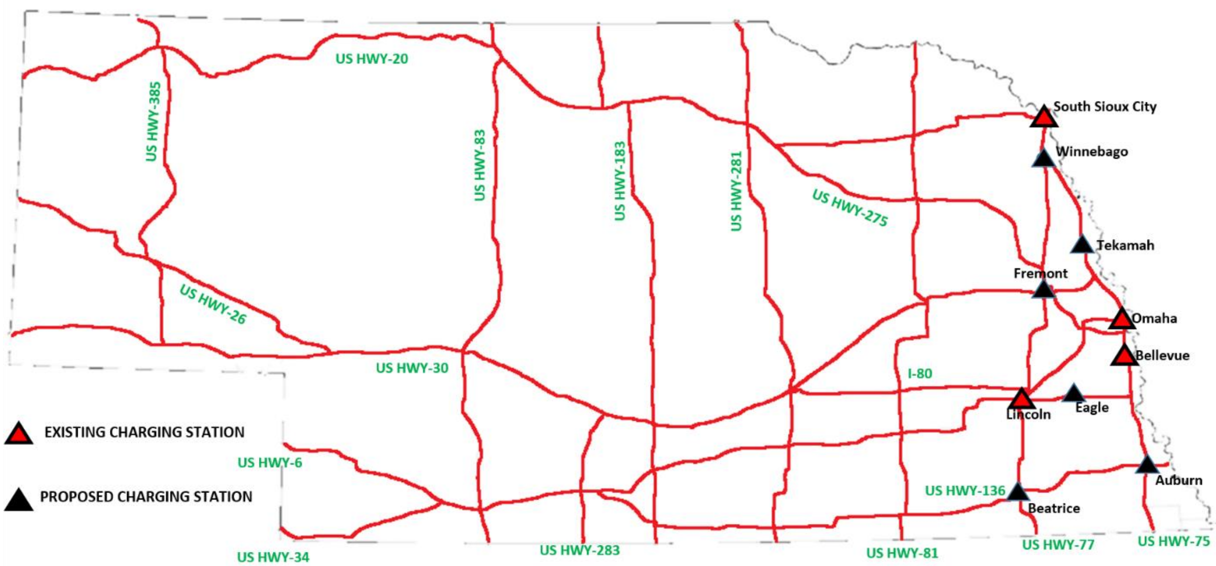

Figure 2.17: Possible locations for EV charging infrastructures in Zone 1 driving Chevrolet Bolt EV 2017 model

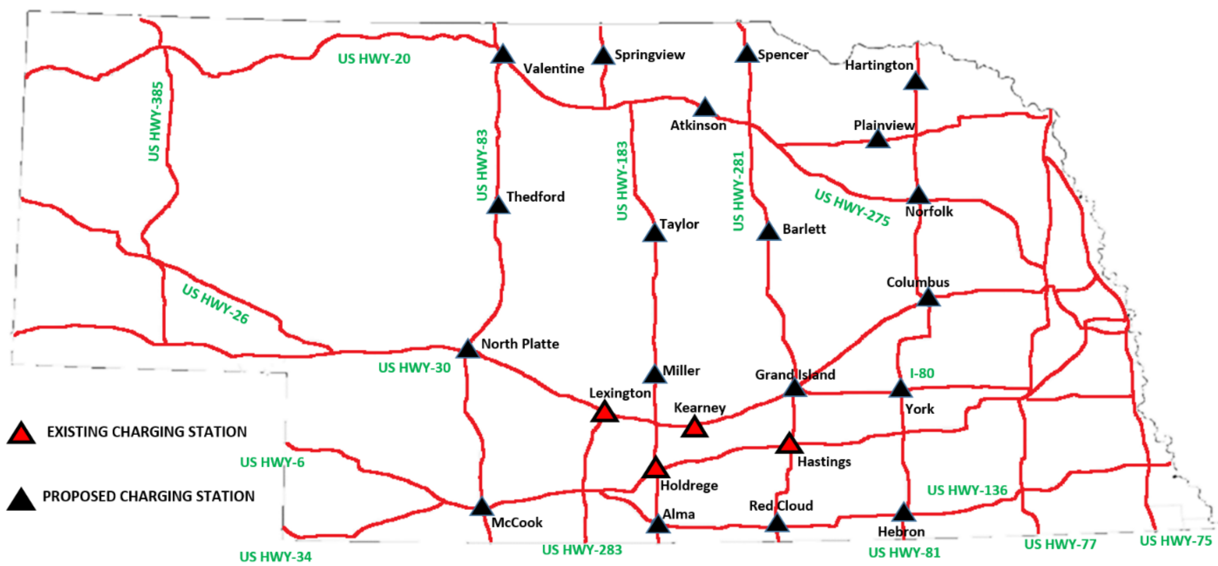

Figure 2.18: Possible locations for EV charging infrastructures in Zone 2 driving Chevrolet Bolt EV 2017 model

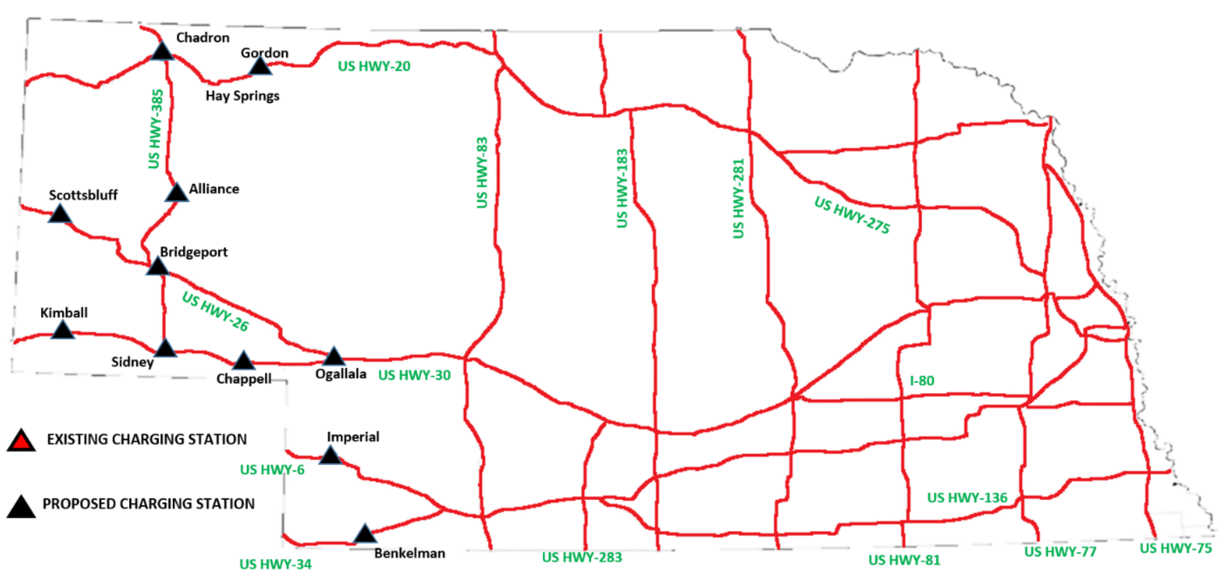

Figure 2.19: Possible locations for EV charging infrastructures in Zone 3 driving Chevrolet Bolt EV 2017 model

Table 2.7: Summary of all three zones in Nebraska driving Chevrolet Bolt EV 2017 model

ZONE	NUMBER OF CITIES	NUMBER OF HIGHWAYS	INTERSTATE/HIGHWAY NAMES
1	10	9	INTERSTATE: 80; US-HIGHWAY: 75, 77, 20, 30, 6, 34, 136, 275
2	23	12	INTERSTATE: 80; US-HIGHWAY: 20, 30, 6, 34, 136, 275, 81, 83, 183, 281, 283
3	11	7	INTERSTATE: 80; US-HIGHWAY: 20, 30, 6, 34, 26, 385

Table 2.8 gives a comparison of the number of charging infrastructures required while driving Nissan leaf 2016 S24 model and Chevrolet Bolt EV 2017 model in each zone in the state of Nebraska.

Table 2.8: Summary table for both models of the EV showing the proposed charging infrastructure location in all three zones

ZONE	NUMBER OF CITIES	
	Nissan Leaf 2016	**Chevy Bolt 2017**
1	28	10
2	49	23
3	24	11
TOTAL	**101**	**44**

c. Prioritization of the determined locations

After identifying the charging infrastructure's location, it is important to prioritize them, as it would be very difficult to install all the Electric Vehicle chargers at the same time considering the financial budget of the respective state. In order to prioritize the locations factors considered are:

- Population of the city
- Number of Interstate(s)/ US-Highways that can be accessed from that location

As per the algorithm developed, any city that has a population greater than 10,000 will be installed with a charging infrastructure, in Nebraska. So, a ranking is designed accordingly and is shown in Table 2.9.

Table 2.9: Population and their weight factor

Population Range	Weight Factor (W)
> 10,000	10
5,000-10,000	9
1,000-5,000	8
< 1,000	7

The number of Interstate(s)/ US-Highways (n) are documented for each locations and the number n is multiplied by a factor of 10. Total score of each location is determined by the equation below:

$$TS = (n*10) + W$$

With the TS calculated for each location for each zone, priority 1, 2 and 3 is assigned as per Table 2.10.

Table 2.10: Priority schedules

Priority conditions	TS	Priority scenario
2 Interstate/ US-Highways & population greater than 5,000	29 & more	1
1 Interstate/ US-Highway & population greater than 5,000	19 – 28	2
1 Interstate/ US-Highways & population less than 5,000	18 & less	3

Figure 2.20, Figure 2.21 and Figure 2.22 shows the locations in each of the zones in the state map of Nebraska based on their priority driving Nissan leaf 2016 S24 model. Table 2.11 gives a summary of the number of locations in each of the zones based on their priority.

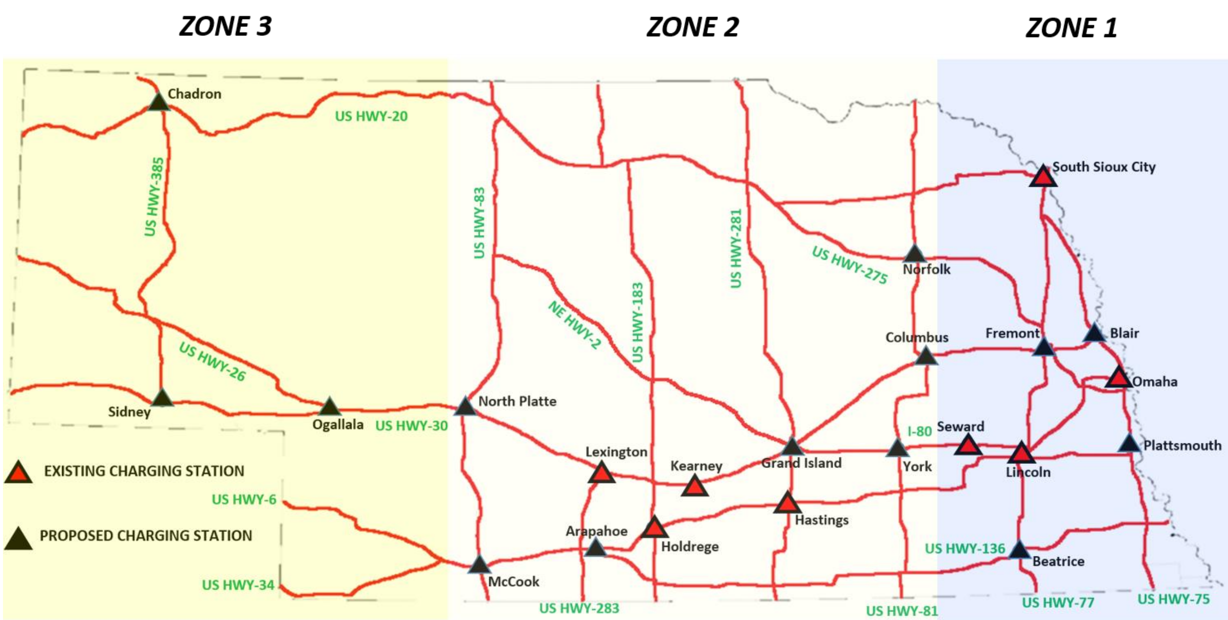

Figure 2.20: Possible locations for EV charging infrastructures for Priority 1 in each zone driving Nissan leaf 2016 S24 model

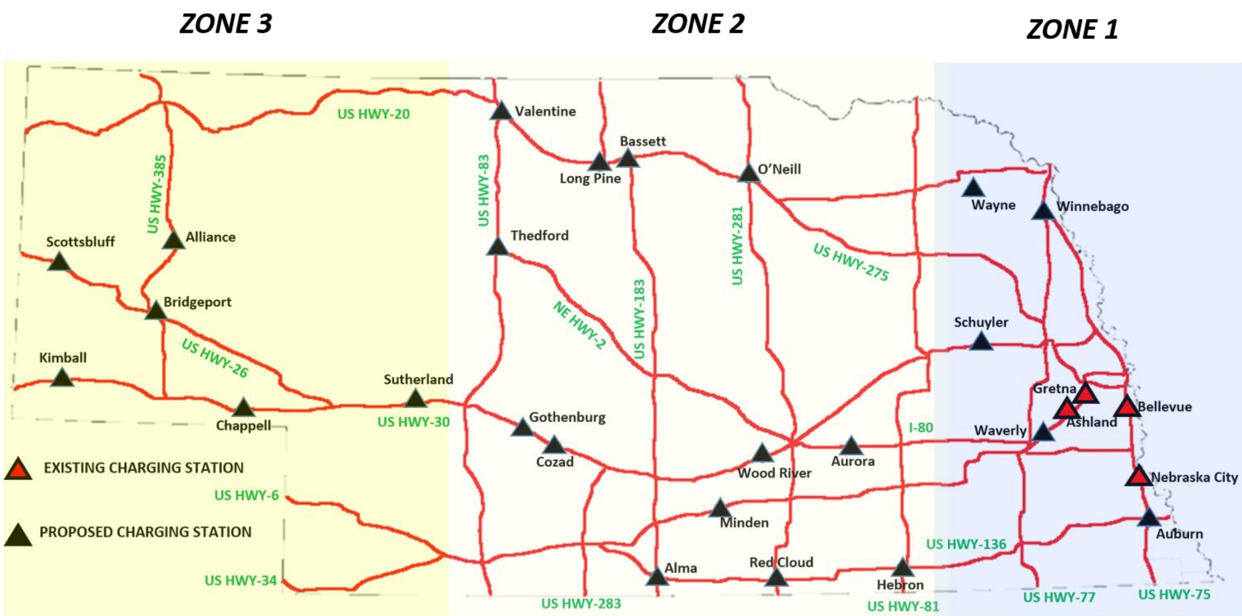

Figure 2.21: Possible locations for EV charging infrastructures for Priority 2 in each zone driving Nissan leaf 2016 S24 model

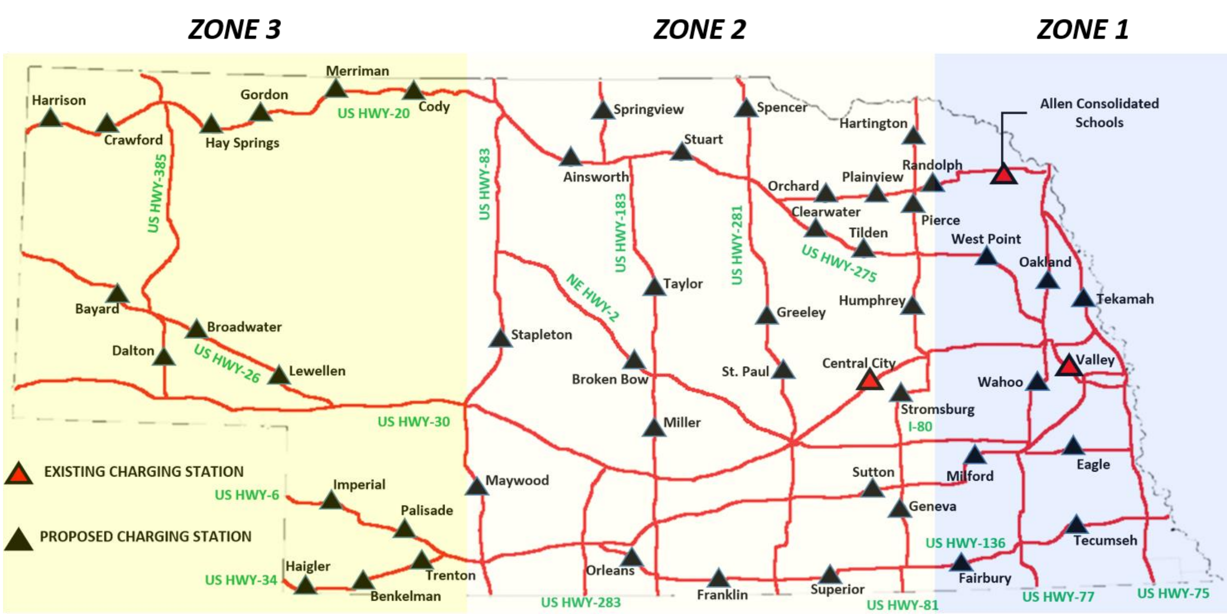

Figure 2.22: Possible locations for EV charging infrastructures for Priority 3 in each zone driving Nissan leaf 2016 S24 model

Table 2.11: Summary Table for all the three zones in Nebraska with priority category while driving Nissan Leaf 2016 S24 model

Priority Category	**Zone 1**	**Zone 2**	**Zone 3**	Total
1	8	11	3	**22**
2	9	13	6	**28**
3	11	25	15	**51**
Total	**28**	**49**	**24**	**101**

Figure 2.23, Figure 2.24, and Figure 2.25 shows the locations in each of the zones in the state map of Nebraska based on their priority driving Chevrolet Bolt EV 2017 model. Table 2.12 gives a summary of the number of locations in each of the zones based on their priority.

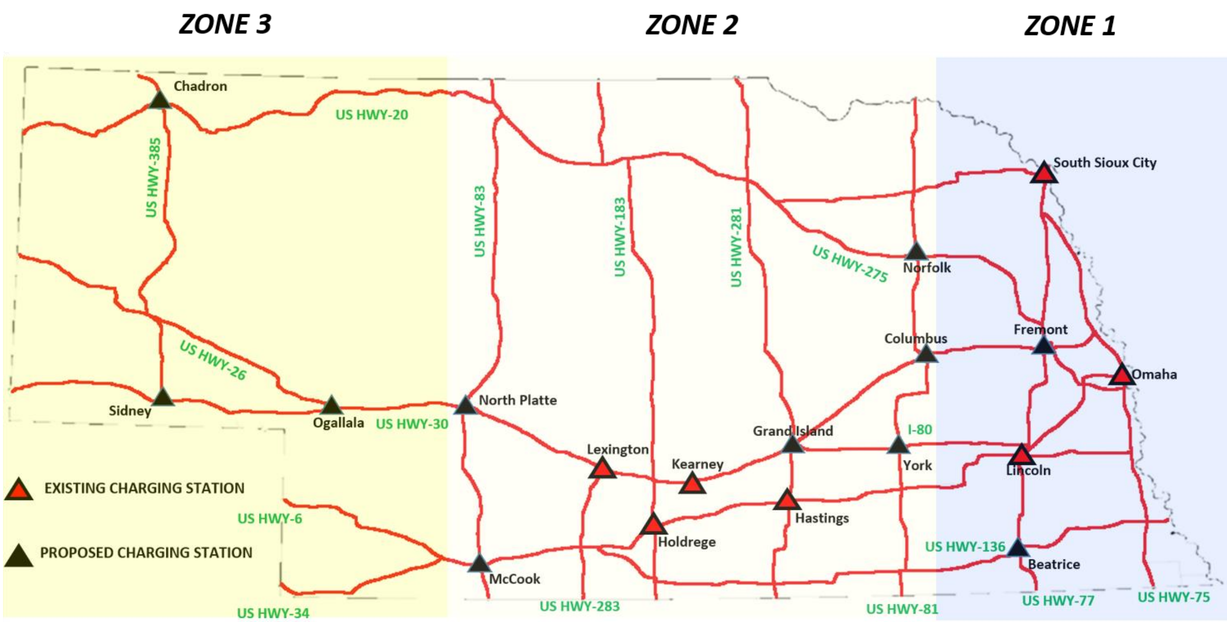

Figure 2.23: Possible locations for EV charging infrastructures for Priority 1 in each zone driving Chevrolet Bolt EV 2017 model

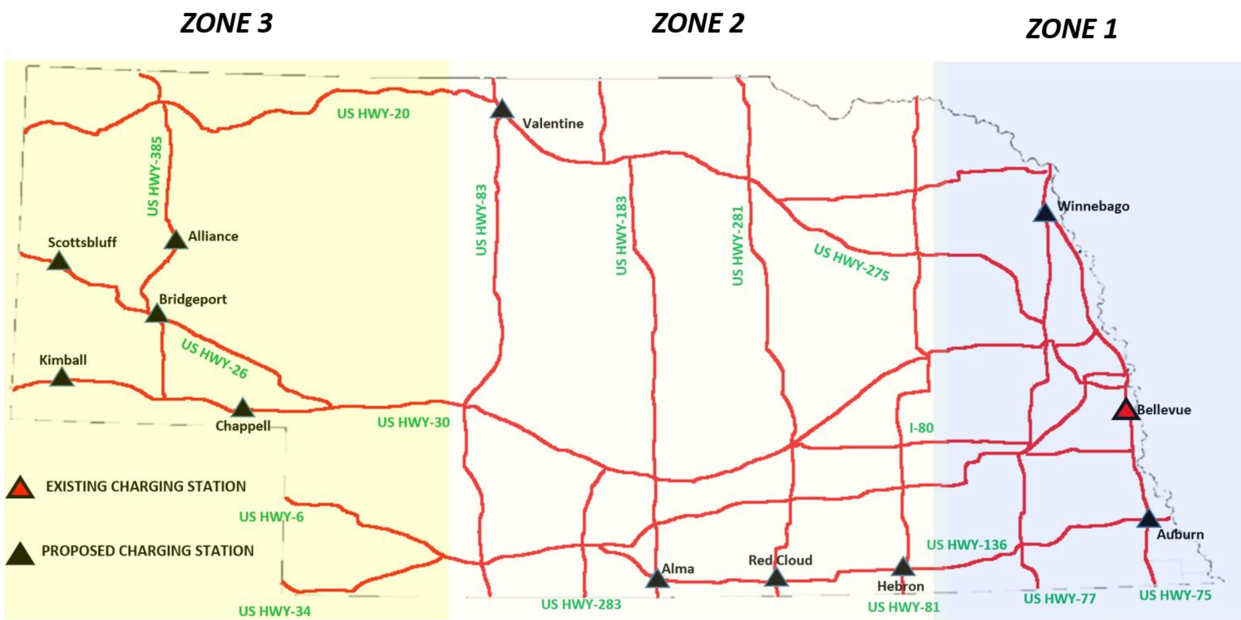

Figure 2.24: Possible locations for EV charging infrastructures for Priority 2 in each zone driving Chevrolet Bolt EV 2017 model

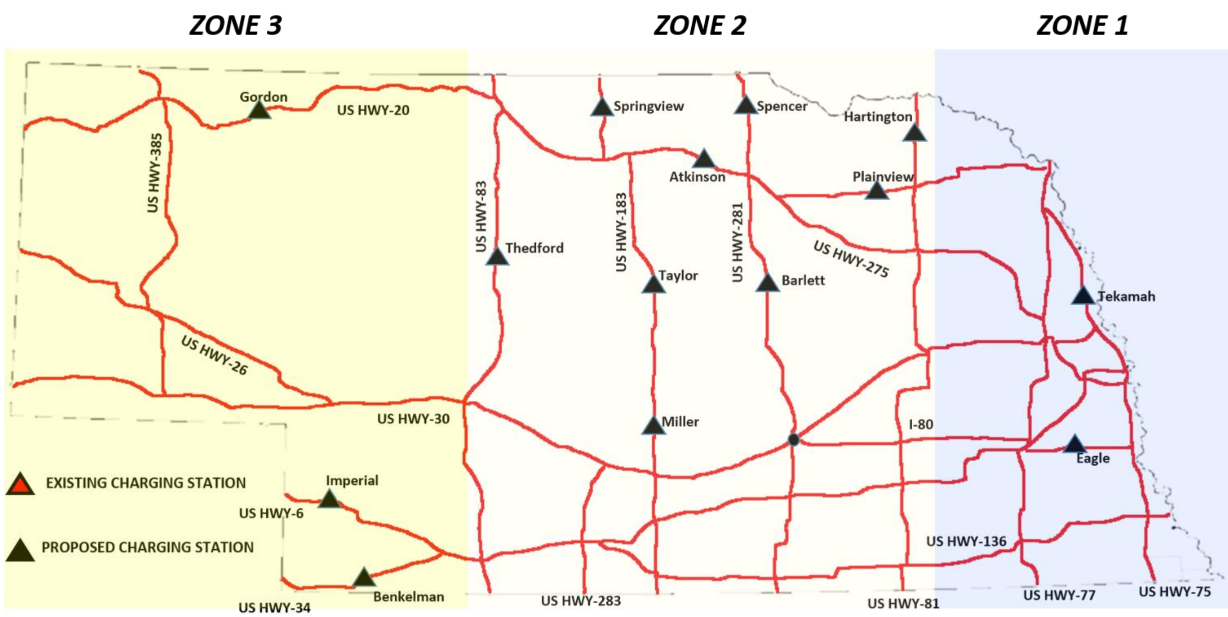

Figure 2.25: Possible locations for EV charging infrastructures for Priority 3 in each zone driving Chevrolet Bolt EV 2017 model

Table 2.12: Summary Table for all the three zones in Nebraska with priority category while driving Chevrolet Bolt 2017 model

Priority Category	**Zone 1**	**Zone 2**	**Zone 3**	Total
1	5	10	3	**18**
2	3	4	5	**12**
3	2	9	3	**14**
Total	**10**	**23**	**11**	**44**

d. Algorithm For Individual Cities

After identifying the locations where the charging infrastructures needs to be placed throughout Nebraska, each location has to be considered in order to determine the number of charging stations along with the number of charging ports required within the city for the Electric Vehicle owners to move in and about the city without having any range anxiety of running out of charge and no place to charge their batteries. These calculations has to be made with present data as well as forecasted data, so that planning can be made adequately for preparing the economy of a city to be ready with a plan. Algorithm used to calculate the number of charging stations includes a lot of factors which is a function of time and hence forecasting of the data is very important.

Some of the factors that is included in this algorithm are:

- City's Population
- Number of existing charging stations and ports
- Estimation of the number of electric vehicles in the city
- Traffic data of the city
- Priority of the city's location

A particular city's population changes over the course of time with people moving in and out of the city based on the city's development. Employment opportunities is an important factor which would determine how the city is developing and in turn will determine the economy of the city, traffic data of the place and the growth of vehicles. A lot of these data is addressed in Long Range Transportation Plan of the city and the State Wide Transportation Plans.

In our present ongoing research, an Efficient and Low-Cost Planning of Charging stations Network (ELPCN) is formulated which takes in to consideration the above mentioned factors and determines the number of charging stations for the city. A Non-dominated Sorting Genetic Algorithm (NSGA)-II based multi-objective optimization method would also be used to minimize the financial cost and the waiting time for charging. This algorithm is so formulated that it can be applied to different cities. The flowchart for ELPCN is shown in Figure 2.26.

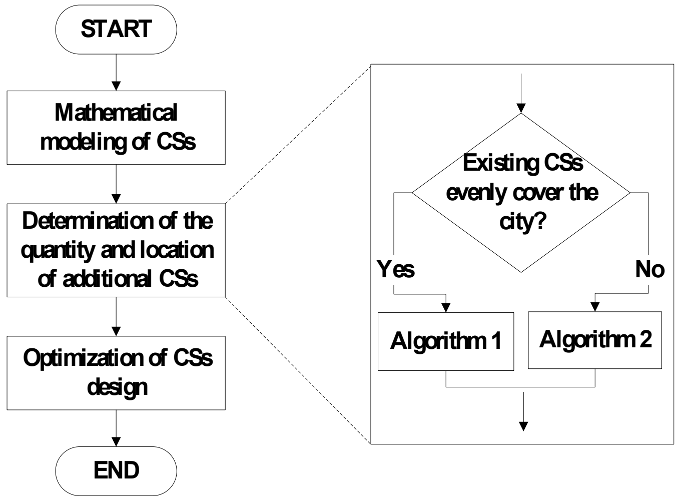

Figure 2.26: Flowchart for ELPCN method

To determine the number of additional charging stations in a city accurately, it must be checked whether the existing charging stations in the city is distributed evenly or not. This gives way to two scenarios:

a) SCENARIO I: The existing charging stations are evenly distributed all over the city.
b) SCENARIO II: The existing charging stations are not evenly distributed in the city.

For both of the scenarios, respective algorithms are to be applied to determine the number of charging stations. After the total number of charging stations in the city are determined, the number of ports is then considered. Ports that support efficient charging process for Electric Vehicles, has to be so determined that excessive ports may not cause waste of hardware installation and huge financial cost. Also, it has to be kept in mind that insufficient ports may lead to the increased waiting time for charging and thus affect the service quality. Therefore, the optimization problem should be modeled as multi-objective optimization. Non-dominated Sorting Genetic Algorithm II (NSGA-II) is seen to be the most efficient in terms of convergence and diversity functional analysis [11]. Three objective functions are designed:

- Minimizing the waiting time for charging (T)
- Minimizing the idle rate of the ports (σ)
- Minimizing the cost (C)

The city of Lincoln is chosen as the city of simulation for the analysis of ELPCN method. The existing number of charging stations in Lincoln is 18. The Scenario II has to be applied as the existing charging stations in Lincoln is not evenly distributed. Applying the necessary algorithm for Scenario II and assuming Level 2 charging station is to be considered, at least 6 new Level 2 charging stations are required. The recommendation for the locations should be adjusted in the certain area with the consideration of the local policy. So in this case the additional charging stations should be placed evenly at the east and south of the city if the local policies permit. Work is still ongoing on the forecasting aspect of the research as well as the optimizing the results to determine the number of charging ports.

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3. Long Range Transportation Plan Analysis

a. Introduction

In our research work, Long Range Transportation Plans have been studied for all of the 50 states and documented. The Long Range Transportation Plan (LRTP) is generally a 25-year plan, which would provide a prospective list of transportation projects to meet the future transportation needs in the area. This is achieved by analyzing demographic forecasts and current conditions of all modes of transportation including highways, roads, transit, bicycle and pedestrian facilities, aviation, and passenger rail. The Long Range Transportation Plan is updated every five years. This plan projects and have probable solutions, which is aimed to increase the quality of life for area residents [1].

b. LRTP across all U.S. States

In our research we focused on the section of LRTP which discusses Electric Vehicle prospective and their consequent charging stations. It was observed that out of 50 states 32 states mention Electric Vehicles and is shown in Figure 3.1. Figure 3.2 shows the documentation date of the LRTP of the state and LRTP plan year. The states which discusses Electric Vehicles did so for three main reasons which are:

- Reduction of Green House Gases (GHG)
- Concern for Motor Fuel Tax- Proposal of Vehicle Miles Traveled (VMT) tax to mitigate this problem
- Emerging technologies (like BEVs and hybrids) and the necessary charging infrastructures to support them

Figure 3.3 shows a Venn diagram which gives a detailed count on which states discuss Electric Vehicle prospective on what basis. Table 3.1 shows each of the 50 states in the U.S. on their stand on Electric Vehicles and the charging infrastructure in their LRTPs. The table shows the documentation date and year of plan of the LRTPs along with the states basis on mentioning Electric Vehicles and the charging infrastructures in their LRTPs.

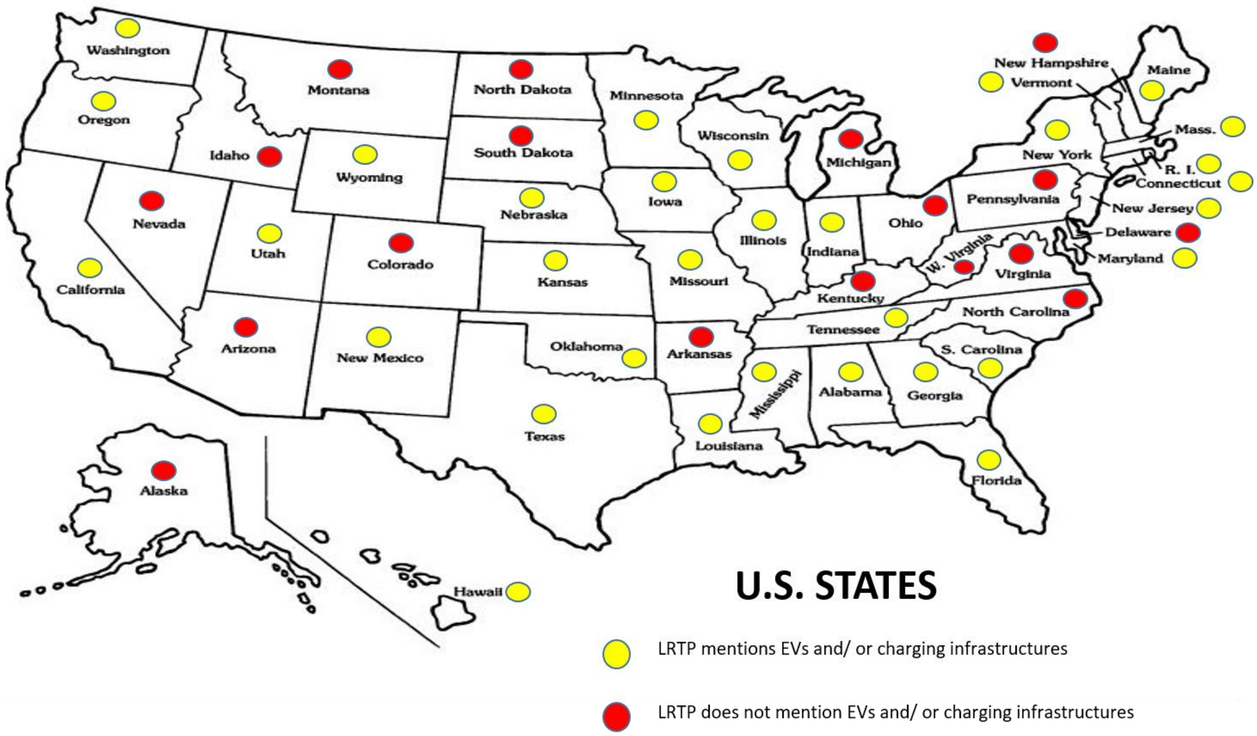


Figure 3.1: U.S. states where Electric Vehicles prospective is mentioned or not in LRTP

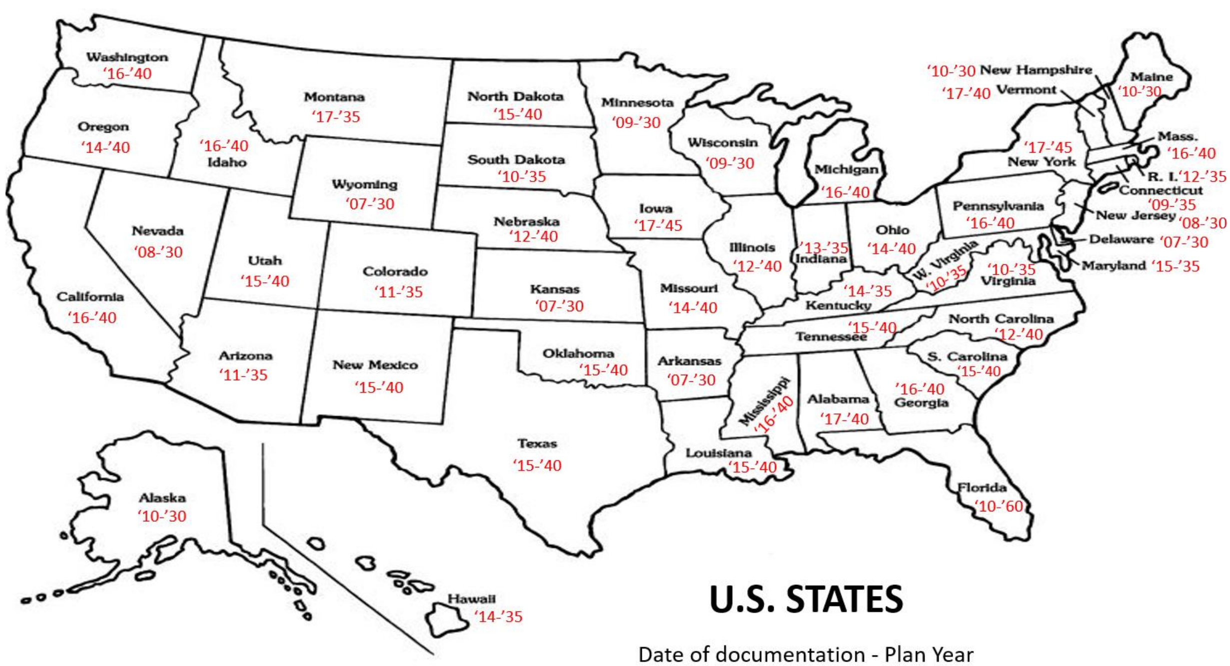


Figure 3.2: U.S. states showing the documentation date and Year of Plan of LRTP

Table 3.1: Details of LRTPs on individual states

States	Documented Date	Latest Plan	Discussion About Future Prospect Of Alternative Fuel Technology (Electric Vehicles)	Discussion About Environment-al Benefits Of Using Alternative Fuel Vehicles (Electric Vehicles)	Discussion About Concerns Of Using Alternative Fuel Vehicles (Electric Vehicles) On Motor Fuel Taxes	No Mention Of Electric Vehicles And Its Charging Infrastruct-ures In The LRTP
Alabama, AL	Jul '17	2040	✓			
Alaska, AK	Dec '10	2030				✓
Arizona, AZ	Nov '11	2035				✓
Arkansas, AR	2007	2030				✓
California, CA	Jun '16	2040		✓		
Colorado, CO	May '11	2035				✓
Connecticut, CT	Jun '09	2035	✓			
Delaware, DE	2007	2030				✓
Florida, FL	2010	2060	✓			
Georgia, GA	Jan '16	2040			✓	
Hawaii, HI	Jul '14	2035		✓		
Idaho, ID	May '16	2040				✓
Illinois, IL	2012	2040		✓	✓	
Indiana, IN	Apr '13	2035			✓	
Iowa, IA	May '17	2045		✓	✓	
Kansas, KS	2007	2030			✓	
Kentucky, KY	2014	2035				✓
Louisiana, LA	Dec '15	2040			✓	
Maine, ME	Jul '10	2030		✓	✓	
Maryland, MD	2015	2035	✓	✓		

Massachusetts, MA	2016	2040	✓			
Michigan, MI	Jul '16	2040				✓
Minnesota, MN	Dec '09	2030			✓	
Mississippi, MS	Jan '16	2040			✓	
Missouri, MO	Feb '14	2040	✓			
Montana, MT	Jun '17(D)	2035				✓
Nebraska, NE	2017(MAPA) Dec '11(Lincoln), Mar '12(SWP)	2050 (MAPA), 2040 (Lincoln) 2040 (SWP)	✓			
Nevada, NV	Sep '08	2030				✓
New Hampshire, NH	Jul '10	2030				✓
New Jersey, NJ	Oct '08	2030		✓		
New Mexico, NM	Sep '15	2040	✓			
New York, NY	Jun '17	2045	✓	✓		
North Carolina, NC	Aug '12	2040				✓
North Dakota, ND	Jan '15	2040				✓
Ohio, OH	May '14	2040				✓
Oklahoma, OK	Aug '15	2040	✓			
Oregon, OR	Jul '14	2040		✓		
Pennsylvania, PA	2016	2040				✓
Rhode Island, RI	Dec '12	2035		✓	✓	
South Carolina, SC	Aug '15	2040		✓		
South Dakota, SD	Sep '10	2035				✓
Tennessee, TN	2015	2040			✓	
Texas, TX	Feb '15	2040			✓	
Utah, UT	2015	2040	✓			

Vermont, VT	Jun '17(D)	2040			✓	
Virginia, VA	Nov '10	2035				✓
Washington, WA	2016	2040		✓		
West Virginia, WV	Jun '10	2035				✓
Wisconsin, WI	Oct '09	2030			✓	
Wyoming, WY	2007	2030		✓		

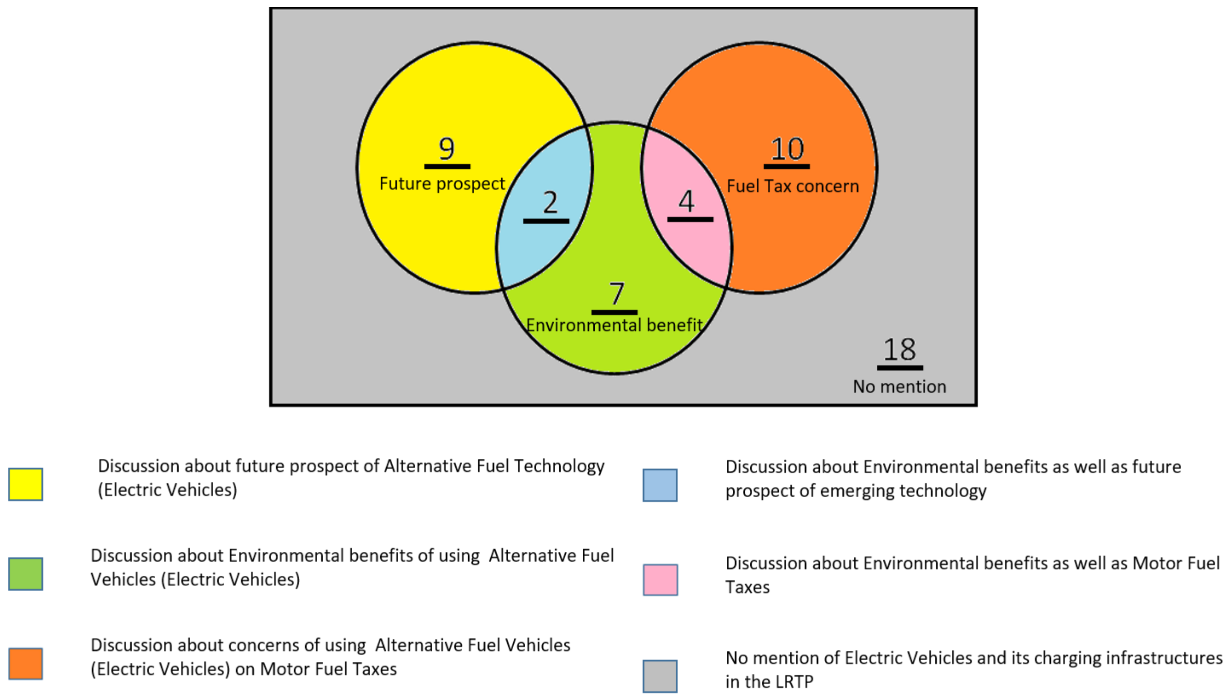


Figure 3.3: Venn diagram showing the classification basis of LRTP's mention for Electric Vehicles

Once all the LRTPs of all the states were documented, similar states to that of Nebraska were compared. Similarity were based on the following:

- Region basis: Midwest region and Oklahoma state
- Population Density Basis: The population of the state per total area of that state
- Number of Vehicles basis: Total number of vehicles in the state

c. LRTP analysis based on Midwest Region and Oklahoma State:

The states included were:

1. Illinois
2. Indiana
3. Iowa
4. Kansas
5. Michigan
6. Minnesota
7. Missouri
8. Nebraska
9. North Dakota
10. Ohio
11. Oklahoma
12. South Dakota
13. Wisconsin

Figure 3.4 shows the states being compared in the U.S. map and demonstrates whether the LRTPs' of those states mention Electric Vehicle and their charging infrastructures or not. Table 3.2 shows the states being compared in the U.S. and their views on Electric Vehicles and the charging infrastructure in their LRTPs. Figure 3.5 shows a Venn diagram which gives a visual count on which states that are being compared, discuss Electric Vehicle prospective on what basis.

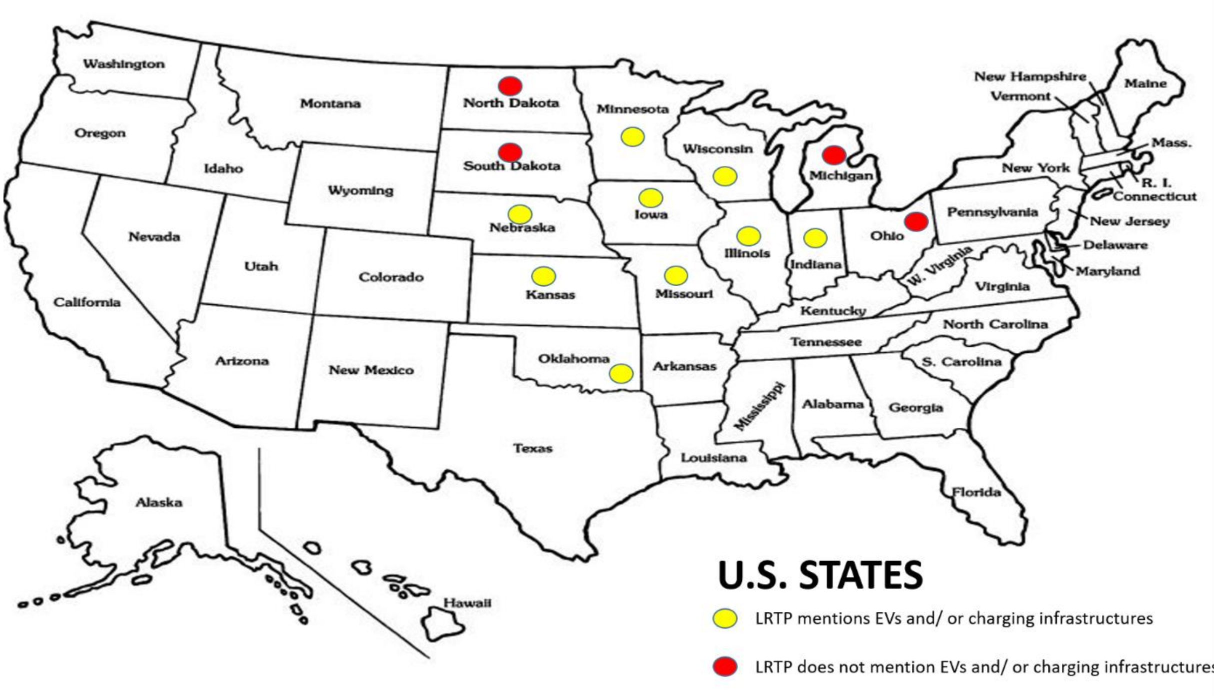


Figure 3.4: U.S. states based on their geographic location where Electric Vehicles prospective is mentioned or not in LRTP

Table 3.2: Comparison of LRTPs of U.S. states based on their geographic location

States	Future prospect of Alternative Fuel Technology	Environmental benefits of using Alternative Fuel Vehicles	Concerns of using Alternative Fuel Vehicles on Motor Fuel Taxes
Illinois	X	✓	✓
Indiana	X	X	✓
Iowa	X	✓	✓
Kansas	X	X	✓
Michigan	X	X	X
Minnesota	X	X	✓
Missouri	✓	X	X
Nebraska	✓	X	X
North Dakota	X	X	X
Ohio	X	X	X
Oklahoma	✓	X	X
South Dakota	X	X	X
Wisconsin	X	X	✓

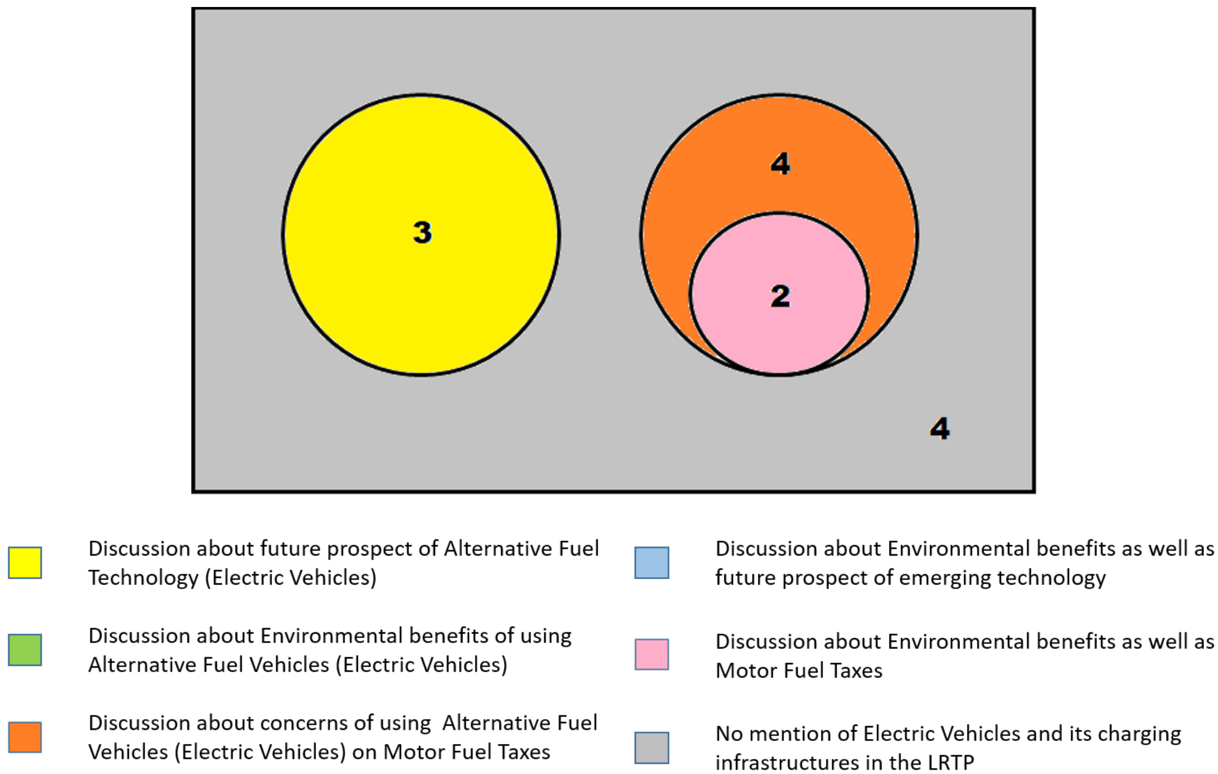


Figure 3.5: Venn diagram showing the classification basis of LRTP's mention for Electric Vehicles for comparison states

d. LRTP analysis based on Population Density

The states included were:

1. Colorado
2. Idaho
3. Kansas
4. Maine
5. Montana
6. Nebraska
7. Nevada
8. New Mexico
9. North Dakota
10. Oregon
11. South Dakota
12. Utah
13. Wyoming

Figure 3.6 shows the states being compared in the U.S. map and demonstrates whether the LRTPs' of those states mention Electric Vehicle and their charging infrastructures or not. Table 3.3 shows the states being compared in the U.S. and their views on Electric Vehicles and the charging infrastructure in their LRTPs. Figure 3.7 shows a Venn diagram which gives a visual count on which states that are being compared, discuss Electric Vehicle prospective on what basis.

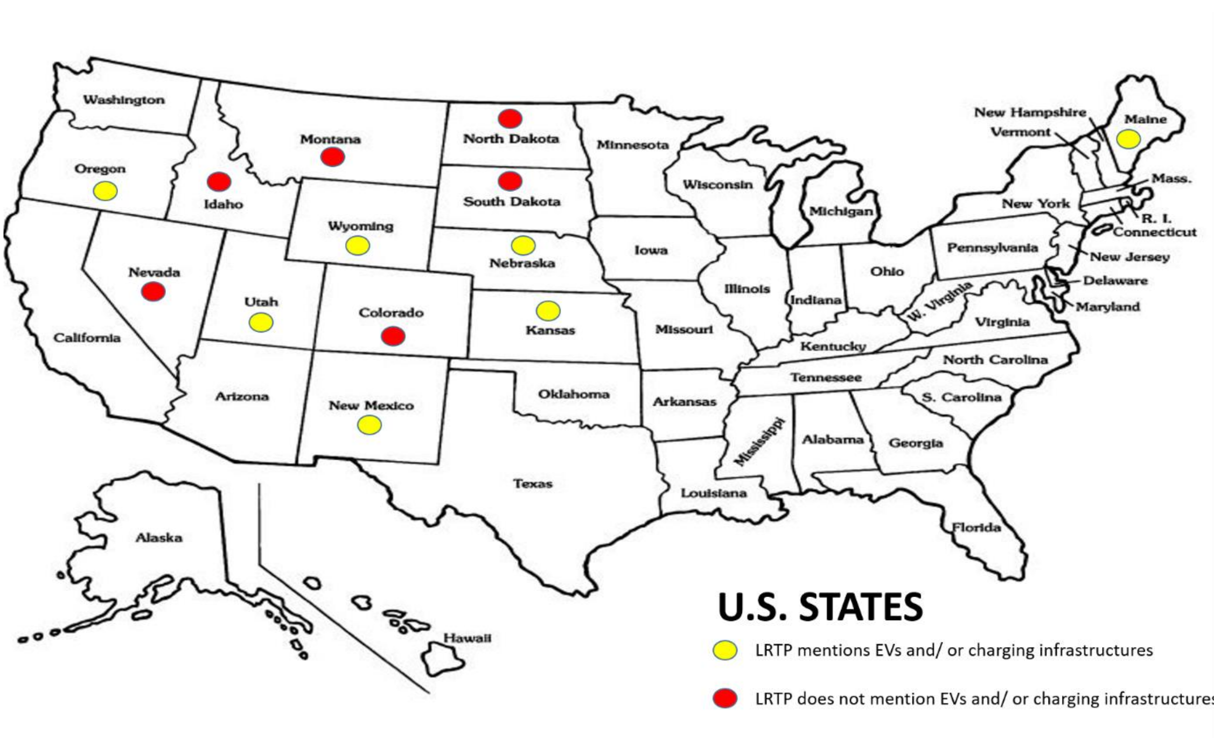
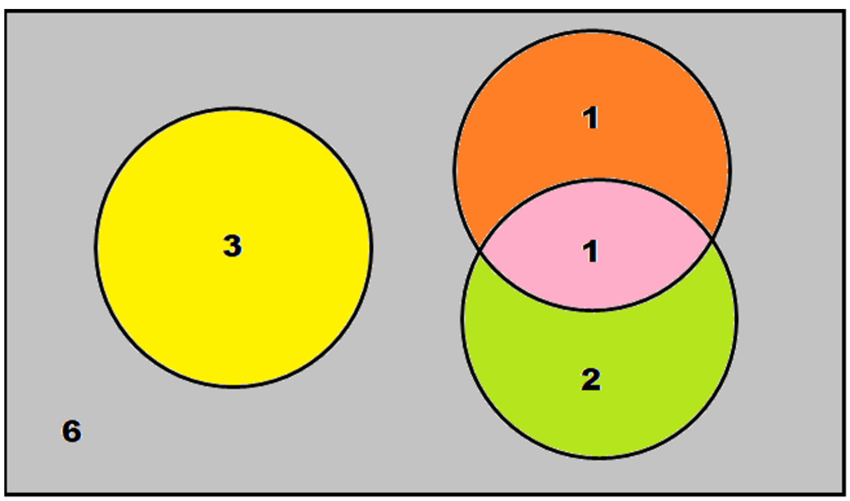


Figure 3.6: U.S. states based on their population density where Electric Vehicles prospective is mentioned or not in LRTP

Table 3.3: Comparison of LRTPs of U.S. states based on their population density

States	Future prospect of Alternative Fuel Technology	Environmental benefits of using Alternative Fuel Vehicles	Concerns of using Alternative Fuel Vehicles on Motor Fuel Taxes
Colorado	X	X	X
Idaho	X	X	X
Kansas	X	X	✓
Maine	X	✓	✓
Montana	X	X	X
Nebraska	✓	X	X
Nevada	X	X	X
New Mexico	✓	X	X
North Dakota	X	X	X
Oregon	X	✓	X
South Dakota	X	X	X
Utah	✓	X	X
Wyoming	X	✓	X



Discussion about future prospect of Alternative Fuel Technology (Electric Vehicles)

Discussion about Environmental benefits of using Alternative Fuel Vehicles (Electric Vehicles)

Discussion about concerns of using Alternative Fuel Vehicles (Electric Vehicles) on Motor Fuel Taxes

Discussion about Environmental benefits as well as future prospect of emerging technology

Discussion about Environmental benefits as well as Motor Fuel Taxes

No mention of Electric Vehicles and its charging infrastructures in the LRTP

Figure 3.7: Venn diagram showing the classification basis of LRTP's mention for Electric Vehicles for comparison states

e. LRTP analysis based on Total Number of Vehicles in the State

The states included were:

1. Arkansas
2. Hawaii
3. Idaho
4. Kansas
5. Mississippi
6. Nebraska
7. New Hampshire
8. New Mexico
9. Utah
10. West Virginia

Figure 3.8 shows the states being compared in the U.S. map and demonstrates whether the LRTPs' of those states mention Electric Vehicle and their charging infrastructures or not. Table 3.4 shows the states being compared in the U.S. and their views on Electric Vehicles and the charging infrastructure in their LRTPs. Figure 3.9 shows a Venn diagram which gives a visual count on which states that are being compared, discuss Electric Vehicle prospective on what basis.

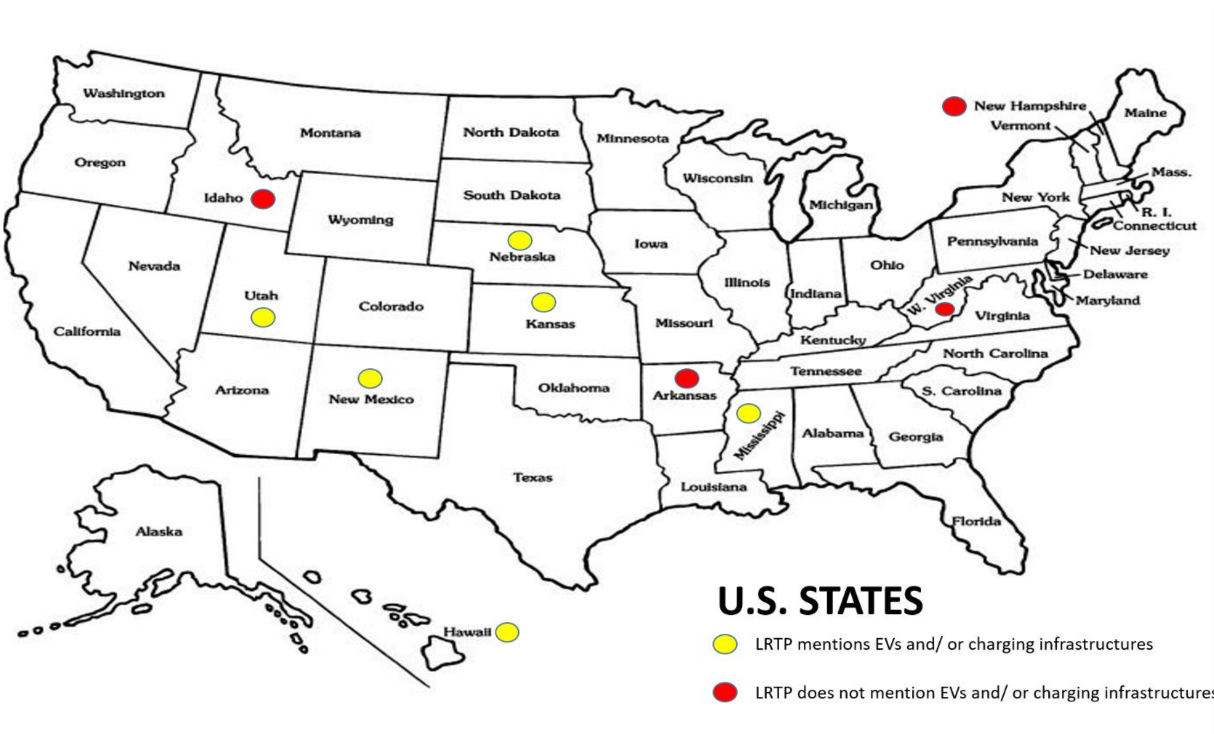


Figure 3.8: U.S. states based on the number of vehicles in the state where Electric Vehicles prospective is mentioned or not in LRTP

Table 3.4: Comparison of LRTPs of U.S. states based on the number of vehicles in the state

States	Future prospect of Alternative Fuel Technology	Environmental benefits of using Alternative Fuel Vehicles	Concerns of using Alternative Fuel Vehicles on Motor Fuel Taxes
Arkansas	X	X	X
Hawaii	X	✓	X
Idaho	X	X	X
Kansas	X	X	✓
Mississippi	X	X	✓
Nebraska	✓	X	X
New Hampshire	X	X	X
New Mexico	✓	X	X
Utah	✓	X	X
West Virginia	X	X	X

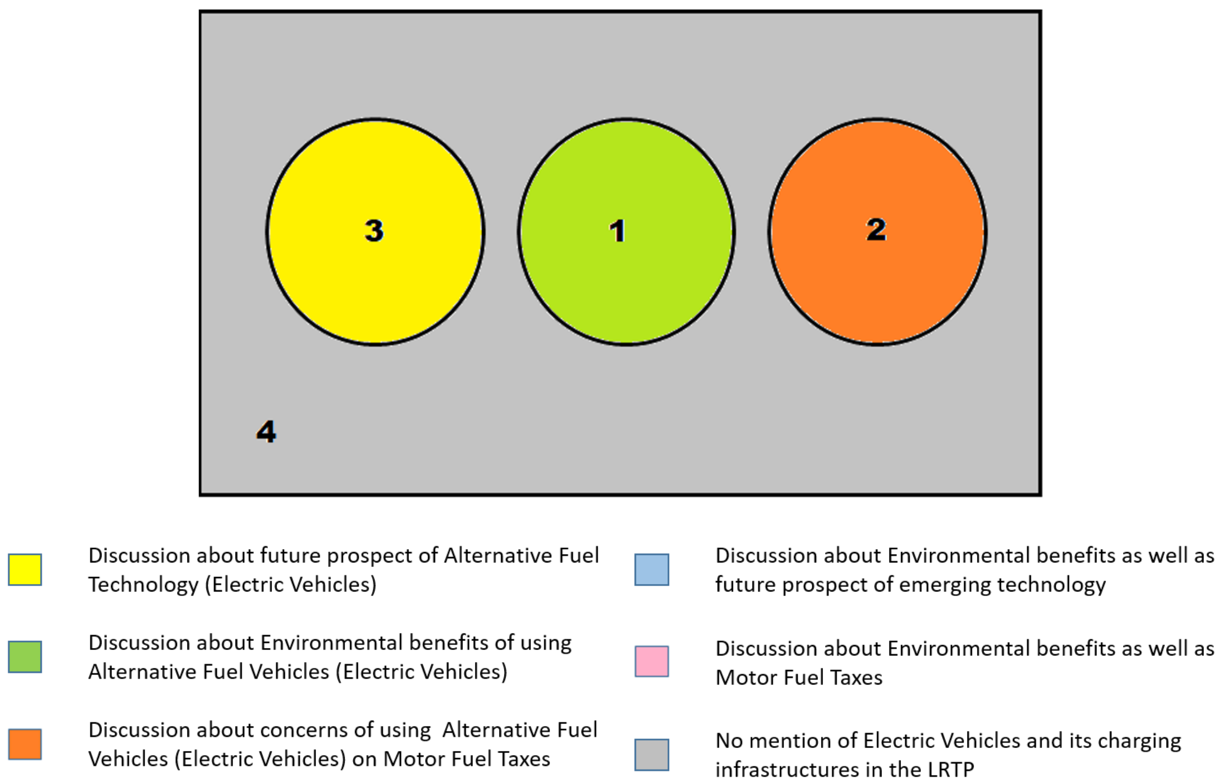


Figure 3.9: Venn diagram showing the classification basis of LRTP's mention for Electric Vehicles for comparison states

References

[1] "Long Range Transportation Plan | Metropolitan Area Planning Agency", Metropolitan Area Planning Agency. [Online]. Available: http://mapacog.org/projects/lrtp/. [Accessed: 24- Sep- 2017].

4. Environmental Benefits of Electrified Transportations

a. Introduction

Greenhouse Gas emission (GHG) data are provided for the following transportation vehicles:

- CV: Vehicles that use gasoline (Conventional Vehicles)
- DV: Vehicles that use Diesel (Diesel Vehicles)
- CNG: Vehicles that use Compressed Natural Gas
- BEV: Vehicles that use electricity (Battery Electric Vehicles)

With respect to Battery Electric Vehicles (BEVs), the calculations are based on how the electricity is generated (what primary energy sources are used in this production and their percentages). This report looks at the following utility companies in Nebraska:

- Omaha Public Power District (OPPD)
- Nebraska Public Power District (NPPD)
- Lincoln Electric System (LES)

The section looks into current and future primary energy sources in use and/or proposed for the generation of electricity by each utility. This information has been obtained from public published information or directly from the utility company via personal contacts.

b. Greenhous Gas Definitions

A greenhouse gas is a gas that contributes to the greenhouse effect by infrared radiation produced by solar warming of the earth's surface. The following information provides a definition of each type of GHG emission and detailed analysis of how these GHG emissions are calculated along with supporting references.

Carbon Dioxide Equivalent (CO2 Equiv.)

The CO2 equivalent gives a total emissions factor for the three most common greenhouse gasses, CO2, CH4, and N2O. Each of the three gasses is multiplied by its global warming potential (GWP) shown below which accounts for the potency of each gas [1]. For example, CH4 has a GWP of 28 which means that one gram of CH4 has the same effect on the climate as 28 grams of CO2. The 100-year time is the period in which the GWP is measured. Certain gasses are more harmful in the short term or in the long term so the 100-year value is usually used as a good average. The equation below, in Table 4.1, shows the formula for calculating CO2 equivalent emissions.

Table 4.1 CO2 Equivalence formula

	100-year GWP value
Carbon Dioxide (CO2)	1
Methane (CH4)	28
Nitrous Oxide (N2O)	265

CO2 Equivalent = 1*CO2 emissions + 28*CH4 emissions + 265*N2O emissions

Carbon Dioxide (CO_2)

Carbon dioxide is the most common greenhouse gas and makes up 76% of all GHG emissions. The majority of CO_2 emissions come directly from electricity generation, transportation, and industry while a smaller fraction comes indirectly from deforestation, increased agriculture, and other activities that reduce the amount of natural land.

Carbon Monoxide (CO)

Carbon monoxide is a very weak direct greenhouse gas, but has important indirect effects on global warming. CO reacts with hydroxyl (OH) radicals in the atmosphere, reducing their abundance.

Methane (CH_4)

Methane is the second most common greenhouse gas at 16% and is also the main component of natural gas. When released into the atmosphere it reacts to form CH_3 and water vapor which is the most potent of greenhouse gasses. Methane is far worse in the short term with a 20 year GWP of 84. The long term GWP of methane is 28.

Nitrous Oxide (N_2O)

Nitrous oxide is the third most common greenhouse gas at 6% of all GHG emissions. N_2O reacts with the air to produce nitric oxide (NO) which then reacts with the ozone layer. N_2O is extremely potent and has a GWP factor 265 times that of CO_2.

Sulfur Dioxide (SO_2)

Exposure to sulfur dioxide can have significant impacts to the human respiratory system. Short term exposure to SO_2 can make breathing difficult and the effect is worse for children, the elderly, and those with asthma. SO_2 also contributes to formation of acid rain.

Nitrogen Oxides (NO_x)

Nitrogen oxides can also cause breathing problems for healthy people and especially for those with asthma. The EPA measured that NO_x concentrations inside vehicles can be 2-3 times higher than at locations away from roadways. Nitrogen oxides also react in the air to produce smog and acid rain.

Volatile Organic Compounds (VOC)

Volatile organic compounds cause many problems as indoor and outdoor air pollutants. Outdoor VOC emissions can create photochemical smog. VOCs are any compound of carbon, not including carbon dioxide, carbon monoxide, carbonic acid, metallic carbides, and ammonium carbonate [23].

c. GHG Emissions Summary

The following parts, provide a general description for each utility company and a summary of the greenhouse gas emissions.

1. Omaha Public Power District (OPPD)

Omaha Public Power District is a publicly owned electric utility that serves a population of 799,000 people, more than any other electric utility in the state. While its headquarters is located in Omaha, Neb., OPPD has several other locations in its 13-county, 5,000-square-mile service area in southeast Nebraska. The majority of OPPD's power comes from three baseload power facilities: North Omaha Station and Nebraska City Station, both coal-fired, and Fort Calhoun Station, a nuclear power unit. The tables below do not take into account the recent plans to shut down the Fort Calhoun Station. Instead it uses published data for their 2018 and 2033 vision as the base for the calculations. Table 4.2 and 4.3 provide a summary of GHG emissions for each vehicle type based on the primary energy source used for one mile and for one year.

TABLE 4.2: Greenhouse Gas Emissions (grams per mile) for OPPD utility company

Emissions (grams per mile)	**CV**	**DV**	**CNG**	**BEV**		
				OPPD 2015 (10% renewable)	**OPPD 2018 Plan (33% renewable)**	**OPPD 2033 Plan (32% renewable)**
CO2 Equiv.	415	377	334	180	88	85
CO2	411	377	311	179	88	85
CO	9.4	0.3001	17.75	0.067	0.03	0.06298
CH4 (Methane)	0.013	0.001	0.48	0.002	0.001	0.001
N2O	0.012	0.001	0.0375	0.003	0.0013	0.0006
NOx	0.252	0.451	0.29	0.159	0.077	0.065
SO2	0.012	0.009	0.0016	0.37	0.17	0.08
VOC	0.2096	0.1610	0.237	0.0031	0.0015	0.0021

TABLE 4.3: Greenhouse Gas Emissions in lbs. for one year using an average driving distance of 12,000 miles. (1 lb. = 453.592 g)

Emissions per year (lbs.)	**CV**	**DV**	**CNG**	**BEV**		
				OPPD 2015 (10% Renewable)	**OPPD 2018 Plan (33% renewable)**	**OPPD 2033 Plan (32% Renewable)**
CO2 Equiv.	10,979	9,973	8,836	4,752	2,332	2,249
CO2	10,873	9,973	8,227	4,726	2,323	2,244
CO	248.7	7.94	469.6	1.77	0.79	1.66
CH4 (Methane)	0.343	0.026	12.7	0.053	0.026	0.026
N2O	0.317	0.026	0.99	0.079	0.034	0.016
NOx	6.65	11.9	7.66	4.20	2.03	1.72
SO2	0.317	0.238	0.042	9.77	4.49	2.11
VOC	5.55	4.26	6.27	0.082	0.040	0.056

2. Nebraska Public Power District (NPPD)

NPPD's revenue is mainly derived from wholesale power supply agreements with 46 towns and 25 rural public power districts and rural cooperatives who rely totally or partially on NPPD's electrical system. NPPD also serves about 80 communities at the retail level. Over 5,200 miles of transmission lines make up the NPPD electrical grid system, which delivers power to about 600,000 Nebraskans.

Table 4.4 and Table 4.5 provide a summary of GHG emissions for each vehicle type based on the primary energy source used in each vehicle type for one mile and for one year.

TABLE 4.4: Greenhouse Gas Emissions Factors (grams per mile) for NPPD utility company

Emissions (grams per mile)	**CV**	**DV**	**CNG**	**BEV**
				NPPD 2015 (12% Renewable)
CO2 Equiv.	415	377	334	132
CO2	411	377	311	131
CO	9.4	0.3001	17.75	0.0465
CH4 (Methane)	0.013	0.001	0.48	0.001
N2O	0.012	0.001	0.0375	0.002
NOx	0.252	0.451	0.29	0.145
SO2	0.012	0.009	0.0016	0.330
VOC	0.2096	0.1610	0.237	0.0021

TABLE 4.5: Greenhouse Gas Emissions in lbs. for one year using an average driving distance of 12,000 miles. (1 lb. = 453.592 g).

Emissions per year (lbs.)	**CV**	**DV**	**CNG**	**BEV**
				NPPD 2015 (12% Renewable)
CO2 Equiv.	10,979	9,973	8,836	3,485
CO2	10,873	9,973	8,227	3,458
CO	248.7	7.94	469.6	1.23
CH4 (Methane)	0.343	0.026	12.7	0.026
N2O	0.317	0.026	0.99	0.053
NOx	6.65	11.9	7.66	3.83
SO2	0.317	0.238	0.042	8.71
VOC	5.55	4.26	6.27	0.056

3. Lincoln Electric System (LES)

LES services approximately 200 square miles within Lancaster County in Nebraska, comprising the cities of Lincoln, Prairie Home, Waverly, Walton, Cheney, and Emerald. Approximately 118,518 residential customers and 16,649 commercial and industrial customers.

Table 4.6 and Table 4.7 provide a summary of GHG emissions for each vehicle type based on the primary energy source used in each vehicle type for one mile and for one year.

TABLE 4.6: Greenhouse Gas Emissions Factors (grams per mile) for LES utility company

Emissions (grams per mile)	**CV**	**DV**	**CNG**	**BEV**	
				LES 2015 (17% Renewable)	**LES 2016 (47.1% Renewable)**
CO2 Equiv.	415	377	334	241	121.68
CO2	411	377	311	241	121.29
CO	9.4	0.3001	17.75	0.0845	0.0373
CH4 (Methane)	0.013	0.001	0.48	0.0027	0.0017
N2O	0.012	0.001	0.0375	0.0038	0.0013
NOx	0.252	0.451	0.29	0.27	0.2
SO2	0.012	0.009	0.0016	0.61	0.107
VOC	0.2096	0.1610	0.237	0.0042	0.0032

TABLE 4.7: Greenhouse Gas Emissions in lbs. for one year using an average driving distance of 12,000 miles. (1 lb. = 453.592 g)

Emissions per year (lbs.)	**CV**	**DV**	**CNG**	**BEV**	
				LES 2015 (17% Renewable)	**LES 2016 (47.1% Renewable)**
CO2 Equiv.	10,979	9,973	8,836	6,376	3219.1
CO2	10,873	9,973	8,227	6,376	3208.78
CO	248.7	7.94	469.6	2.24	0.986
CH4 (Methane)	0.343	0.026	12.7	0.071	0.0441
N2O	0.317	0.026	0.99	0.101	0.0343
NOx	6.65	11.9	7.66	7.14	5.291
SO2	0.317	0.238	0.042	16.14	2.83
VOC	5.55	4.26	6.27	0.111	0.085

d. Detailed GHG Calculations

1. Conventional Vehicle (CV)

Carbon Dioxide (CO2) Emissions

The EPA has calculated that the average US vehicle emits 411 grams of CO2 per mile [2]. The calculation below shows how they arrived at this number.

CO2 emissions from burning 1 gallon of gasoline = 8,887 grams

Average fuel economy as of 2012 = 21.6 mpg

CO2 emissions per mile = 8,887 / 21.6 = **411 grams CO2 per mile**

Methane (CH4) Emissions

In 2004 the EPA found that the average US passenger car emits **0.013 grams of CH4 per mile** [3].

Nitrous Oxide (N2O) Emissions

In 2004 the EPA found that the average US passenger car emits **0.012 grams of N2O per mile** [3].

Carbon Monoxide (CO) Emissions

In 2008 the EPA found that the average US passenger car emits **9.4 grams of CO per mile** [4].

Sulfur Dioxide (SO2) Emissions

Using the 2004 model year for consistency with the above values, the average 2004 vehicle emits **0.012 grams of SO2 per mile** [5].

Nitrogen Oxides (NOx) Emissions

The study as above found that the average 2004 vehicle emits **0.252 grams of NOx per mile** [5].

Volatile Organic Compound (VOC) Emissions

The study as above found that the average 2001 gasoline vehicle emits **0.2096 grams of VOC per mile** [5].

Carbon Dioxide Equivalent Emissions

Using the individual emissions values calculated above, CVs have a CO2 equivalent emissions rate of **415 grams CO2 per mile.**

CO2 Equiv. = (1*411) + (28*0.013) + (265*0.012) = 415 g

2. Diesel Vehicle (DV)

Carbon Dioxide (CO2) Emissions

There aren't many figures documenting average diesel mpg over the years but for comparison we selected a standard 2005 Volkswagen Passat diesel achieving 27 mpg.

CO2 emissions from burning 1 gallon of diesel = 10,180 grams [2]

Average fuel economy = 27 mpg [6]

CO2 emissions per mile = 10,180 / 27 = **377 grams CO2 per mile**

Methane (CH_4) Emissions

A 2004 study by the EPA found that average diesel vehicles emits **0.001 grams CH_4 per mile** [3].

Nitrous Oxide (N_2O) Emissions

The same study by the EPA found that average diesel vehicles emits 0**.001 grams N_2O per mile** [3].

Carbon Monoxide (CO) Emissions

The same 2004 study showed that the average diesel vehicle emits **0.3001 grams of CO per mile** [5].

Nitrogen Oxides (NO_x) Emissions

A 2013 study found the emissions rate for a model year 2006 diesel passenger vehicle to be **0.451 grams NO_x per mile** [5].

Sulfur Dioxide (SO_2) Emissions

The same 2013 study found the emission rate to be **0.0092 grams SO_2 per mile** [5].

Volatile Organic Compound (VOC) Emissions

The study as above found that the average 2001 diesel vehicle emits **0.1610 grams of VOC per mile** [5].

Carbon Dioxide Equivalent (CO_2) Emissions

Using the individual emission rates calculated ABOVE, the CO_2 equivalent rate is **377 grams CO_2 per mile.**

3. Compressed Natural Gas Vehicle (CNG)

Carbon Dioxide (CO_2) Emissions

Vehicles converted to CNG generally achieve a mpg equivalent similar to its mpg rating when running on gasoline. The calculation below is for the average vehicle getting 21.6 mpg.

CO_2 emitted from burning natural gas = 53.1 grams CO_2 per cubic feet [7]

Convert cubic feet to gallons = 126.67 cubic feet per gallon

Emissions per mile = 53.115 * 126.67 / 21.6 = **311 grams CO_2 per mile**

Methane (CH_4) Emissions

A 2002 study found that CNG light duty vehicles emit **0.48 grams of CH_4 per mile** [8].

Nitrous Oxide (N_2O) Emissions

The same 2002 study as above found that CNG light duty vehicles emit **0.0375 grams of N_2O per mile** [8].

Carbon Monoxide (CO) Emissions

A 2008 study found that CNG refuse trucks emit **17.75 grams of CO per mile** [9]**.**

Nitrogen Oxides (NO_x) Emissions

The same 2008 study found that CNG passenger vehicles emit **0.29 grams NO_x per mile** [9].

Sulfur Dioxide (SO_2) Emissions

Calculation below is for a 21.6 mpg vehicle.

SO2 emitted when burning natural gas = 272.2 grams per million cubic feet [10].

Convert cubic feet to gallon = 126.67 cubic feet per gallon

Emissions per mile = 272.2 / 1,000,000 * 126.67 / 21.6 = **0.0016 grams SO2 per mile.**

Volatile Organic Compound (VOC) Emissions

The 2008 study as above found that CNG passenger vehicles emits **0.237 grams of VOC per mile** [9].

Carbon Dioxide Equivalent (CO2) Emissions

Using the individual emissions values calculated above, CNG passenger vehicles have a CO2 equivalent emissions rate of **334 grams CO2 per mile.**

4. Battery Electric Vehicle (BEV) – Based on OPPD Data

Vehicle Efficiency Calculation

The majority of the BEVs in this project are Nissan LEAFs. This vehicle has an EPA city/highway rating of 126/101 MPGe [11]. Since BEVs are almost entirely used for city driving we will only use the 126 MPGe rating for our calculations. Below shows the conversion from MPGe to miles per kWh.

1 gallon equivalent = 33.7 kWh (it takes 33.7 kWh to create the same amount of heat as burning 1 gallon of gasoline) [11]

126 MPGe / 33.7 kWh/gallon = **3.7 miles per kWh**

Electricity Generation Mix

The data for the actual generation mix in 2015 was given by request to OPPD. The planned 2018 and 2033 mixes are taken from OPPD's energy portfolio webpage. However, these plans have not been updated recently and have not taken into account the likely shutdown of the Fort Calhoun station, OPPD's only nuclear plant [12].

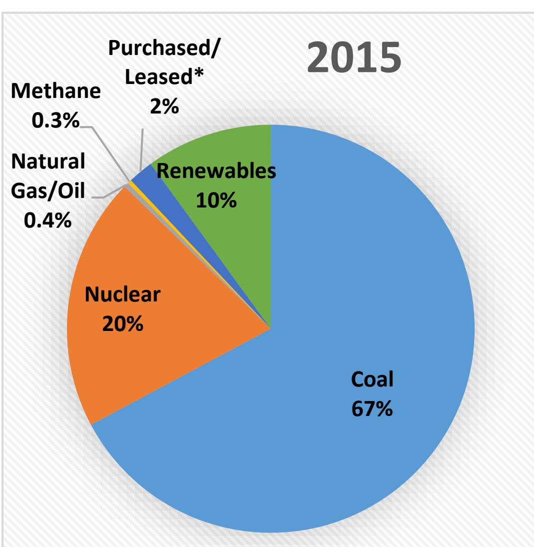


Figure 4.1: 2015 Electricity Generation Mix

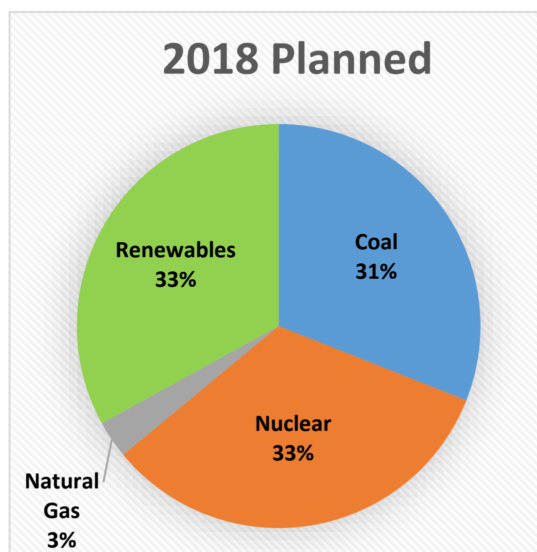


Figure 4.2: 2018 Planned Electricity Generation Mix

*Purchased/leased electricity is primarily hydroelectric

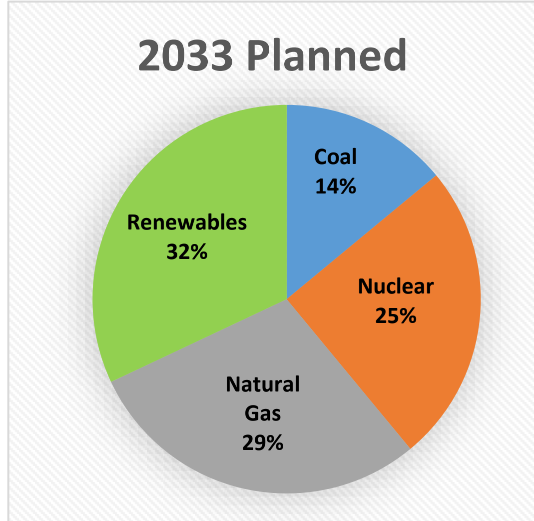


Figure 4.3: 2033 Planned Electricity Generation Mix

Greenhouse gas emissions per kWh for each fuel type are taken from EPA eGRID database which measures GHG emissions for every power plant in the US. The numbers shown below only use the emissions per kWh for the actual OPPD stations [13]. Detailed calculations and raw data can be found in the Plant Emission Rates spreadsheet.

Carbon Dioxide Equivalent (CO2) Emissions

2015 Actual – Using the individual emission rates calculated below, the equivalent rate is **180 grams CO2 per mile.**
2018 Planned – **88 grams CO2 per mile.**
2033 Planned – **85 grams CO2 per mile.**

Carbon Dioxide (CO2) Emissions

Table 4.8: 2015 Actual CO2 Emissions

Energy Source	Percentage of Total Energy Production		Grams of CO2 Emitted per kWh [13]		Contribution to Total CO2 Emitted per kWh
Coal	67%	x	986g	=	661g
Natural Gas	0.4%	x	607g	=	2.4g
Landfill Gas	0.3%	x	3.1g	=	0g
Nuclear	20.2%	x	0	=	0
Renewables	12%	x	0	=	0
			Total	=	663g per kWh or 179g per mile

Table 4.9: 2018 Planned CO2 Emissions

Energy Source	Percentage of Total Energy Production		Grams of CO2 Emitted per kWh		Contribution to Total CO2 Emitted per kWh
Coal	31%	x	986g	=	306g
Natural Gas	3%	x	607g	=	18g
Nuclear	33%	x	0	=	0
Renewables	33%	x	0	=	0
			Total	=	324g per kWh or 88g per mile

Table 4.10: 2033 Planned CO2 Emissions

Energy Source	Percentage of Total Energy Production		Grams of CO2 Emitted per kWh		Contribution to Total CO2 Emitted per kWh
Coal	14%	x	986g	=	138g
Natural Gas	29%	x	607g	=	176g
Nuclear	33%	x	0	=	0
Renewables	33%	x	0	=	0
			Total	=	314g per kWh or 85g per mile

Carbon Monoxide (CO) Emissions

Table 4.11: 2015 Actual CO Emissions

Energy Source	Percentage of Total Energy Production		Grams of CO Emitted per kWh [19]		Contribution to Total CO Emitted per kWh
Coal	67%	x	0.321g	=	0.21635g
Natural Gas	0.4%	x	0.0662g	=	0.000248g
Landfill Gas	0.3%	x	2.68g	=	0.00804g
Nuclear	20.2%	x	0	=	0
Renewables	12%	x	0	=	0
			Total	=	0.225g per kWh or 0.067g per mile

Table 4.12: 2018 Planned CO Emissions

Energy Source	Percentage of Total Energy Production		Grams of CO Emitted per kWh		Contribution to Total CO Emitted per kWh
Coal	31%	x	0.321g	=	0.09951g
Natural Gas	3%	x	0.062g	=	0.00186g
Nuclear	33%	x	0	=	0
Renewables	33%	x	0	=	0
			Total	=	0.10137g per kWh or 0.03g per mile

Table 4.13: 2033 Planned CO Emissions

Energy Source	Percentage of Total Energy Production		Grams of CO Emitted per kWh		Contribution to Total CO Emitted per kWh
Coal	14%	x	0.321g	=	0.045g
Natural Gas	29%	x	0.062g	=	0.01798g
Nuclear	33%	x	0	=	0
Renewables	33%	x	0	=	0
			Total	=	0.06298g per kWh or 0.01878g per mile

Methane (CH4) Emissions

Table 4.14: 2015 Actual CH4 Emissions

Energy Source	Percentage of Total Energy Production		Grams of CH4 Emitted per kWh [13]		Contribution to Total CH4 Emitted per kWh
Coal	67%	x	0.011g	=	0.007g
Natural Gas	0.4%	x	0.012g	=	0
Landfill Gas	0.3%	x	0	=	0
Nuclear	20.2%	x	0	=	0
Renewables	12%	x	0	=	0
			Total	=	0.007g per kWh or 0.002g per mile

Table 4.15: 2018 Planned CH4 Emissions

Energy Source	Percentage of Total Energy Production		Grams of CH4 Emitted per kWh		Contribution to Total CH4 Emitted per kWh
Coal	31%	x	0.011g	=	0.003g
Natural Gas	3%	x	0.011g	=	0
Nuclear	33%	x	0	=	0
Renewables	33%	x	0	=	0
			Total	=	0.003g per kWh or 0.001g per mile

Table 4.16: 2033 Planned CH4 Emissions

Energy Source	Percentage of Total Energy Production		Grams of CH4 Emitted per kWh		Contribution to Total CH4 Emitted per kWh
Coal	14%	x	0.011g	=	0.002g
Natural Gas	29%	x	0.012g	=	0.003g
Nuclear	33%	x	0	=	0
Renewables*	33%	x	0	=	0
			Total	=	0.005g per kWh or 0.001g per mile

Nitrous Oxide (N2O) Emissions

Table 4.17: 2015 Actual N2O Emissions

Energy Source	Percentage of Total Energy Production		Grams of N2O Emitted per kWh [13]		Contribution to Total N2O Emitted per kWh
Coal	67%	x	0.016g	=	0.011g
Natural Gas	0.4%	x	0.001g	=	0
Landfill Gas	0.3%	x	0	=	0
Nuclear	20.2%	x	0	=	0
Renewables	12%	x	0	=	0
			Total	=	0.011g per kWh or 0.003g per mile

Table 4.18: 2018 Planned N2O Emissions

Energy Source	Percentage of Total Energy Production		Grams of N2O Emitted per kWh		Contribution to Total N2O Emitted per kWh
Coal	31%	x	0.016g	=	0.005g
Natural Gas	3%	x	0.001g	=	0
Nuclear	33%	x	0	=	0
Renewables	33%	x	0	=	0
			Total	=	0.005g per kWh or 0.0013g per mile

Table 4.19: 2033 Planned N2O Emissions

Energy Source	Percentage of Total Energy Production		Grams of N2O Emitted per kWh		Contribution to Total N2O Emitted per kWh
Coal	14%	x	0.016g	=	0.002g
Natural Gas	29%	x	0.001g	=	0
Nuclear	33%	x	0	=	0
Renewables*	33%	x	0	=	0
			Total	=	0.002g per kWh or 0.0006g per mile

Sulfur Dioxide (SO2) Emissions

Table 4.20: 2015 Actual SO2 Emissions

Energy Source	Percentage of Total Energy Production		Grams of SO2 Emitted per kWh [13]		Contribution to Total SO2 Emitted per kWh
Coal	67%	x	2.05g	=	1.37g
Natural Gas	0.4%	x	0.005g	=	0
Landfill Gas	0.3%	x	0	=	0
Nuclear	20.2%	x	0	=	0
Renewables	12%	x	0	=	0
			Total	=	1.37g per kWh or 0.37g per mile

Table 4.21: 2018 Planned SO2 Emissions

Energy Source	Percentage of Total Energy Production		Grams of SO2 Emitted per kWh		Contribution to Total SO2 Emitted per kWh
Coal	31%	x	2.05g	=	0.636g
Natural Gas	3%	x	0.005g	=	0
Nuclear	33%	x	0	=	0
Renewables	33%	x	0	=	0
			Total	=	0.64g per kWh or 0.17g per mile

Table 4.22: 2033 Planned SO2 Emissions

Energy Source	Percentage of Total Energy Production		Grams of SO2 Emitted per kWh		Contribution to Total SO2 Emitted per kWh
Coal	14%	x	2.05g	=	0.287g
Natural Gas	29%	x	0.005g	=	0.001g
Nuclear	33%	x	0	=	0
Renewables*	33%	x	0	=	0
			Total	=	0.29g per kWh or 0.08g per mile

Nitrogen Oxides (NOx) Emissions

Table 4.23: 2015 Actual NOx Emissions

Energy Source	Percentage of Total Energy Production		Grams of NOx Emitted per kWh [13]		Contribution to Total NOx Emitted per kWh
Coal	67%	x	0.876g	=	0.587g
Natural Gas	0.4%	x	0.401g	=	0.002g
Landfill Gas	0.3%	x	0.037g	=	0g
Nuclear	20.2%	x	0	=	0
Renewables	12%	x	0	=	0
			Total	=	0.589g per kWh or 0.159g per mile

Table 4.24: 2018 Planned NOx Emissions

Energy Source	Percentage of Total Energy Production		Grams of NOx Emitted per kWh		Contribution to Total NOx Emitted per kWh
Coal	31%	x	0.876g	=	0.272g
Natural Gas	3%	x	0.401g	=	0.012g
Nuclear	33%	x	0	=	0
Renewables	33%	x	0	=	0
			Total	=	0.284g per kWh or 0.077g per mile

Table 4.25: 2033 Planned NOx Emissions

Energy Source	Percentage of Total Energy Production		Grams of NOx Emitted per kWh		Contribution to Total NOx Emitted per kWh
Coal	14%	x	0.876g	=	0.123g
Natural Gas	29%	x	0.401g	=	0.116g
Nuclear	33%	x	0	=	0
Renewables*	33%	x	0	=	0
			Total	=	0.239g per kWh or 0.065g per mile

Volatile Organic Compound (VOC) Emissions

Table 4.26: 2015 Actual VOC Emissions

Energy Source	Percentage of Total Energy Production		Grams of VOC Emitted per kWh [21],[22]		Contribution to Total VOC Emitted per kWh
Coal	67%	x	0.014g	=	0.0093800g
Natural Gas	0.4%	x	0.0169g	=	0.0000676g
Landfill Gas	0.3%	x	0.272g	=	0.0008160g
Nuclear	20.2%	x	0	=	0
Renewables	12%	x	0	=	0
			Total	=	0.0102636g per kWh or 0.0031g per mile

Table 4.27: 2018 Planned VOC Emissions

Energy Source	Percentage of Total Energy Production		Grams of VOC Emitted per kWh [21],[22]		Contribution to Total VOC Emitted per kWh
Coal	31%	x	0.014g	=	0.00434g
Natural Gas	3%	x	0.0169g	=	0.000507g
Nuclear	33%	x	0	=	0
Renewables	33%	x	0	=	0
			Total	=	0.004847g per kWh or 0.0015g per mile

Table 4.28: 2033 Planned VOC Emissions

Energy Source	Percentage of Total Energy Production		Grams of VOC Emitted per kWh [21],[22]		Contribution to Total VOC Emitted per kWh
Coal	14%	x	0.014g	=	0.00196g
Natural Gas	29%	x	0.0169g	=	0.004901g
Nuclear	33%	x	0	=	0
Renewables*	33%	x	0	=	0
			Total	=	0.006861g per kWh or 0.0021g per mile

5. Battery Electric Vehicle (BEV) – Based on NPPD Data

Electricity Generation Mix

The current electricity mix is published on the NPPD website [14].

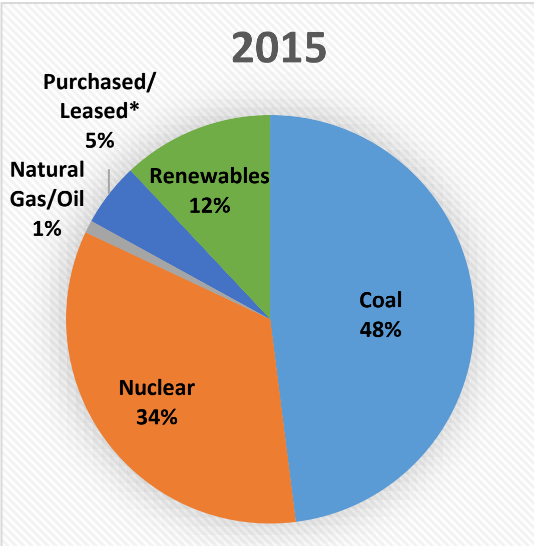


Figure 4.4: 2015 Electricity Generation Mix NPPD

* Purchased/leased electricity is primarily hydroelectric

Carbon Dioxide Equivalent (CO2) Emissions

Using the individual emissions rates calculated below, the equivalent rate is **132 grams CO2 per mile.**

Carbon Dioxide (CO2) Emissions

Table 4.29: 2015 Actual CO2 Emissions BEV

Energy Source	Percentage of Total Energy Production		Grams of CO2 Emitted per kWh [13]		Contribution to Total CO2 Emitted per kWh
Coal	48.4%	x	989g	=	479g
Natural Gas	1%	x	546g	=	5.4g
Nuclear	33.8%	x	0	=	0
Renewables	16.8%	x	0	=	0
			Total	=	484g per kWh or 131g per mile

Carbon Monoxide (CO) Emissions

Table 4.30: 2015 Actual CO Emissions BEV

Energy Source	Percentage of Total Energy Production		Grams of CO Emitted per kWh [13]		Contribution to Total CO Emitted per kWh
Coal	48.4%	x	0.321g	=	0.15536g
Natural Gas	1%	x	0.062g	=	0.00062g
Nuclear	33.8%	x	0	=	0
Renewables	16.8%	x	0	=	0
			Total	=	0.15598g per kWh or 0.0465g per mile

Methane (CH4) Emissions

Table 4.31: 2015 Actual CH4 Emissions BEV

Energy Source	Percentage of Total Energy Production		Grams of CH4 Emitted per kWh [13]		Contribution to Total CH4 Emitted per kWh
Coal	48.4%	x	0.011g	=	0.005g
Natural Gas	1%	x	0.011g	=	0
Nuclear	33.8%	x	0	=	0
Renewables	16.8%	x	0	=	0
			Total	=	0.005g per kWh or 0.001g per mile

Nitrous Oxide (N2O) Emissions

Table 4.32: 2015 Actual N2O Emissions BEV

Energy Source	Percentage of Total Energy Production		Grams of N2O Emitted per kWh [13]		Contribution to Total N2O Emitted per kWh
Coal	48.4%	x	0.016g	=	0.0077g
Natural Gas	1%	x	0.001g	=	0
Nuclear	33.8%	x	0	=	0
Renewables	16.8%	x	0	=	0
			Total	=	0.0077g per kWh or 0.002g per mile

Sulfur Dioxide (SO_2) Emissions

Table 4.33: 2015 Actual SO2 Emissions BEV

Energy Source	Percentage of Total Energy Production		Grams of SO2 Emitted per kWh [13]		Contribution to Total SO2 Emitted per kWh
Coal	48.4%	x	2.54g	=	1.23g
Natural Gas	1%	x	0.015g	=	0
Nuclear	33.8%	x	0	=	0
Renewables	16.8%	x	0	=	0
			Total	=	1.23g per kWh or 0.33g per mile

Nitrogen Oxides (NO_x) Emissions

Table 4.34: 2015 Actual NOx Emissions BEV

Energy Source	Percentage of Total Energy Production		Grams of NOx Emitted per kWh [13]		Contribution to Total NOx Emitted per kWh
Coal	48.4%	x	1.10g	=	0.534g
Natural Gas	1%	x	0.272g	=	0.003g
Nuclear	33.8%	x	0	=	0
Renewables	16.8%	x	0	=	0
			Total	=	0.537g per kWh or 0.145g per mile

Volatile Organic Compound (VOC) Emissions

Table 4.35: 2015 Actual VOC Emissions BEV

Energy Source	Percentage of Total Energy Production		Grams of VOC Emitted per kWh [21],[22]		Contribution to Total VOC Emitted per kWh
Coal	48.4%	x	0.014g	=	0.006776g
Natural Gas	1%	x	0.0169g	=	0.000169g
Nuclear	33.8%	x	0	=	0
Renewables	16.8%	x	0	=	0
			Total	=	0.006945g per kWh or 0.0021g per mile

6. Battery Electric Vehicle (BEV) – Based on LES Data

Electricity Generation Mix

The current electricity mix is published on the LES 2015 Official Report [18]. LES also constructed a 5 MW community solar energy project that went online in June 2016. LES is expected to produce 48% of its retail energy from renewable resources. The nameplate generation is planned to be composed on one-third renewables, one-third gas, and one-third coal. The planned 2016 generation was taken from the LES website [20]. The renewable generation is made up of wind, hydro, and solar. The planned coal and natural gas generation is estimated based on their future nameplate generation.

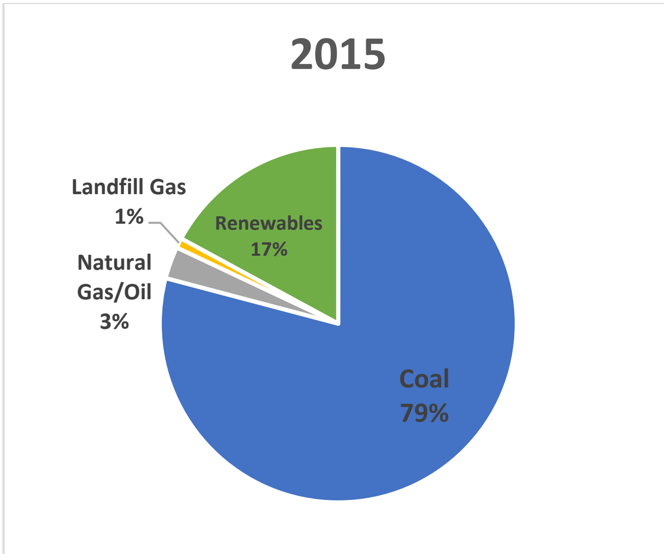


Figure 4.5: 2015 Electricity Generation Mix LES

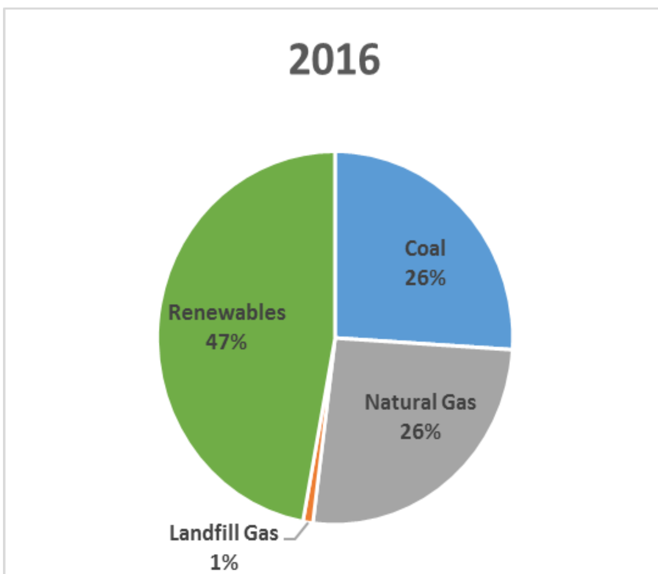


Figure 4.6: 2016 Electricity Generation Mix LES

Carbon Dioxide (CO_2) Emissions

Using the individual emissions rates calculated below, the equivalent rate is **240.89 grams CO2 per mile.**

Table 4.36: 2015 Actual CO2 Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of CO2 Emitted per kWh [13]		Contribution to Total CO2 Emitted per kWh
Coal	79.1%	x	989g	=	782.3g
Natural Gas	2.9%	x	546g	=	15.834g
Landfill Gas	0.9%	X	3.1g	=	0.0279g
Renewables	17.1%	x	0	=	0
			Total	=	798.1619g per kWh or 240.89g per mile

Table 4.37: 2016 planned CO2 Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of CO2 Emitted per kWh [13]		Contribution to Total CO2 Emitted per kWh
Coal	26%	x	989g	=	257.14g
Natural Gas	26%	x	546g	=	141.96g
Landfill Gas	0.9%	X	3.1g	=	2.79g
Renewables	47.1%	x	0	=	0
			Total	=	401.89g per kWh or 121.29g per mile

Carbon Monoxide (CO) Emissions

Using the individual emissions rates calculated below, the equivalent rate is **0.0845 grams CO per mile.**

Table 4.38: 2015 Actual CO Emissions BEV LES

Energy Source	Percentage of Total Energy Production		Grams of CO Emitted per kWh [19]		Contribution to Total CO Emitted per kWh
Coal	79.1%	x	0.321g	=	0.253911g
Natural Gas	2.9%	x	0.062g	=	0.001798g
Landfill Gas	0.9%	x	2.68g	=	0.02412g
Renewables	17.1%	x	0	=	0
			Total	=	0.279829g per kWh or 0.0845g per mile

Table 4.39: 2016 Planned CO Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of CO Emitted per kWh [19]		Contribution to Total CO Emitted per kWh
Coal	26%	x	0.321g	=	0.08346g
Natural Gas	26%	x	0.062g	=	0.01612g
Landfill Gas	0.9%	x	2.68g	=	0.02412g
Renewables	47.1%	x	0	=	0
			Total	=	0.1237g per kWh or 0.0373g per mile

Methane (CH4) Emissions

Using the individual emissions rates calculated below, the equivalent rate is **0.0027 grams CH4 per mile.**

Table 4.40: 2015 Actual CH4 Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of CH4 Emitted per kWh [13]		Contribution to Total CH4 Emitted per kWh
Coal	79.1%	x	0.011g	=	0.008701g
Natural Gas	2.9%	x	0.011g	=	0.000319g
Landfill Gas	0.9%	x	0	=	0
Renewables	17.1%	x	0	=	0
			Total	=	0.00902g per kWh or 0.0027g per mile

Table 4.41: 2016 Planned CH4 Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of CH4 Emitted per kWh [13]		Contribution to Total CH4 Emitted per kWh
Coal	26%	x	0.011g	=	0.00286g
Natural Gas	26%	x	0.011g	=	0.00286g
Landfill Gas	0.9%	x	0	=	0
Renewables	47.1%	x	0	=	0
			Total	=	0.00572g per kWh or 0.0017g per mile

Nitrous Oxide (N2O) Emissions

Using the individual emissions rates calculated below, the equivalent rate is **0.0038 grams N2O per mile.**

Table 4.42: 2015 Actual N2O Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of N2O Emitted per kWh [13]		Contribution to Total N2O Emitted per kWh
Coal	79.1%	x	0.016g	=	0.012656g
Natural Gas	2.9%	x	0.001g	=	0.000029g
Landfill Gas	0.9%	x	0	=	0
Renewables	17.1%	x	0	=	0
			Total	=	0.012685g per kWh or 0.0038g per mile

Table 4.43: 2016 Planned N2O Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of N2O Emitted per kWh [13]		Contribution to Total N2O Emitted per kWh
Coal	26%	x	0.016g	=	0.00416g
Natural Gas	26%	x	0.001g	=	0.00026g
Landfill Gas	0.9%	x	0	=	0
Renewables	47.1%	x	0	=	0
			Total	=	0.00442g per kWh or 0.0013g per mile

Sulfur Dioxide (SO_2) Emissions

Using the individual emissions rates calculated below, the equivalent rate is **0.61 grams SO2 per mile.**

Table 4.44: 2015 Actual SO2 Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of SO2 Emitted per kWh [13]		Contribution to Total SO2 Emitted per kWh
Coal	79.1%	X	2.54g	=	2.00914g
Natural Gas	2.9%	X	0.015g	=	0.000435g
Landfill Gas	0.9%	X	0	=	0
Renewables	17.1%	X	0	=	0
			Total	=	2.009575g per kWh or 0.61g per mile

Table 4.45: 2016 Planned SO2 Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of SO2 Emitted per kWh [13]		Contribution to Total SO2 Emitted per kWh
Coal	26%	X	2.54g	=	0.6604g
Natural Gas	26%	X	0.015g	=	0.0039g
Landfill Gas	0.9%	X	0	=	0
Renewables	47.1%	X	0	=	0
			Total	=	0.6643g per kWh or 0.2g per mile

Nitrogen Oxides (NO_x) Emissions

Using the individual emissions rates calculated below, the equivalent rate is **0.27 grams NOx per mile.**

Table 4.46: 2015 Actual NOx Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of NOx Emitted per kWh [13]		Contribution to Total NOx Emitted per kWh
Coal	79.1%	x	1.10g	=	0.8701g
Natural Gas	2.9%	x	0.272g	=	0.007888g
Landfill Gas	0.9%	x	0.037g	=	0.000333g
Renewables	17.1%	x	0	=	0
			Total	=	0.878321g per kWh or 0.27g per mile

Table 4.47: 2016 Planned NOx Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of NOx Emitted per kWh [13]		Contribution to Total NOx Emitted per kWh
Coal	26%	x	1.10g	=	0.286g
Natural Gas	26%	x	0.272g	=	0.07072g
Landfill Gas	0.9%	x	0.037g	=	0.000333g
Renewables	47.1%	x	0	=	0
			Total	=	0.357g per kWh or 0.107g per mile

Volatile Organic Compound (VOC) Emissions

Table 4.48: 2015 Actual VOC Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of VOC Emitted per kWh [21],[22]		Contribution to Total VOC Emitted per kWh
Coal	79.1%	x	0.014g	=	0.0110740g
Natural Gas	2.9%	x	0.0169g	=	0.0004901g
Landfill Gas	0.9%	x	0.272g	=	0.0024480g
Renewables	17.1%	x	0	=	0
			Total	=	0.0140121g per kWh or 0.0042g per mile

Table 4.49: 2016 Planned VOC Emissions BEV LES Data

Energy Source	Percentage of Total Energy Production		Grams of VOC Emitted per kWh [21],[22]		Contribution to Total VOC Emitted per kWh
Coal	26%	x	0.014g	=	0.0036400g
Natural Gas	26%	x	0.0169g	=	0.0043940g
Landfill Gas	0.9%	x	0.272g	=	0.0024480g
Renewables	47.1%	x	0	=	0
			Total	=	0.0104820g per kWh or 0.0032g per mile

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5. Economic Benefits of Electrified Transportations

a. Introduction

In this economic analysis section, five types of alternative fuel vehicles are considered:

- **CV – Conventional vehicles (Internal combustion Engine (ICE) Cars) running on gasoline fuel**
- **DV – Cars (Internal combustion Engine (ICE) Cars) running on Diesel fuel**
- **CNG – Trucks running on Compressed natural gas (CNG) fuel**
- **BEV – Battery electric vehicles (all electric) running a 100% on Electricity fuel**
- **HEV – Plug-in Hybrid electric vehicles (combination of electricity and gasoline fuel**

b. Economic benefits due to fuel type price differences

Data calculations are based on the following average prices and assumptions:

- Gas price of $2.43 per gallon (based on 2015 average [1]).
- Diesel price of $2.71 per gallon (based on 2015 average [1]).
- CNG price of $1.97 per gallon based on average CNG price by state. [2]
- Hybrid electric vehicles calculations are based on the vehicle using electricity only [3].
- Electricity price is dependent on the utility serving the cities in the study: there are four companies that supply power for the cities in this study, each with their own energy makeup and pricing:
    - Omaha Public Power District (OPPD)
    - Nebraska Public Power District (NPPD)
    - Northeast Nebraska Public Power District (NeNPPD)
    - Lincoln Electric System (LES)

To perform the calculations, we selected cities that are participating in the NCEA, NET grant. The participating cities are shown in Table 5.1 with their service provider and the price per kilowatt. The price per kilowatt is based on the average commercial rate for each city provided by Electricity Local [4]. NeNPPD delivers power to Allen, Dakota County, and Wayne over NeNPPD transmission lines, but the electricity is generated by NPPD [5].

Table 5.1: Participating Cities and their electric rates bases on the service provider

Participating communities	Provider	Price per kWh ($)
Allen Consolidated Schools	NeNPPD	0.066
Ashland	OPPD (retail)	0.094
Bellevue	OPPD (retail)	0.094
Central City	NPPD (wholesale power supply)	0.102
Dakota County	NeNPPD	0.066
Ferguson House (Lincoln)	LES	0.0706
Gothenburg	NPPD (wholesale power supply)	0.081
Gretna	OPPD (retail)	0.094
Hastings	Provides own service	0.076
Holdrege	NPPD (wholesale power supply)	0.092
Kearney	NPPD (retail)	0.0889
Lexington	NPPD (wholesale power supply)	0.0939
Lincoln	LES	0.0706
Nebraska City	Provides own service	0.1084
OPPD	OPPD	0.084
Seward	NPPD (wholesale power supply)	0.0935
South Sioux City	NPPD (wholesale power supply)	0.0855
Valley	OPPD	0.094
Wayne	NeNPPD	0.0635

Table 5.2 shows the costs for driving one mile for each fuel type. The cost of fuel for a BEV is based on the price per kWh for OPPD, NPPD, NeNPPD, and LES calculated by averaging the data shown in Table 5.1. Hastings and Nebraska City are not included in this calculation as these cities provide their own power. HEV is not shown in Table II since it has the same analysis as the BEV.

Table 5.2: Cost for driving one mile

	CV	DV	CNG	BEV			
				OPPD	NPPD	NeNPPD	LES
Cost of "Fuel"	$2.43 per gallon	$2.71 per gallon	$1.97 per gallon	$0.092 per kWh	$0.091 per kWh	$0.065 per kWh	$0.0706 per kWh
Fuel Efficiency	21.6 miles per gallon	35 miles per gallon	31 miles per gallon	3.4 miles per kWh	3.4 miles per kWh	3.4 miles per kWh	3.4 miles per kWh
Cost per mile	**$0.11**	**$0.08**	**$0.06**	**$0.027**	**$0.0267**	**$0.019**	**$0.0208**

Table 5.3 shows the cost savings for alternative fuel vehicles when compared with the conventional vehicle (CV). The calculations shown are for driving one mile and then for driving an average of 12,000 miles (one year).

Table 5.3: Cost savings for Alternative fuel vehicles when compared to CV

	CV	DV	CNG	BEV			
				OPPD	NPPD	NeNPPD	LES
Cost per mile	$0.11	$0.08	$0.06	$0.027	$0.0267	$0.019	$0.0208
Savings over CV per mile	--------	**$0.03**	**$0.05**	**$0.083**	**$0.0833**	**$0.091**	**$0.0892**
Estimated savings over CV per year	--------	**$360**	**$600**	**$996**	**$999.60**	**$1,092**	**$1,070.40**

Table 5.4 shows the cost savings for driving BEV with varying gas prices. In this analysis, the price of gasoline varies from $1.50 to $3.00 in 50 cent increments. Table 5.4 also shows the savings with the actual price of gas when the project was initially deployed in the summer of 2014. The calculations for the BEV prices are based on an average kWh price for OPPD, NPPD, NeNPPD and LES ($0.0234/kWh)

Table 5.4: Cost savings for driving BEV with varying gas prices

Cost of Gasoline $/Gallon	$1.50	$2.00	$2.50	$3.00	$3.61 (Summer 2014)
Savings over CV per mile	4.6 cents	6.9 cents	9.3 cents	11.6 cents	14.4 cents
Savings over CV per year (12,000 miles)	**$552**	**$828**	**$1,116**	**$1,392**	**$1,728**

c. Economic benefits due to other factors effecting each fuel type

In addition to the fuel savings, additional cost savings for BEVs are attributed to car maintenance requirements. Table 5.5 shows the average maintenance cost for each type of car and calculates the yearly savings for the DV and BEV over the CV.

Table 5.5: Cost savings calculations for DV and BEV due to maintenance and other savings [6-8]

	CV	**DV**	**BEV***
Cost per mile	$0.0511	$0.043	$0.033
Cost per year	$613.2	$516	$396
Savings over CV per year	--------	$97.2	$217.2

*BEV's annual maintenance are estimated to be 35% less than the maintenance requirement for CVs [9].

d. Total economic benefits

Table 5.6 shows the average combined fuel and maintenance cost savings for BEV in Nebraska.

Table 5.6: Total economic savings for DV and BEV over the CV

	CV	**DV**	**BEV**			
			OPPD	NPPD	NeNPPD	LES
Cost per mile	$0.1611	$0.123	0.06	0.0597	0.052	0.0538
Savings over CV per mile	--------	**$0.0381**	**0.1011**	**0.1014**	**0.1091**	**0.1073**
Estimated savings over CV per year	--------	**$457.2**	**$1,213.2**	**$1,216.8**	**$1,309.2**	**$1,287.6**

References

[1] https://www.eia.gov/forecasts/steo/report/prices.cfm

[2] http://www.cngnow.com/average-cng-prices/pages/default.aspx

[3] https://www.fueleconomy.gov/feg/label/learn-more-PHEV-label.shtml

[4] http://www.electricitylocal.com/states/nebraska/

[5] http://www.nnppd.com/about_us/profile/

[6] https://www.les.com/residential/rates/rate-schedules

[7] http://exchange.aaa.com/wp-content/uploads/2015/04/Your-Driving-Costs-2015.pdf

[8] http://www.vtpi.org/tca/tca0501.pdf

[9] https://www.fpl.com/environment/pdf/get-charged-up.pdf

6. Electrified Transportation Needs and Feasibility

a. Electric Vehicle Survey Report

A survey is developed to identify interest, awareness or support for public EV charging infrastructure in Nebraska. This survey aims to gather more detailed information regarding the needs and benefits of DC fast charging infrastructure in Nebraska through questions of various detail and response type. The survey consists of two parts. Part I consists of open-ended and yes/no questions while Part II utilizes a Likert-Scale method to gather student's response. Both parts of the survey aim to identify interests and possible needs for public EV charging infrastructure in Nebraska. The complete survey questionnaire is provided in appendix 6.4

The survey is conducted on a focused age group ranging from 18-22 years. Specifically, convenience sampling is utilized through the distribution of the surveys in three different college-level engineering courses over a span of two years. Convenience sampling is a non-probability form of survey sampling that relies on an easy-to-access population for data collection.

Through survey analysis, general trends can be observed from one year to the next regarding the responses of the three groups studied.

Survey distribution occurred across three groups; Group A, Group B, and Group C.

- Group A consists of 56 engineering students with an average age of 21.1 years old and a median age of 19 years old. This group is surveyed in Fall 2016 and the majority of these students are in their first year of college.
- Group B consists of 65 engineering students with an average age of 18.8 years old and a median age of 18 years old. This group is surveyed in Fall 2017 and the majority of these students are in their first year of college.
- Group C consists of 38 engineering students with an average age of 21.1 years old and a median age of 19 years old. This group is surveyed in Fall 2017 and the majority of these students are in their second or third year of college.

It is also important to note that in general, Group C consists of many of the same students as Group A but they are surveyed one year later. This is purposefully chosen so that Group A can be compared against Group C to see [mostly] the responses of the same students from one year to the next, while comparing Group A to Group B can show different students who are [mostly] both in their first year of college and how their responses may be different. Group A may be compared with the combination of data from Group B and Group C to show a change from students surveyed in 2016 vs 2017 in total.

Methodology

To facilitate the gathering of this survey data, paper copies of the survey forms are distributed in three different engineering class sessions. The survey forms have been developed over the recent years to adapt to the changing relevance of electric vehicle infrastructure in Nebraska. The survey consists of two parts. Part I consists of a combination of 16 open-ended and yes/no type questions regarding the characteristics and opinions of the participants on electric vehicle use in Nebraska. Part II consists of a Likert-Scale analysis of the participant's likeliness to adopt the technology of four different factors. These factors are as follows:

- Factor 1: *Public charging infrastructure in Nebraska*
- Factor 2: *Barrier to the likelihood that you will adopt a BEV (Battery Electric Vehicle)*
- Factor 3: *Barrier to the likelihood that you will adopt a PHEV (Plug-in Hybrid Electric Vehicle)*
- Factor 4: *Barrier to the likelihood that you will adopt a HEV (Hybrid Electric Vehicle)*

The respondents can select a relative importance for individual aspects related to each of these four factors, ranging from "Very Important" to "Unimportant". These responses are then assigned a numerical value from 5 to 1 during the analysis, respectively decreasing from "Very Important" to "Unimportant". Participants can also select "Not Applicable" for each individual aspect of the four factors. A response of "Not Applicable" is not included when analyzing the data for the average importance level and standard deviation.

Participants who choose to take the survey complete it during one class session and return it to the instructor prior to leaving the class. The survey data is then manually input into Microsoft® Excel and errors are checked against the individual forms. Omissions of the numerical data occur if respondents select "Not Applicable" for any barrier. Data analysis and graph formation is completed using Excel. Also, an IRB approval to conduct the survey is obtained prior to the administration of the survey.

Note: The results reported can only be considered the opinions of the survey participants. They cannot be generalized to represent the entire population as a whole.

Survey Results

In analyzing this survey, the intent is to observe changes in the overall interest and awareness of EV public charging infrastructure in Nebraska across Group A and Group B, as well as across Group A and Group C. These changes are observed in both Part I and Part II of the survey through the analysis of various key questions or trends.

Survey Part I

The first influential question pertaining to the internal goal of this survey is “Would you consider purchasing an electric vehicle? Why or why not?”. Across all data sets, 56% of all respondents answered “Yes”. Figure 6.1 shows the total results across all data sets, while Figure 6.2 shows the breakdown of responses for each group surveyed. The most common answers to why or why not are listed in Table 6.1.

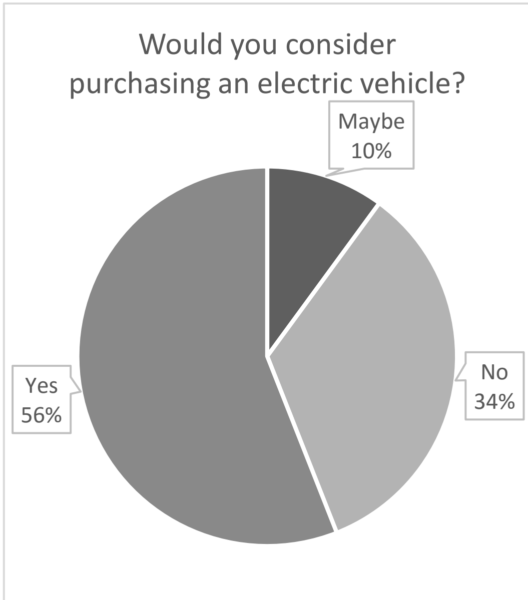


Figure 6.1: Consider purchasing an EV pie chart

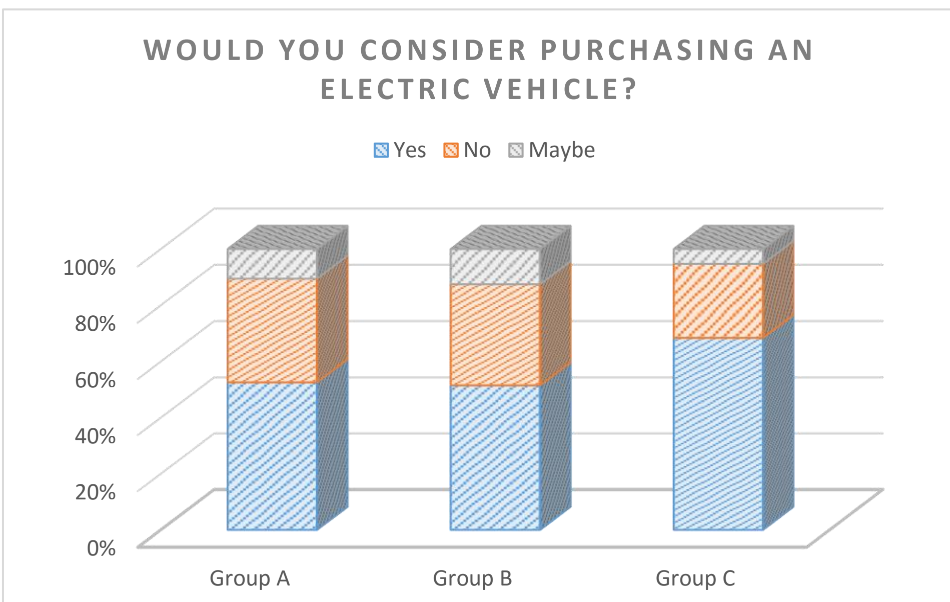


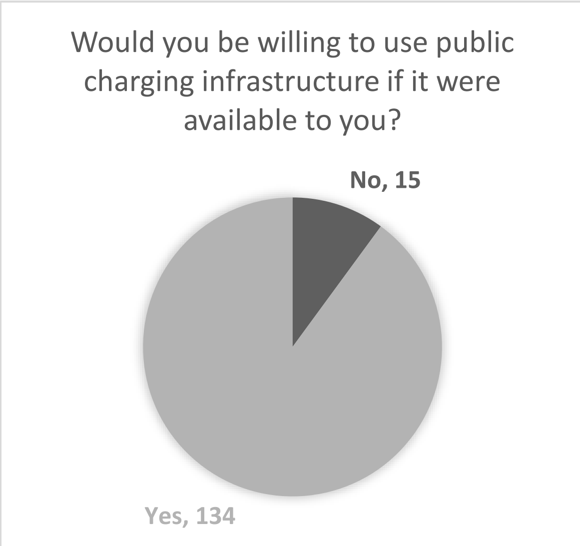
Figure 6.2: Consider purchasing an EV bar graph

Table 6.1 Would you consider purchasing an electric vehicle - responses

Would you consider purchasing an electric vehicle?	YES (number of responses)	NO (number of responses)
Group A	Environmentally friendly (15)	Expensive (10)
	Save money on gas (8)	Range of a battery charge (10)
	Better mileage (hybrid) (3)	Charging station availability (6)
	Tesla (2)	Horsepower (3)
		Charging time (2)
Group B	Better for the environment (15)	Availability of charging (8)
	Less expensive, save money (15)	More expensive, cost (8)
	Overall appeal (cool) (5)	Prefer conventional (7)
	Advanced technology (2)	Trust (4)
Group C	Better for the environment (10)	Availability of charging (4)
	Less expensive, save money (8)	Range (3)
	Overall appeal (cool) (6)	More expensive, cost (3)
	Advanced technology (2)	Prefer conventional (2)

To compare the groups, the percentage of participants who said “Yes” in Group A is 53%, Group B is 52%, and Group C is 68%. It then follows that the change in the percent of participants who answered “yes” from Group A to Group B is -1%, and from Group A to Group C is +16%. However, comparing Group A with the combined data of Group B and Group C, the change in participants who answered “yes” from 2016 to 2017 is +5%. See Appendix B for visual representations of the score breakdowns. This data shows an overall positive increase of willingness to consider purchasing an electric car from 2016 to 2017 within our groups.

The next pertinent question asked is “Would you be willing to use public charging infrastructure if it were available to you? Why or why not?”. Across all data sets, 90% of all respondents answered “Yes”. Figure 6.3 shows the total results across all data sets, while Figure 6.4 shows the breakdown of responses from 2016 to 2017. The most common answers to why or why not are listed in Table 6.2.



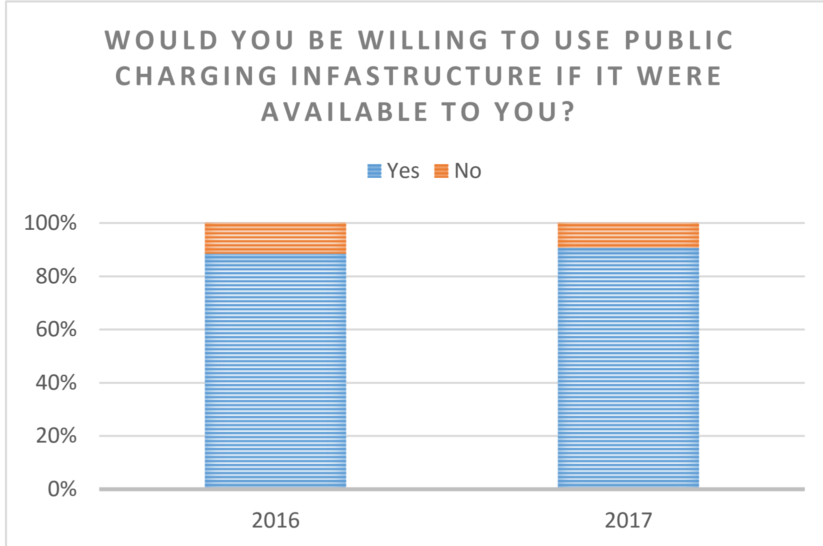


Figure 6.3: Willing to use public EV charging pie chart

Figure 6.4: Willing to use public EV charging bar graph

Table 6.2: Would you be willing to use public charging infrastructure if it were available to you - responses

Would you be willing to use public charging infrastructure if it were available to you?	YES (number of responses)	NO (number of responses)
Group A	If I had an EV (15)	Don't have/want an EV (6)
	Convenient (10)	
	If it's cheaper (5)	
	Better for the environment (3)	
	It's just like getting gas (3)	
Group B	If I had an EV (16)	Don't have/want an EV (5)
	Convenient (10)	Cost (1)
	It's just like getting gas (8)	
	Better for the environment (5)	
	If it's cheaper (3)	
Group C	If I had an EV (9)	Don't have/want an EV (1)
	Convenient (8)	
	It's just like getting gas (6)	
	If it's cheaper (3)	

To compare the groups, the percentage of participants who said "Yes" in Group A was 88%, Group B was 88%, and Group C was 95%. It then follows that the change in the percent of participants who answered "yes" from Group A to Group B is 0%, and from Group A to Group

C is +7%. However, comparing Group A with the combined data of Group B and Group C, the change in participants who answered "yes" from 2016 to 2017 is +2%. See Appendix B for visual representations of the score breakdowns. This data shows a majority willingness to use public charging infrastructure in Nebraska.

The next pertinent question asked is "Have you seen or visited a place with any type of public EV charging infrastructure?". Across all data sets, only 40% of all respondents answered "Yes". Figure 6.5 shows the total results across all data sets, while Figure 6.6 shows the breakdown of responses from 2016 to 2017. Additionally, of the participants that answered "yes" for Group A, 11% said they had seen a place in Nebraska with public EV charging, while for the combination of Group B and Group C, 59% said they had seen a place in Nebraska with public EV charging. This is a 48% increase in the number of participants who have seen any type of public charging infrastructure in Nebraska from 2016 to 2017.

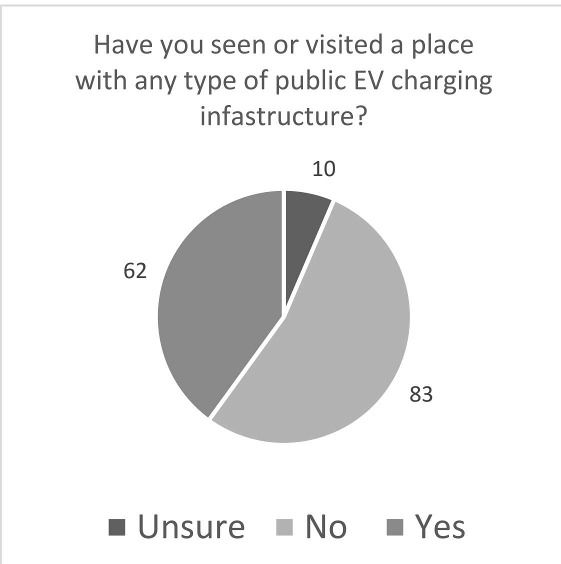


Figure 6.5: Seen public EV charging pie chart

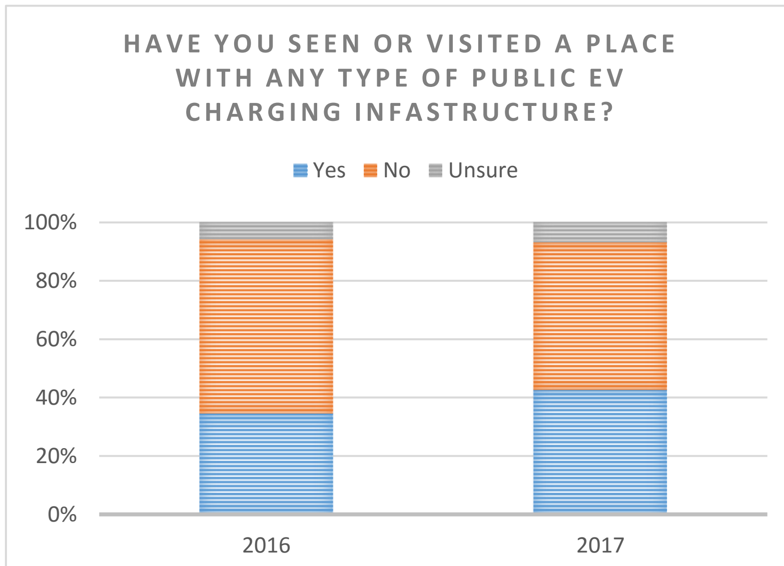


Figure 6.6: Seen public EV charging bar graph

To compare the groups, the percentage of participants who said "Yes" in Group A was 35%, Group B was 43%, and Group C was 42%. It then follows that the change in the percent of participants who answered "yes" from Group A to Group B is +8%, and from Group A to Group C is +7%. However, comparing Group A with the combined data of Group B and Group C, the change in participants who answered "yes" from 2016 to 2017 is +8%. This data shows that while from group to group the increase in the number of public EV charging stations is fairly small, from 2016 to 2017 there is an increase of almost 50% of the number of participants who have seen public EV charging in Nebraska specifically, going from 2 out of 18 participants in 2016 to 26 out of 44 participants in 2017.

Additionally, in Part I the respondents were asked "Which of the following factors would be more likely to motivate you to purchase an electric vehicle for use in Nebraska?". This was a multiple choice question with the following options as responses:

A. The availability of more public EV charging infrastructure in Nebraska (including more users)
B. The presence and use of more electric vehicles in Nebraska
C. Options **A and B** would need to be in place before I would be motivated to purchase an EV
D. I do not consider either of options **A or B** to be a motivator

Figure 6.7 shows the breakdown of the total responses across all survey groups, while Table 6.3 shows the response totals for each group. Overall, this question demonstrates the needs related to public charging for success in Nebraska, with the majority of responders choosing either A or C across each group.

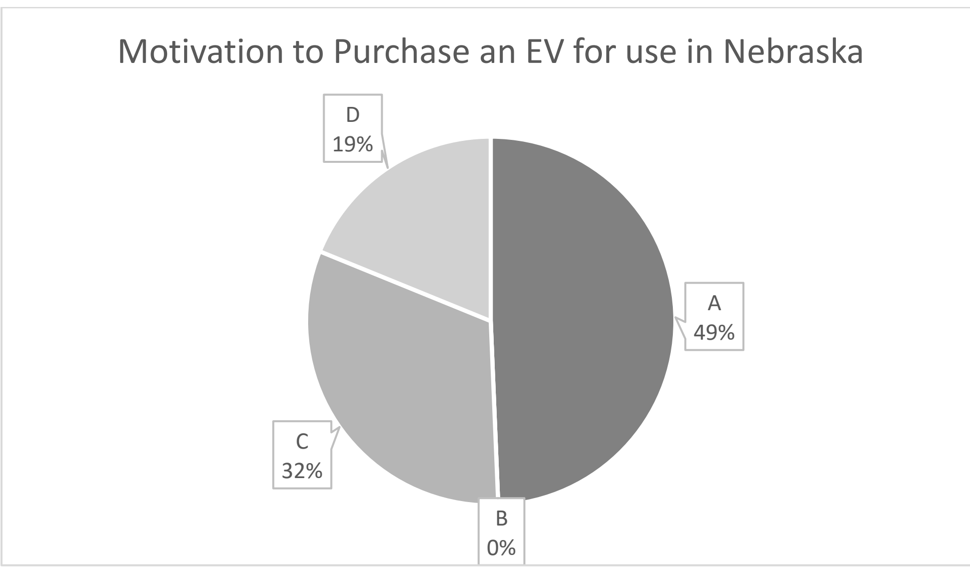


Figure 6.7: Motivation to purchase an EV for use in Nebraska pie chart

Table 6.3: Which of the following factors would be more likely to motivate you to purchase an electric vehicle for use in Nebraska - responses

	2016	2017			**TOTAL**
Response	Group A	Group B	Group C	TOTAL	
A	24	35	17	52	76
B	0	0	0	0	0
C	15	19	15	34	49
D	13	10	6	16	29

Survey Part II

From 2016 to 2017, Part II of the survey was expanded to be more specific to the type of electric vehicles. For Group A, the factors are as follows:

- Factor 1: Which of the following do you consider concerns with regards to public charging infrastructure in Nebraska?
- Factor 2: Do you consider any of the following a barrier to the likelihood that you will adopt an Electric Vehicle?

However, for Group B and Group C, the survey follows the four factors listed in the methodology section.

- Factor 1: Public charging infrastructure in Nebraska
- Factor 2: Barrier to the likelihood that you will adopt a BEV (Battery Electric Vehicle)
- Factor 3: Barrier to the likelihood that you will adopt a PHEV (Plug-in Hybrid Electric Vehicle)
- Factor 4: Barrier to the likelihood that you will adopt a HEV (Hybrid Electric Vehicle)

Because of this change, in order to compare data from both Group A to Group B and Group A to Group C, the data for Factors 2-4 was combined for Groups B and C when comparing across groups. This allows for an analysis of a general trend pertaining to all types of electric vehicles, rather than the specific types listed in Factors 2-4.

To begin, the responses for Part II of the survey show the overall importance of several barriers on the adoption of EV infrastructure and technology in Nebraska. Please reference the graphs in Appendix C for breakdowns of the average responses for Groups A-C for each of the four factors. When calculating the standard error to use for error bars on these graphs, the standard error was calculated for each barrier and was then multiplied by 1.96 to obtain a 95% confidence interval.

Looking at the comparisons across groups, the data suggests of these barriers asked about in the survey, there exists increased importance levels and awareness as expressed by the participants. This trend is observed both from Group A to B as well as Group A to C. Figures 6.8 and 6.9 show the change in survey results from Group A to Group B for Factor 1 and 2, respectively, while Figures 6.10 and 6.11 show the change from Group A to C for Factor 1 and 2, respectively.

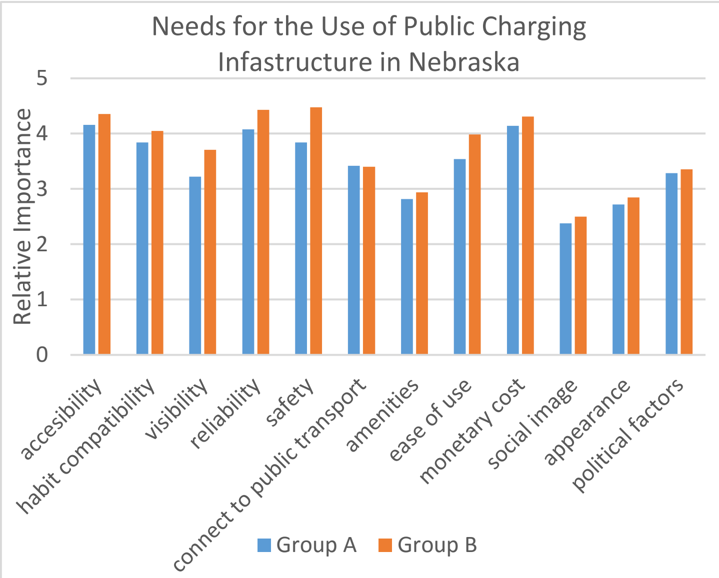


Figure 6.8: Public charging Group A vs B

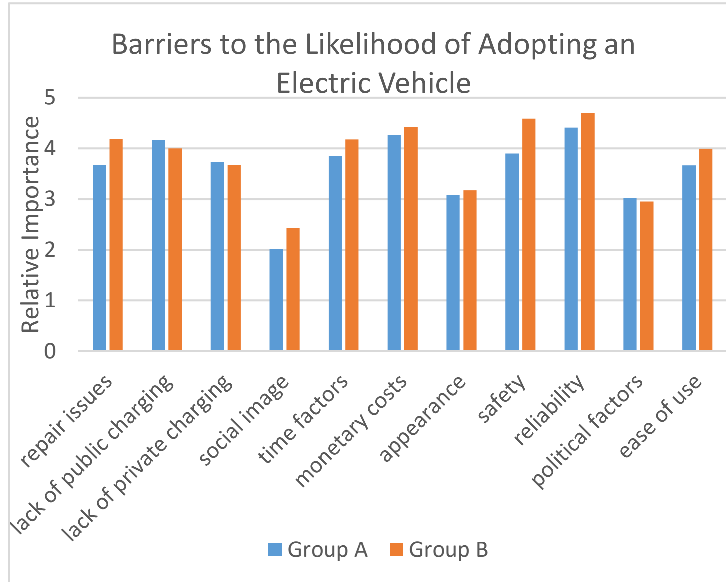


Figure 6.9: Barriers to adopting an EV Group A vs B

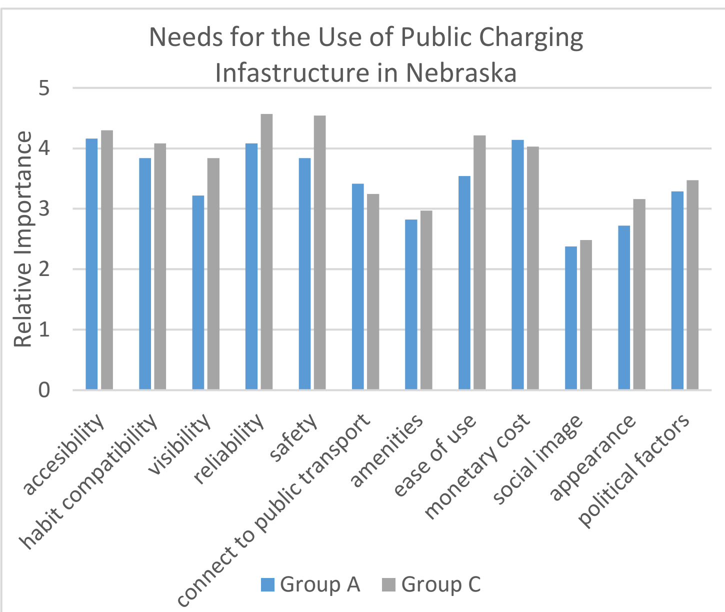


Figure 6.10: Public charging Group A vs C

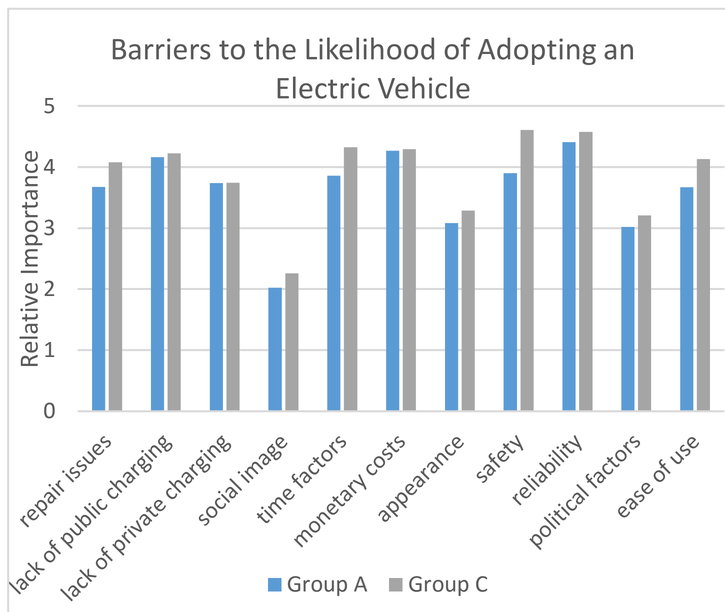


Figure 6.11: Barriers to adopting an EV Group A vs C

Additionally, the overall weighted average of importance for both Factor 1 and Factor 2 is calculated to show a general trend across each of the groups. The standard deviation of the importance values is also calculated for each barrier within Factor 1 and 2. The average value of the standard deviation for all the barriers for both Factor 1 and Factor 2 were then obtained. The results can be seen below comparing across the groups.

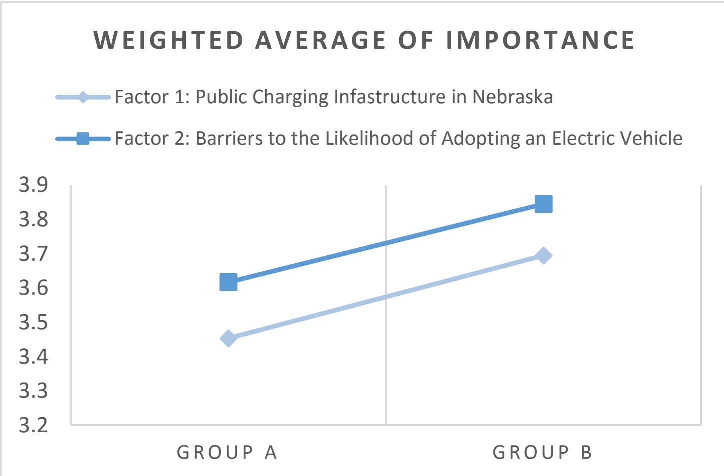


Figure 6.12: Weighted average of importance Group A vs B

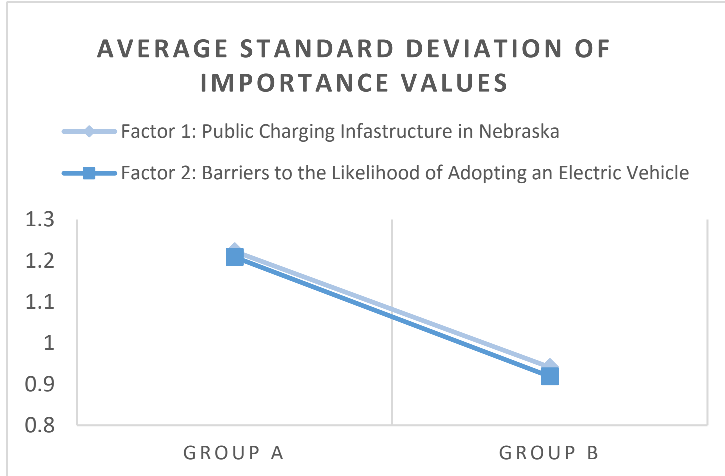


Figure 6.13: Average standard deviation Group A vs B

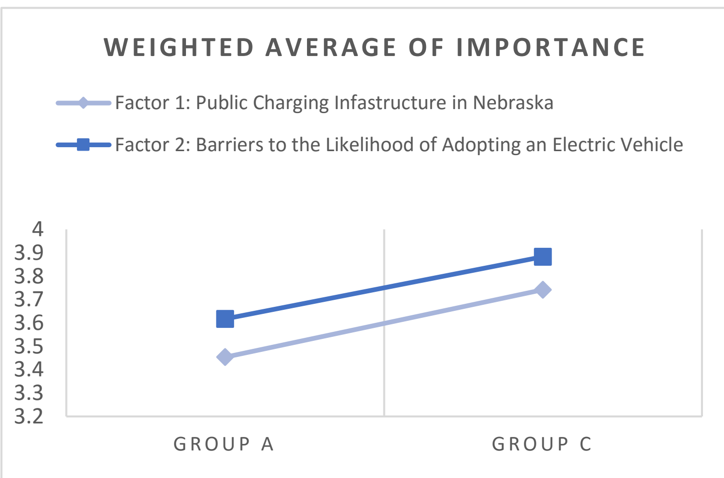


Figure 6.14: Weighted average of importance Group A vs C

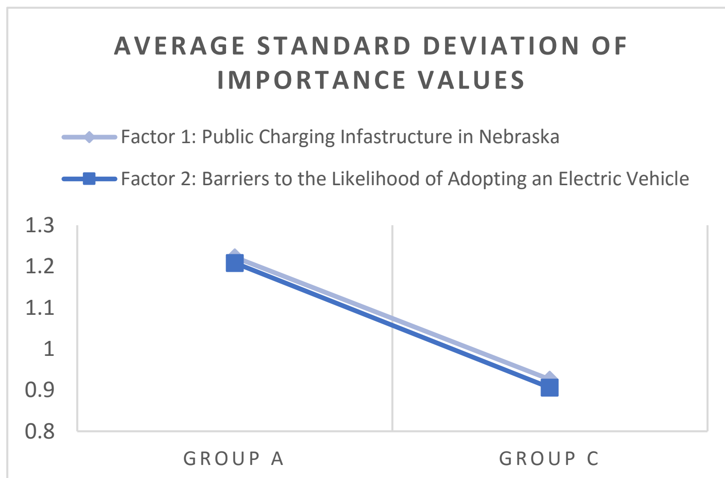


Figure 6.15: Average standard deviation Group A vs C

As visualized in Figures 6.12 through 6.15, on average the relative importance of Factor 1 and Factor 2 alike increased across Group A to B and Group A to C. An increase of over 4.5% and 4.8% is calculated from Group A to Group B for Factors 1 and 2, respectively, while an increase of over 5.3% and 5.7% is calculated from Group A to Group C for Factors 1 and 2, respectively. This suggests that for both sets of groups the barriers on the adoption of EV charging infrastructure in Nebraska are becoming increasingly important as we move forward.

Similarly, a decrease in the average standard deviation values across groups for both factors is observed. The average change in standard deviation values across Group A and B, as well as across Group A and C for both Factor 1 and Factor 2 is consistently within 0.01 of -0.29. This is a fairly considerable decrease in the standard deviation of the average importance values for each of the barriers to these respective factors. What this means is that as the average standard deviation gets smaller (i.e. a negative change) the individual responses from the survey participants are closer together. This suggests that the participants have more similar thoughts about the factors described. At the same time, if these importance values being measured are getting higher, there exists a less spread-out group consensus towards the greater importance of Factor 1 and Factor 2. In other words, the data suggests that the participants are becoming more on the same page regarding the increasing importance of public EV charging infrastructure in Nebraska.

Conclusion

While it may not be easy to reach any definite conclusions with a survey of this nature, general trends and changes can still be systematically analyzed to reach a conclusion of the state of the surveyed population. Based on the data collected and analysis conducted, there seems to be a trend towards the greater importance and awareness towards electric vehicle use in the state of Nebraska, as well as towards the needs for certain aspects related to the use of such EV's (as shown in Figures 6.8 and 6.9). In the future, more detailed and complex analysis of the meaning of the data is desired to reach more definite changes. The continuation of the survey distribution among many more years to map the trend over a larger span of time is also desired.

b. State–by-State Comprehensive EVs and Charging Infrastructure Study

As part of this project to develop a vision and deployment strategy, research on what other federal, state, and local agencies – including DOTs and MPOs – are planning, doing, or have done with respect to EVs and their charging infrastructures is conducted. A large percentage of the documents accumulated over the course of the project came from each state's DOT and DOE websites, and documentation of research projects conducted by the relative departments. 50 states including District of Columbia are intensively researched into to determine the public demand for EV charging, clean mobility and the public expectations for EV charging. The research focused on the state's experiences with the effort of installing EV chargers, funding mechanisms and economic benefits of installing EV chargers both for the state and for the public. Detailed analysis for each state is presented in Appendix 6.5.

The research concluded that, there are many incentives associated with installing EV chargers from federal tax incentives to electricity incentives. 16 states that represent 32% have grants available for the installation of EV chargers. 19 states have rebates for the purchase and installation of EV chargers. All 50 states have Auto insurers discount for EV users. 27 states representing 54% EV users are exempted from emission test and only 3 states offered reduced licensed fees for EV users. Another point worth mentioning is, 17 states representing 34% offer electric bill discount for EV users in their workplaces and homes. Example Pepco, a utility company in DC offer a lower rate to DC residents who own electric vehicles. These owners pay a lower rate for plugging in between 8pm to noon. 13 states allow EV's to use HOV lanes. For example, in Hawaii, EVs have HOV lane exemption and are allowed to park in carpool areas. Additionally, 9 states allow free charging for EV users. Finally, 9 states allow affordable parking ranging from $0.75-$2.00 per hour for EV users. For instance, Drive clean an initiative by California Air Resources Board made public charging stations available at public parking lots, retail chains, tourist destinations, entertainment venues, and airports. Many of these charging stations are free to charge or are offered at affordable prices, usually much less than the cost of gasoline.

The following paragraphs additional summary of the findings:

U.S. Designates Electric Vehicle charging corridors

The federal government is designating 48 electric vehicle charging corridors along 25,000 miles of major U.S. highways. Installed at every 50 miles within corridors. The federal Highway administration is championing the project. The corridors are part of the Obama administration's plan to cut U.S. greenhouse gas emissions 80 percent by 2050. The US Department of Energy has been charged with researching into installations and standardization around the country. General Electric, BMW, Nissan, are among the companies working with the federal government to establish the charging stations.

How utilities play a major role in the future of EV charging infrastructure

The state of California aims to have 1 million PEVs on the road by 2020 and 1.5 by 2025. They are thinking of deploying smart charging systems and shift parking to off peak systems or when solar/wind generation is highest. Awareness of EV's mostly comes about when a company launches a new brand of EV. An example is, the launch of Tesla Model 3 which brought EV awareness on a large scale.

Workplace charging: Charging up University campuses

As an academic advantage, some schools task their engineering students to plan installation of charging stations for PEV's. Also, the presence of charging stations spark dialogue and creates sustainability awareness among students. Campus transportation department is always the administrator of charging stations. For an optimal location of charging locations however, Level 1, 120V is for long parking periods and level 2, 240 V works well for more irregular charging schedules. Some schools locate EV charging stations in secures parking whiles others in places that can be evident. Permanent locations should be considered due to future expansion. University of Massachusetts Lowell is an example of a university with PEV charging stations for community and campus. Potential funding sources are through research awards, donations or from state, federal incentives. Universities also collaborate "clean cities coalition" for charging station installations. The New York State Energy Research and Development Authority's (NYSERDA) Charge NY program has provided funding to support installation of PEV charging stations at many New York colleges and universities.

State Efforts Promote Hybrid and Electric Vehicles

US department of Energy in November 2015 postulates that it costs $1.18 on average to drive an EV as compared to $2.09 gas per gallon of a gasoline car. More than 8000 charging stations are now available in the US. The electric grid of the U.S. has the capacity to support over 150 million cars hence having a lot of PEV's will not affect the national grid. As of June 2015, EV's will have these incentives: "high vehicle lane exemptions, financial incentives, parking incentives and utility rate reductions. Tax credits are $1000 in Maryland and $6000 for EV's. California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island and Vermont have an action plan to put 3.3 million (Zero Emission Vehicles) ZEV's on the road by 2025.

• In Arizona, a maximum of $75 is available for individuals for installing EV charging outlets. Arizona Public Service Company offers a residential time- of- use plan to PEV customers.

• California has designated HOV lanes and EV's are exempted from toll fees on (High Occupancy Toll (HOT) lanes. Manufacturers has a sale tax exclusion by California alternative Energy and advanced financing authority (CAEATFA). The California Energy commission also provides financial incentives for manufacturers, fleet owners and academic institutions who are advancing transportation techniques. Farmers Insurance offers a discount of 10% on insurance coverage on HEV and AFV customers. There are also discounted rate price for residential customers of Los Angeles Department of Water and Power (LADWP) for charging EV's in their residents. Los Angeles Department of Water and Power (LADWP) also offers rebates for EV residential and commercial customers who install 240-volt (level 2) chargers. Likewise, Glendale Water and Power (GWP) gives $200 of cash back to residential customers that own EV's and install 240 volts charging station. There is also free parking available in downtown parking garages in Sacramento for EV's.

• Colorado Energy Office (CEO) and Regional Air Quality Council (RAQC) give grants to support PEV’s.

• The Connecticut Department of Energy and Environmental protection provides funding for states agencies and municipalities for the cost and installation of EV’s supply equipment. EV’s have reduced registration fee of $38.

ZEV Action Plan

• Eight states spanning east to west have created a collaborative “Multi-State ZEV Action Plan” that will guide efforts to put 3.3 million zero emission vehicles on the roads by 2025. Oregon, California, Connecticut, Maryland, Massachusetts, New York, Rhode Island and Vermont created the first promised milestone for the bi-coastal collaboration aimed at paving the way for the cleanest cars in the nation – ZEVs. The plan focuses on infrastructure, policies, standards and other components critical for the success of a growing market [1].

Table 6.4 and 6.5 provide a list of states and benefits provided by each state with respect to EV and charging. Specific benefits are categorized as follows:

- Incentives
- Donation/Grants
- Rebates
- Auto Insurers Discount
- Federal Tax Credit
- Emission Test Exemption
- Reduced License Fees
- Electric Bills Discount
- Hov Lanes Use
- Free Charging
- Free Parking

The “I” in each Box indicate the benefits is provided by that state.

Table 6.4: List of states showing the benefits associated with EV charging

	LIST OF STATES	INCENTIVES	DONATION /GRANTS	REBATES	AUTO INSURERS DISCOUNT	FEDERAL TAX CREDIT
1	Alabama	I	I	I	I	I
2	Alaska	I	I		I	I
3	Arizona	I			I	I
4	Arkansas	I			I	I
5	California	I	I	I	I	I
6	Colorado	I	I	I	I	I
7	Connecticut	I	I	I	I	I
8	Delaware	I	I	I	I	I
9	Florida	I	I	I	I	I
10	Georgia	I			I	I
11	Hawaii	I			I	I
12	Idaho	I	I	I	I	I
13	Illinois	I	I	I	I	I
14	Indiana	I			I	I
15	Iowa	I		I	I	I
16	Kansas	I		I	I	I
17	Kentucky	I			I	I
18	Louisiana	I			I	I
19	Maine	I			I	I
20	Maryland	I			I	I
21	Massachusetts	I	I		I	I
22	Michigan	I			I	I
23	Minnesota	I	I		I	I
24	Mississippi	I			I	I
25	Missouri	I	I		I	I

26	Montana	I			I	I
27	Nevada	I			I	I
28	New Hampshire	I			I	I
29	New Jersey	I			I	I
30	New Mexico	I			I	I
31	New York	I	I	I	I	I
32	North Carolina	I	I	I	I	I
33	North Dakota	I			I	I
34	Ohio	I			I	I
35	Oklahoma	I		I	I	I
36	Oregon	I			I	I
37	Pennsylvania	I			I	I
38	Rhode Island	I			I	I
39	South Carolina	I			I	I
40	South Dakota	I		I	I	I
41	Tennessee	I			I	I
42	Texas	I		I	I	I
43	Utah	I	I		I	I
44	Vermont	I			I	I
45	Virginia	I		I	I	I
46	Washington	I	I		I	I
47	West Virginia	I	I		I	I
48	Wisconsin	I		I	I	I
49	Wyoming	I		I	I	I
50	District of Columbia	I		I	I	I

Table 6.5: List of states showing the benefits associated with EV charging

	LIST OF STATES	EMISSION TEST EXEMPTION	REDUCED LICENCE FEES	ELECTRIC BILLS DISCOUNT	HOV LANES USE	FREE CHARGING	FREE PARKING
1	Alabama			I		I	$2.00/hr
2	Alaska			I			$0.75/hr
3	Arizona		I	I	I		
4	Arkansas						
5	California	I		I		I	Affordable
6	Colorado	I			I	I	$1.00/hr
7	Connecticut						
8	Delaware						
9	Florida			I	I		
10	Georgia			I	I		
11	Hawaii				I	I	I
12	Idaho	I		I		I	
13	Illinois	I	I	I			
14	Indiana	I				I	
15	Iowa		I	I			
16	Kansas						
17	Kentucky						$2.88/hr
18	Louisiana					I	
19	Maine	I					
20	Maryland	I		I	I		
21	Massachusetts	I					
22	Michigan	I		I			
23	Minnesota			I			
24	Mississippi						
25	Missouri	I		I			

26	Montana						
27	Nevada				I		I
28	New Hampshire	I					
29	New Jersey	I			I		
30	New Mexico	I					
31	New York	I					
32	North Carolina	I			I		
33	North Dakota	I					
34	Ohio	I					
35	Oklahoma						
36	Oregon	I					
37	Pennsylvania	I			I		
38	Rhode Island	I				I	
39	South Carolina					I	
40	South Dakota			I		I	
41	Tennessee	I			I		
42	Texas	I		I			$4.17/hr
43	Utah	I			I		
44	Vermont	I					
45	Virginia	I			I		
46	Washington	I					
47	West Virginia	I					
48	Wisconsin			I			
49	Wyoming						
50	District of Columbia	I		I			$2.00/hr

c. Optimal Locations for EV charging Infrastructure

In order to determine the need for a DC fast charging in Nebraska, other states with EV charging infrastructure were intensively researched into to determine optimal locations for EV charging stations in Nebraska. The research focused on the states experiences with the effort of installing EV chargers and funding mechanisms. Four major optimal locations were found from the review namely; highways, universities, City buildings and commercial facilities. Source of funding for these projects are from university Alumni's, Department of Transportation (DOT), Department of Energy and from state departments. The following are examples from the states studied.

Locating EV Charging Stations in university campuses

MARYLAND DOT

- Charging stations are installed at the University of Maryland College Park campus in 2011. DOT of Maryland was motivated by the two presidential goals to reduce GHG emissions and blur the line between campuses and the community. The charging vehicles charge two vehicles per station. One port (110 volts) takes 8hrs to charge and the other, 220 volts take 4hrs to charge. There are 16 stations in 7 locations. All locations are open to the public. Charging is free. The source of funding was not mentioned [2].

Locating EV Charging Stations along highways

- The "West Coast Electric Highway" is a network electric vehicle (EV) DC fast charging stations located every 25 to 50 miles along Interstate 5 and other major roadways in the Pacific Northwest. **The Washington State Department of Transportation** leads the charge on the Washington segment, the **Oregon Department of Transportation** heads up the Oregon segment, and the California segment is coordinated by a Governor's Office interagency group. EV's can now charge up within half a mile of interchanges (where most restaurants and shopping malls are located) [3].

Locating EV Charging Stations in Commercial facilities (malls, shopping centers etc.)

New York DOT

- Beam Charging LLC, Roslyn has been given $300,000 by The New York State Energy Research and Development Authority (NYSERDA) to install 21 EV charging stations at locations in upper Manhattan, Brooklyn and Long Island. The stations will be located in public parking garages and parking lots, including mall locations.
- EVPass, Syracuse has been given $300,000 by NYSERDA to install of 26 EV charging stations at retail shopping mall parking lots throughout New York State [4].
- Simon Property Group has installed 436 EV charging stations at 101 locations in 20 states. These charging stations are in malls including Arizona Mills, Auburn mall, Georgia malls, Miami International mall, Philadelphia Mills, San Francisco premium outlets, University park mall [5].

References

[1] https://www.oregon.gov/ODOT/HWY/OIPP/Pages/inn_ev-charging.aspx

[2] http://www.transportation.umd.edu/chargingstation.html

[3] http://www.westcoastgreenhighway.com/electrichighway.htm

[4] https://www.governor.ny.gov/news/governor-cuomo-announces-installation-hundreds-electric-vehicle-charging-stations

[5] http://www.simon.com/electric-vehicle-charging-stations

7. Ashland DC fast Charger Data

In March 2017, the city of Ashland installed the state's first high-speed public DC charger. Figure 7.1 shows the location and the actual DC fast charger that was installed.

Figure 7.1 Location and the actual DC fast charger installed at Ashland

The economic and environment data are recorded for analysis. Table 7.1 shows the economic savings for this charger for the month of November 2017 as well as since it was installed. Table 7.2 shows the environmental savings for the month of November 2017 as well as since it was installed. The information provided are based on the economic and environmental calculations in Section 4 and section 5.

Table 7.1: Economic Savings Data

<table>
<tr><th colspan="2"></th><th>This Month (November)</th><th>All Time</th></tr>
<tr><td colspan="2">Miles driven</td><td>492.82</td><td>993.58</td></tr>
<tr><td colspan="2">Energy consumed (kWh)</td><td>144.95</td><td>292.24</td></tr>
<tr><td rowspan="3">Fuel cost Savings:</td><td>Usage Cost Using CV (Gas)</td><td>$42.39</td><td>$91.61</td></tr>
<tr><td>Usage Cost Using EV (Electricity)</td><td>$14.73</td><td>$28.93</td></tr>
<tr><td>Total Fuel Savings</td><td>$27.66</td><td>$62.68</td></tr>
<tr><td rowspan="3">Other Cost Savings:</td><td>CV Costs</td><td>$27.84</td><td>$53.78</td></tr>
<tr><td>EV Costs</td><td>$18.09</td><td>$36.58</td></tr>
<tr><td>Total Other Cost Savings</td><td>$9.75</td><td>$17.20</td></tr>
<tr><td colspan="2">Overall Economic Savings</td><td>$37.41</td><td>$79.88</td></tr>
</table>

Table 7.2: Environmental Savings Data

		This Month (November)	All Time
Miles driven		492.82	993.58
Energy consumed (kWh)		144.95	292.24
CO2 Emissions (lbs.)	CV (Gas)	328.43	744.87
	EV (Electricity)	193.33	283.65
	Overall Emission Reductions	135.1	461.22
CO Emissions (lbs.)	CV (Gas)	3.1124	10.8943
	EV (Electricity)	0.0651	0.1320
	Overall Emission Reductions	3.0473	10.7623
SO2 Emissions (lbs.)	CV (Gas)	0.0046	0.0227
	EV (Electricity)	0.3998	0.7771
	Overall Emission Reductions	(0.3952)	(0.0360)
NOx Emissions (lbs.)	CV (Gas)	0.1306	0.6993
	EV (Electricity)	0.2629	0.4608
	Overall Emission Reductions	(0.1323)	0.2385
CH4 Emissions (lbs.)	CV (Gas)	0.0188	0.0536
	EV (Electricity)	0.0022	0.0043
	Overall Emission Reductions	0.0166	0.0493
VOC Emissions (lbs.)	CV (Gas)	0.1824	0.3915
	EV (Electricity)	0.003	0.0056
	Overall Emission Reductions	0.1794	0.3859

Usage Pattern

Table 7.3 and Figure 7.2 show the number of unique users per month since the unit was installed

Table 7.3: Number of unique users since installation

Month	Unique Drivers
Feb`17	5
Mar`17	2
Apr`17	2
May`17	2
June`17	0
July`17	2
Aug`17	7
Sep`17	4
Oct`17	4
Nov`17	9

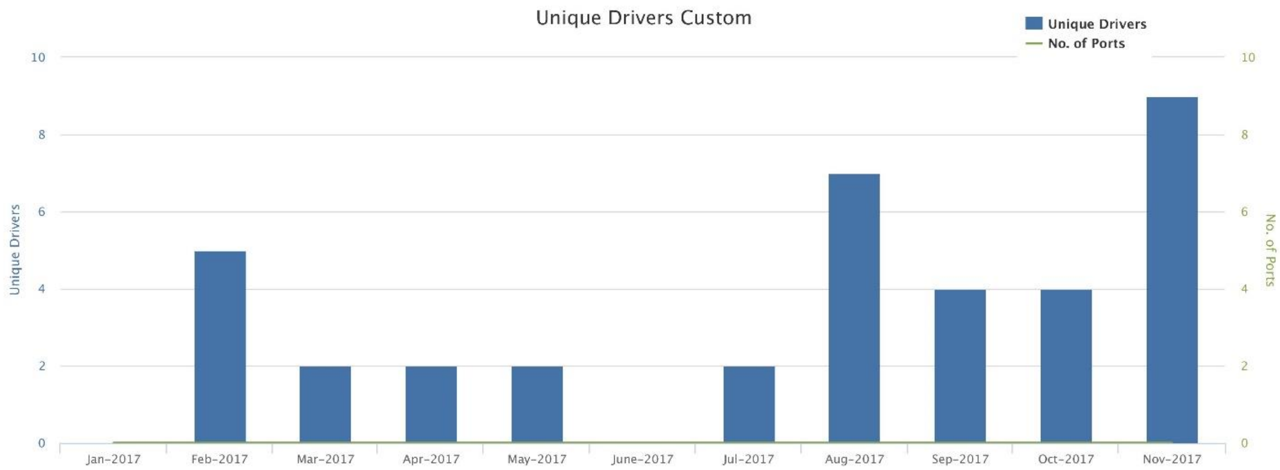


Figure 7.2: Number of unique users since installation

8. Promotion and Education

Public awareness and public education is an important element of this research project. It is important that the public is informed about the location of existing charging infrastructures and the benefits derived out of them. Furthermore, ongoing research and planning for the location of the DC fast charging infrastructure as determined by this work need to be disseminated, discussed and explored with the public. Three avenues and initiatives are considered to interact with the public and the scientific community:

- Nebraska Smart Energy Talks, October 28, 2017.
- Nebraska Smart Energy Expo November 5, 2016.
- Presentations/Talks and conference publications.

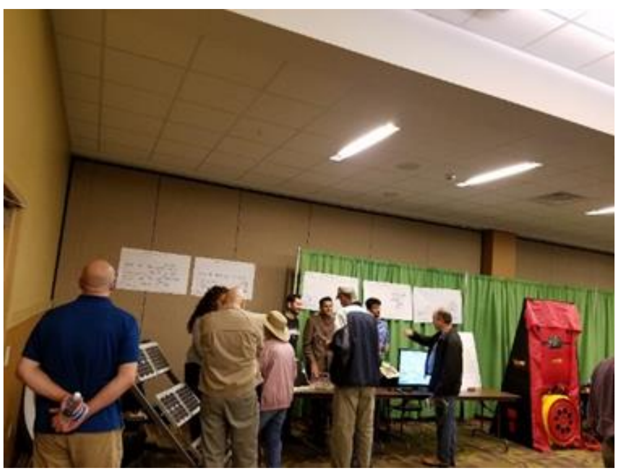
The following subsections will briefly describe each initiative.

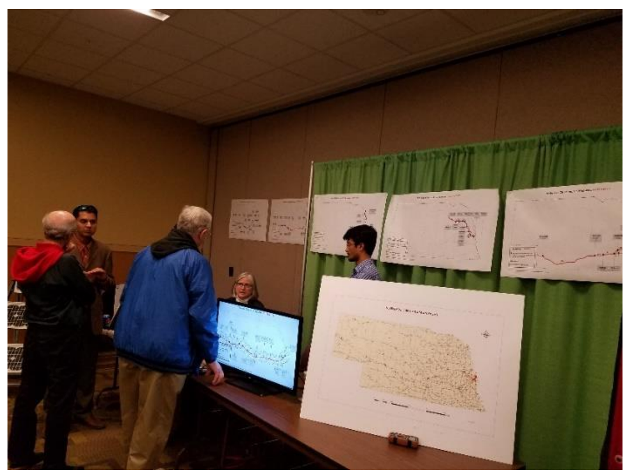
Nebraska Smart Energy Talks, October 28, 2017

This public event took place on October 28 from 9:00AM – 2:00 PM at the University of Nebraska- at Omaha. More than 100 people attended the event. Detailed information on the specifics of the event can be found at http://www.omaha.com/events/smart-energy-talks/. The PI presented data on the benefits and needs of charging infrastructure and electrified transportations. In addition, posters showcasing the results from this research were used to engage the public during the exhibition portion of the event. The pictures below show a snapshot of the event.

Nebraska Smart Energy Expo November 5, 2016.

This public event took place on November 5, 2016 from 9:00AM – 2:00 PM at the University of Nebraska- at Omaha. More than 200 people attended the event. Maps showing Nebraska highways, cities and potential locations for DC fast charging were presented during the exhibition portion of the event. The following two pictures were taken during the event.





Presentations and Conference publications

This results of this research has been discussed in public events and presented and published in national conferences. The following is a list of these events:

Presentations/Discussions/Talks

• "**Our Research Shows the Benefits are Real**" Presentation at the 2017 Smart Energy Talks, October 28, 2017, Omaha, Nebraska. A copy of this presentation is provided in Appendix 8.1.

• Participated in an NET Radio Interview with NCEA on Tuesday April 4, 2017 to discuss Economic and environmental benefits of electrified transportation. The story was aired on Wednesday, April 26, 2017.

• Participated with NCEA, Nebraska Power Association and the Nebraska Energy Office in a NPA EV Charging Initiative Meeting on Thursday May 25, 2017 and presented summaries for the economic and environmental benefits.

• Testified during the LR455 Special committee – Carbon Emission Reduction hearing that was held on October 21, 2016 in Lincoln, Nebraska.

Conference publications

• Subhaditya Shom, Mahmoud Alahmad "**Determining Optimal Locations of Electrified Transportation Infrastructure on Interstate/ US-Highways**"; Proceeding of the CEWIT2017, the 13th International Conference on Emerging Technologies for a Smarter World. Long Island, NY, November 7-8, 2017. A copy of this paper is provided in Appendix 8.2.

• Subhaditya Shom, Fares AlJuheshi, Ala'a Rayyan, Mahmoud Alahmad, Mohammad Abdul-Hafez, Khaled Shuaib "**Characterization of a Search Algorithm to Determine Number of Electric Vehicle Charging Stations Between Two Points on an Interstate or Us-Highway**," Proceeding of the 2017 IEEE Transportation Electrification Conference & Expo, Chicago, IL; June 22-24, 2017. A copy of this paper is provided in Appendix 8.3.

• Subhaditya Shom, Fares AlJuheshi, Ala'a Rayyan, Mahmoud Alahmad, Mohammad Abdul-Hafez, Khaled Shuaib "**Case Studies validating algorithm to determine the number of charging station placed in an Interstate and US-Highway**," Proceeding of the 2017 IEEE International Conference on Electro Information Technology (EIT), Lincoln, NE; May 15-17, 2017. A copy of this paper is provided in Appendix 8.4.

9. Conclusion & Future Work

a. Conclusion

Building and understanding scaled electrified transportation and fueling infrastructure are key components in the reduction of greenhouse gases (GHG). States are beginning to address electrified transportation and infrastructure in their Long Range Transportation Plans (LRTP). In addition, a key factor to increase market penetration of electrified transportation is to increase the number and output capabilities of the public charging infrastructure, effectively extending the battery range of electric vehicles.

The specific outcome of this research are:

1- Developed a search algorithm to identify the locations of electric vehicle charging infrastructure for a given state along its Interstate and US-Highways.
2- Developed a prioritization method based on set criteria for further planning and deployment of each location.
3- Investigated Long Range Transportation Plans (LRTP) for all 50 states in the USA.
4- Developed economic and environmental benefits for electrified transportation for the state of Nebraska.
5- Investigated feasibility needs and benefits of electrified transportations in all 50 states in the USA.

The specific findings of the research are:

- For Nissan Leaf 2016 S24 model:
  - Number of charging infrastructure locations:101
  - Number of charging infrastructure in Zone 1: 28 (Highways benefitted: 9)
  - Number of charging infrastructure in Zone 2: 49 (Highways benefitted: 13)
  - Number of charging infrastructure in Zone 3: 24 (Highways benefitted: 7)

- For Chevrolet Bolt 2017 model:
  - Number of charging infrastructure locations: 44
  - Number of charging infrastructure in Zone 1: 10 (Highways benefitted: 9)
  - Number of charging infrastructure in Zone 2: 23 (Highways benefitted: 13)
  - Number of charging infrastructure in Zone 3: 11 (Highways benefitted: 7)

- 32 States discuss EVs or charging infrastructures in their LRTPs.

- U.S. States discussed EVs in their LRTPs for:
  - Reduction of Green House Gases (GHG)
  - Concern for Motor Fuel Tax- Proposal of Vehicle Miles Traveled (VMT) tax to mitigate this problem
  - Emerging technologies and the necessary charging infrastructures to support them

- Environmental impact of electrified transportation in Nebraska is dependent on the energy mix used to generate electricity from each utility provider. The reduction in GHG, when driving an EV compared to a conventional vehicle, ranges from 40-80% reduction.

- Economic impact of electrified transportation in Nebraska is dependent on gasoline and electricity fuel cost. The economic savings range from 4-14 cents per mile when driving an EV compared to a conventional vehicle.

- The survey analysis revealed that there is a trend towards the greater importance and awareness towards electric vehicle use in the state of Nebraska, as well as towards the needs for certain aspects related to the use of such EV's that include charging infrastructure.

Future Work

As for future work, the existing research can be extended in the following areas:

1- Continue research on analyzing each proposed location to determine the required number of charging ports to allow electric vehicle owners to move in and about the city without having any range anxiety. Factors in the determination will include key driving patterns, vehicle specifications, driving routes and forecasted data among others. An optimization technique will then be used to minimize waiting time for charging, idle rate of ports and cost.
2- Develop a city-readiness index will be formulated for each city in the state to determine whether a selected city location is market ready for electrified transportation and charging infrastructure. If a city is not ready, this index will aid in providing the necessary requirements and changes to make that city electric vehicle market ready.
3- Study the effects of Nebraska Public Power EV Home Charging initiative, approach a phased-in charging infrastructure for electrified transportation in Nebraska, provide a resource for policy-makers undertaking Nebraska's LRTP, and to develop the tools necessary to improve Nebraska's EV charging environment.
4- Continue to collect actual electrified transportations data in Nebraska to provide key data to support the economic and enviormental benefits of electrified transportation in the state.
5- Come up with a more effective interactive state map which will display the results.
6- Continue working on the LRTPs of different states to determine probabilistic (or futuristic) data to determine a predictive model of the charging infrastructure network.

10. APPENDIX

a. Appendix 1.1: Research proposal
b. Appendix 2.1: Databases for the Algorithm to Determine the Location and Number of Charging Infrastructures Required in the State of Nebraska
c. Appendix 2.2: Results Showing the Number of Charging Infrastructures Required and their Locations Plotted in the State Map of Nebraska
d. Appendix 2.3: Round Trip Coverage Area of 2016 Nissan Leaf from a Charging Infrastructure Location
e. Appendix 2.4: One-Way Coverage Area of 2016 Nissan Leaf from a Charging Infrastructure Location
f. Appendix 6.1: Key Terms Used in the Survey Report
g. Appendix 6.2: Graphical Representation of Survey Part I Data
h. Appendix 6.3: Graphical Representation of Survey Part II Data
i. Appendix 6.4: Electric Vehicle Survey
j. Appendix 6.5: Detailed Benefits and Needs analysis in each State
k. Appendix 8.1: Smart Energy Talk 2017 Presentation
l. Appendix 8.2: Conference Paper - Determining Optimal Locations of Electrified Transportation Infrastructure on Interstate/ US-Highways
m. Appendix 8.3: Conference Paper - Characterization of a Search Algorithm to Determine Number of Electric Vehicle Charging Stations between Two Points on an Interstate or US- Highway
n. Appendix 8.4: Conference Paper - Case Studies validating algorithm to determine the number of charging station placed in an Interstate and US-Highway

APPENDIX 1.1

RESEARCH PROPOSAL

Research Proposal

NTRC Number

RHC-15

Project Title

Battery Electric Vehicles and DC Fast Charging Infrastructure: Needs and Feasibility in Nebraska

Submitting Principal Investigator

Moe Alahmad, Ph.D. (University of Nebraska-Lincoln, Durham School of Architectural Engineering and Construction, Associate Professor of Architectural Engineering)

Background

A key factor to increase market penetration of battery electric vehicles (EVs) and support the electrification of transportation at scale is to increase the number and output capabilities of Electric Vehicle Charging Stations (EVSE) deployed in public spaces; in other words, an adequate public charging infrastructure is needed to effectively extend EVs' battery ranges when it is away from home charging access. Currently, there are three types of EVSE stations: Level 1 (110 V) for home charging, Level 2 (240 V) for workplace and commercial charging, and Level 3 (480 V) DC fast charging for commercial and highway travel. DC fast charging can recharge a dead battery to 80% of its full capacity in 30 minutes or less. In contrast, Level 2 charging can take between four and six hours, depending on the size of the vehicle's onboard charger and Level 1 takes 8-12 hours. As technology advances to make EVs more convenient, as technology such as DC fast charging becomes more available, and as production costs continue to decrease, the improved economic and environmental benefits will make it more practical for consumers to purchase electric vehicles. As of August 2014, a total of 11,712 battery electric vehicles (171 EVs and 11,541 hybrid EVs) were registered in Nebraska. Following national-level trends, this number is expected to grow in Nebraska; the market share of electrified vehicle sales is expected to reach eight percent nationwide by

2020. Nationwide, 123,049 EVs were sold in 2014, accounting for four percent of the market share.

The proposed project will build on the current work of the Nebraska Community Energy Alliance (NCEA), which formed in 2014 in order to execute a Nebraska Environmental Trust (NET) grant. This $403,000 grant has demonstrated the economic and air quality benefits of EVs, and to a smaller extent, compressed natural gas (CNG) vehicles through the provision of municipal EVs and CNGs and Level 2 EVSE stations in the nine Nebraska communities that originally formed the alliance: South Sioux City, Wayne, Bellevue, Nebraska City, Seward, Holdrege, Lexington, Gothenburg, and Central City. While our research team has developed an understanding of the properties and benefits involved in Level 2 EVSE charging, we now need to investigate the elements that make DC fast charging economically and environmentally beneficial and determine the best locations for these systems. Level 2 charging is a decidedly different experience for the EV owner than DC fast charging that takes a fraction of the time. Of available electronic charging technology, DC fast charging most closely approximates the gasoline refueling experience and Nebraskans buying EVs will increasingly expect public access to a refueling infrastructure that can deliver any of the charging technologies on the market. We presently have 29 Level 2 chargers in Nebraska with plans for more, but there are currently no DC fast chargers. In order for Nebraskans to realize the full benefit of EVs, the refueling infrastructure for EVs must be as robust and ubiquitous as that in existence for gasoline-powered vehicles.

There are a number of global, national, and local market signals that indicate this is an ideal time to conduct a feasibility study for DC charging in Nebraska, including:

1. ***Every major auto manufacturer has introduced or is bringing to market an electric vehicle.*** This trend is indicative of the need to develop a modern and forward-thinking EV recharging infrastructure in Nebraska, particularly when considering that electricity is the best substitute or supplement to gasoline as a transportation fuel. The feedstock for electrical generation is derived locally and not subject to global pricing or the price volatility of national or world economies. Furthermore, the distribution system for electricity as a transportation fuel is already in place, operating with abundant excess capacity to service electric vehicles.

2. ***Nebraska municipalities are demonstrating interest for a statewide EV refueling infrastructure that promotes electric travel between and among communities.*** As a strong show of support for EV infrastructure, the original NCEA member cities contributed 50/50 local matching funds in support of the NET project, and support for our work has continued to grow throughout the state. Since its formation, the alliance has since added members of the Metropolitan Area Planning Agency, the City of Lincoln's Metropolitan Planning Organizations (MPO), the Omaha Public Power District, Metro Community College in Omaha, the University of Nebraska-Lincoln's Durham School at the Peter

Kiewit Institute (PKI), the University of Nebraska at Omaha's Center for Urban Sustainability, the cities of Valley, Gretna, Ashland, Hastings, and Kearney, Dakota County, and Allan Consolidated Schools. In response, the NCEA has submitted a 2016 NET grant to expand the L2 charging infrastructure in Nebraska and increase the number of EV cars.

3. ***Existing quantifiable data supporting the economic and environmental benefits of a public charging infrastructure in Nebraska.*** The Level 2 EVSE charging stations, which are primarily used for workplace and commercial travel, installed in the NET grant collect real time data from working municipal fleet EVs in order to prove the economic and air quality benefits of these vehicles. Our preliminary findings indicate that EVs saved each of the nine communities between $900 and $1,700 (depending on gas prices) per vehicle in fuel and maintenance costs and cut the CO2 emissions in half when compared to similar gas-powered vehicles. Detailed results can be viewed here: www.engineering.unl.edu/e-vehicle/.

Objective

The ***goal of this research proposal*** is to lay the informational foundation necessary for a comprehensive understanding of current EV needs in Nebraska and the planning, analysis, and execution of a robust networked DC fast charging infrastructure for Nebraska and its citizens. This proposed work is part of a larger build out effort that is taking place at multiple coordinated entities within Nebraska agencies. To capture the full benefits of this research and collect quantifiable data supporting this effort, a demonstration site is proposed for the installation of one EVSE – a Level 3 networked DC fast charging station – using grant funding from NDOR's Congestion Mitigation and Air Quality (CMAQ) program and matching funds from the City of Gretna to cover installation costs. When approved, the networked station will be deployed at Nebraska Crossing, located on Interstate 80 between Lincoln and Omaha on land owned by the City of Gretna, a NCEA member. It is expected that the installation of this unit will take place midway through this project, and the networked DC Fast Charger will allow us to capture data from each charge in real time regarding CO2 emissions reductions, electricity used and gasoline saved as well as other data, such as how much time was spent charging the vehicle, how often the station was accessed, when the most usage occurred as examples. The deployment of the networked DC fast charger at Nebraska Crossing is part of a larger infrastructure plan being phased in by the joint efforts of the Metropolitan Area Planning Agency, the City of Lincoln MPO, SIMPCO, and the Nebraska Community Energy Alliance.

Using literature research, interviews, and surveys, as well as data collection from the new DC fast charging station, this project will achieve its goal through the following **five objectives**:

1. Determine the needs for a DC fast charging infrastructure in Nebraska.

2. Determine the benefits of a DC fast charging infrastructure to Nebraska's Department of Transportation (DOT) and Nebraska communities and citizens.
3. Develop a vision and deployment strategy for Nebraska's policymakers based on research on what other federal, state, and local agencies – including DOTs and MPOs – are planning, doing, or have done with respect EVs and their charging infrastructures.
4. Determine the necessary elements for successful DC fast charging installation across Nebraska by collecting and documenting data from the proposed charging station at Gretna.
5. Implement a high impact public education campaign in order to promote and advertise the new charging station's availability and to build interest, usage, and acceptance.

Expected Benefits

The proposed project will combine targeted literature research, information from surveys and interviews, and data collected by the new DC fast charging station in Gretna in order to plan, analyze, and execute a DC fast charging infrastructure in Nebraska. While the economic and environmental benefits of this infrastructure to Nebraska and its citizens will be great, several important research findings are needed to guide us in this effort in Nebraska and to ensure that the plan maximizes these benefits. By the end of this project, we will have developed a plan to implement this infrastructure based on the needs of the state and our citizens, detailed evidence of the environmental and economic benefits that will result, best practices resulting from comparative analyses of other states and agencies, and user data from the first DC charging station to be installed in Nebraska (i.e., the proposed Gretna charging station).

Implementation

Objective 1. Determine the needs for a DC fast charging infrastructure in Nebraska. We will initiate various research activities including surveys and interviews to determine the need. We will use this information to determine: 1) public demand for EV charging and clean mobility; 2) public expectations for EV charging infrastructure, and 3) optimal locations for EV charging infrastructure types. These findings about consumer and state needs will play an integral role in planning the DC fast charging infrastructure for Nebraska.

Objective 2. Determine the benefits of EVs and an associated DC fast charging infrastructure to Nebraska's Department of Transportation (DOT) and Nebraska communities and citizens. We will initiate various research activities including surveys and interviews and data from our on-going project to determine the benefits. In particular, this will result in a platform for analyzing and documenting air quality benefits, economic benefits to the user and the community, and the demand benefit of DC fast charging installations. For example, important questions that will be answered include: what is the air quality benefit or economic impact that a DC fast charger might have on the surrounding area or how can we quantify the number of gasoline-powered vehicles we displace by offering DC fast charging capability?

Objective 3. Develop a vision and deployment strategy for Nebraska's policymakers based on research on what other federal, state, and local agencies – including DOTs and MPOs – are planning, doing, or have done with respect EVs and their charging infrastructures. This comparative analysis will allow us to learn from others' experiences in implementing this Nebraska initiative and to answer several questions of relevance to the proposed fast charging station infrastructure, including:

- What development strategies should Nebraska pursue and how should phases of infrastructure development be prioritized?
- What locations in Nebraska would result from the highest benefit in ED and AQ (e.g., along the interstate or in urban areas)?
- How can public/private partnerships benefit from the investment in EV infrastructure and what are the pros and cons to publicly- versus privately-owned and operated vehicles?
- What are the shorter- and longer-term trends of the EV manufacturing market and networked charging station technology innovations, and how can we deploy charging technology today that is capable of evolving with the future market?

Objective 4. Determine the necessary elements for successful DC fast charging installation across Nebraska by collecting and documenting data from the proposed charging station at Gretna. These data will document current EV user experience and behavior, specifically: how often the station is being used; where users are coming from and going to; if and how users spend money while charging; how users spend their time while charging; the length and purpose of users' trips; if users stay longer at the station in order to charge longer; and how users can best be incentivized to complete a survey. This objective will inform statewide planning for optimal infrastructure development and use of public funds and will result in a platform for understanding the EV driver experience and quantifying key factors for measuring impact of the fast charging infrastructure.

Objective 5. Implement a high impact public education campaign in order to promote and advertise the new charging station's availability and to build interest, usage, and acceptance. This objective will include a dedication of the DC fast charger upon its installation. In addition, the results of this objective will help to address several important questions for our overall plan, including: what is the public interest in DC fast chargers; does access to DC fast charging in a region affect how comfortable people feel with purchasing an EV; and does support from local leadership affect public acceptance?

Technical Advisory Committee (TAC)

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Tasks

The proposed objectives of this project will be accomplished using the following tasks, including regular coordination with Technical Advisory Committee (TAC). The project will be accomplished over the course of 18 months, as shown in the proposed schedule.

1. Project initiation, organization, and meeting with TAC for initial planning.
2. Conduct targeted literature research, interviews, and surveys to determine EV needs.
3. Conduct targeted literature research, interviews, and surveys to determine EV benefits.
4. Meet with TAC to provide project progress and updates.
5. Setup installed networked DC fast charging station to collect economic, environmental, and user-specific data.
6. Analyze the collected research data and model and simulate the optimal locations for stations in a charging infrastructure in Nebraska.
7. Collect and analyze data from the Gretna station.
8. Conduct promotional activities to promote the EV charging station and the benefits of EVs, capitalizing on the NCEA presence in member communities of the alliance.
9. Meet with the TAC to provide final project results and report; revise and finalize report.
10. Meet with NDOR/TAC to present the outcomes of the project and submit the final Technical Report.

Schedule

Task	Description	Year 1				Year 2	
		QTR 1	QTR 2	QTR 3	QTR 4	QTR 1	QTR 2
1	Project Initiation, organization and TAC meeting						
2	Conduct targeted research to determine EV needs						
3	Conduct targeted research to determine EV benefits						
4	Meet with TAC /provide progress and updates.		X		X		X
5	Setup Installed DC fast charging station						
6	Analyze research data/develop a model for Nebraska						
7	Collect and analyze Data from Gretna station.						
8	Conduct Highly visible promotional activities						
9	Meet with TAC /provide Final project						
10	Present the project and submit Technical report.						

APPENDIX 2.2

RESULTS SHOWING THE NUMBER OF CHARGING INFRASTRUCTURES REQUIRED AND THEIR LOCATIONS PLOTTED IN THE STATE MAP OF NEBRASKA

APPENDIX 2.2.1: ZONE 1

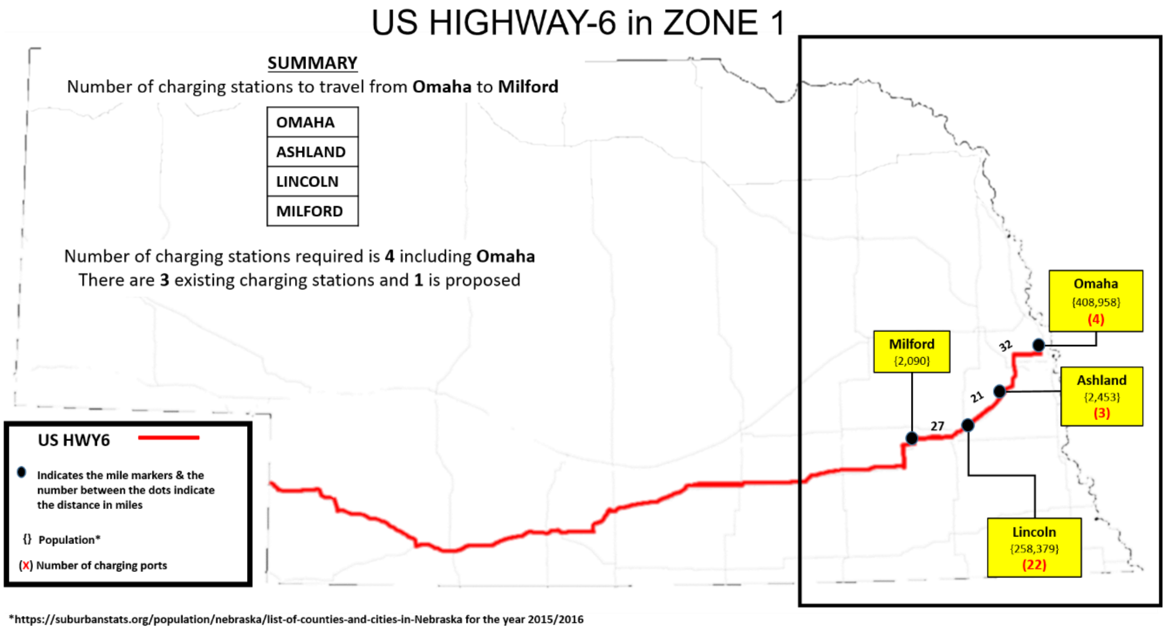


Figure **2.2.**1.1: Results for US-Highway 6

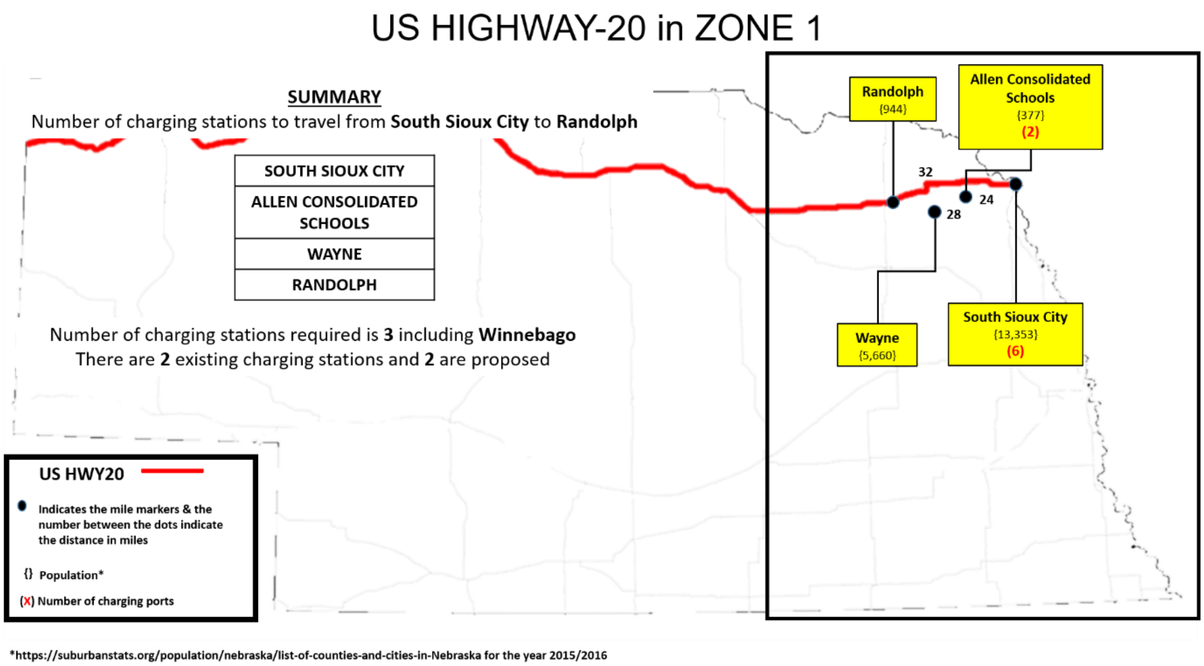


Figure **2.2.**1.2: Results for US-Highway 20

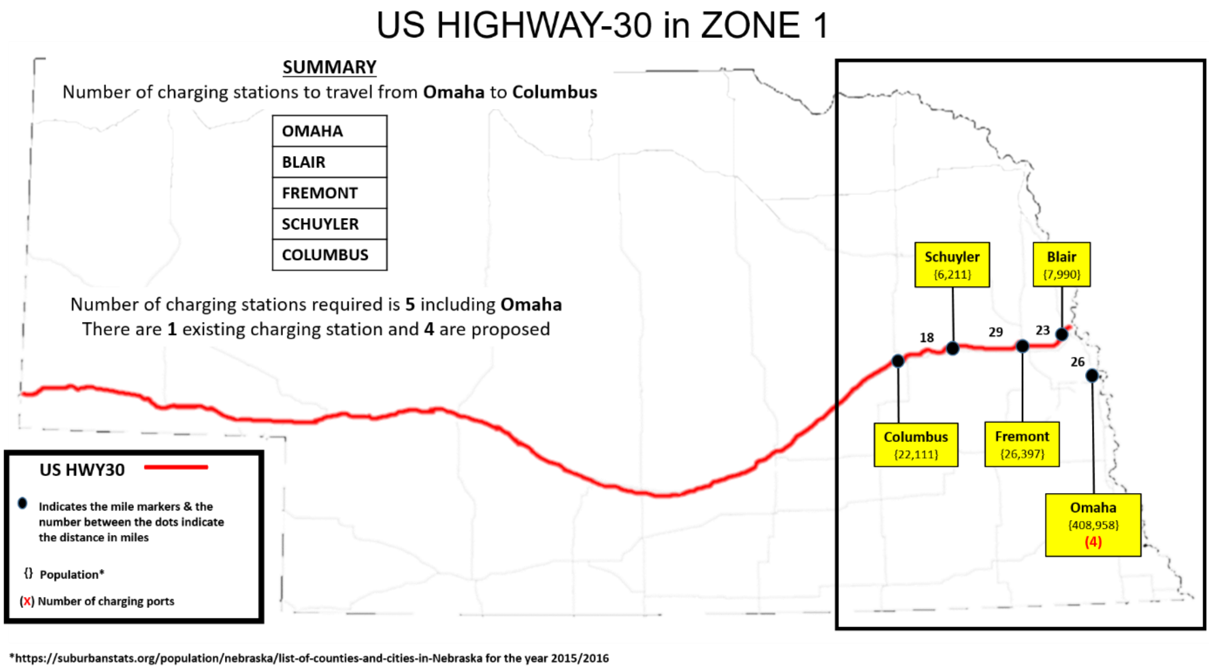


Figure **2.2.**1.3: Results for US-Highway 30

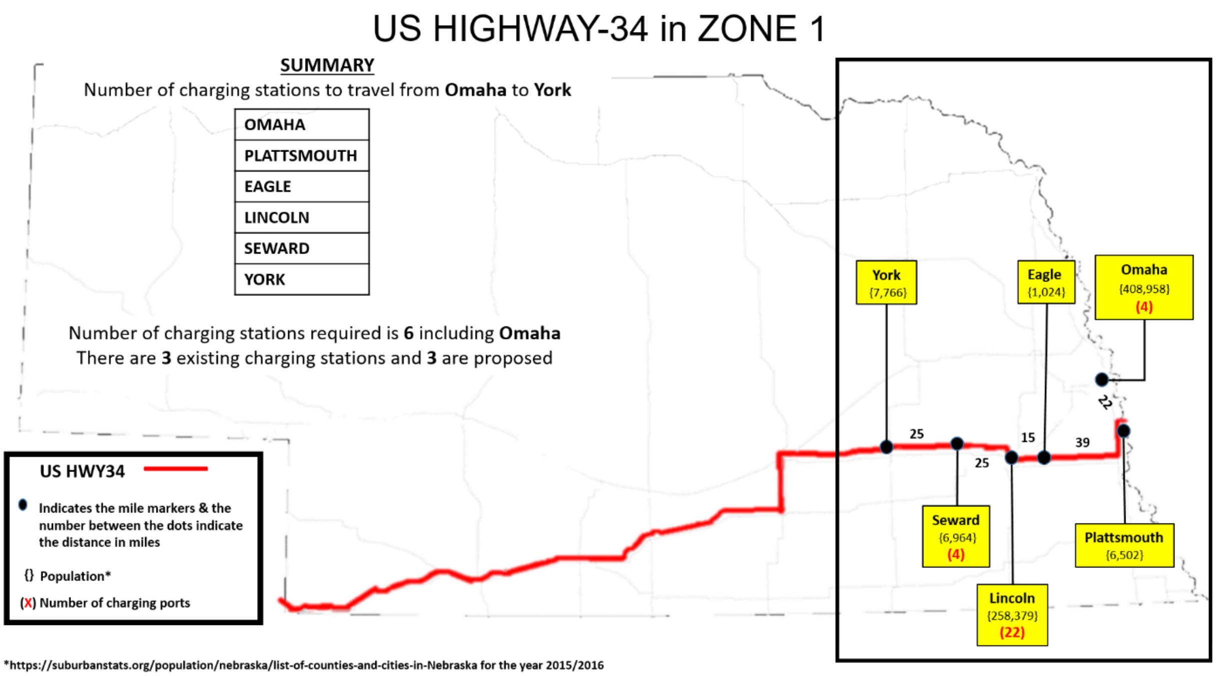


Figure **2.2.**1.4: Results for US-Highway 34

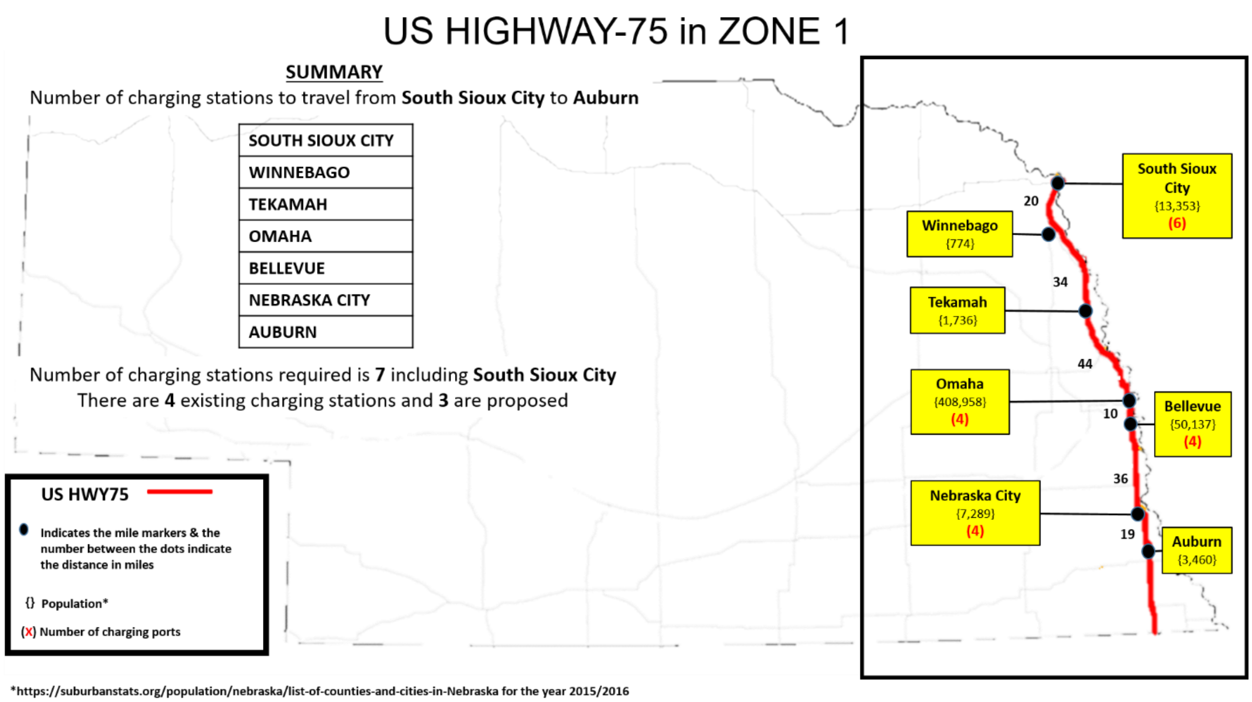


Figure **2.2.**1.5: Results for US-Highway 75

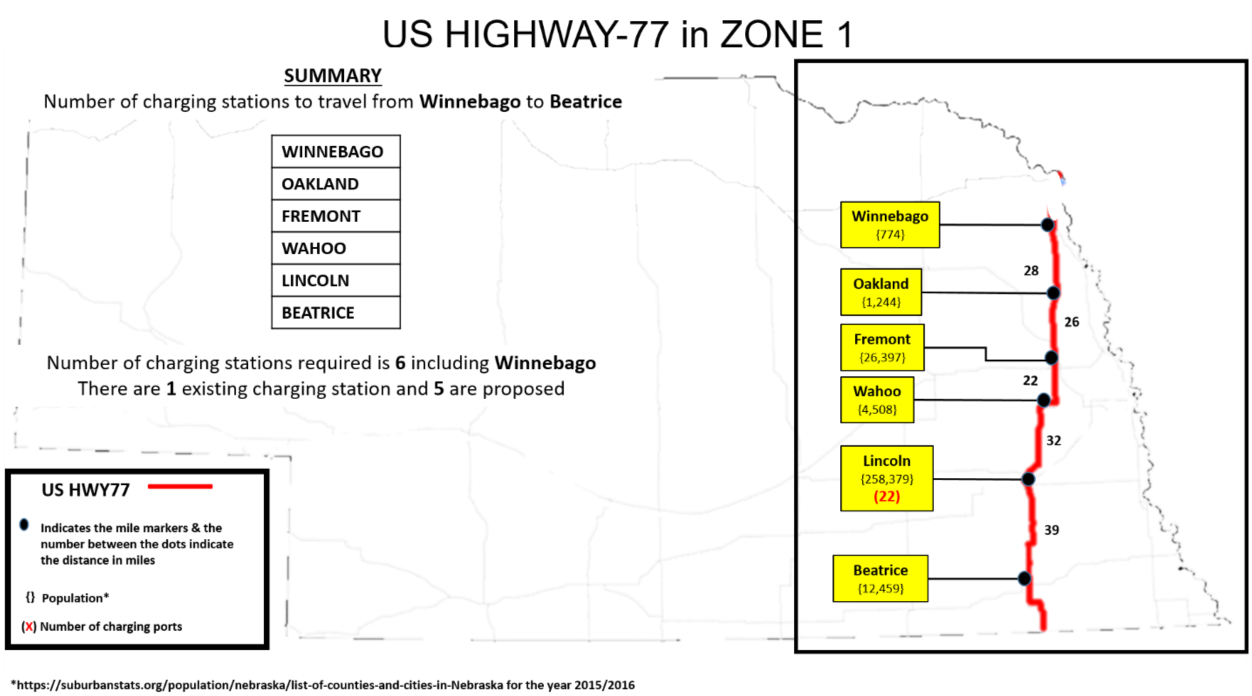


Figure **2.2.**1.6: Results for US-Highway 77

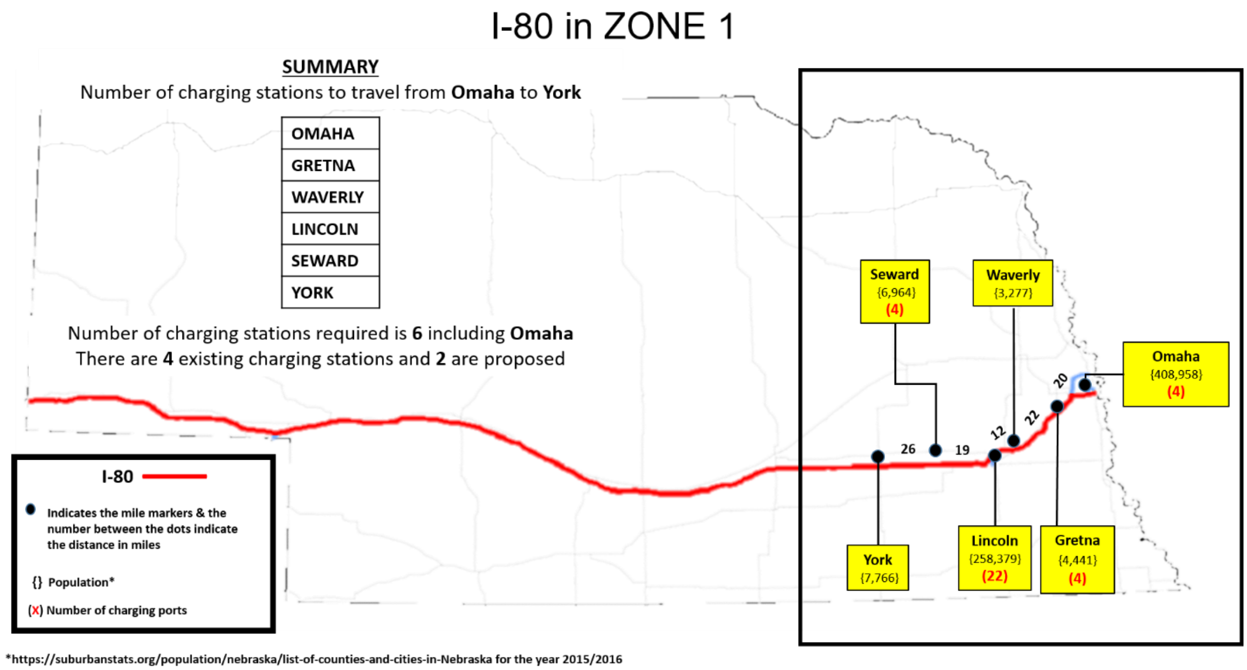


Figure **2.2.**1.7: Results for Interstate 80

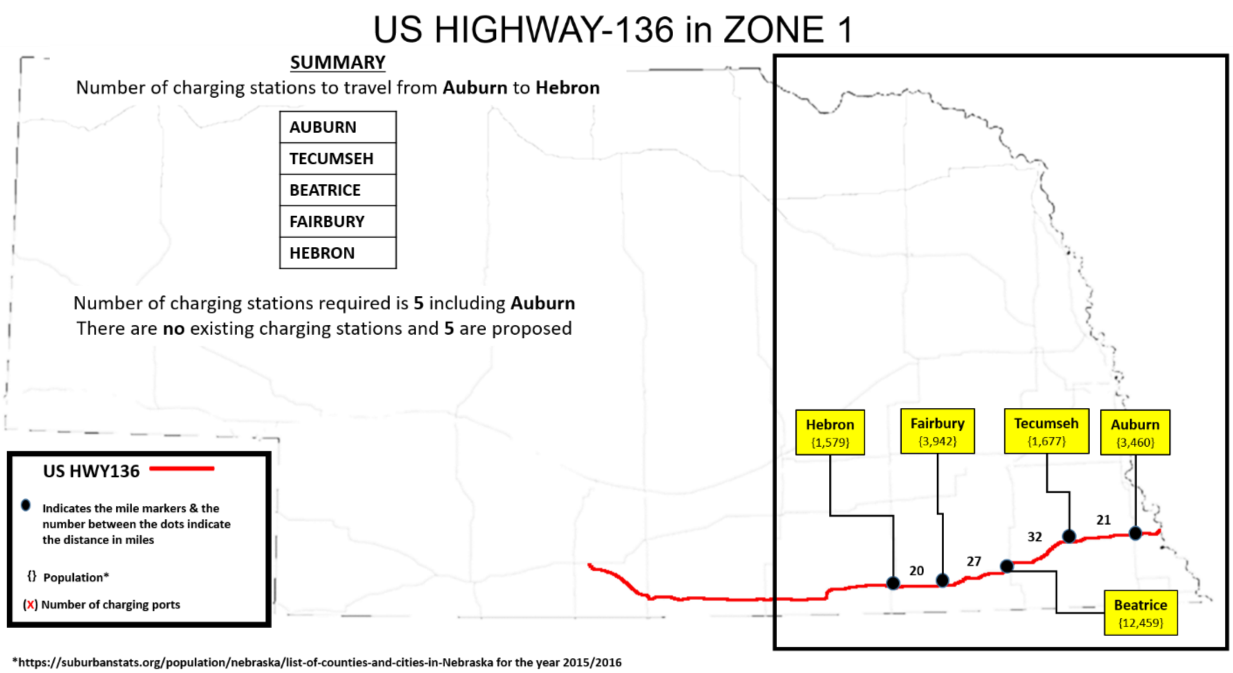


Figure **2.2.**1.8: Results for US-Highway 136

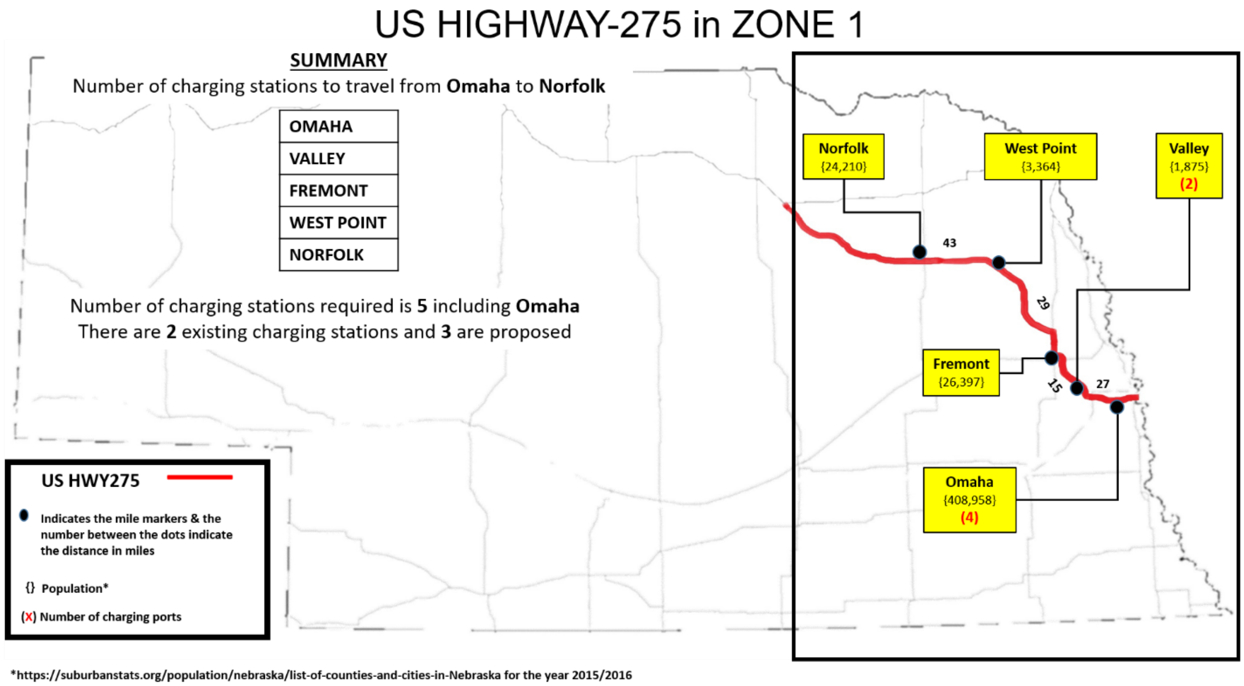


Figure **2.2.**1.9: Results for US-Highway 275

APPENDIX 2.2.2: ZONE 2

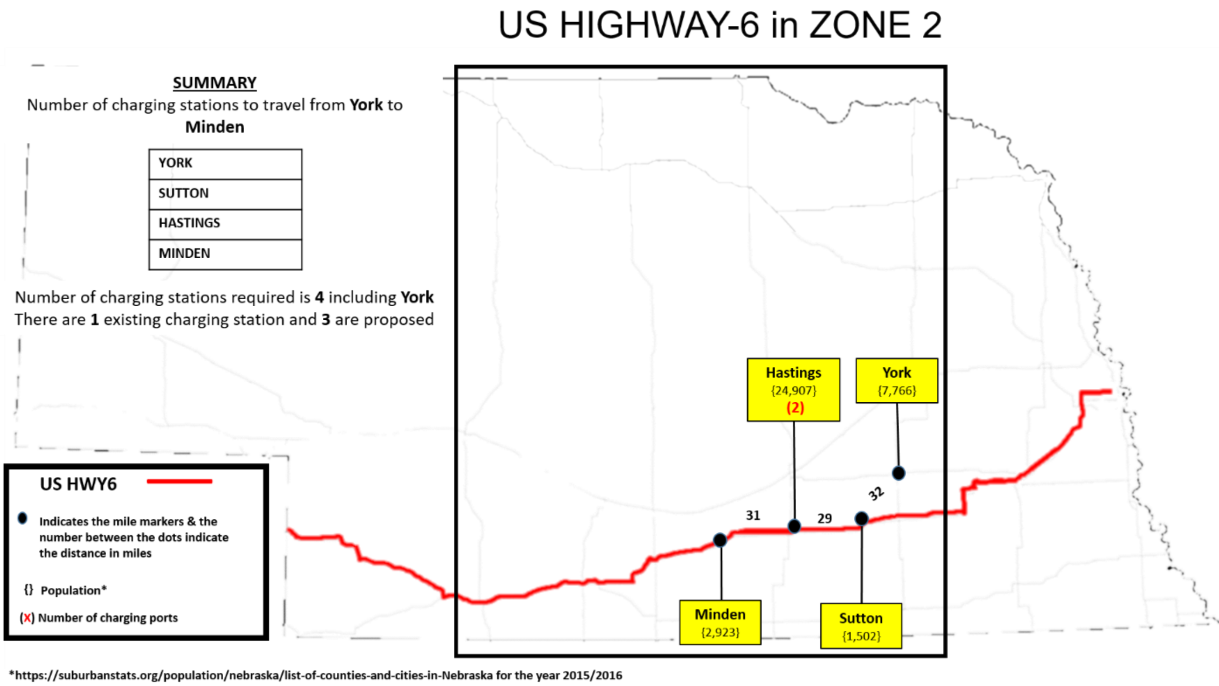


Figure **2.2.**2.1: Results for US-Highway 6

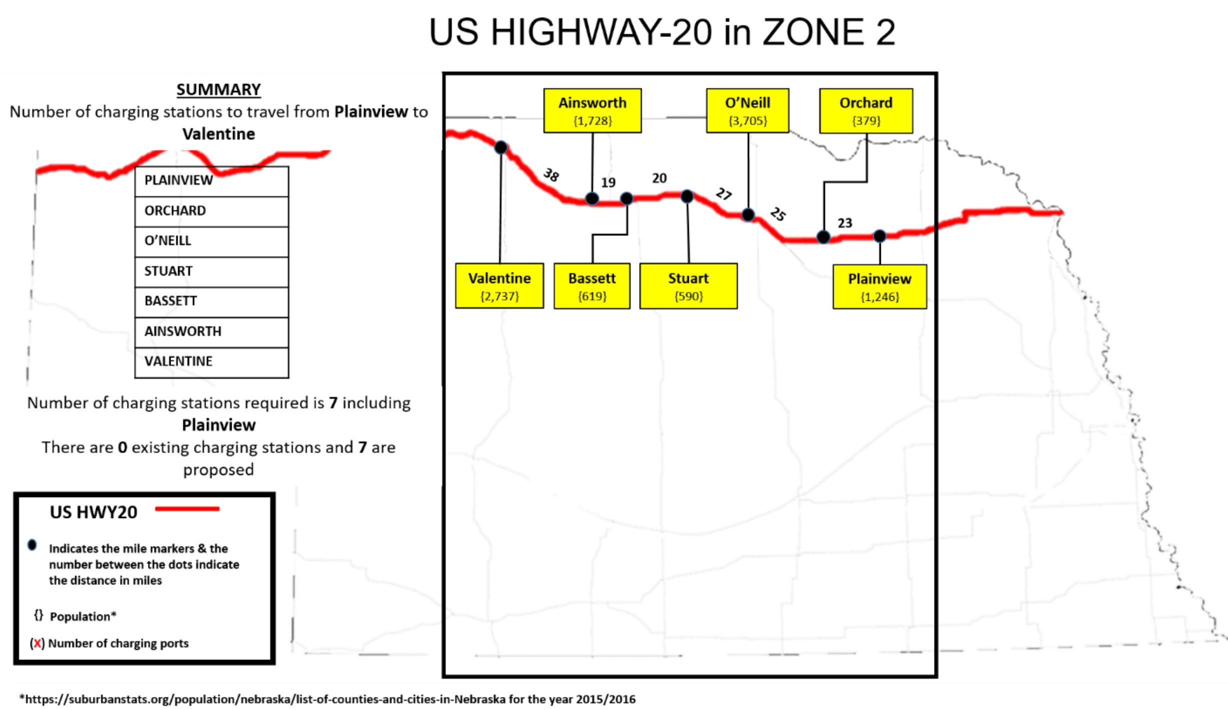


Figure **2.2.**2.2: Results for US-Highway 20

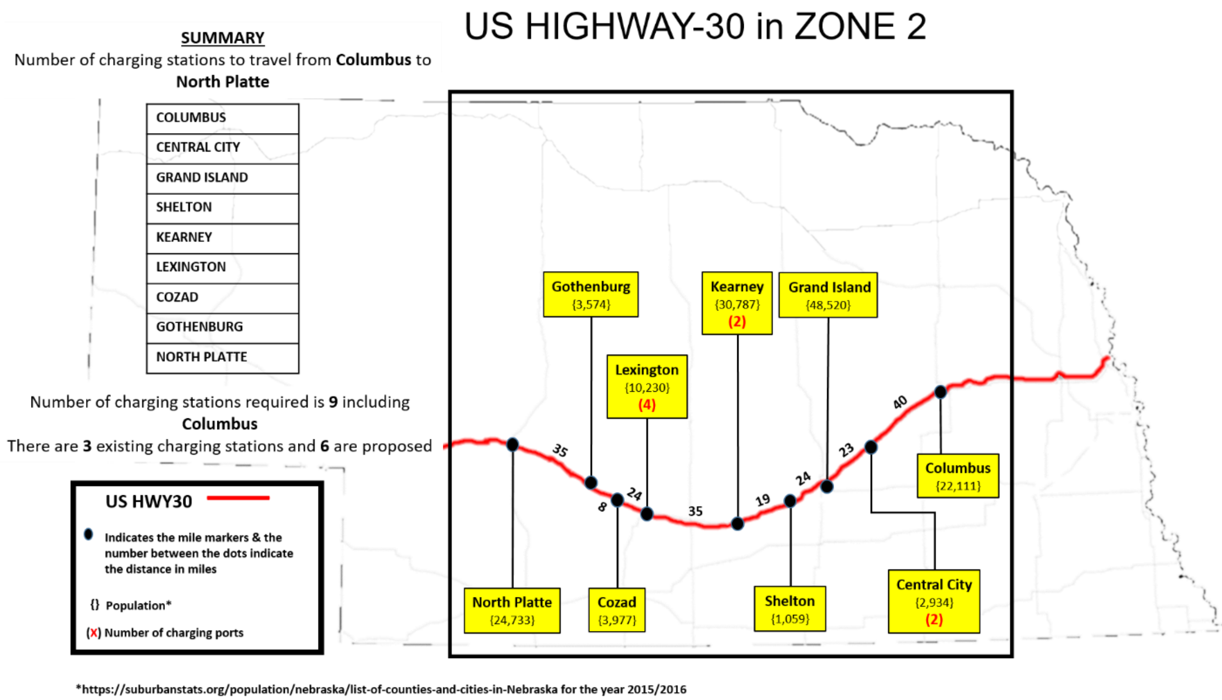


Figure **2.2.**2.3: Results for US-Highway 30

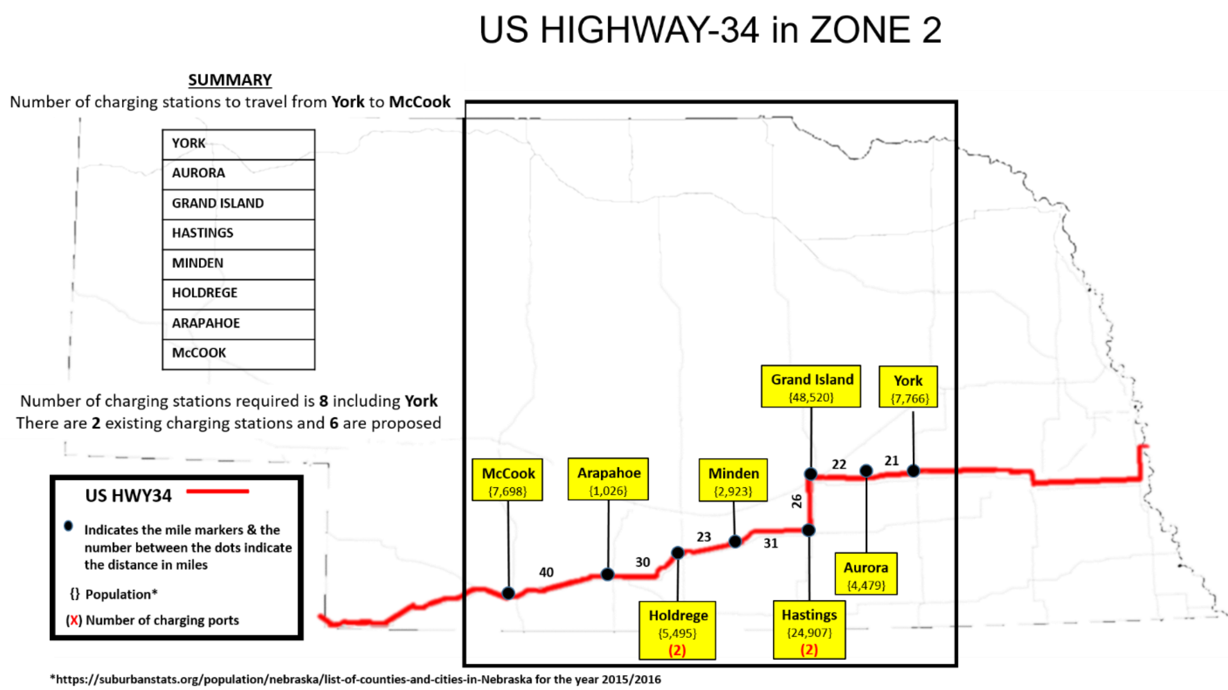


Figure **2.2.**2.4: Results for US-Highway 34

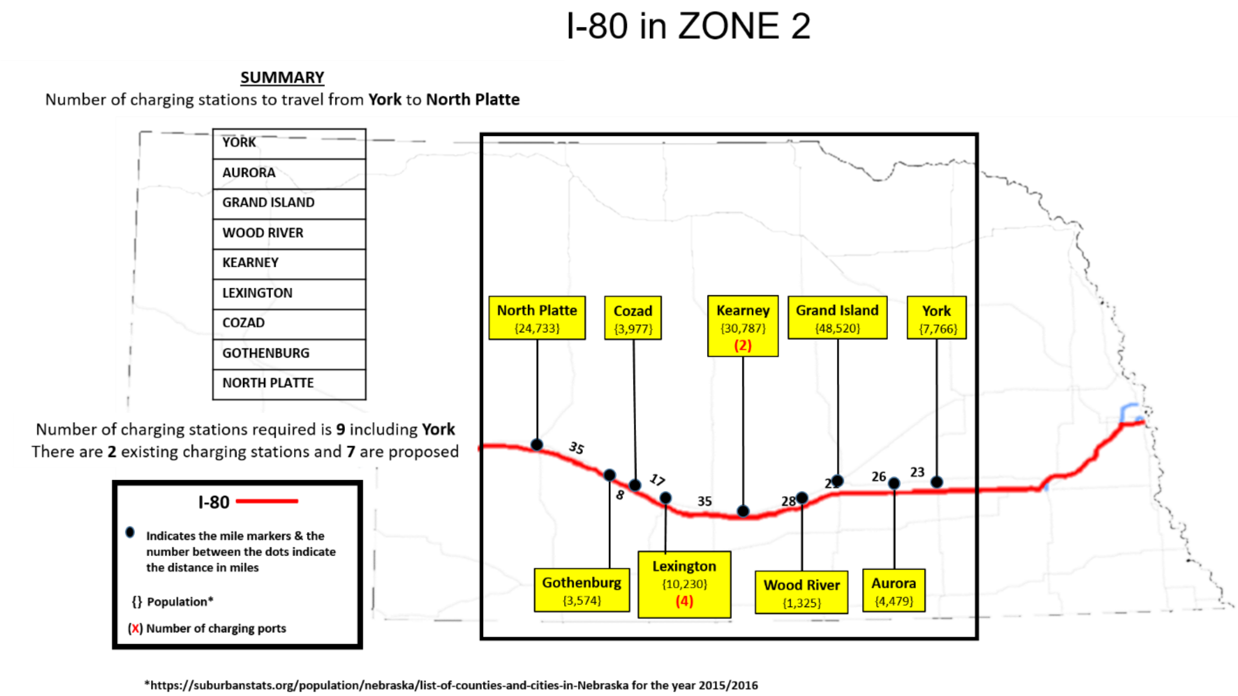


Figure **2.2.**2.5: Results for Interstate 80

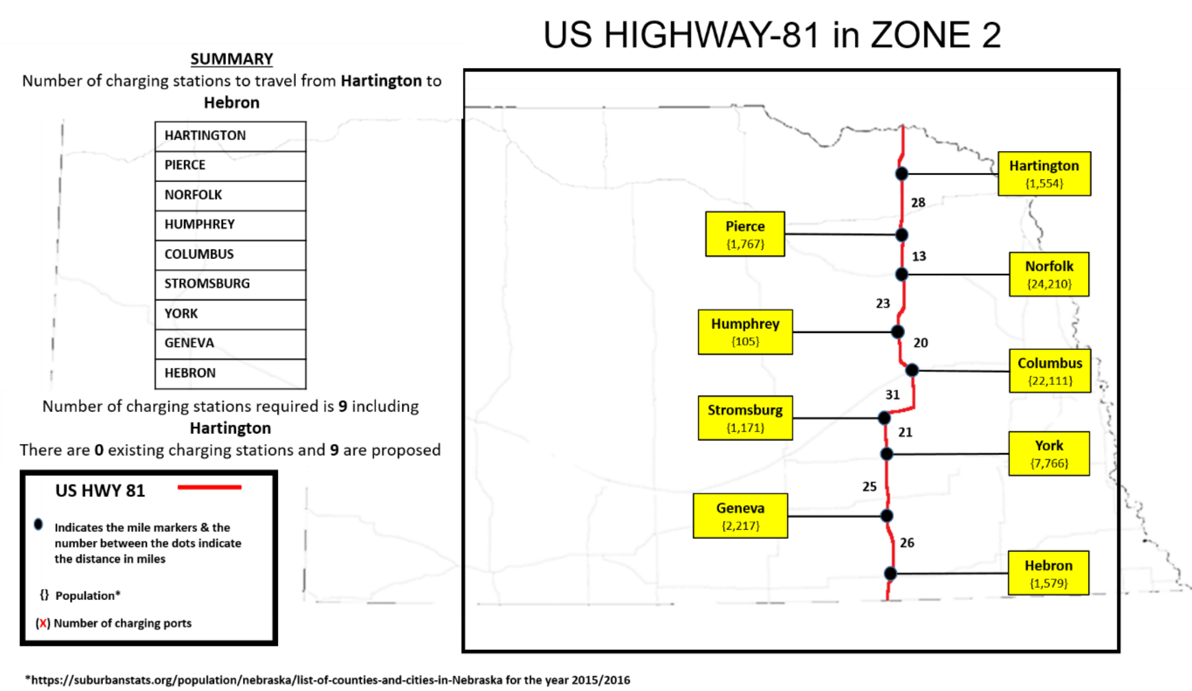


Figure **2.2.**2.6: Results for US-Highway 81

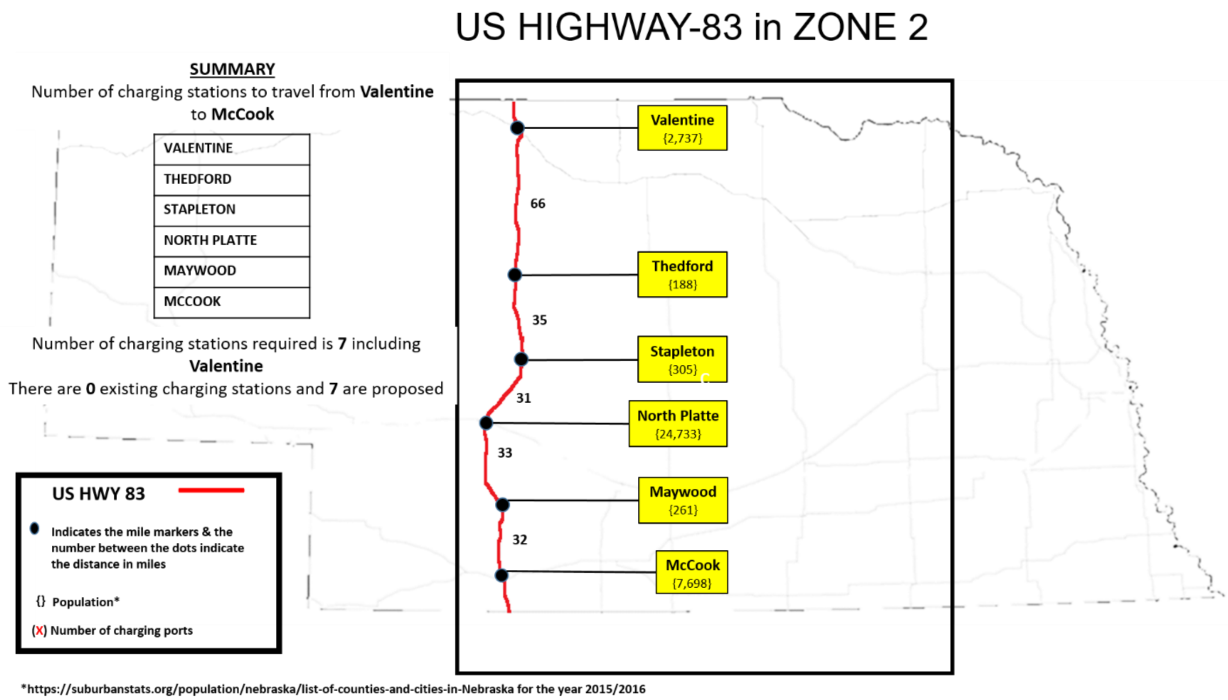


Figure **2.2.**2.7: Results for US-Highway 83

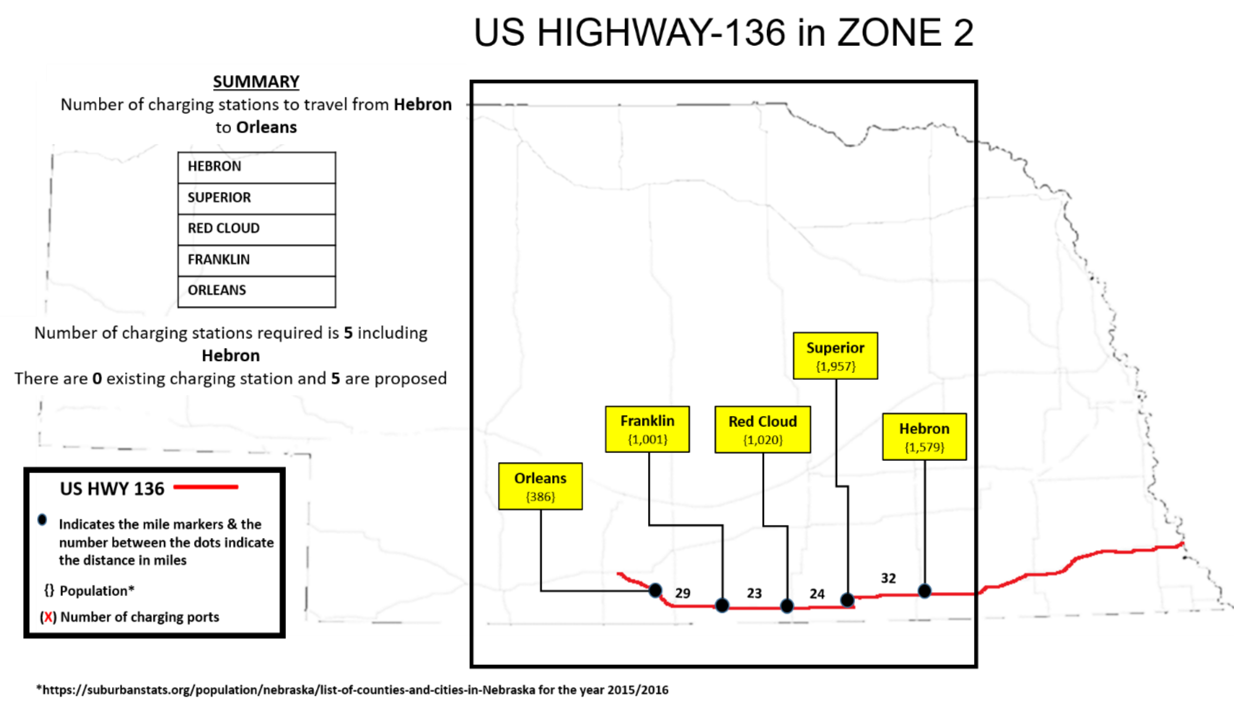


Figure **2.2.**2.8: Results for US-Highway 136

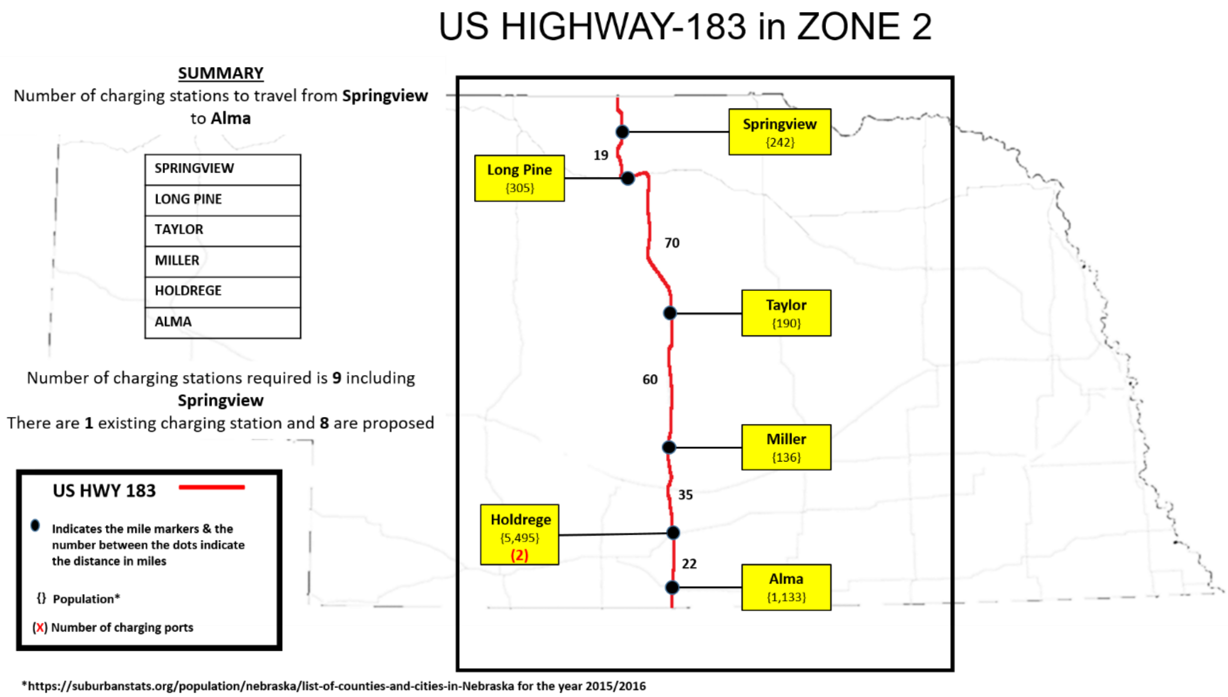


Figure **2.2.**2.9: Results for US-Highway 183

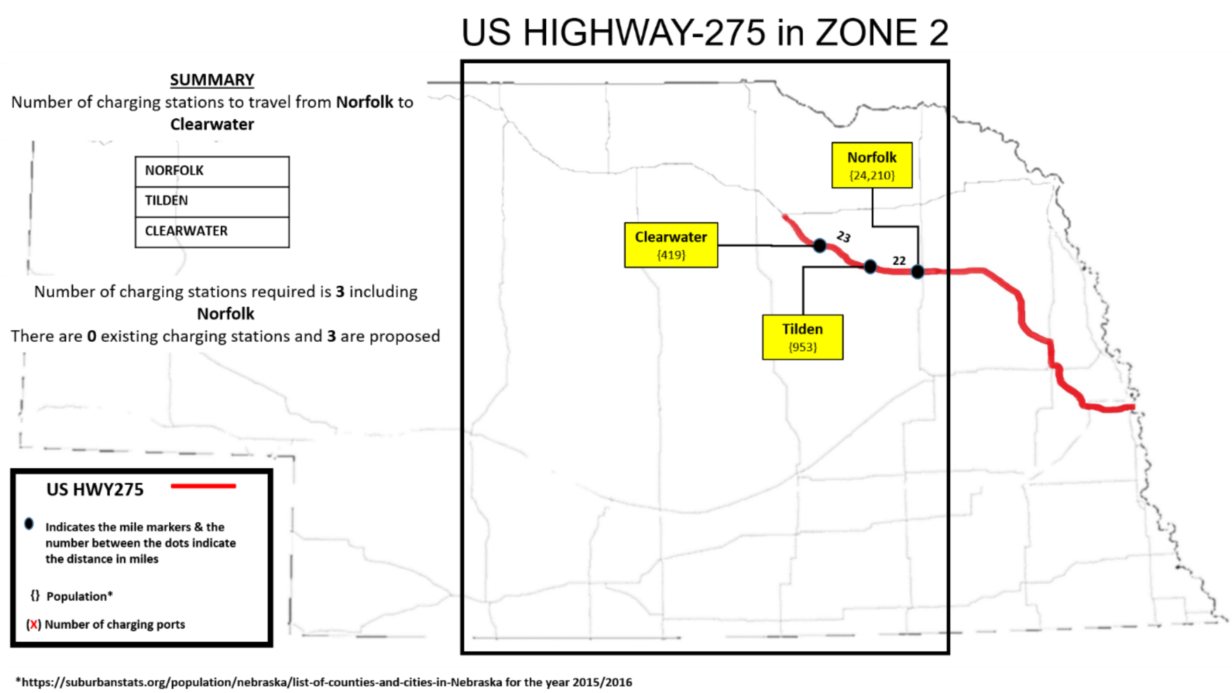


Figure **2.2.**2.10: Results for US-Highway 275

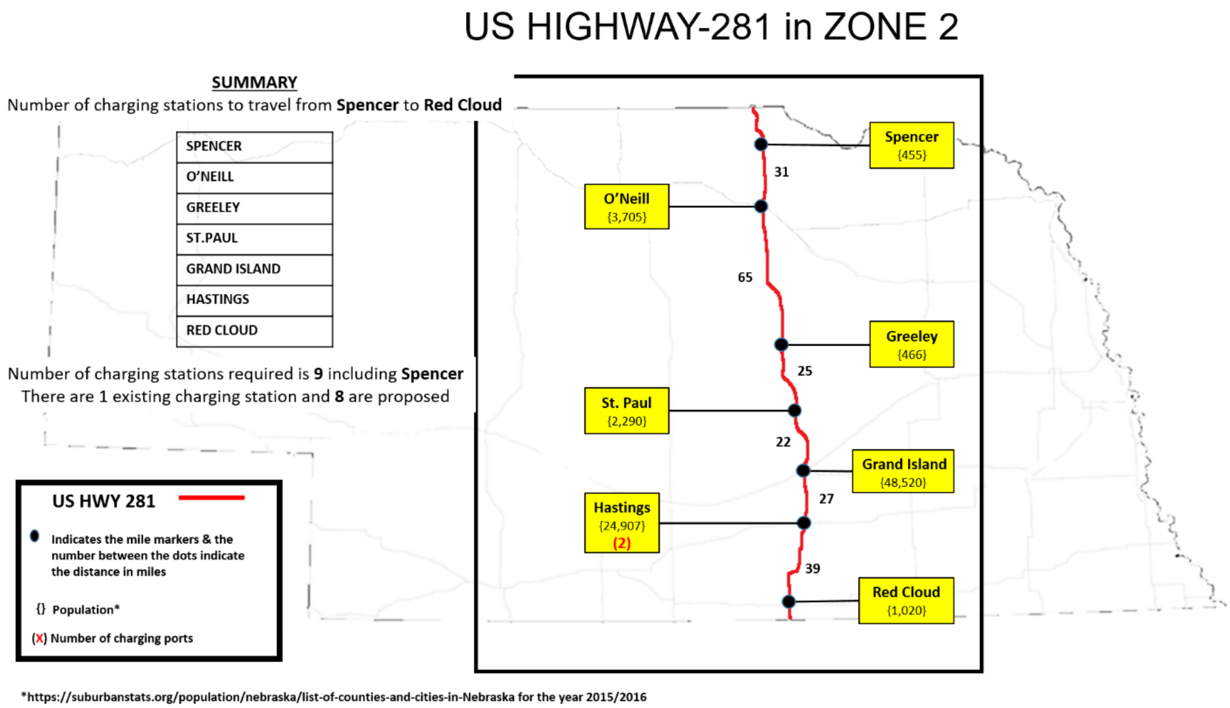


Figure **2.2.**2.11: Results for US-Highway 281

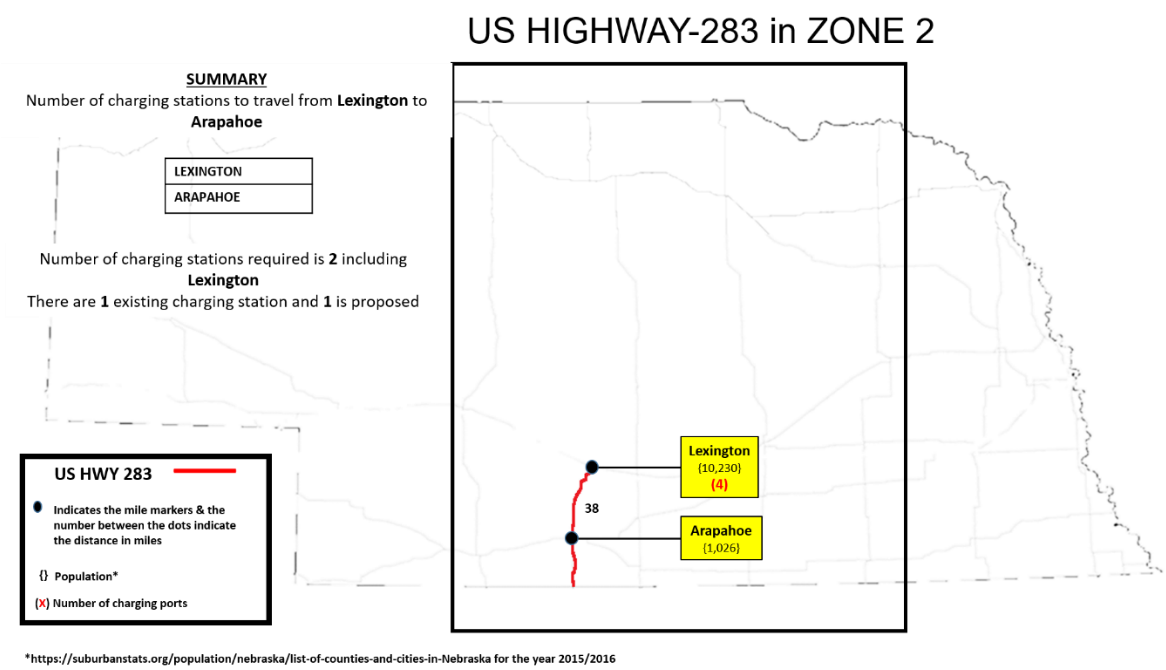


Figure **2.2.**2.12: Results for US-Highway 283

APPENDIX 2.2.3: ZONE 3

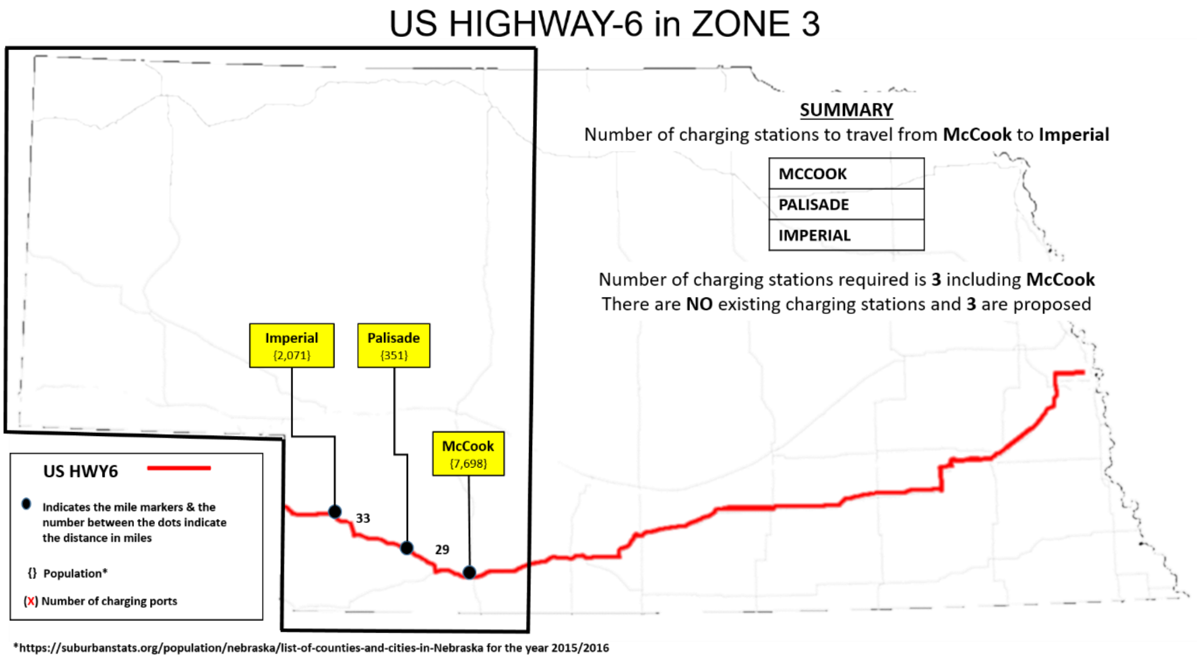


Figure **2.2.**3.1: Results for US-Highway 6

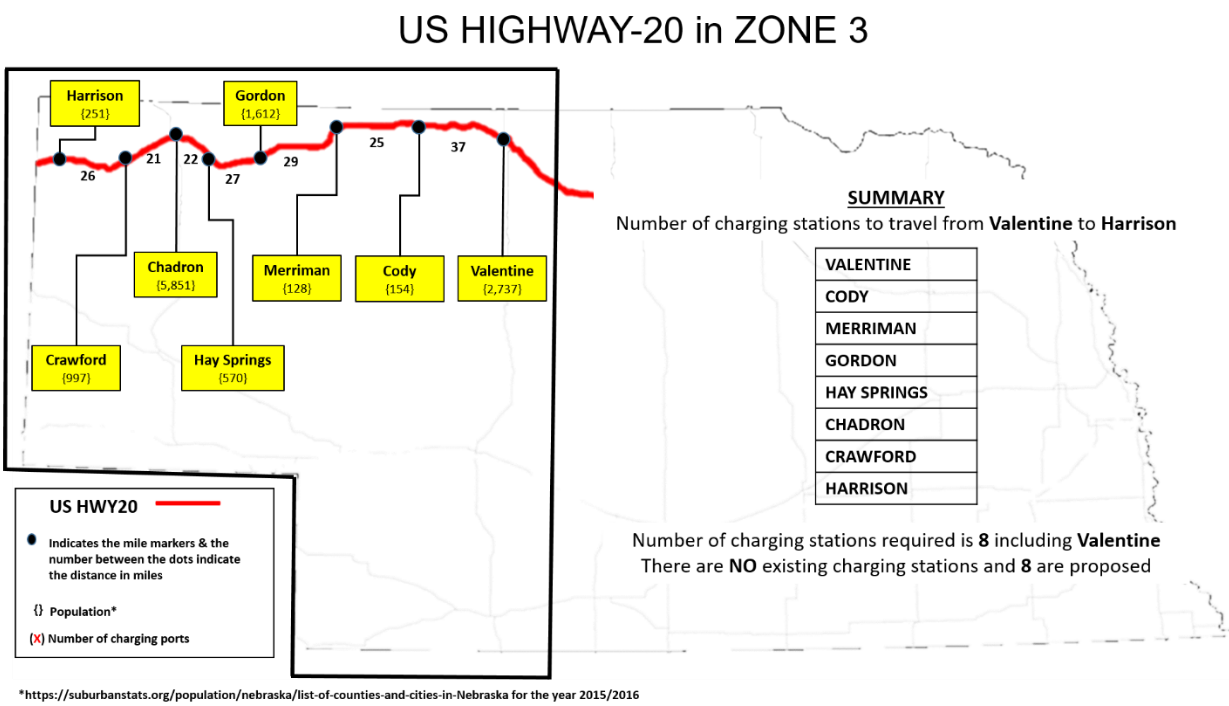


Figure **2.2.**3.2: Results for US-Highway 20

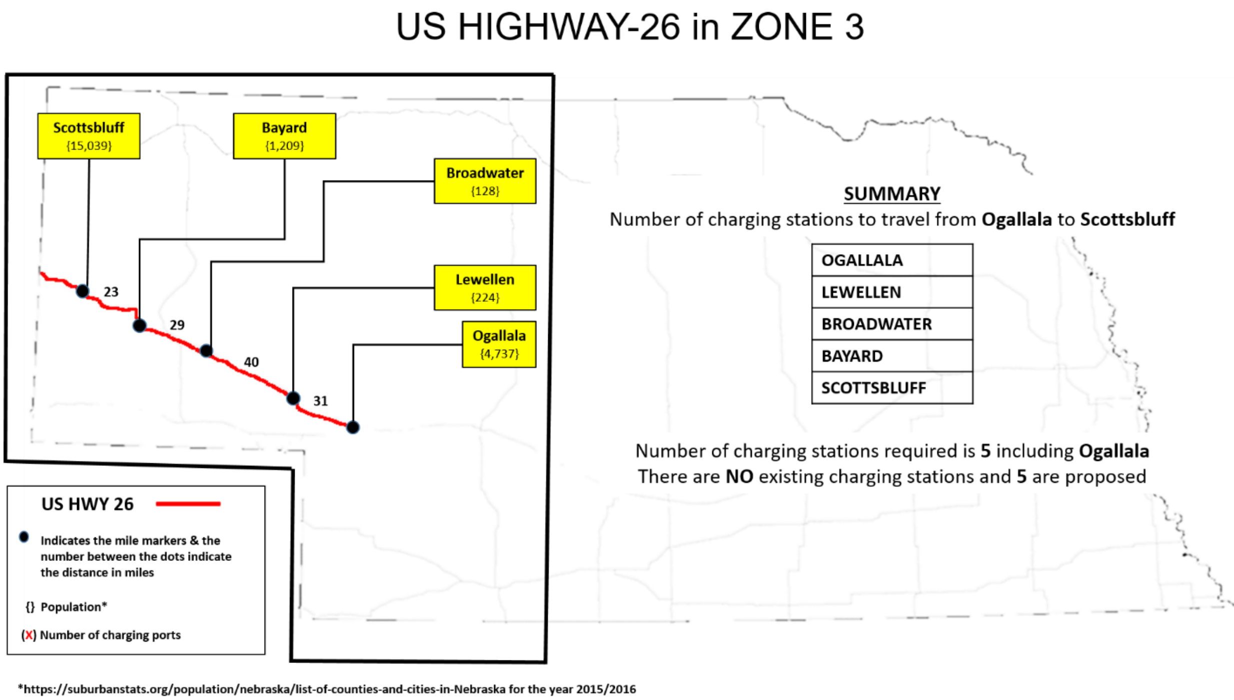


Figure **2.2.**3.3: Results for US-Highway 26

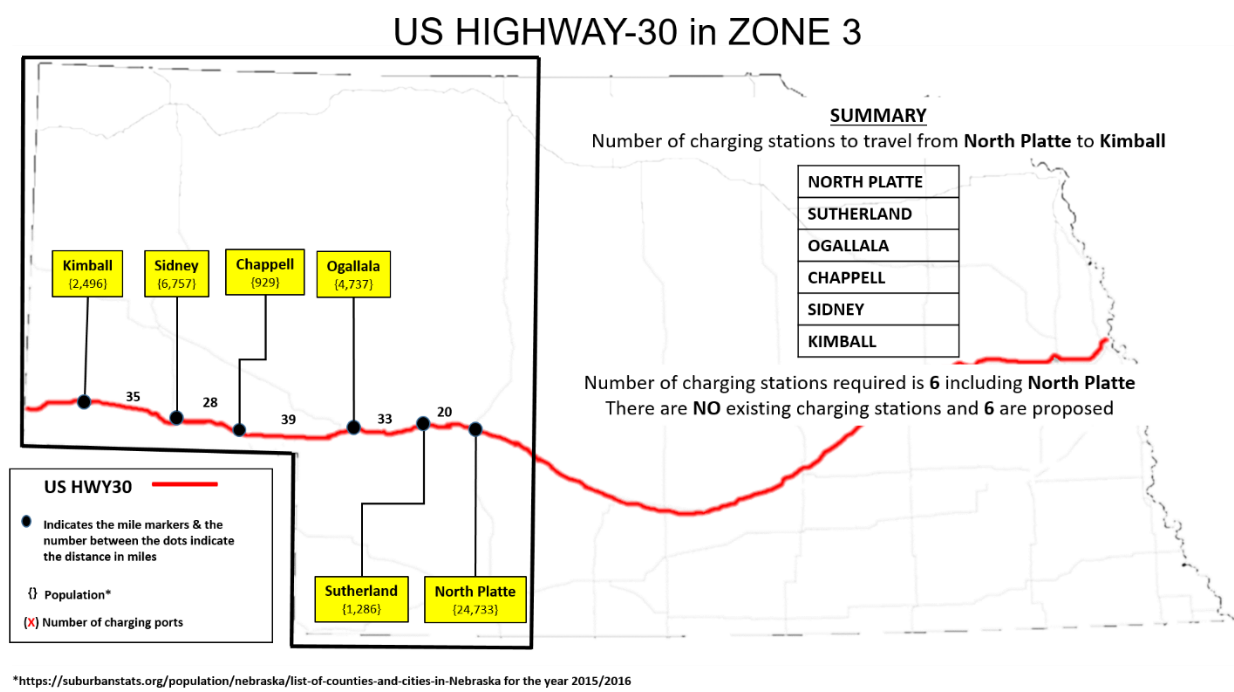


Figure **2.2.**3.4: Results for US-Highway 30

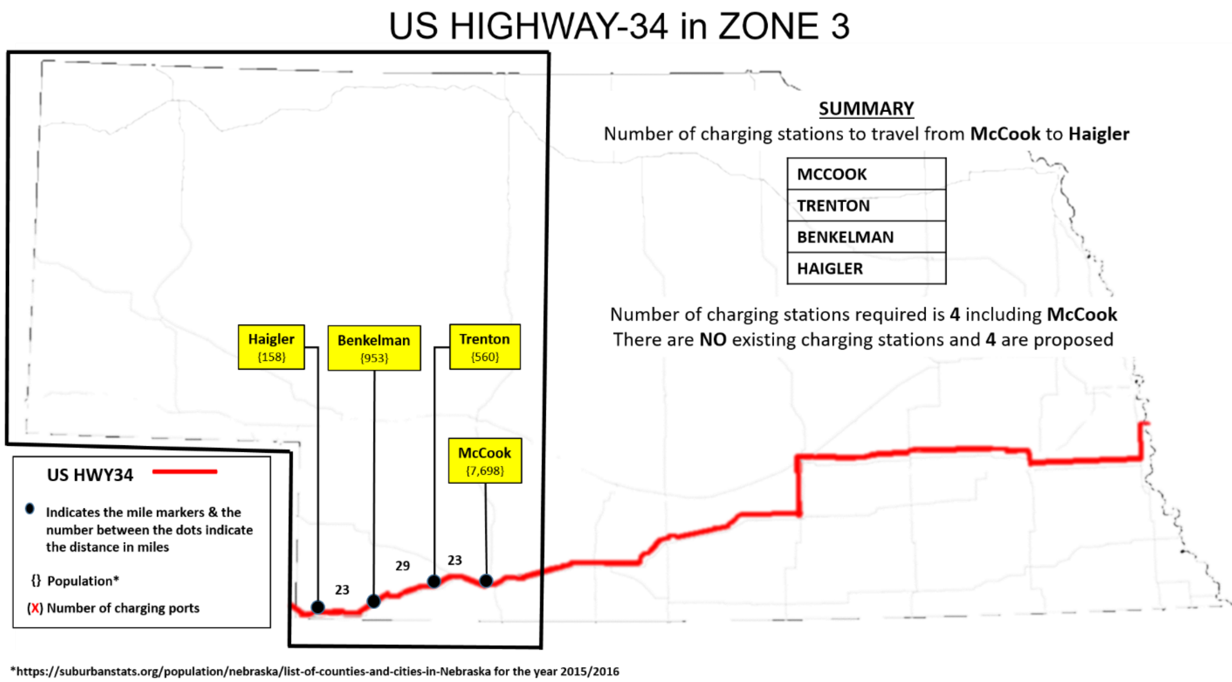


Figure **2.2.**3.5: Results for US-Highway 34

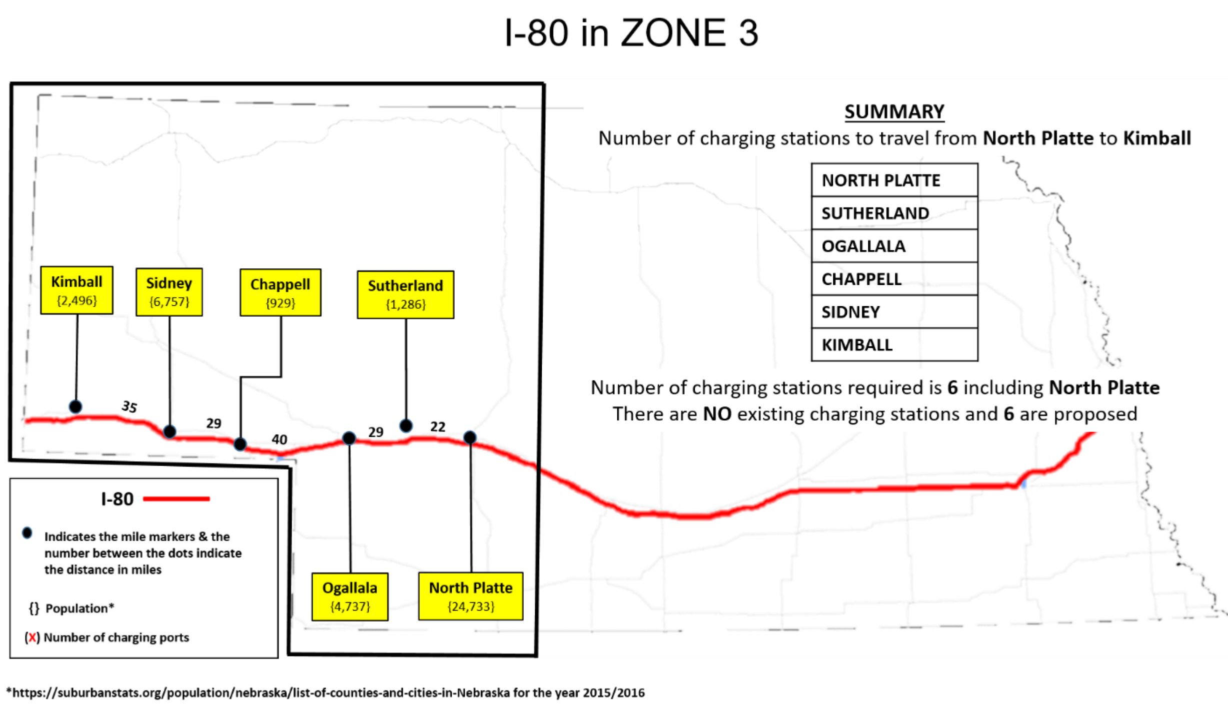


Figure **2.2.**3.6: Results for Interstate 80

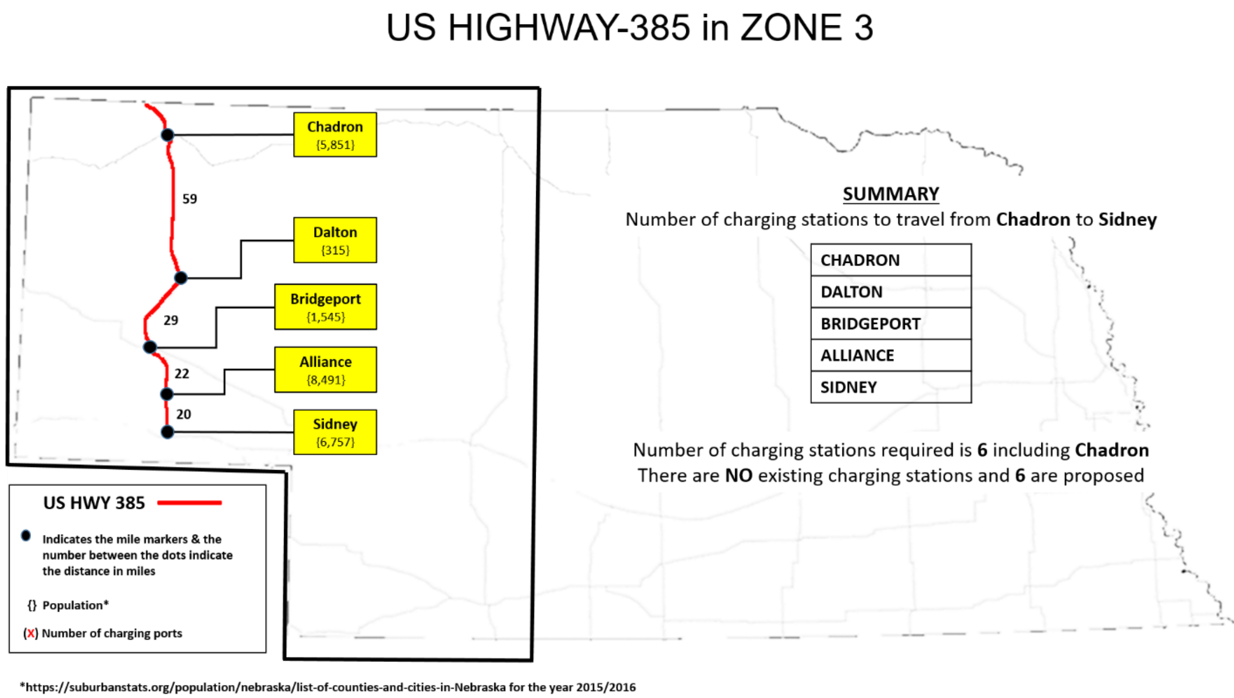


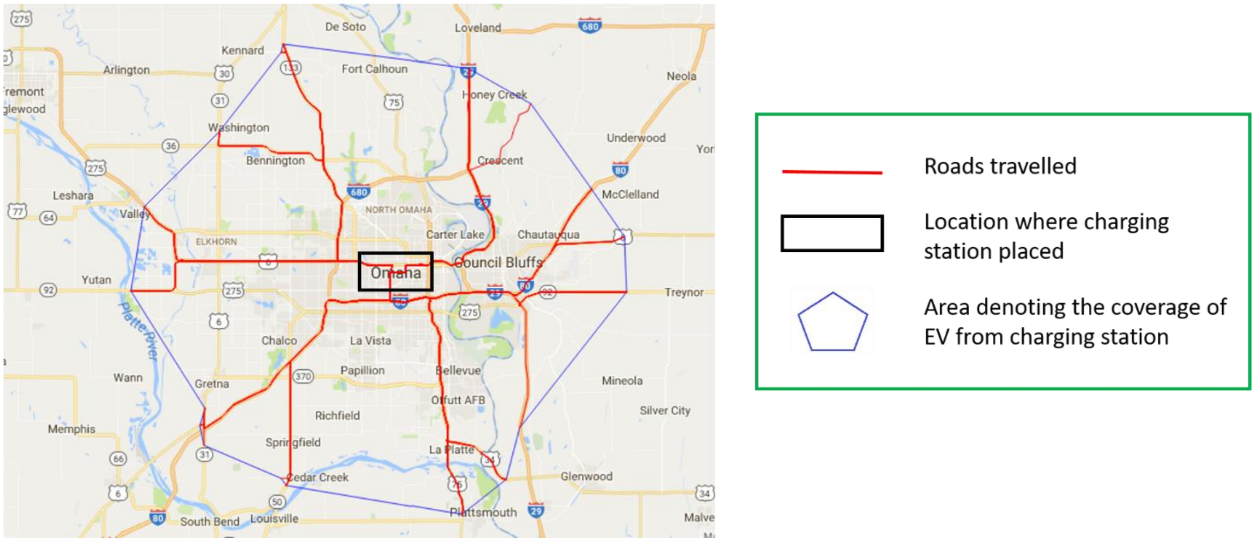
Figure **2.2.**3.7: Results for US-Highway 385

APPENDIX 2.3

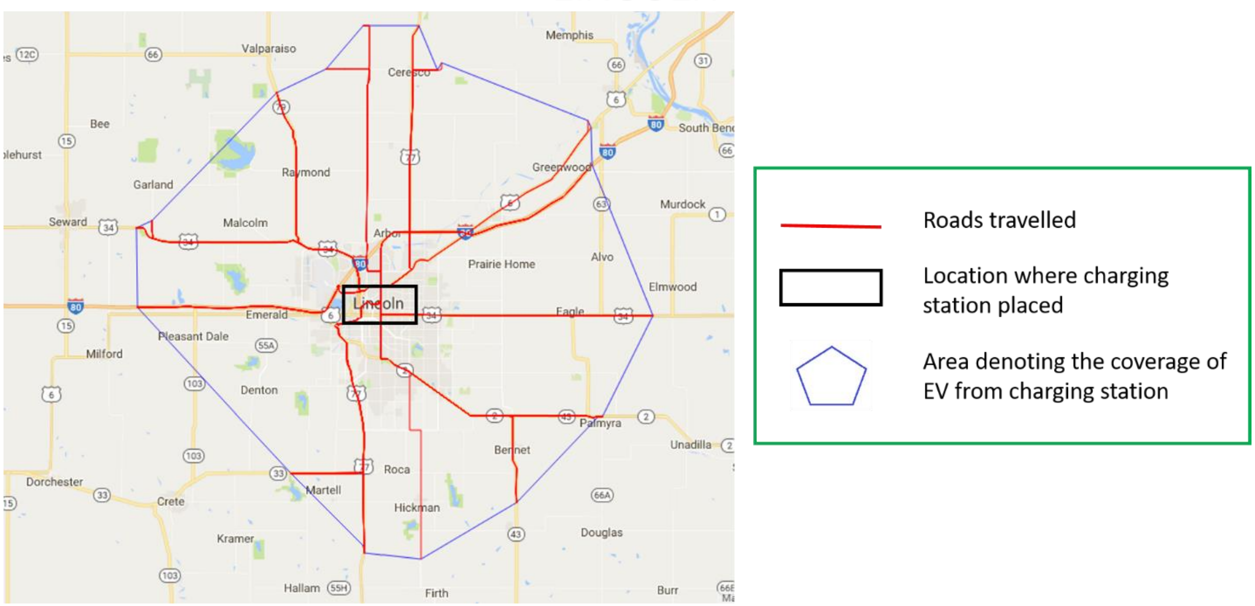
ROUND TRIP COVERAGE AREA OF 2016 NISSAN LEAF FROM A CHARGING INFRASTRUCTURE LOCATION

APPENDIX 2.3.1: COVERAGE AREA FOR INDIVIDUAL LOCATIONS IN ZONE 1

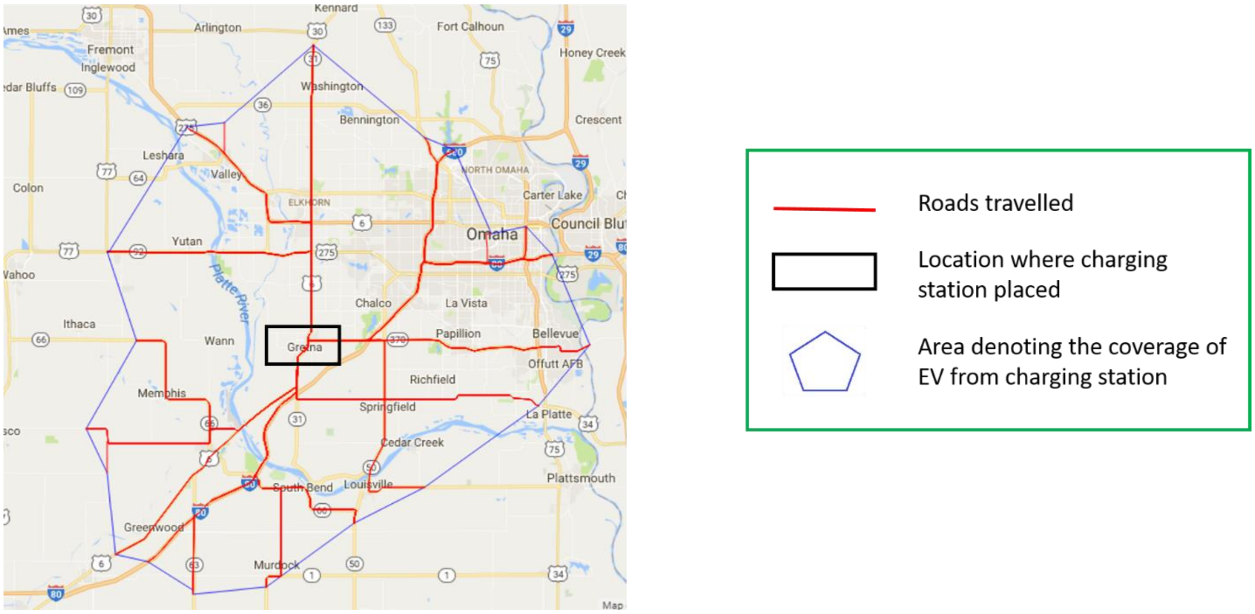
Coverage area of the EV when the Charging station is placed on OMAHA



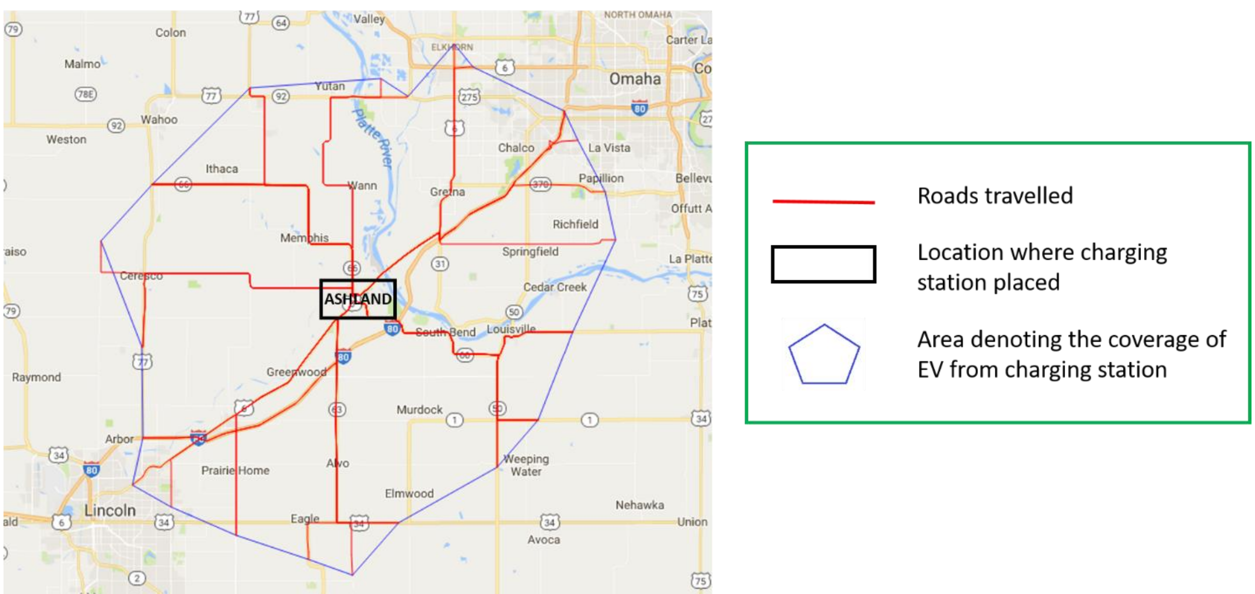
Coverage area of the EV when the Charging station is placed on LINCOLN



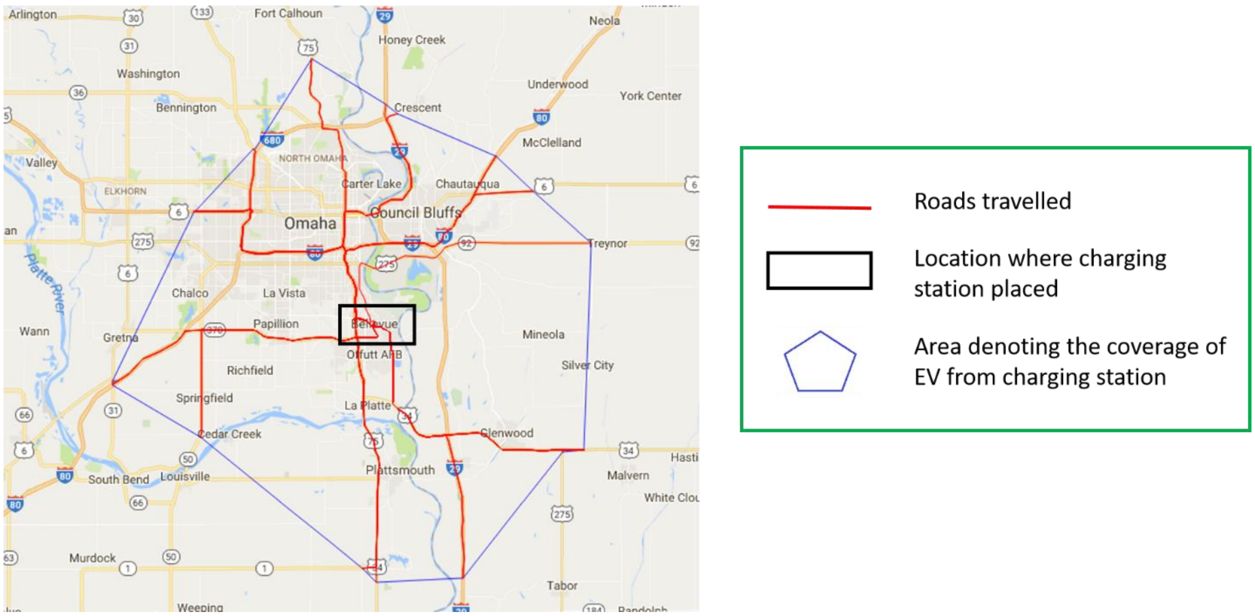
Coverage area of the EV when the Charging station is placed on GRETNA



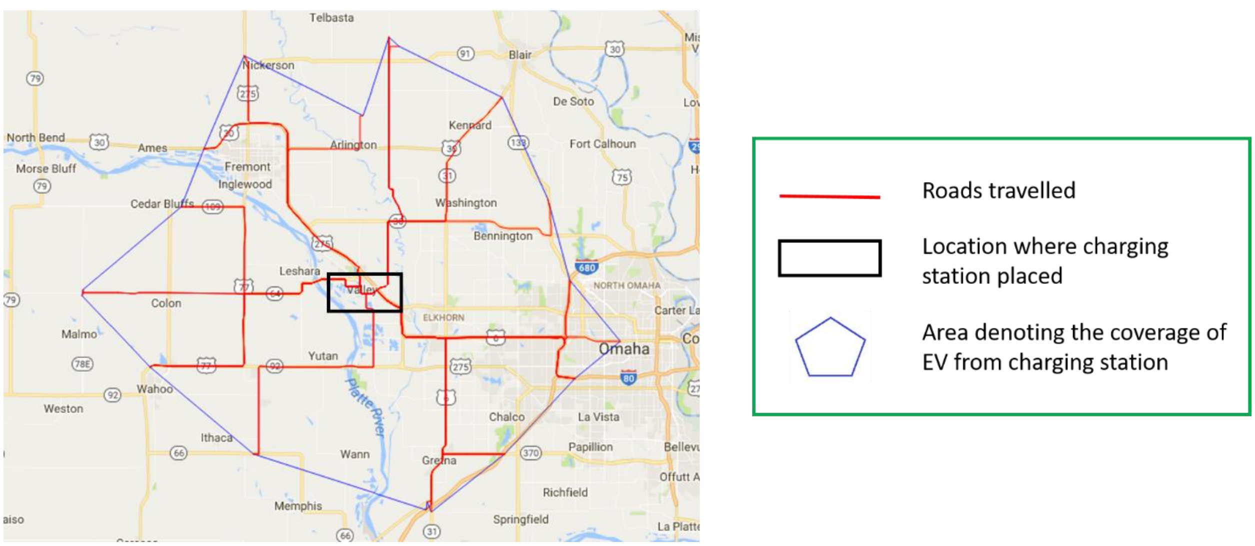
Coverage area of the EV when the Charging station is placed on ASHLAND



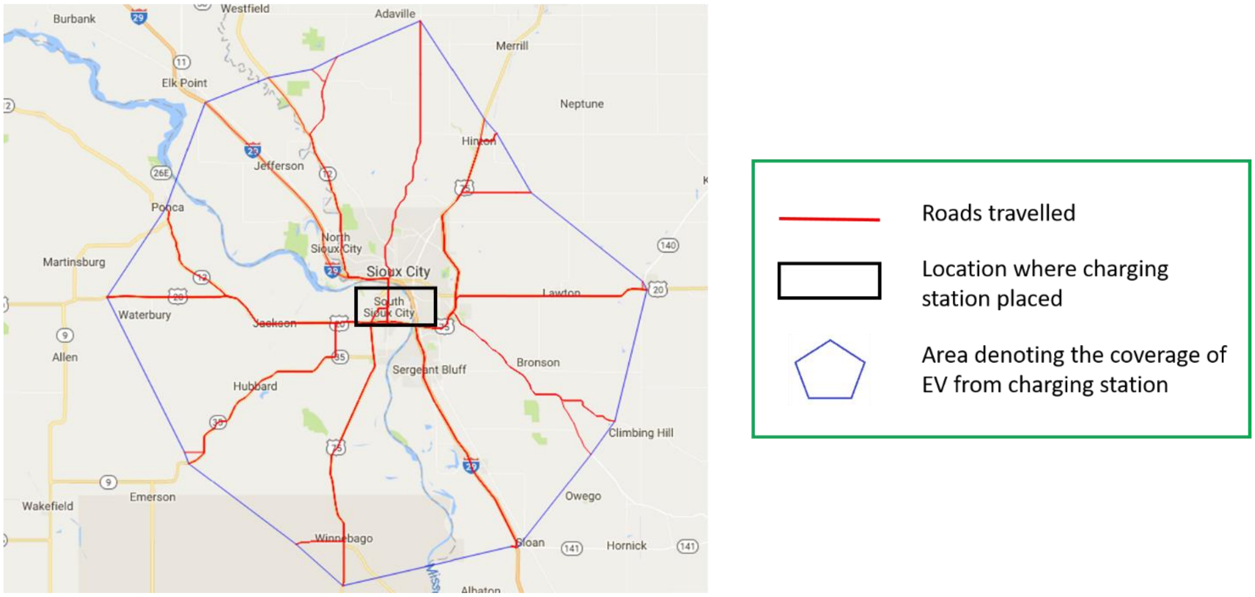
Coverage area of the EV when the Charging station is placed on BELLEVUE



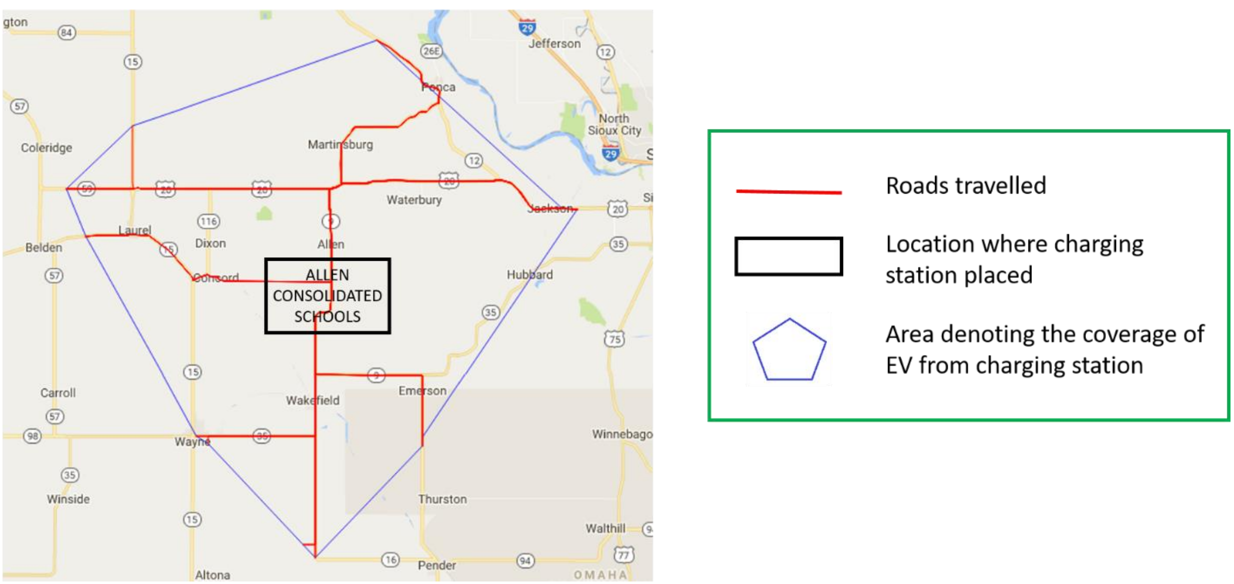
Coverage area of the EV when the Charging station is placed on VALLEY



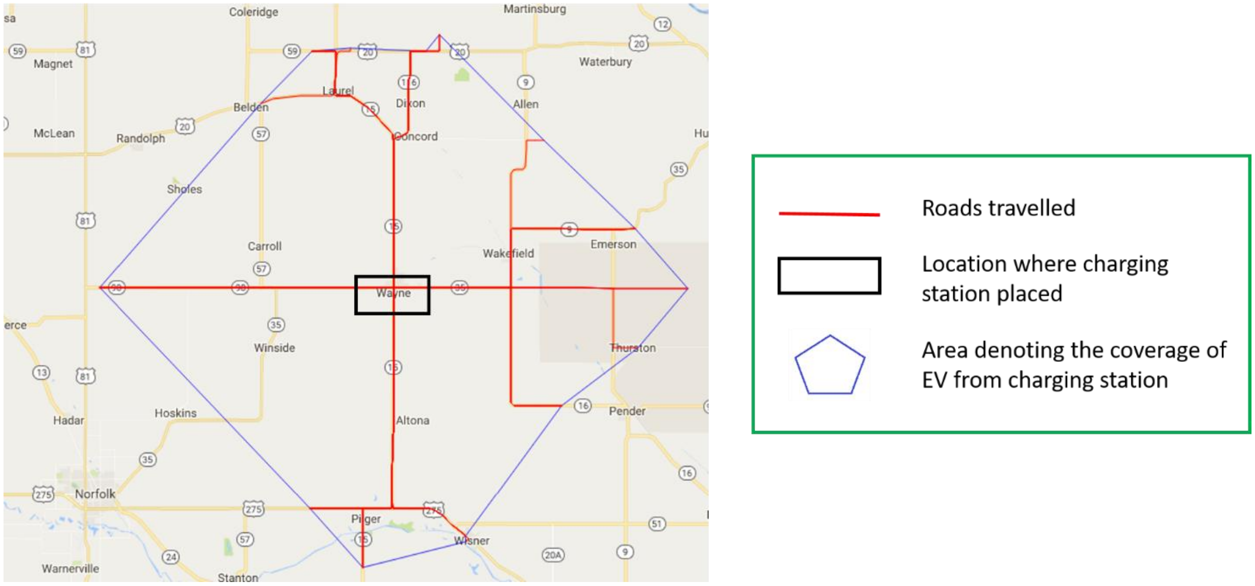
Coverage area of the EV when the Charging station is placed on SOUTH SIOUX CITY



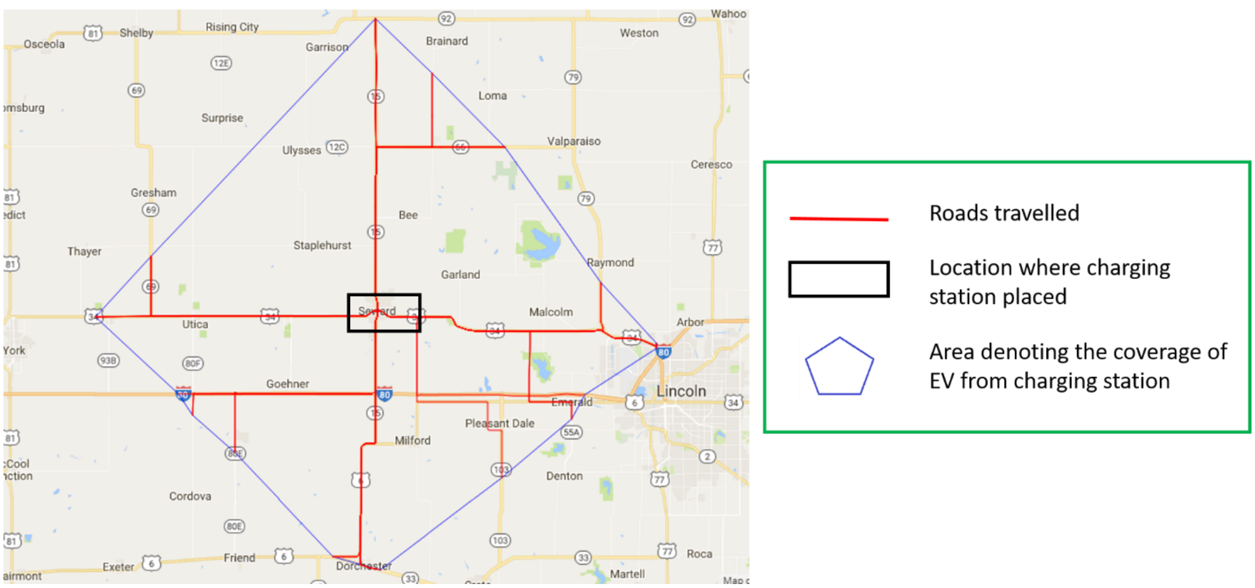
Coverage area of the EV when the Charging station is placed on ALLEN CONSOLIDATED SCHOOLS



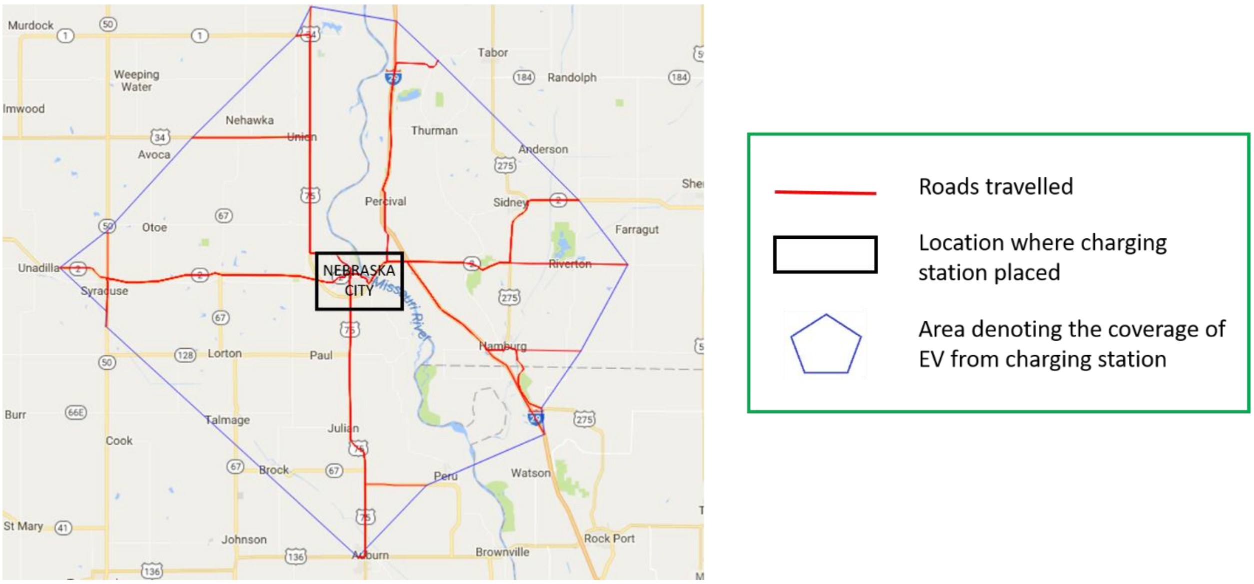
Coverage area of the EV when the Charging station is placed on WAYNE



Coverage area of the EV when the Charging station is placed on SEWARD

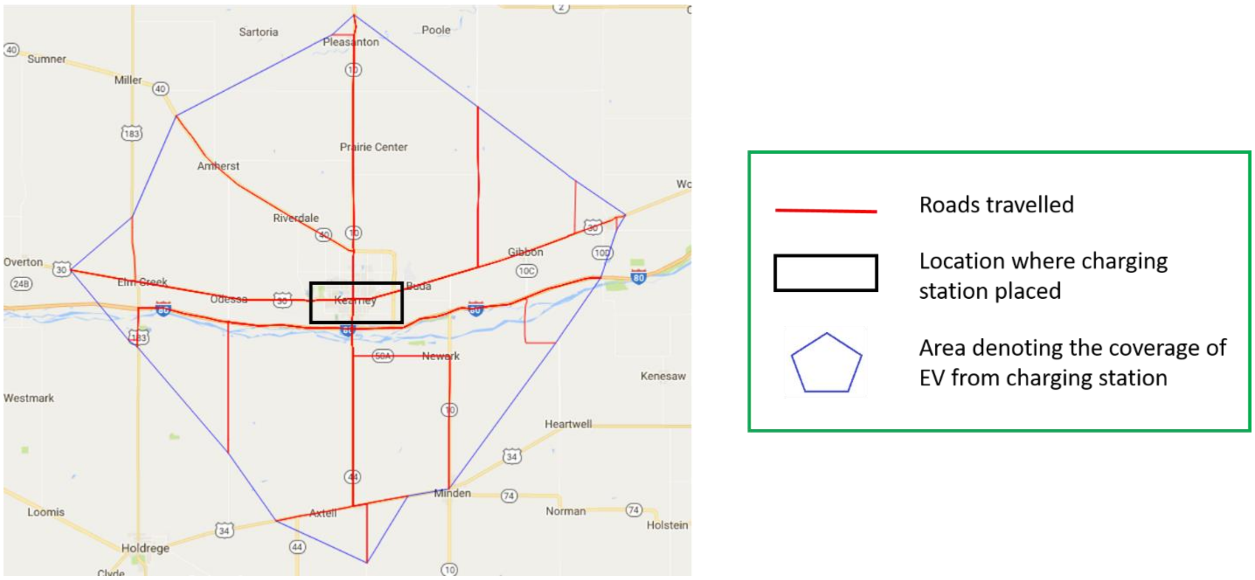


Coverage area of the EV when the Charging station is placed on NEBRASKA CITY

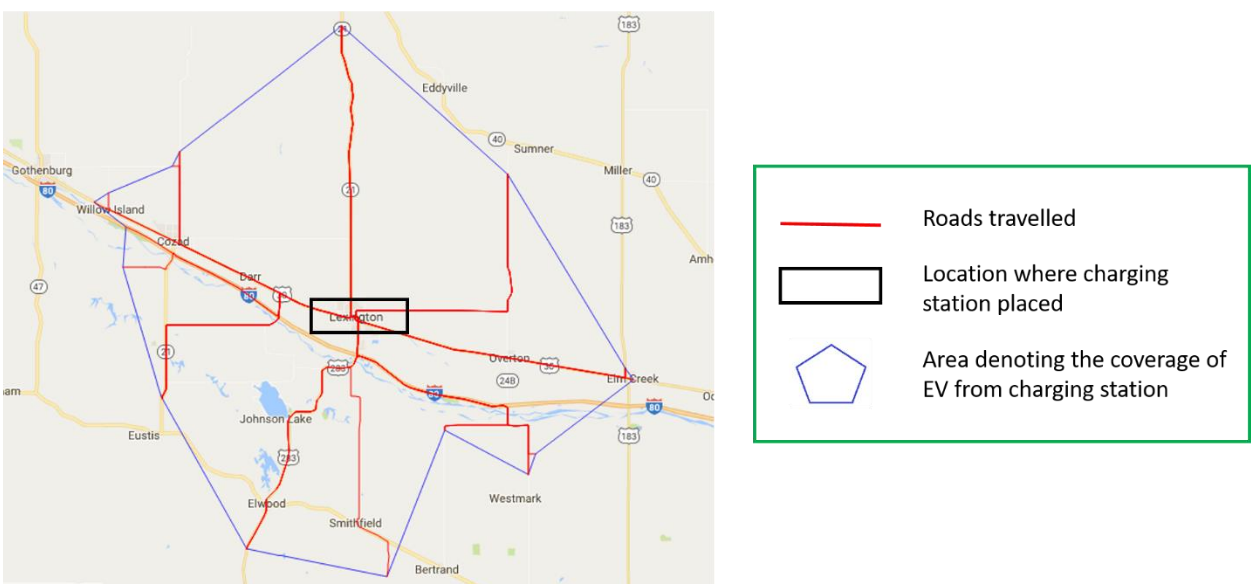


APPENDIX 2.3.2: COVERAGE AREA FOR INDIVIDUAL LOCATIONS IN ZONE 2

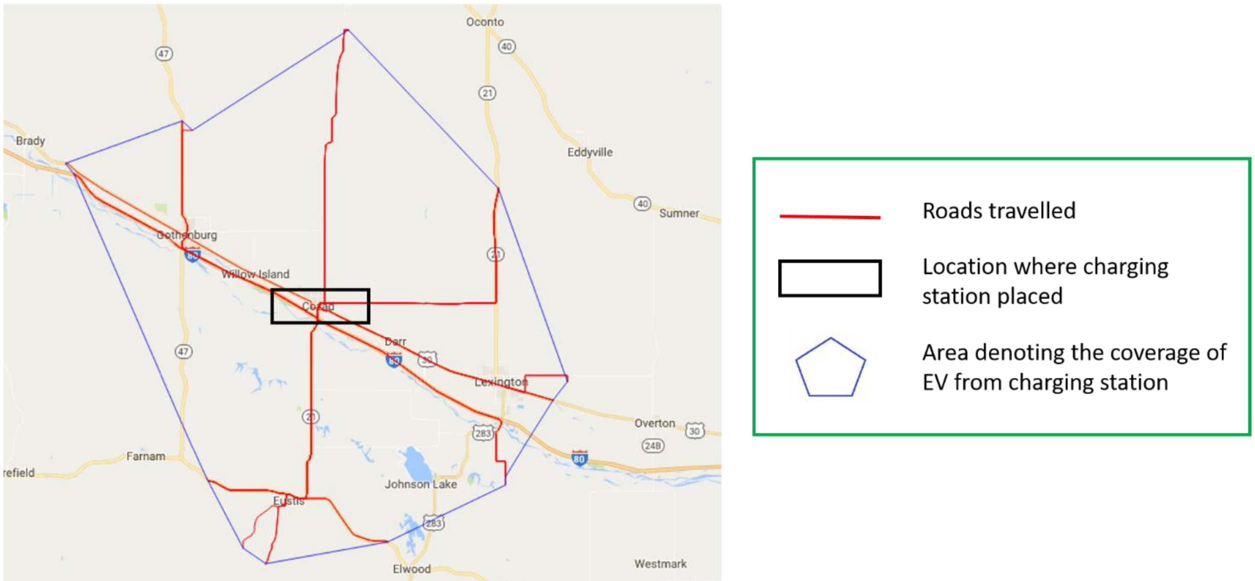
Coverage area of the EV when the Charging station is placed on KEARNEY



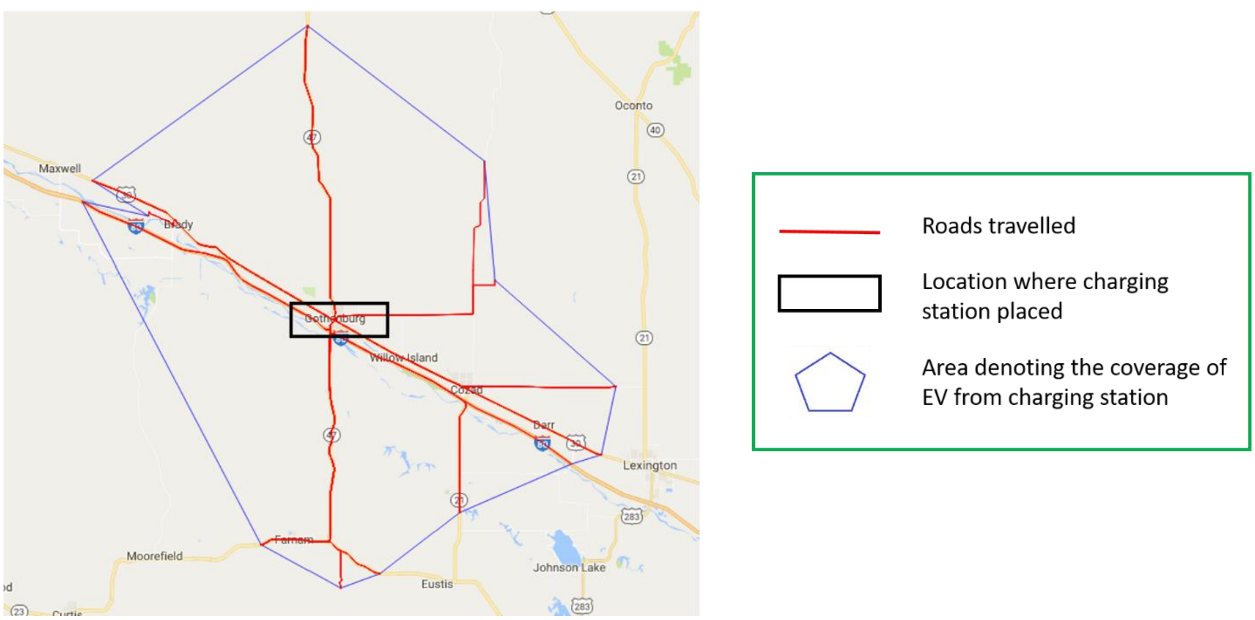
Coverage area of the EV when the Charging station is placed on LEXINGTON



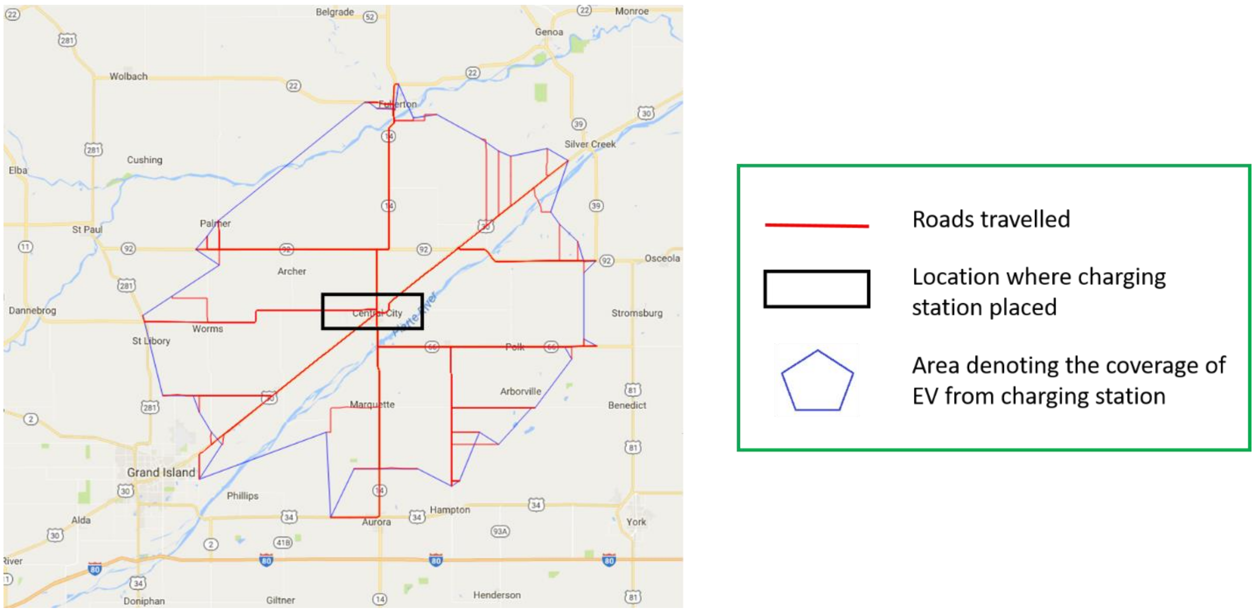
Coverage area of the EV when the Charging station is placed on COZAD



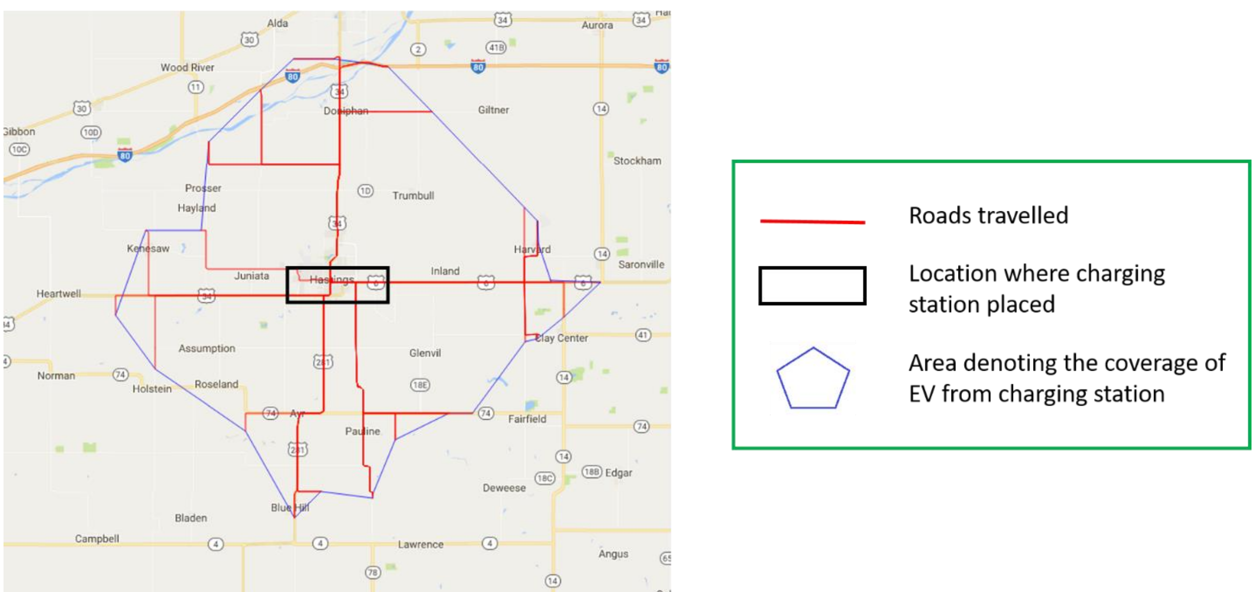
Coverage area of the EV when the Charging station is placed on GOTHENBURG



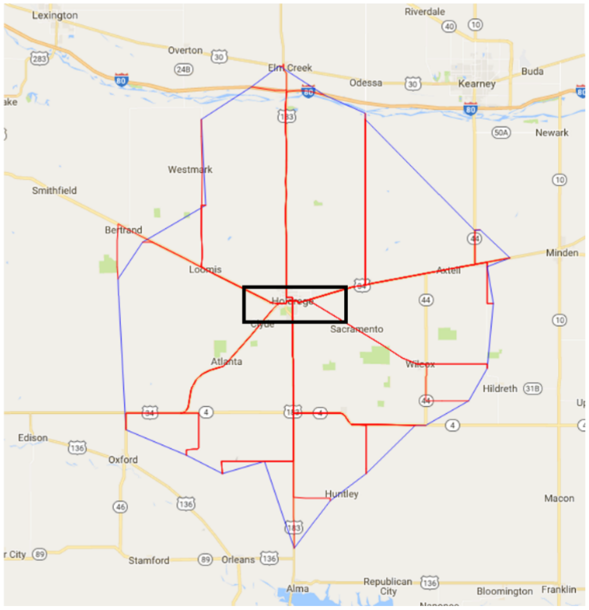
Coverage area of the EV when the Charging station is placed on CENTRAL CITY

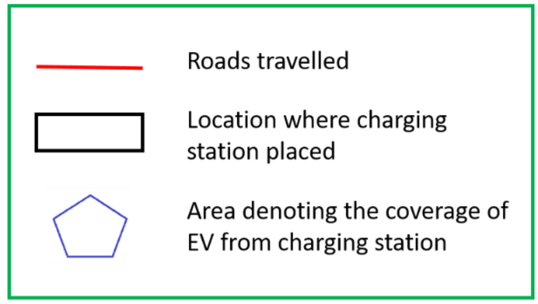


Coverage area of the EV when the Charging station is placed on HASTINGS

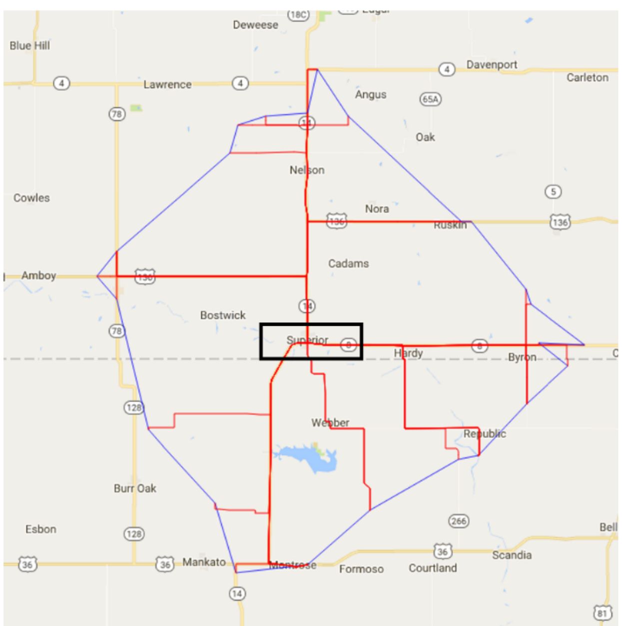


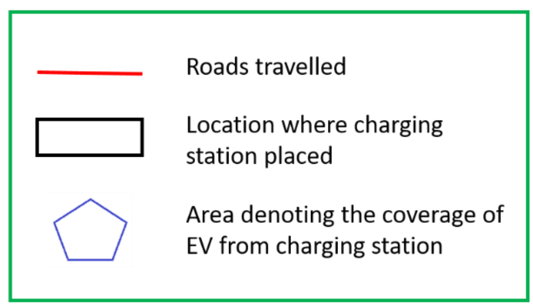
Coverage area of the EV when the Charging station is placed on HOLDREGE



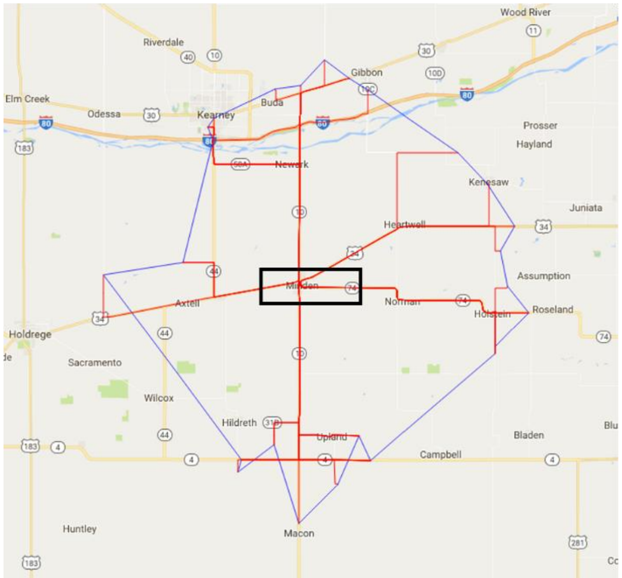


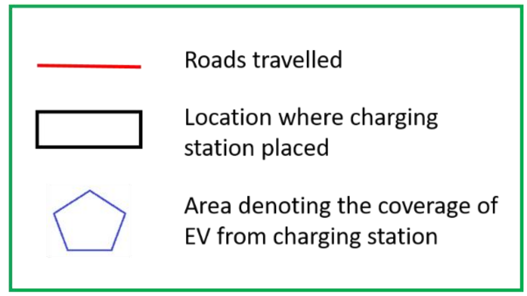
Coverage area of the EV when the Charging station is placed on SUPERIOR





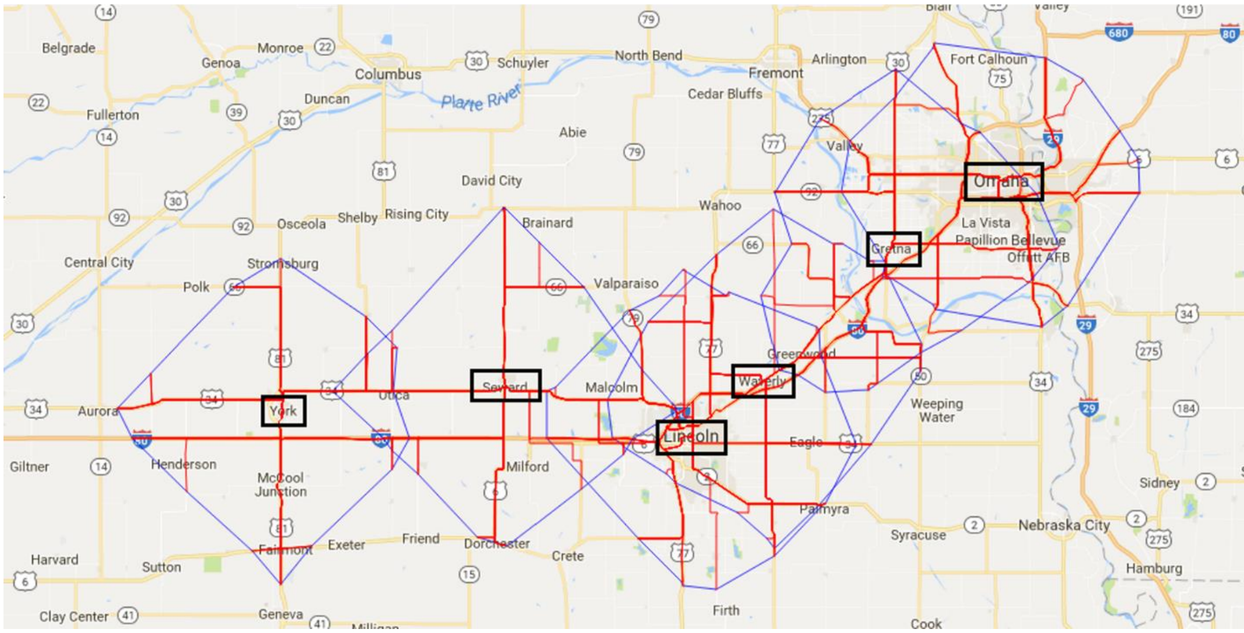
Coverage area of the EV when the Charging station is placed on MINDEN



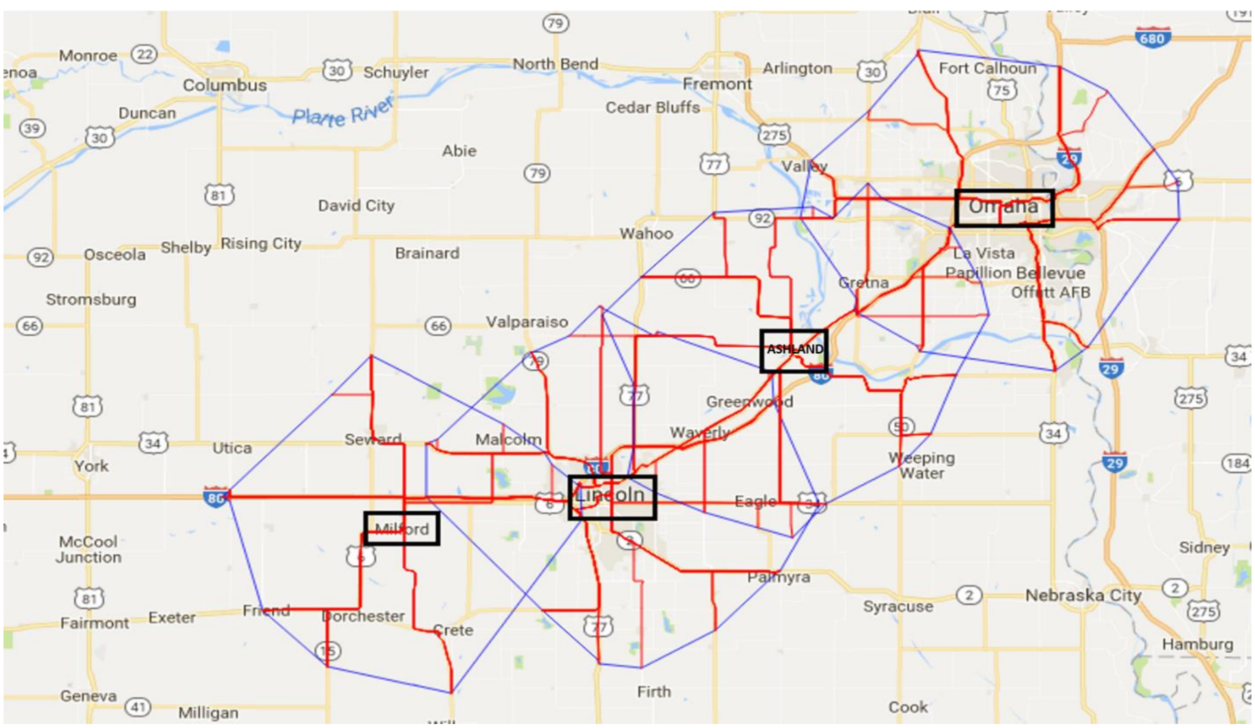


APPENDIX 2.3.3: COVERAGE AREA ON THE INTERSTATE OR THE US-HIGHWAYS IN ZONE 1

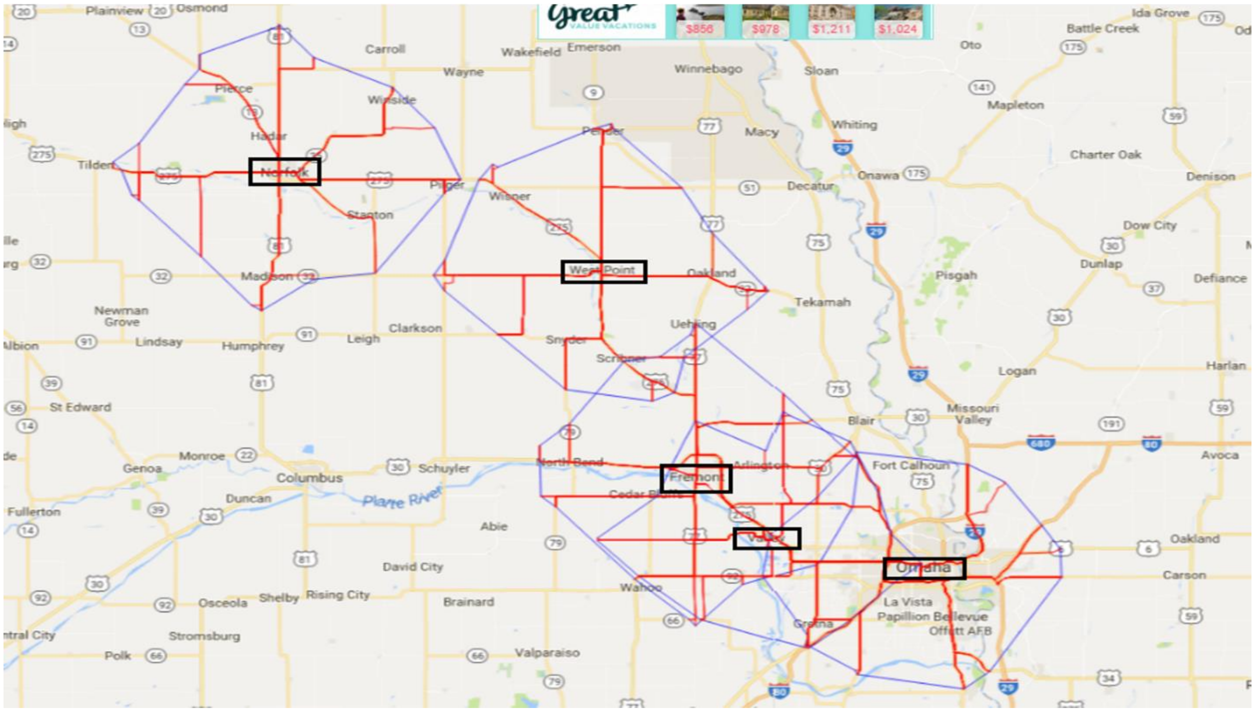
Coverage area of the EV in I-80



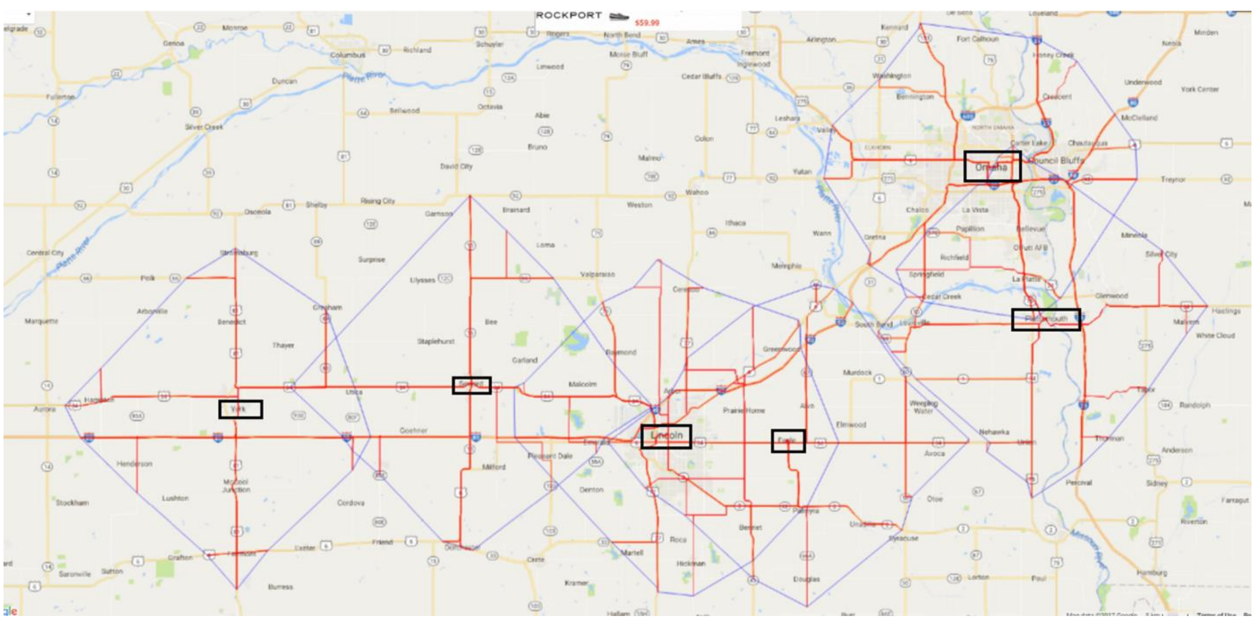
Coverage area of the EV in US-HWY-6



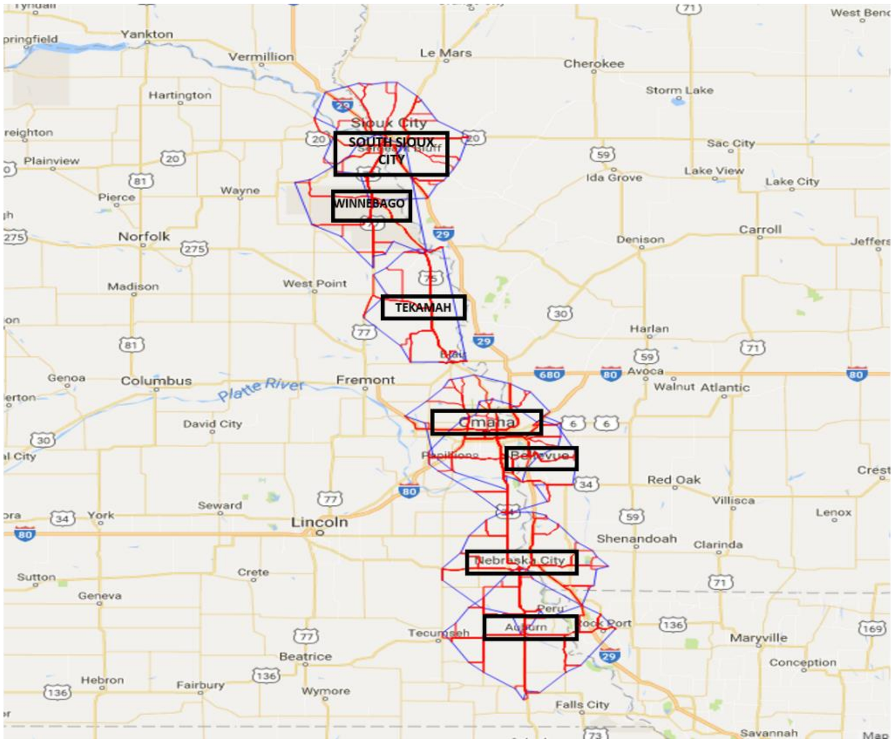
Coverage area of the EV in US-HWY-275



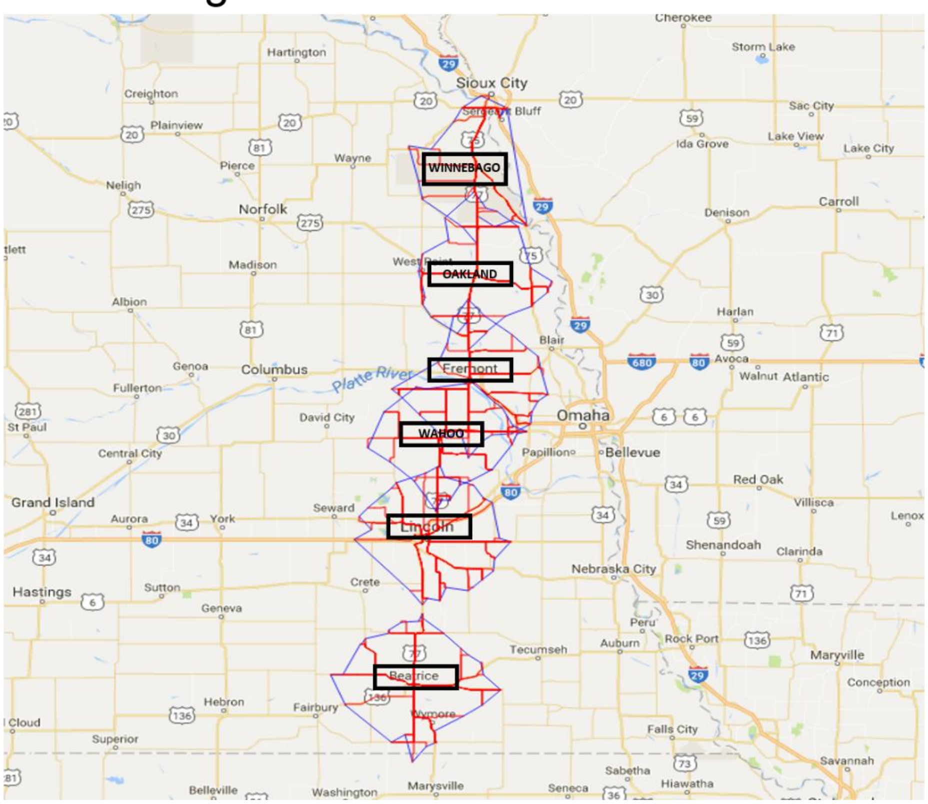
Coverage area of the EV in US-HWY-34



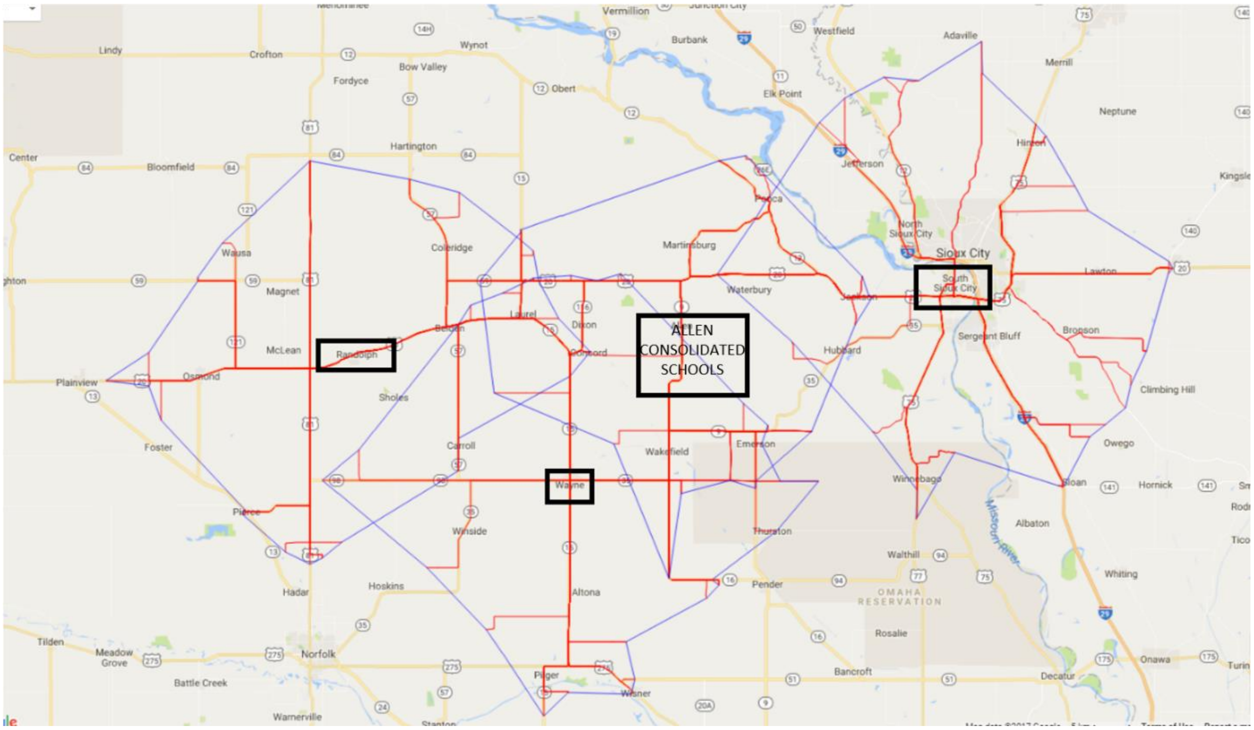
Coverage area of the EV in US-HWY-75



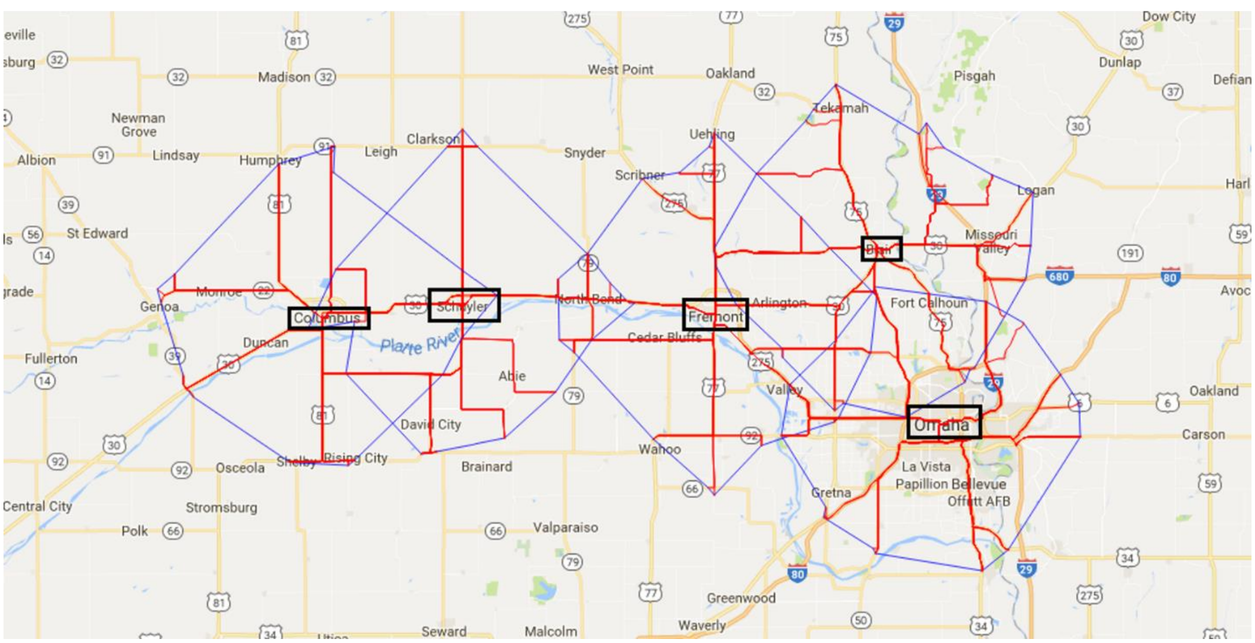
Coverage area of the EV in US-HWY-77



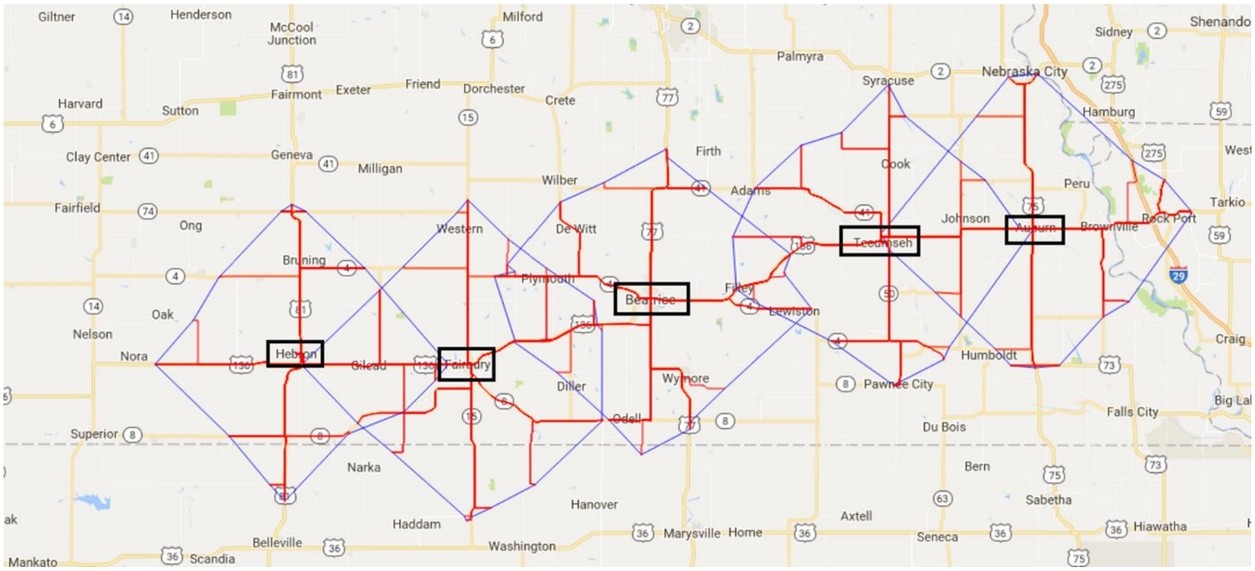
Coverage area of the EV in US-HWY-20



Coverage area of the EV in US-HWY-30

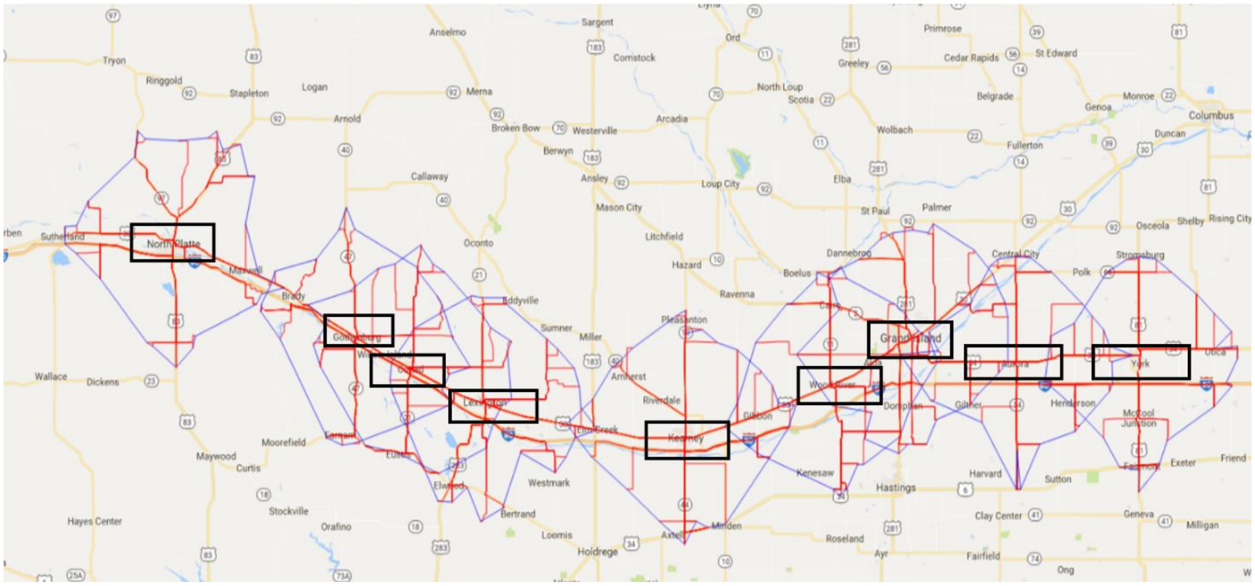


Coverage area of the EV in US-HWY-136

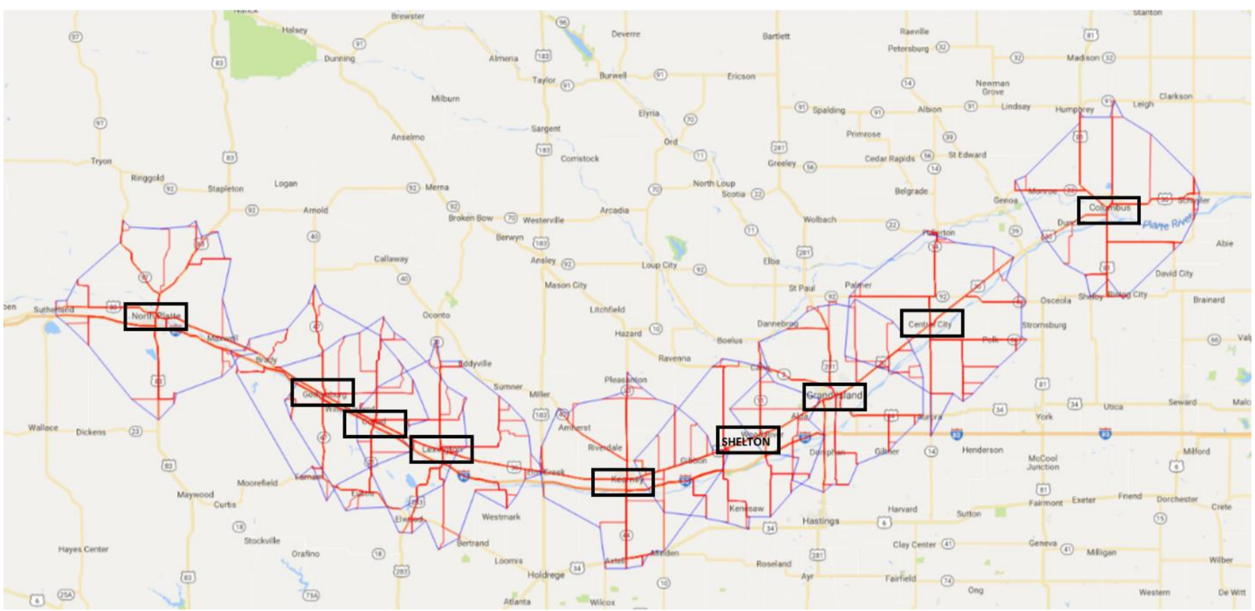


APPENDIX 2.3.4: COVERAGE AREA ON THE INTERSTATE OR THE US-HIGHWAYS IN ZONE 2

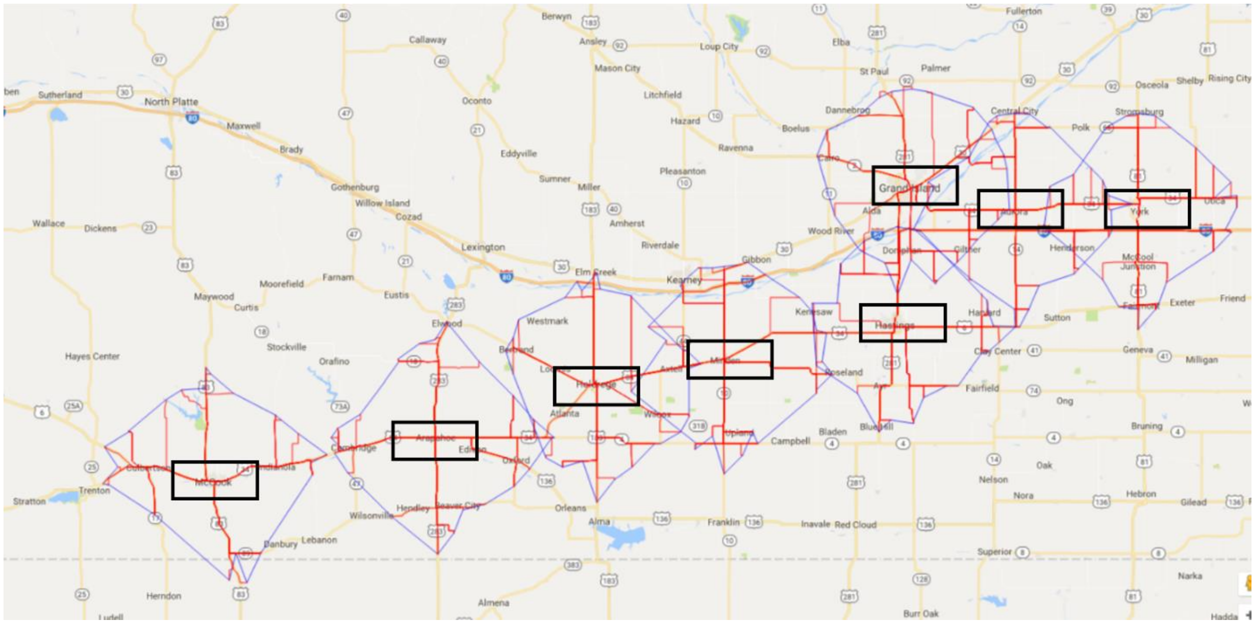
Coverage area of the EV in I-80



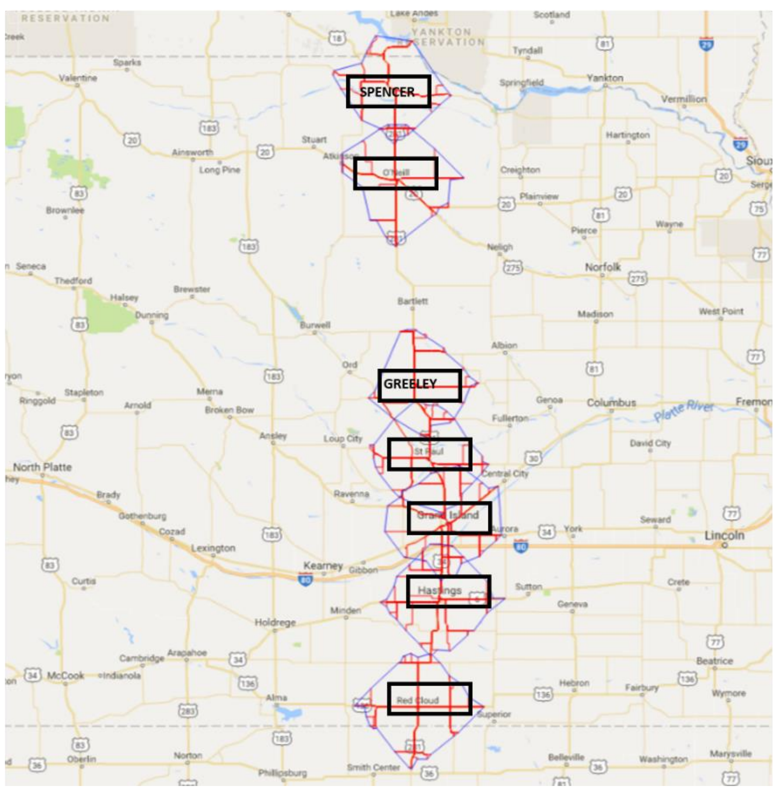
Coverage area of the EV in US-HWY-30



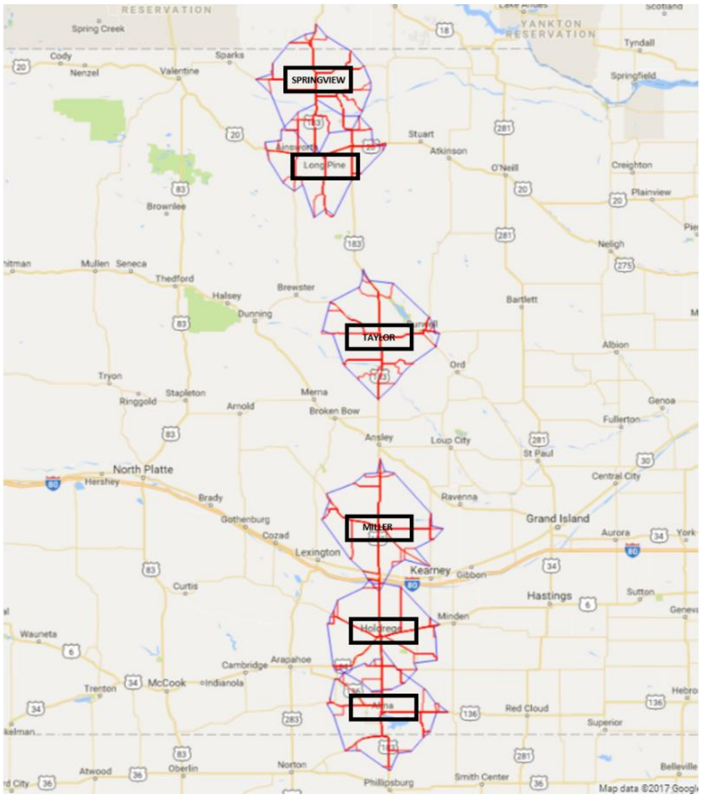
Coverage area of the EV in US-HWY-34



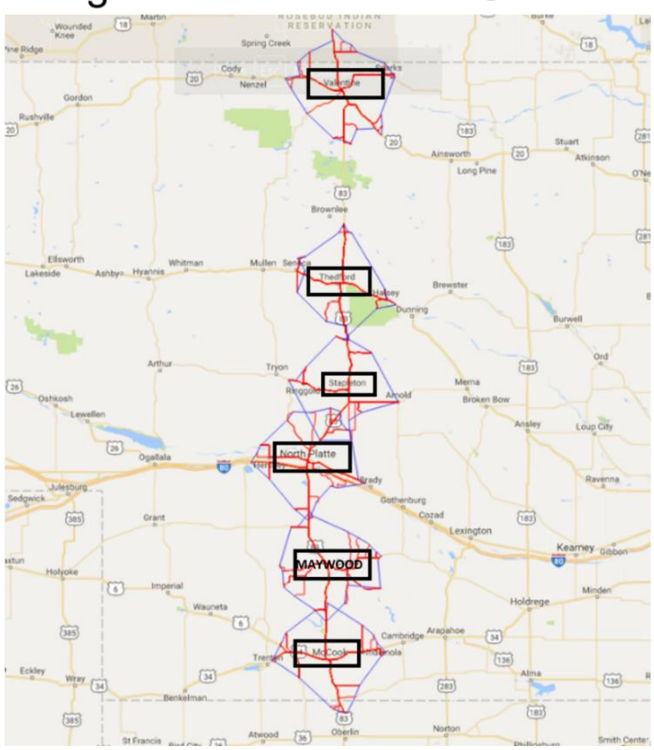
Coverage area of the EV in US-HWY-281



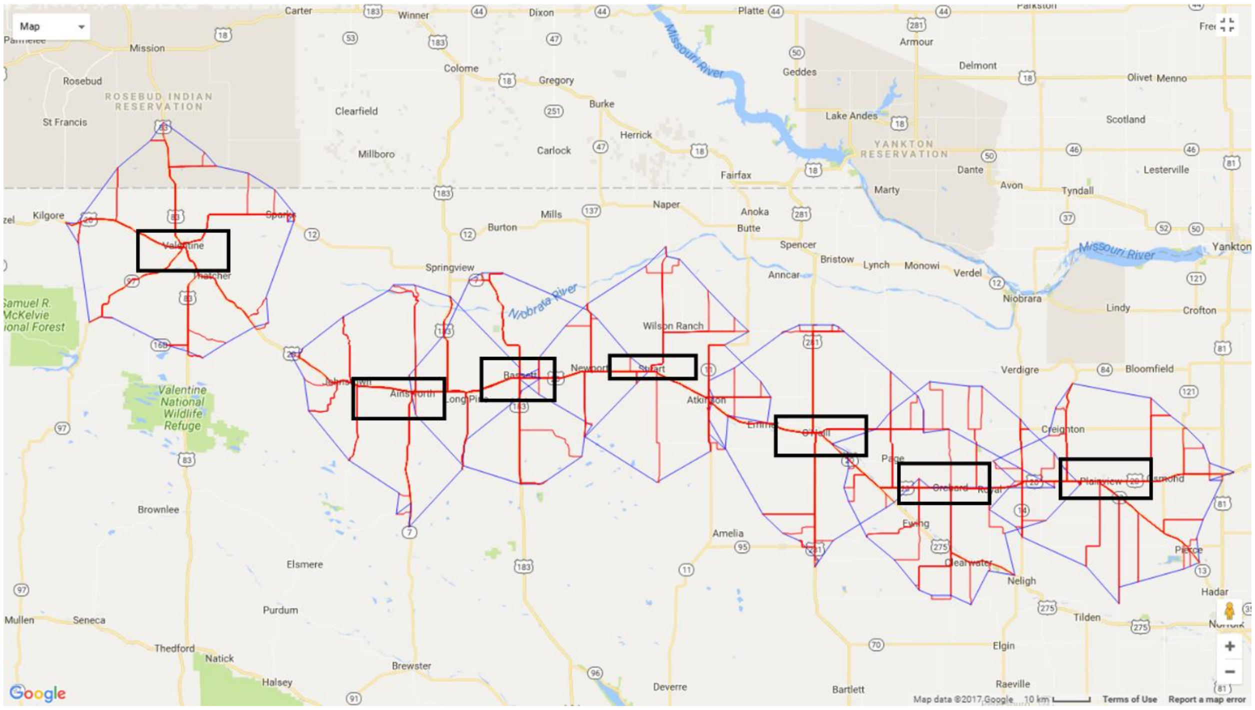
Coverage area of the EV in US-HWY-183



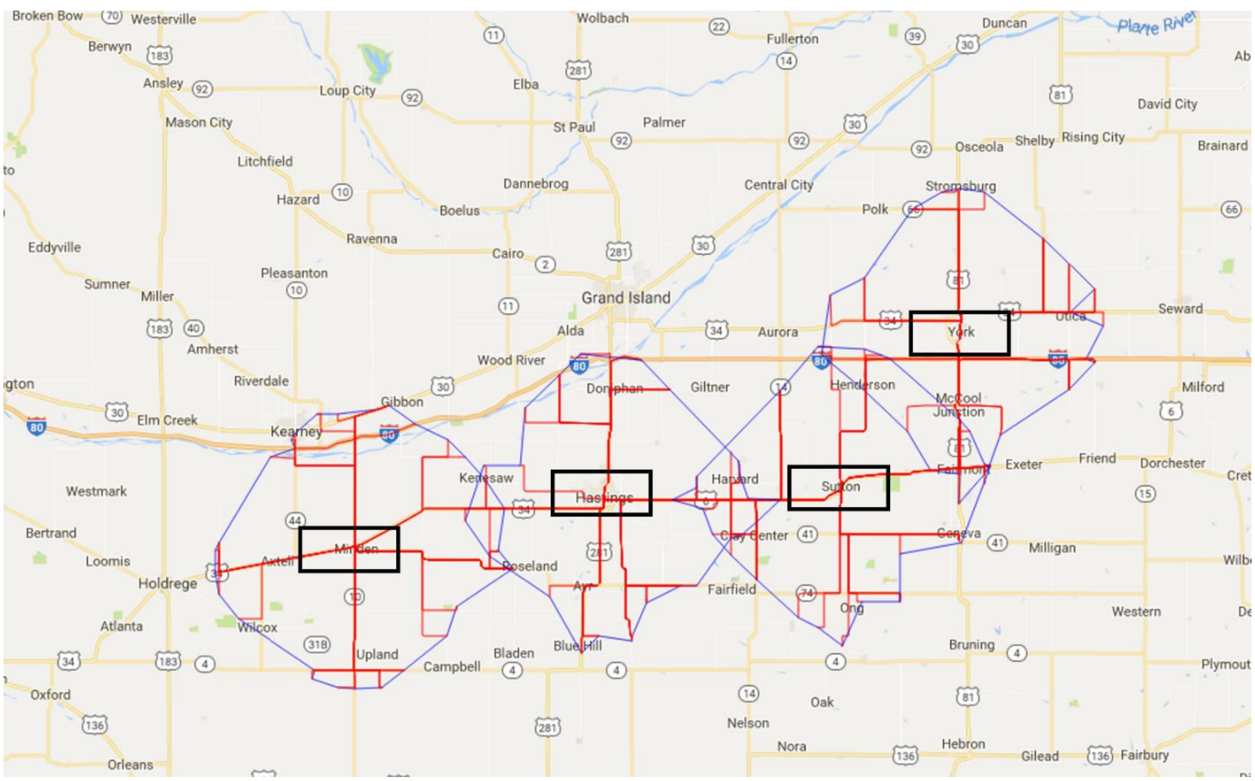
Coverage area of the EV in US-HWY-83



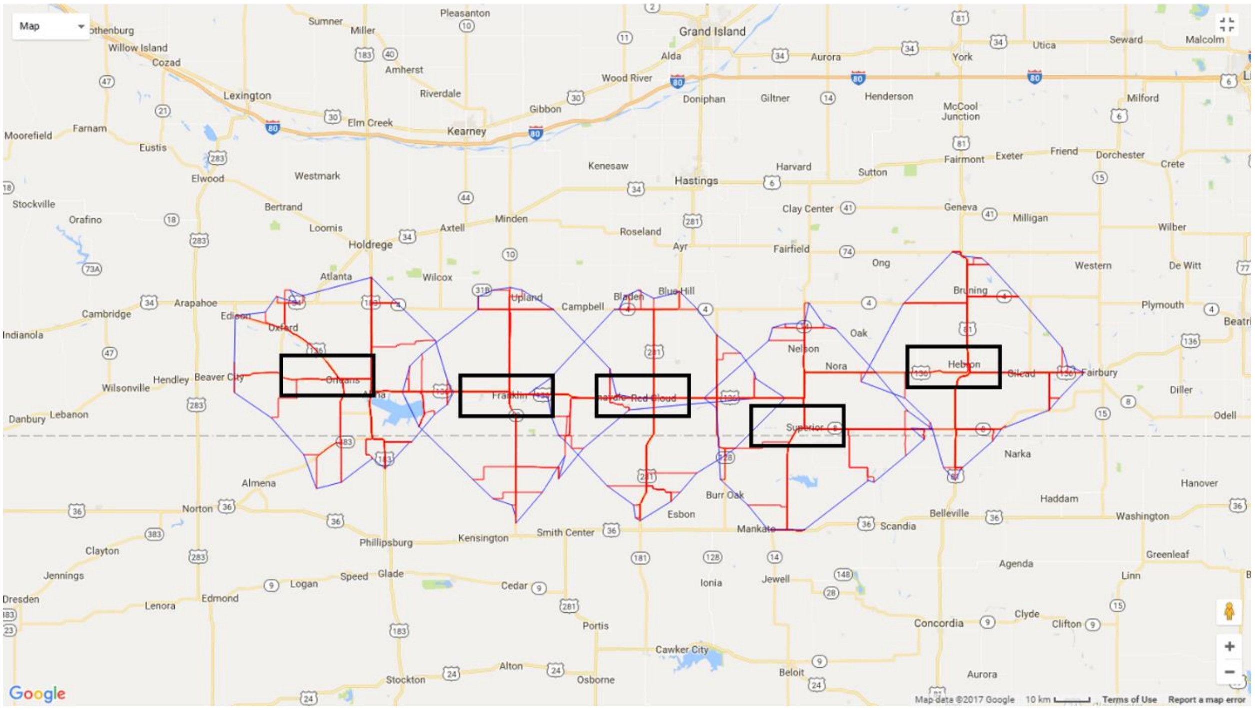
Coverage area of the EV in US-HWY-20



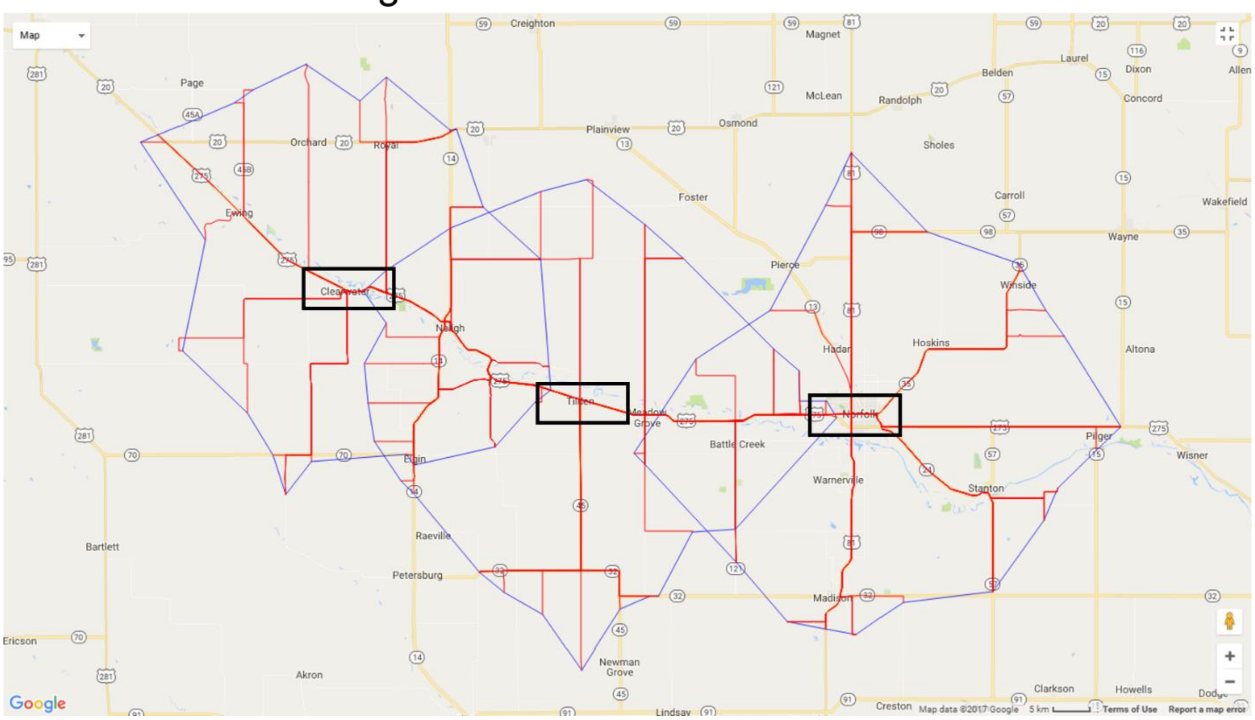
Coverage area of the EV in US-HWY-6



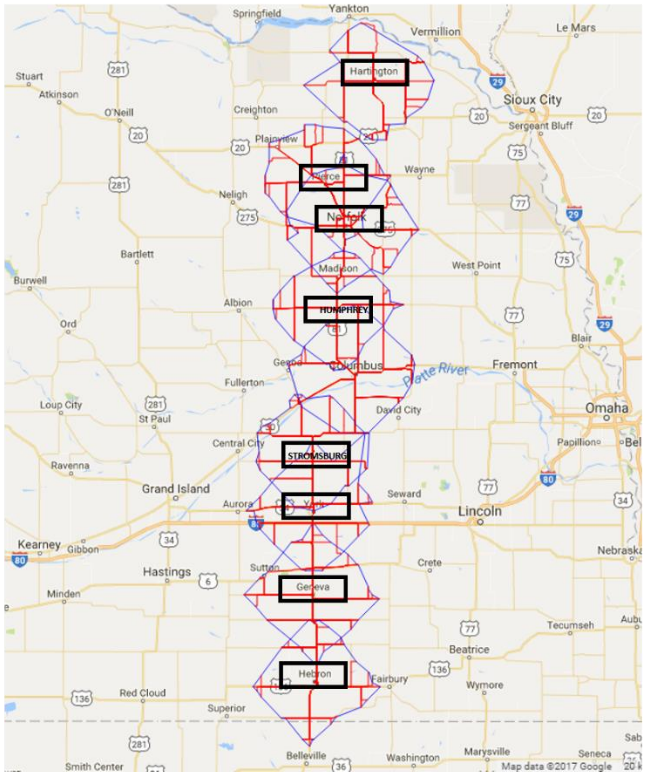
Coverage area of the EV in US-HWY-136



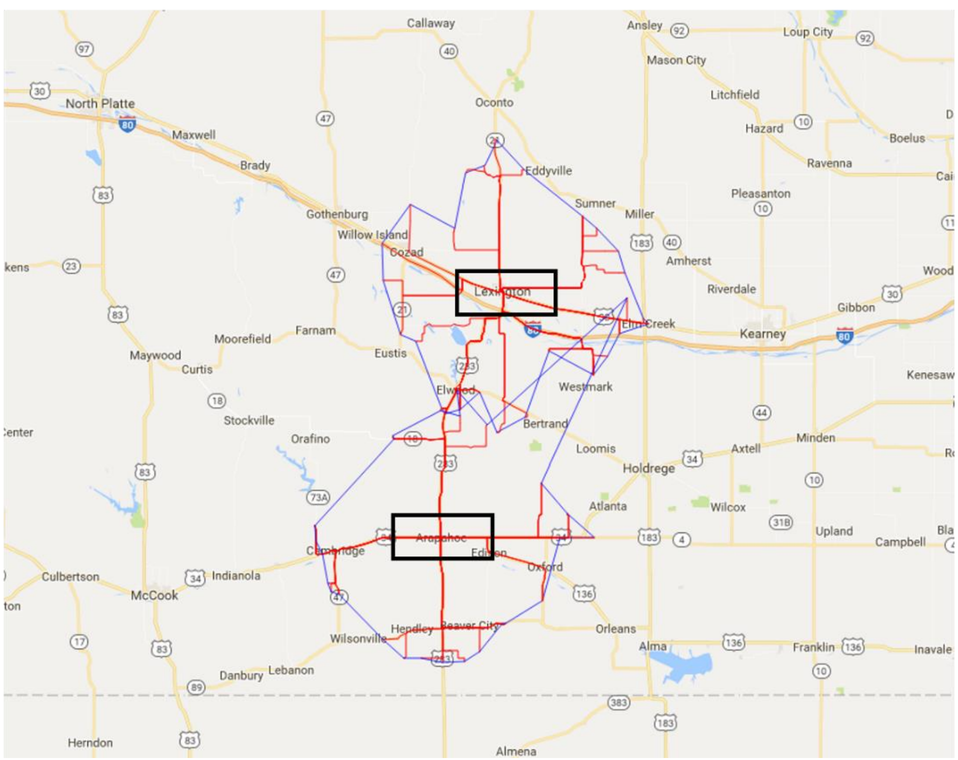
Coverage area of the EV in US-HWY-275



Coverage area of the EV in US-HWY-81

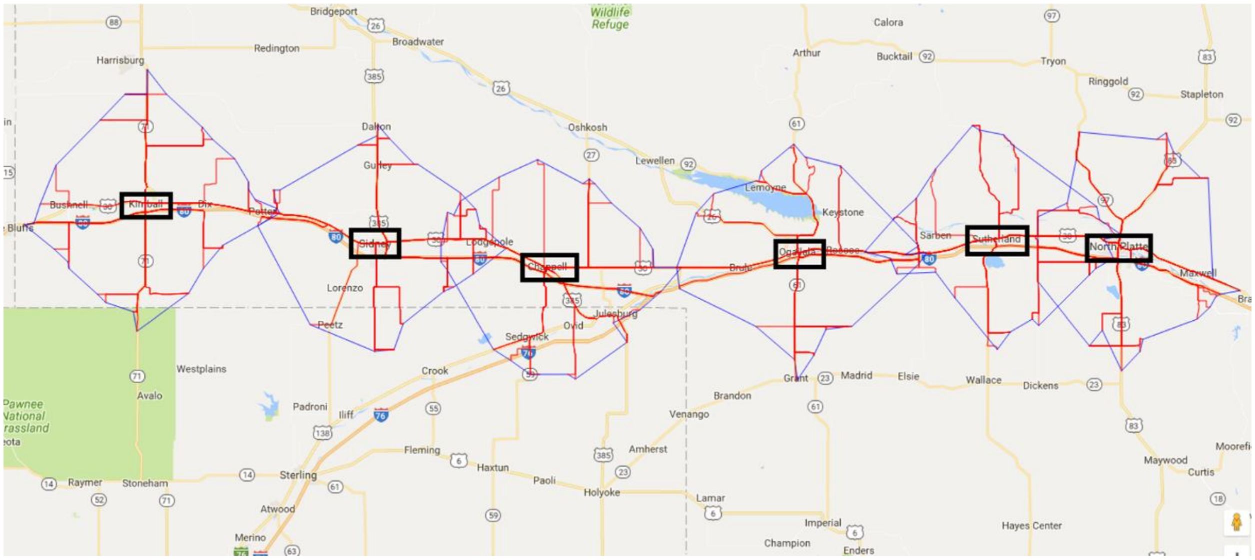


Coverage area of the EV in US-HWY-283

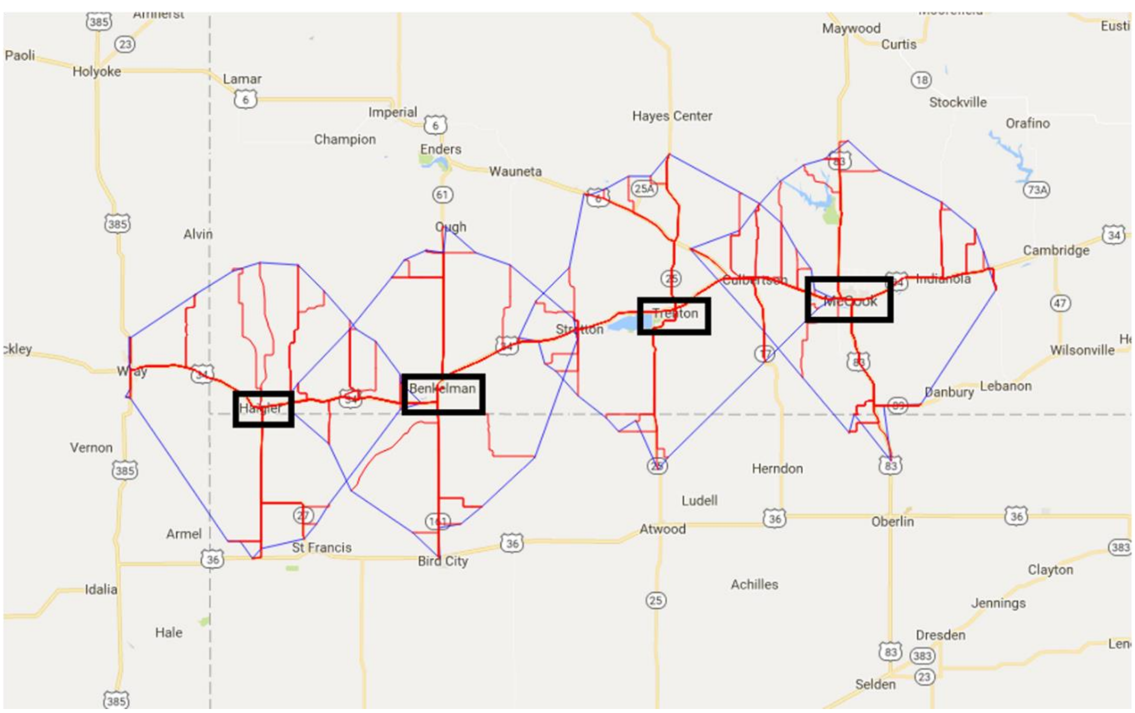


APPENDIX 2.3.5: COVERAGE AREA ON THE INTERSTATE OR THE US-HIGHWAYS IN ZONE 3

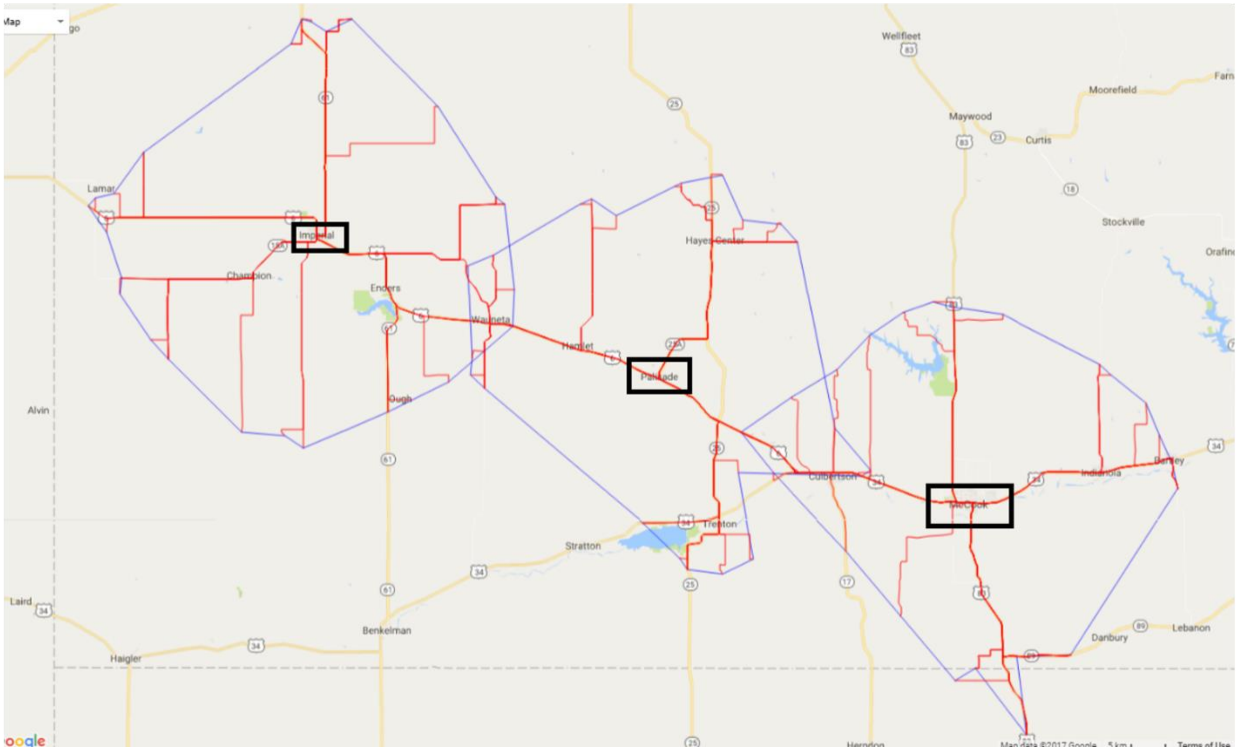
Coverage area of the EV in I-80 and US-HWY-30



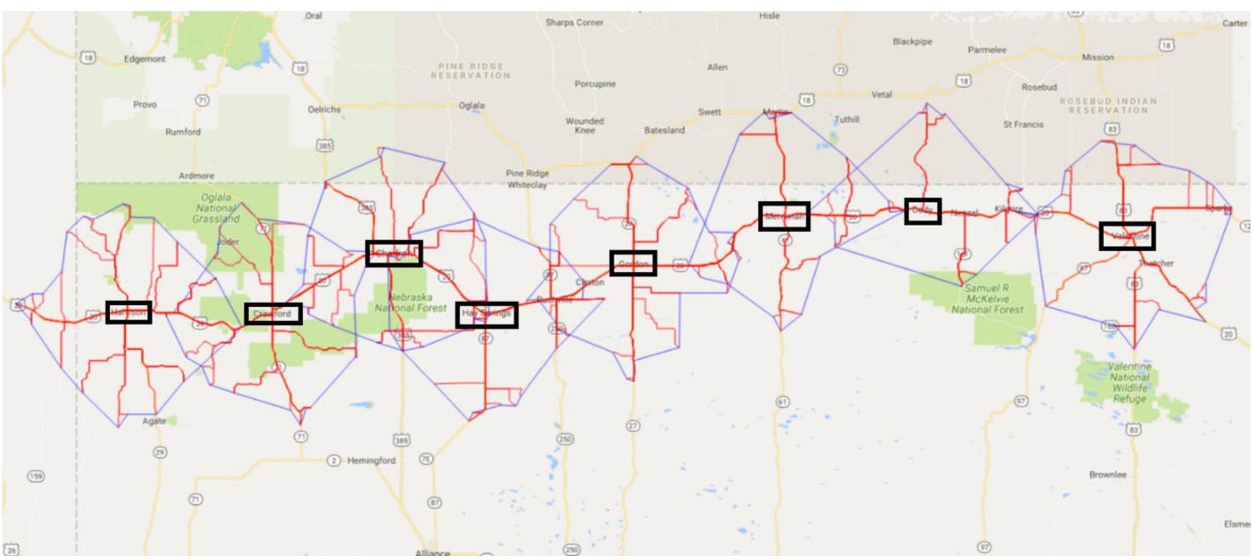
Coverage area of the EV in US-HWY-34



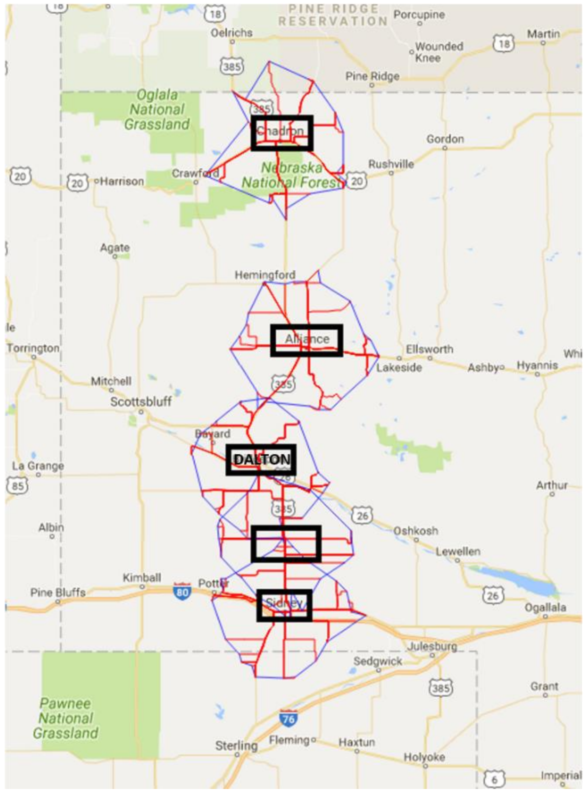
Coverage area of the EV in US-HWY-6



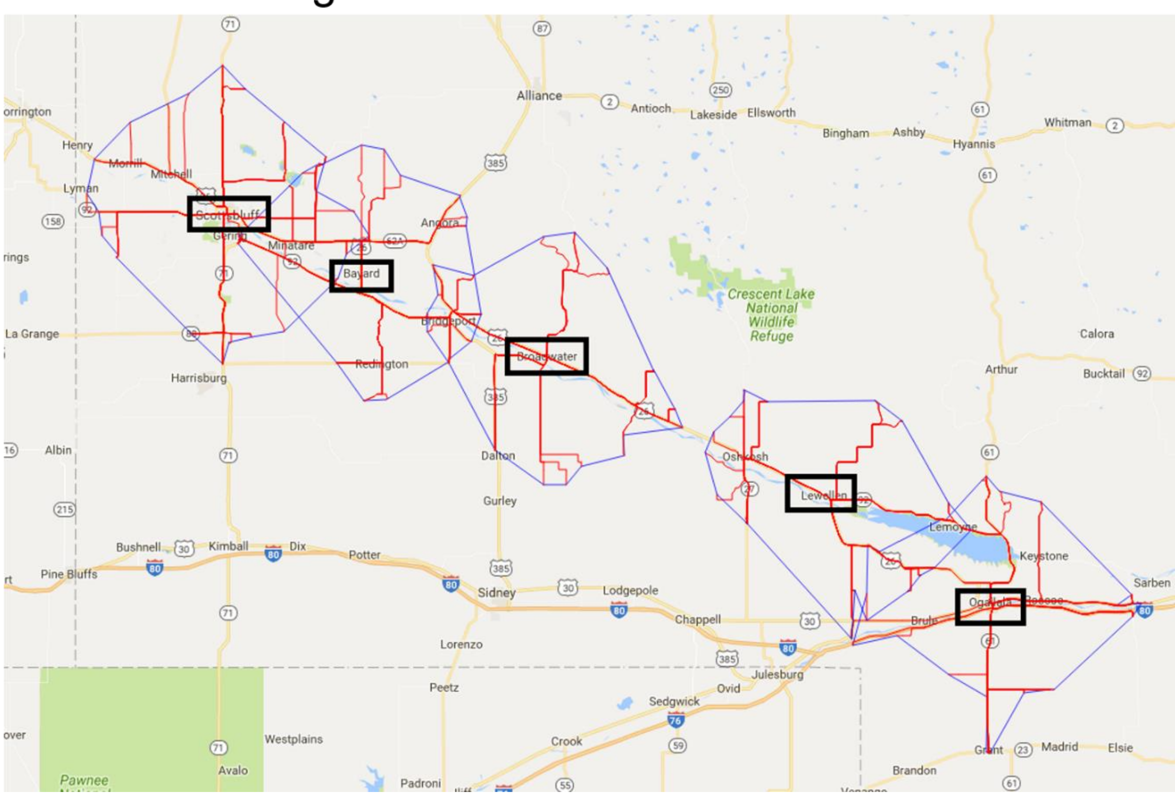
Coverage area of the EV in US-HWY-20



Coverage area of the EV in US-HWY-385



Coverage area of the EV in US-HWY-26

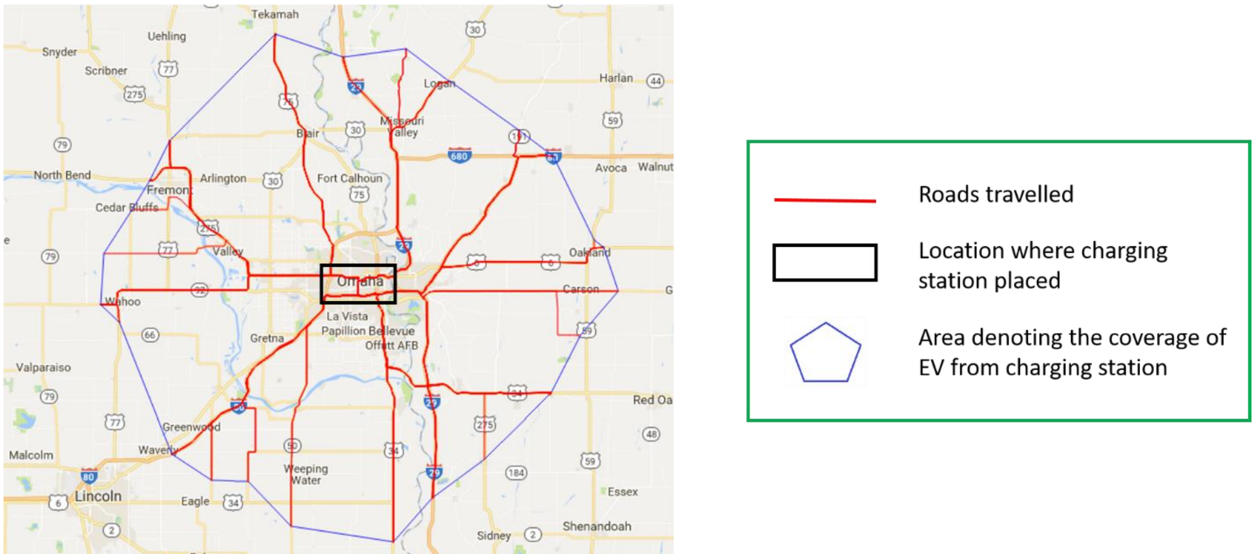


APPENDIX 2.4

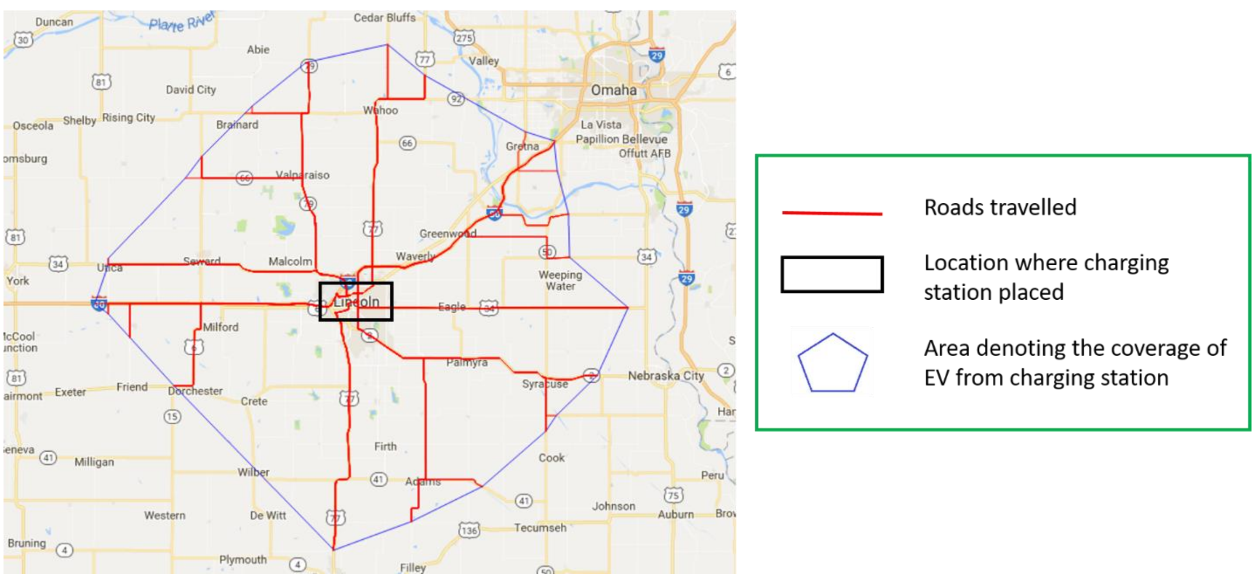
ONE-WAY COVERAGE AREA OF 2016 NISSAN LEAF FROM A CHARGNG INFRASTRUCTURE LOCATION

APPENDIX 2.4.1: COVERAGE AREA FOR INDIVIDUAL LOCATIONS IN ZONE 1

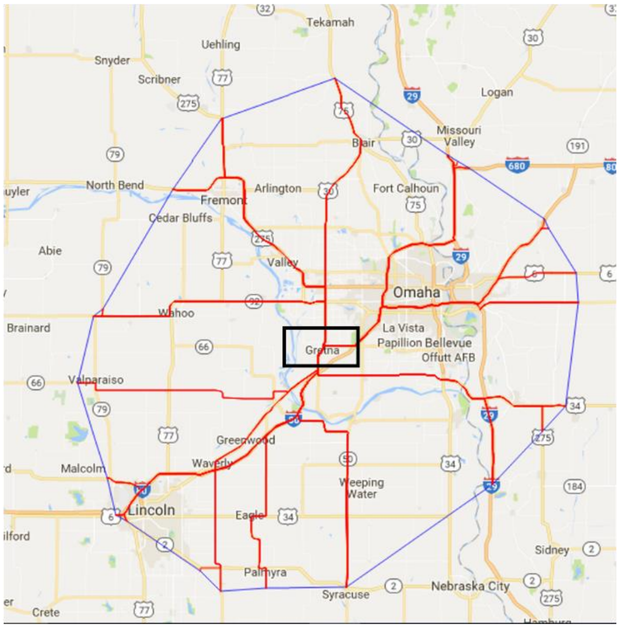
Coverage area of the EV when the Charging station is placed on OMAHA



Coverage area of the EV when the Charging station is placed on LINCOLN



Coverage area of the EV when the Charging station is placed on GRETNA

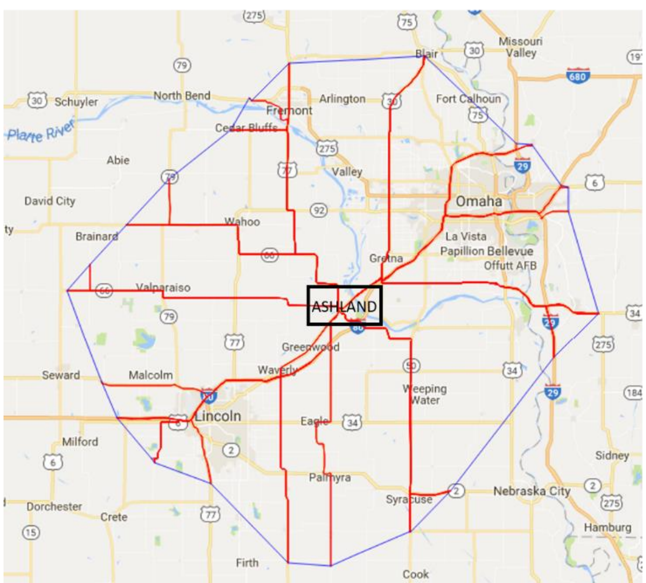


Roads travelled

Location where charging station placed

Area denoting the coverage of EV from charging station

Coverage area of the EV when the Charging station is placed on ASHLAND

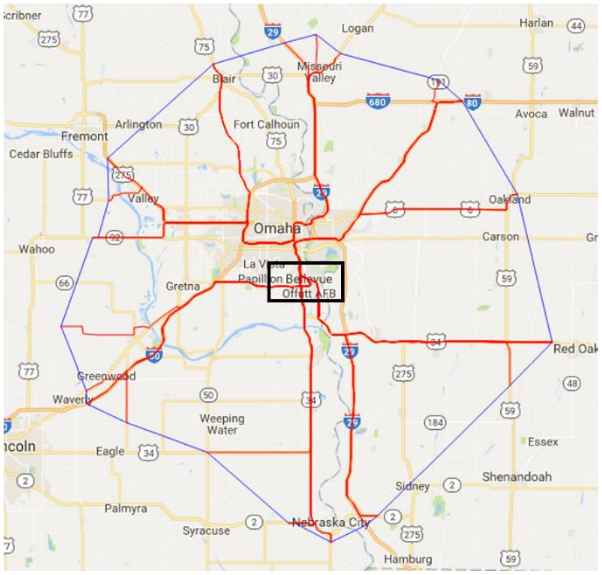


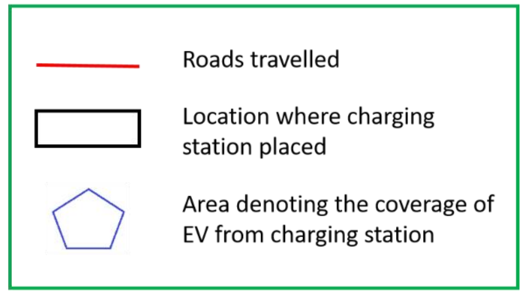
Roads travelled

Location where charging station placed

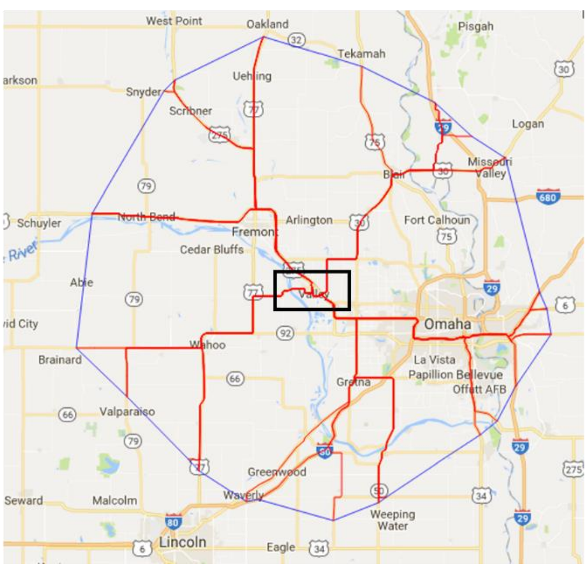
Area denoting the coverage of EV from charging station

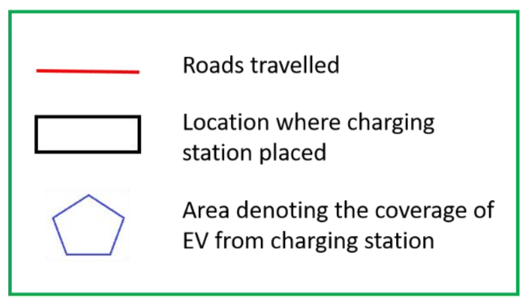
Coverage area of the EV when the Charging station is placed on BELLEVUE



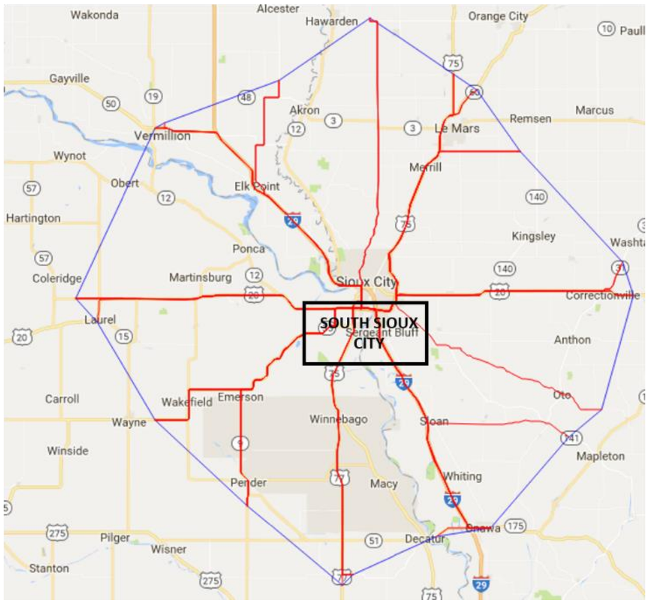


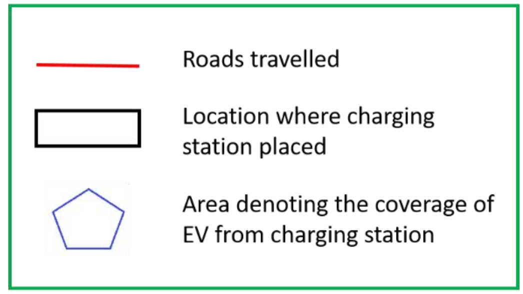
Coverage area of the EV when the Charging station is placed on VALLEY



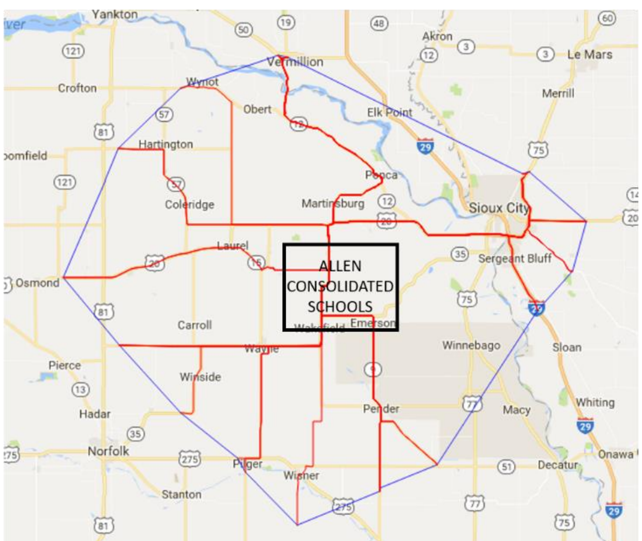


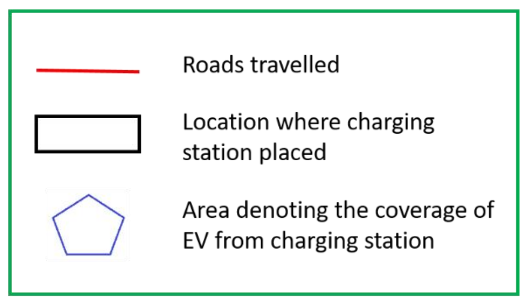
Coverage area of the EV when the Charging station is placed on SOUTH SIOUX CITY



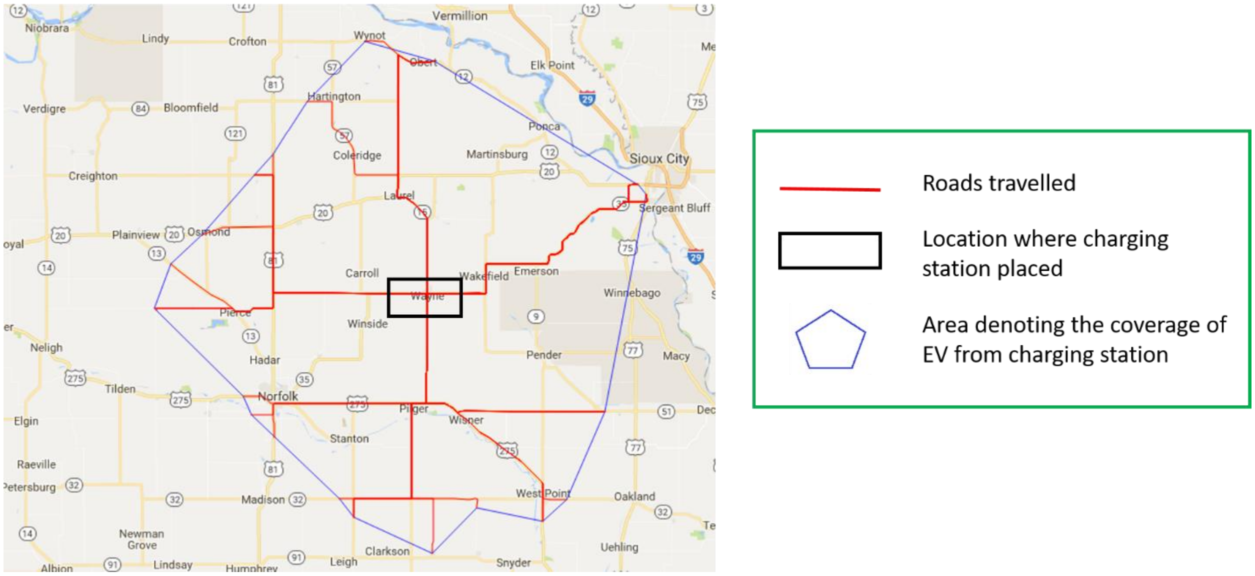


Coverage area of the EV when the Charging station is placed on ALLEN CONSOLIDATED SCHOOLS

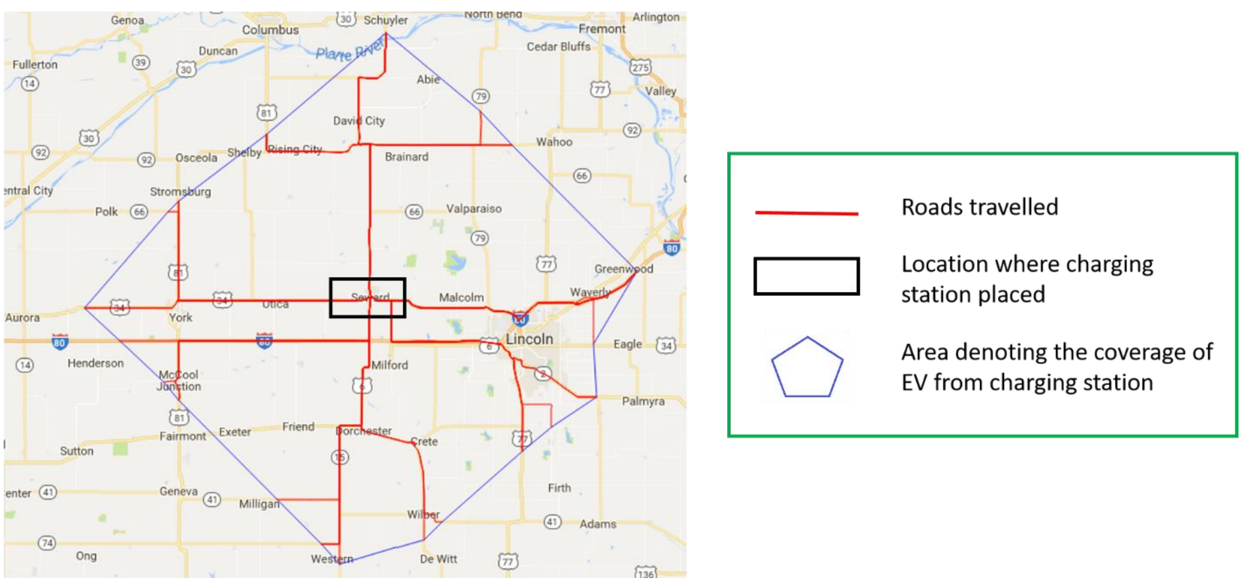




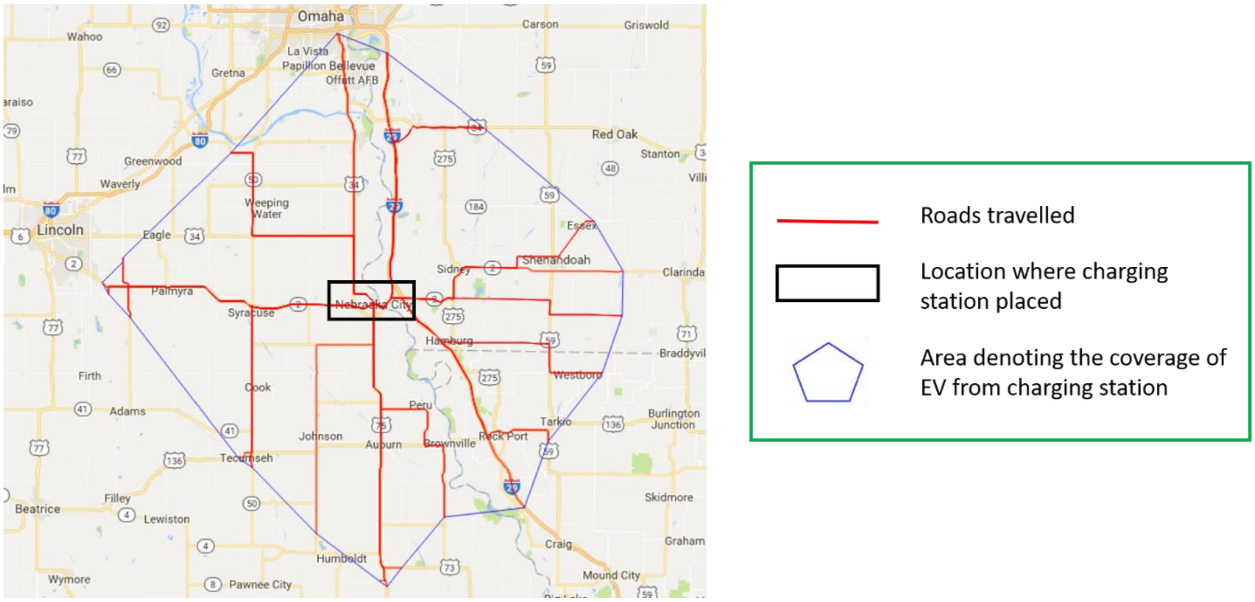
Coverage area of the EV when the Charging station is placed on WAYNE



Coverage area of the EV when the Charging station is placed on SEWARD

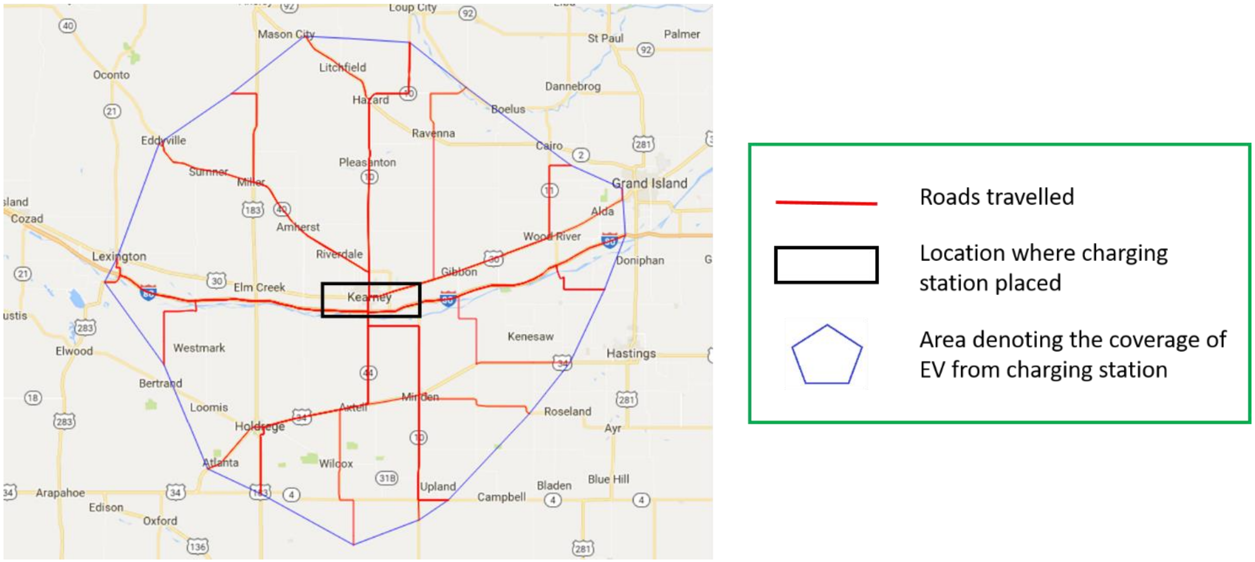


Coverage area of the EV when the Charging station is placed on NEBRASKA CITY

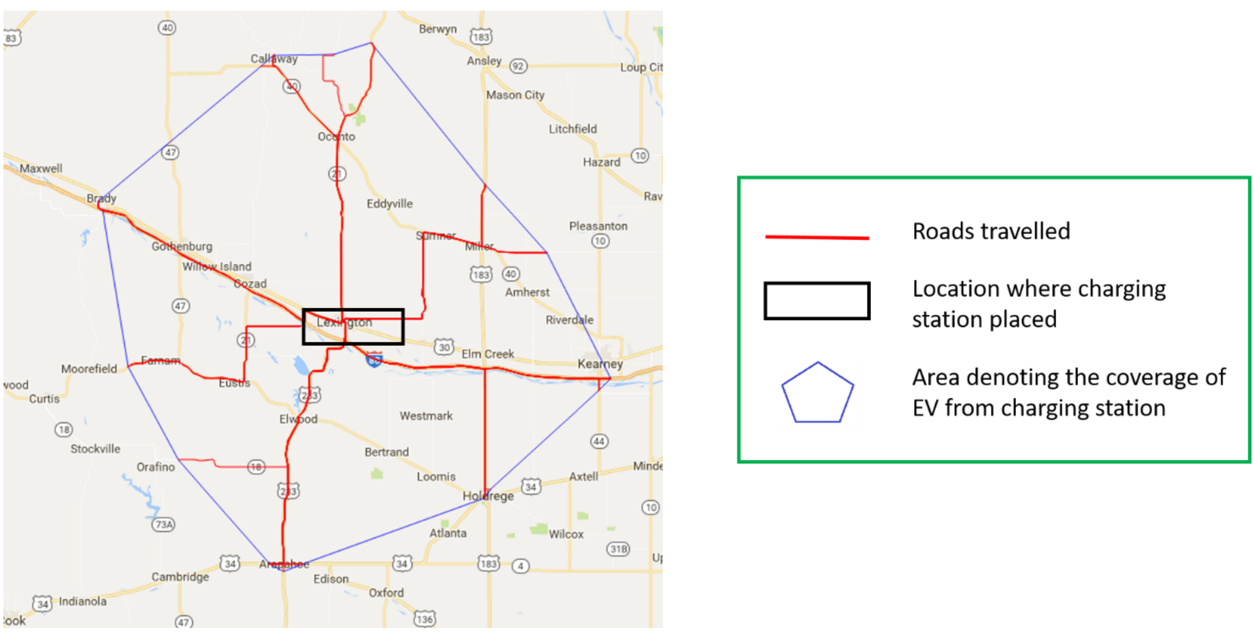


APPENDIX 2.4.2: COVERAGE AREA FOR INDIVIDUAL LOCATIONS IN ZONE 2

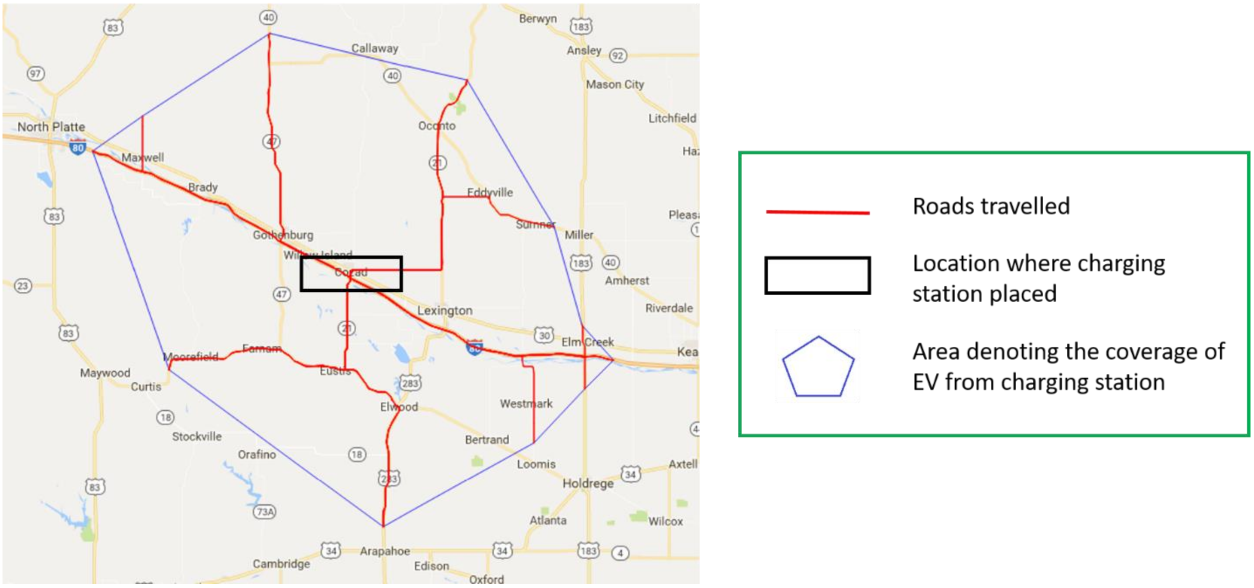
Coverage area of the EV when the Charging station is placed on KEARNEY



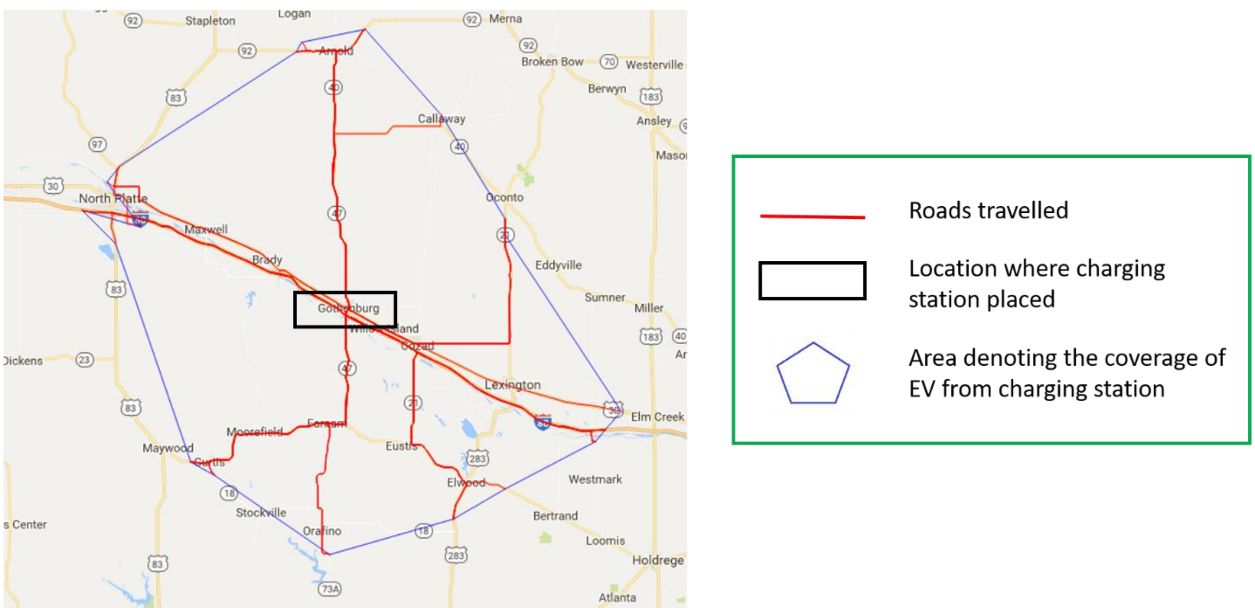
Coverage area of the EV when the Charging station is placed on LEXINGTON



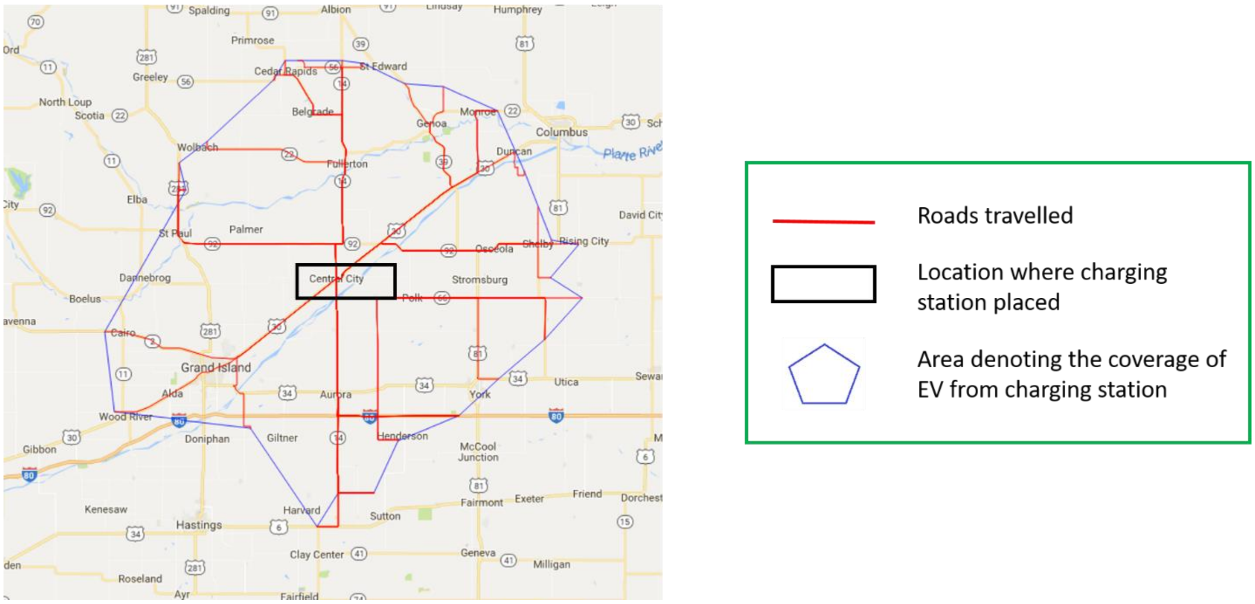
Coverage area of the EV when the Charging station is placed on COZAD



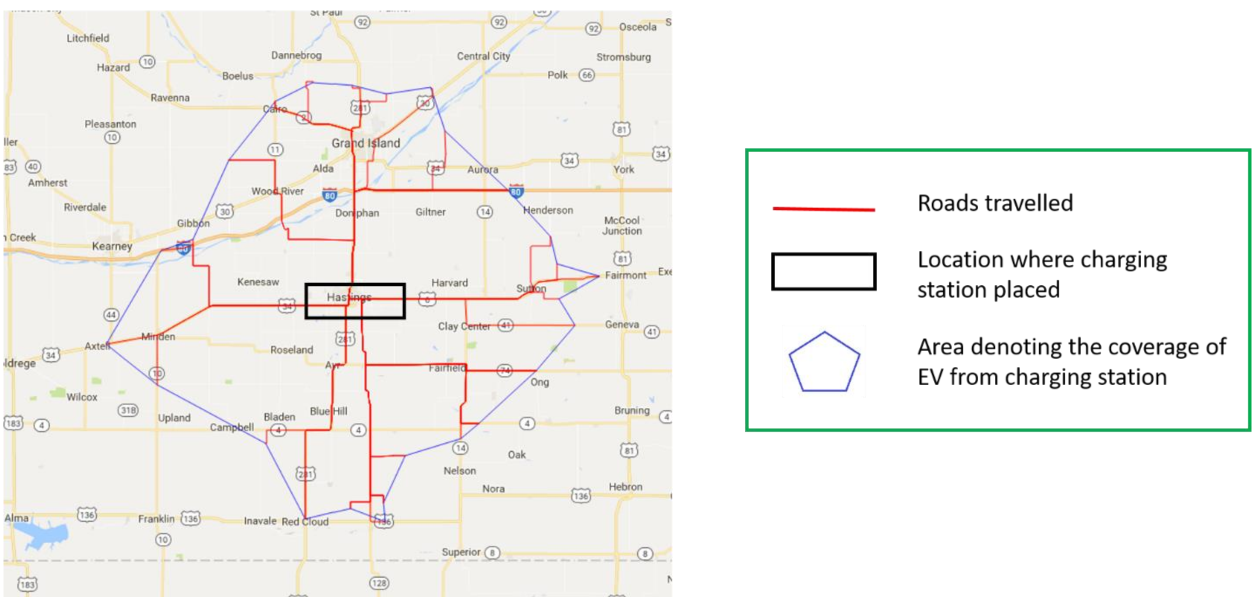
Coverage area of the EV when the Charging station is placed on GOTHENBURG



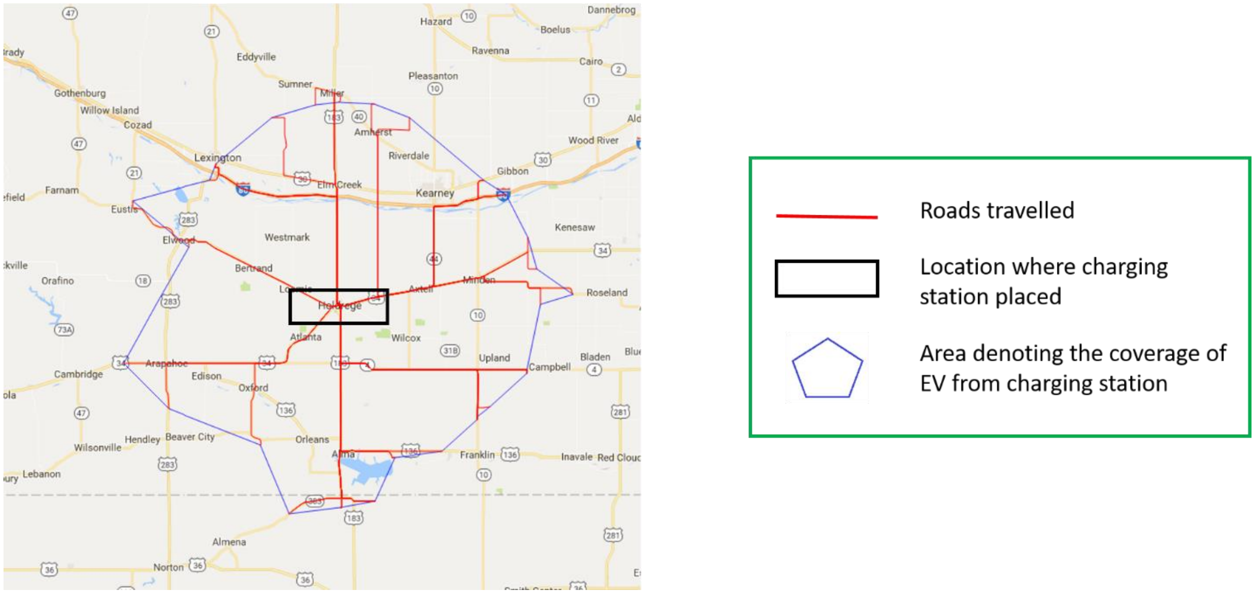
Coverage area of the EV when the Charging station is placed on CENTRAL CITY



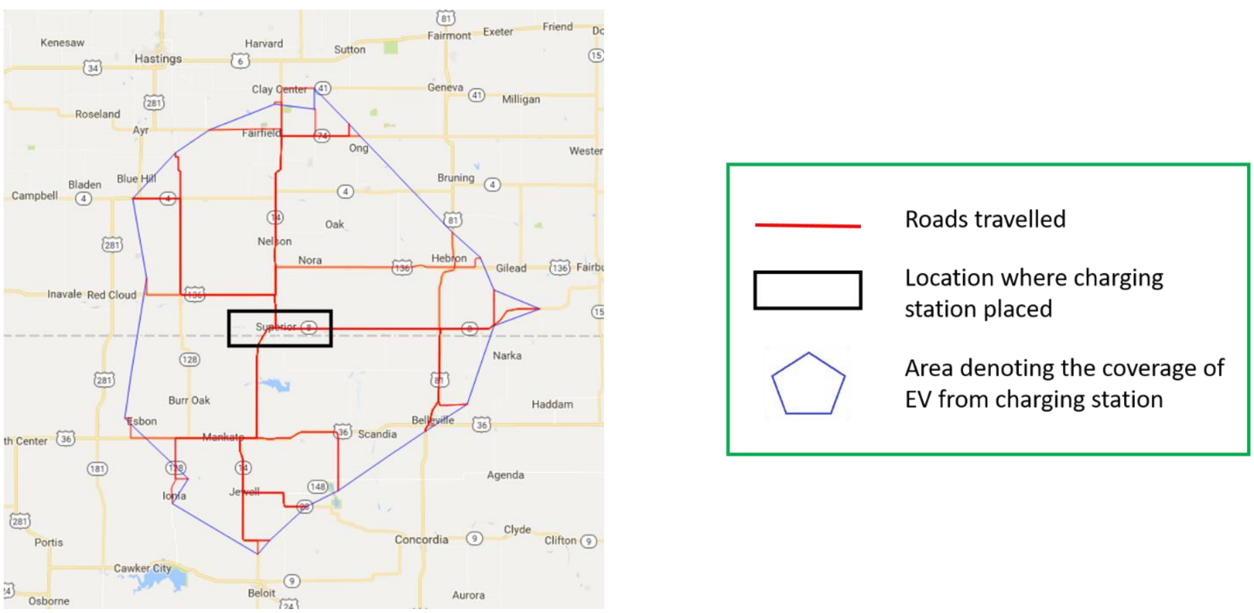
Coverage area of the EV when the Charging station is placed on HASTINGS



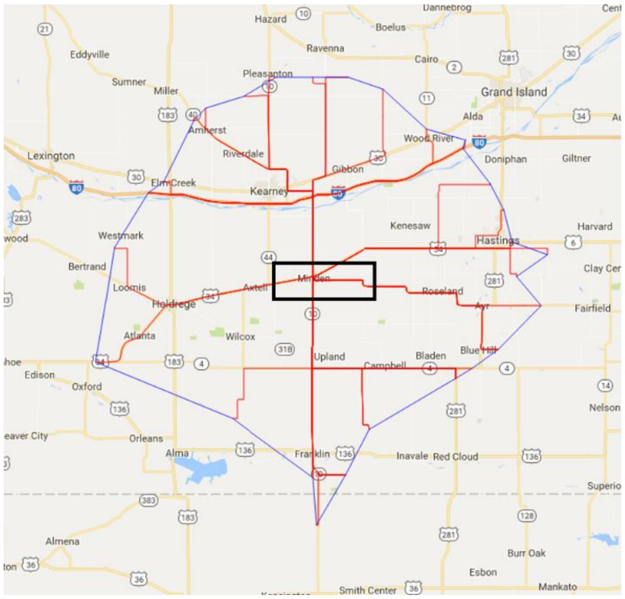
Coverage area of the EV when the Charging station is placed on HOLDREGE



Coverage area of the EV when the Charging station is placed on SUPERIOR



Coverage area of the EV when the Charging station is placed on MINDEN



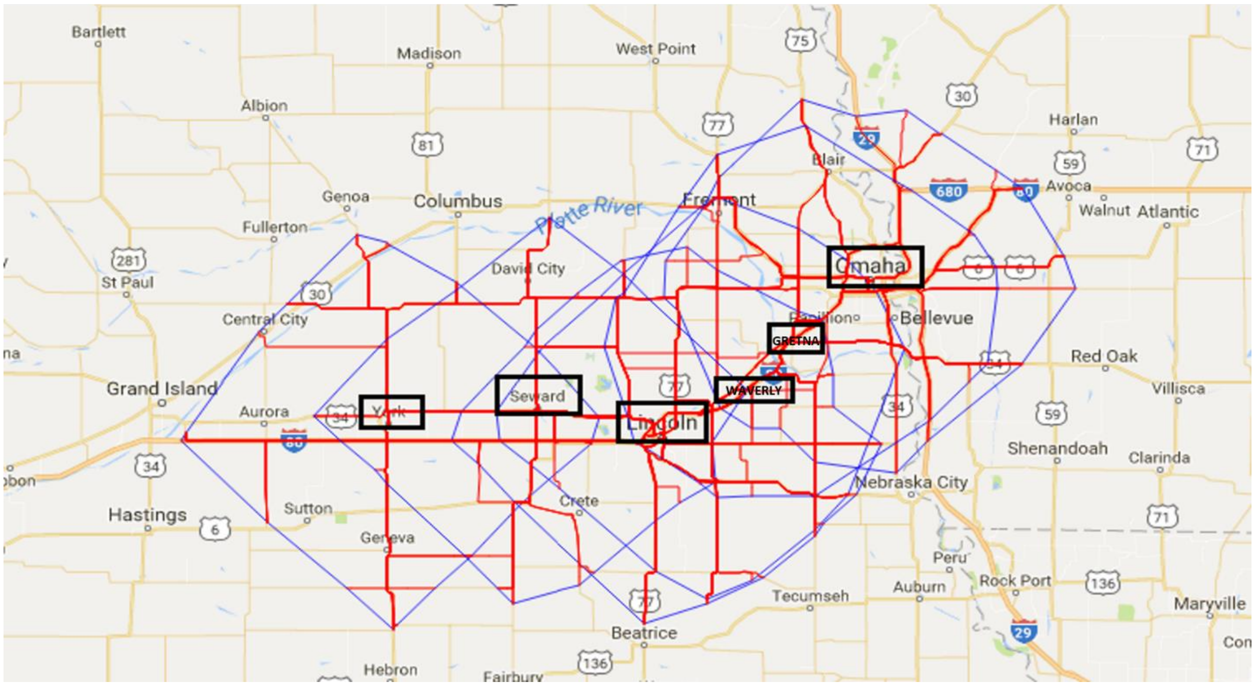
Roads travelled

Location where charging station placed

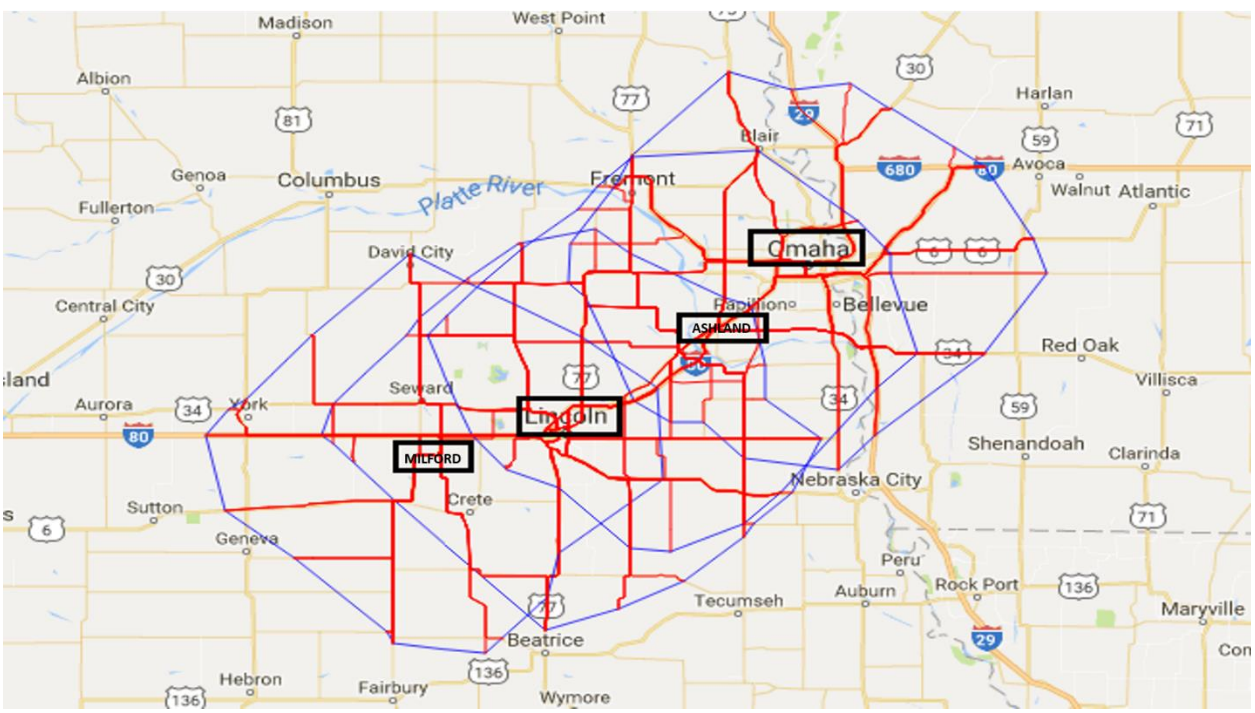
Area denoting the coverage of EV from charging station

APPENDIX 2.4.3: COVERAGE AREA ON THE INTERSTATE OR THE US-HIGHWAYS IN ZONE 1

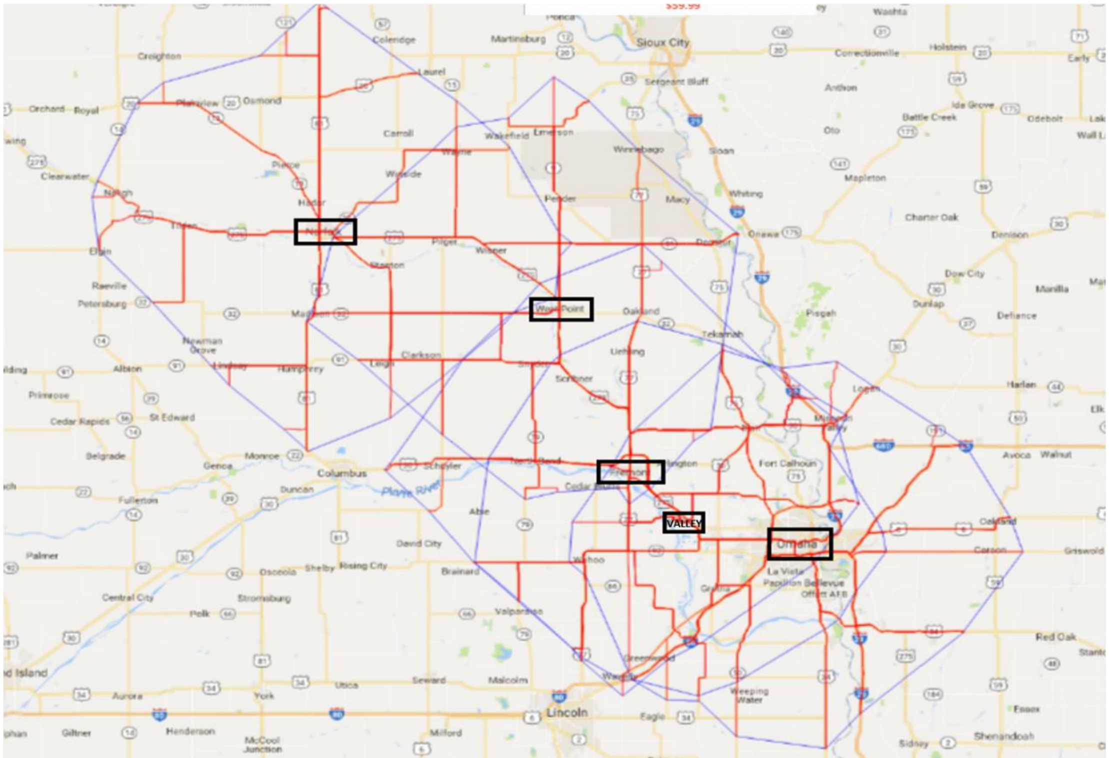
Coverage area of the EV in I-80



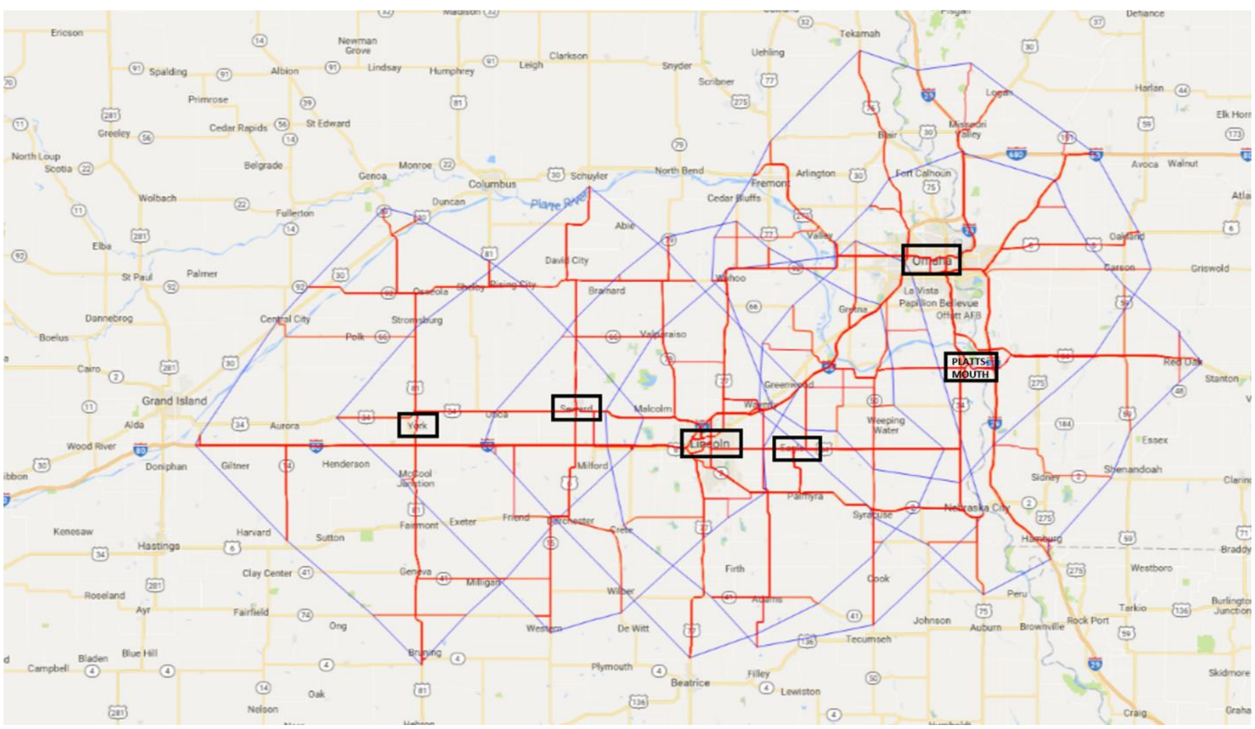
Coverage area of the EV in US-HWY-6



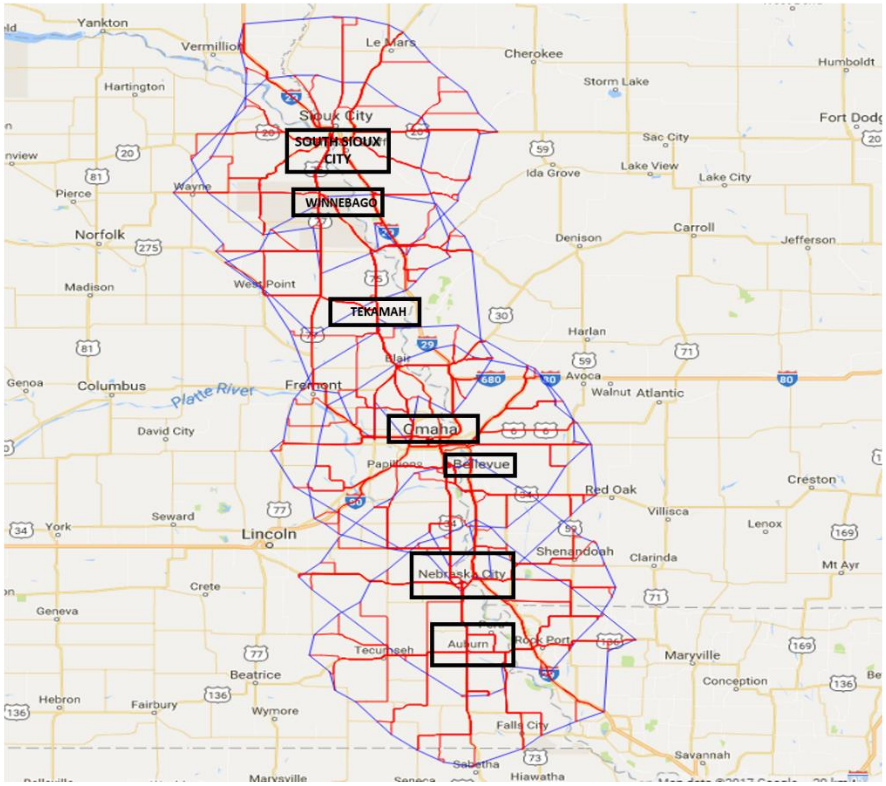
Coverage area of the EV in US-HWY-275



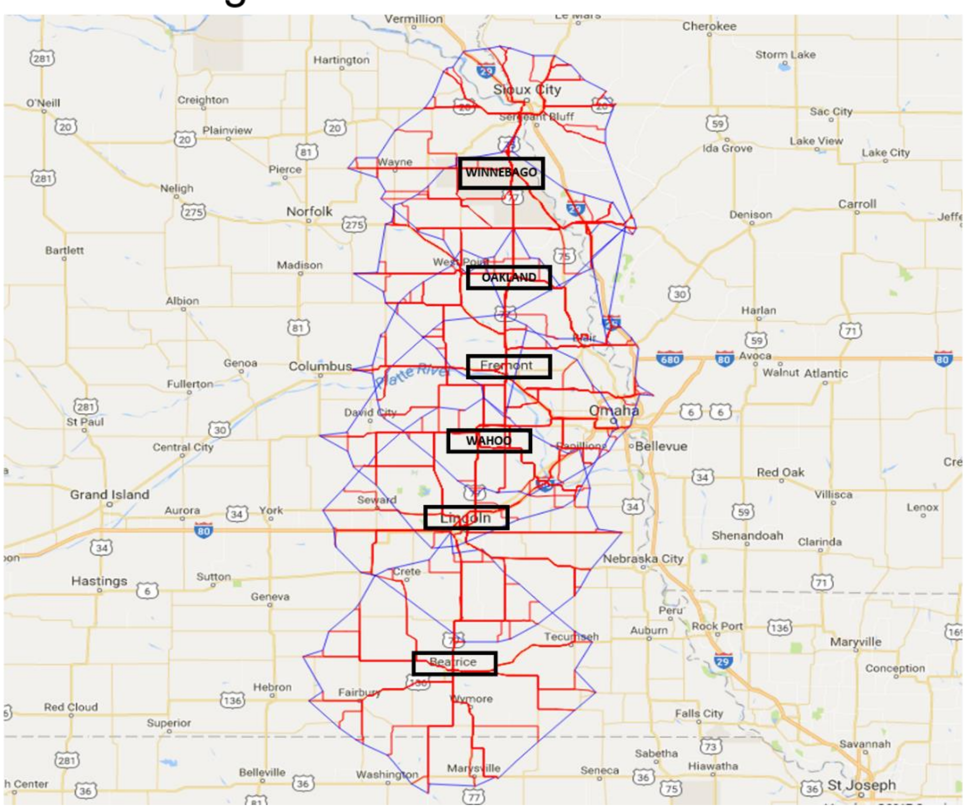
Coverage area of the EV in US-HWY-34



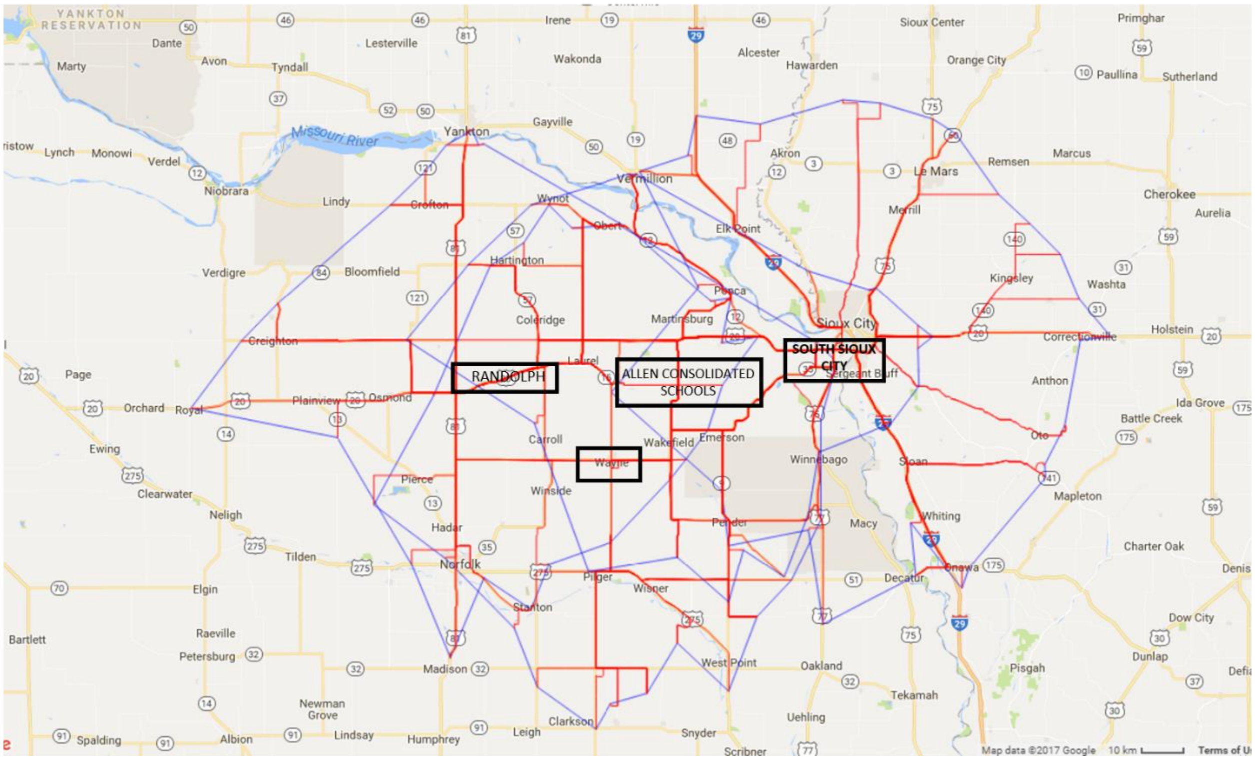
Coverage area of the EV in US-HWY-75



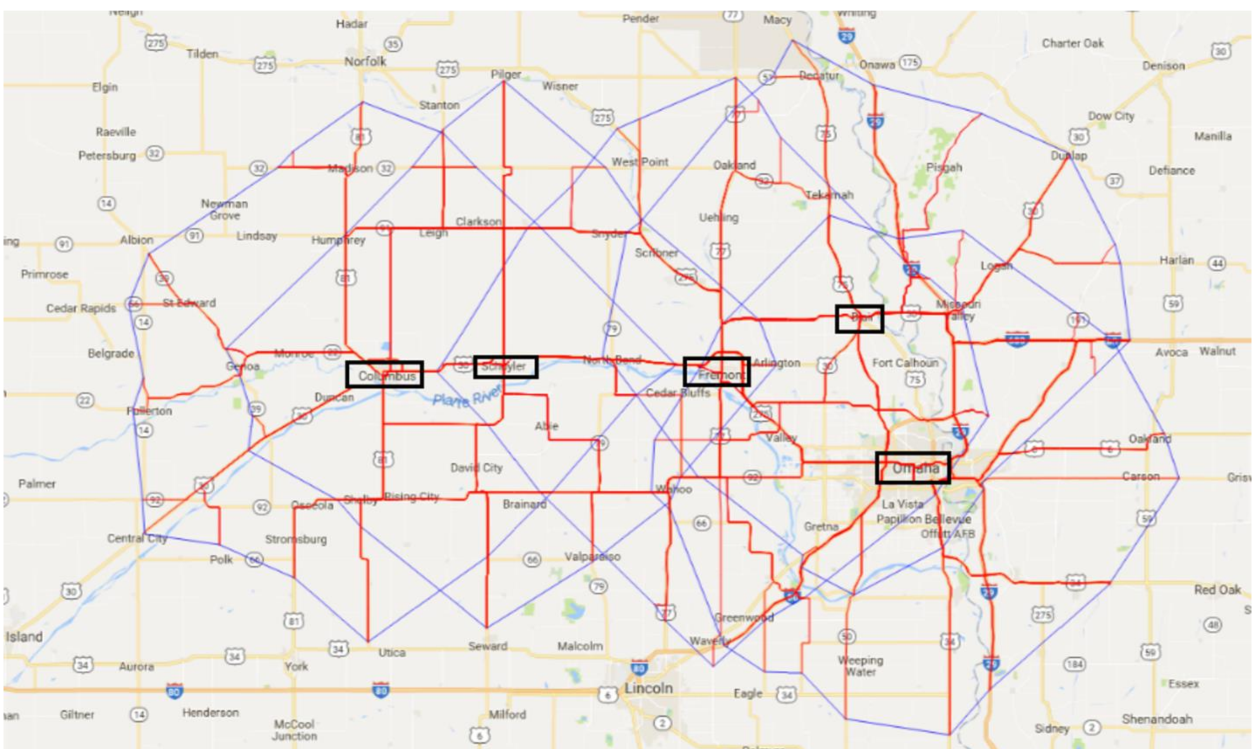
Coverage area of the EV in US-HWY-77



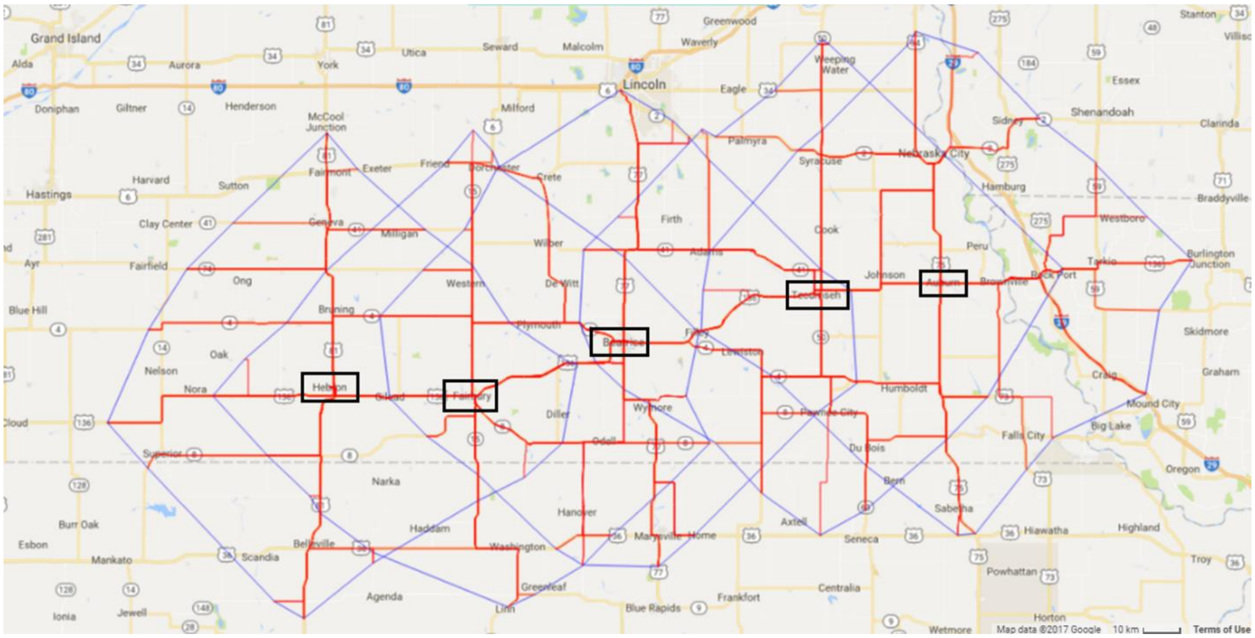
Coverage area of the EV in US-HWY-20



Coverage area of the EV in US-HWY-30

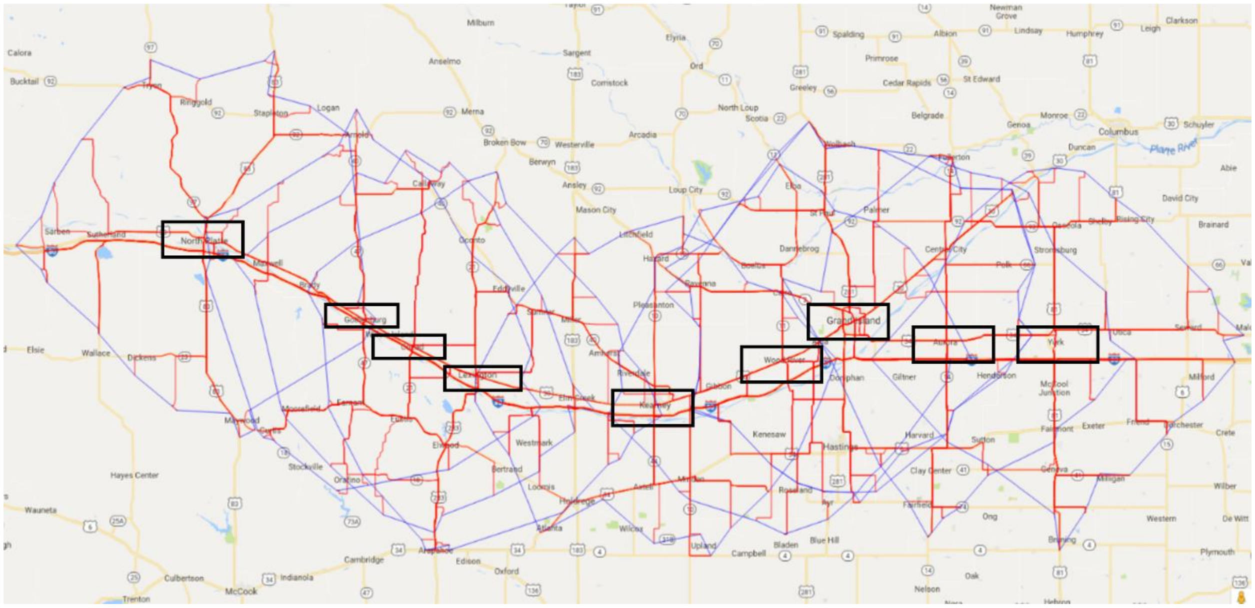


Coverage area of the EV in US-HWY-136

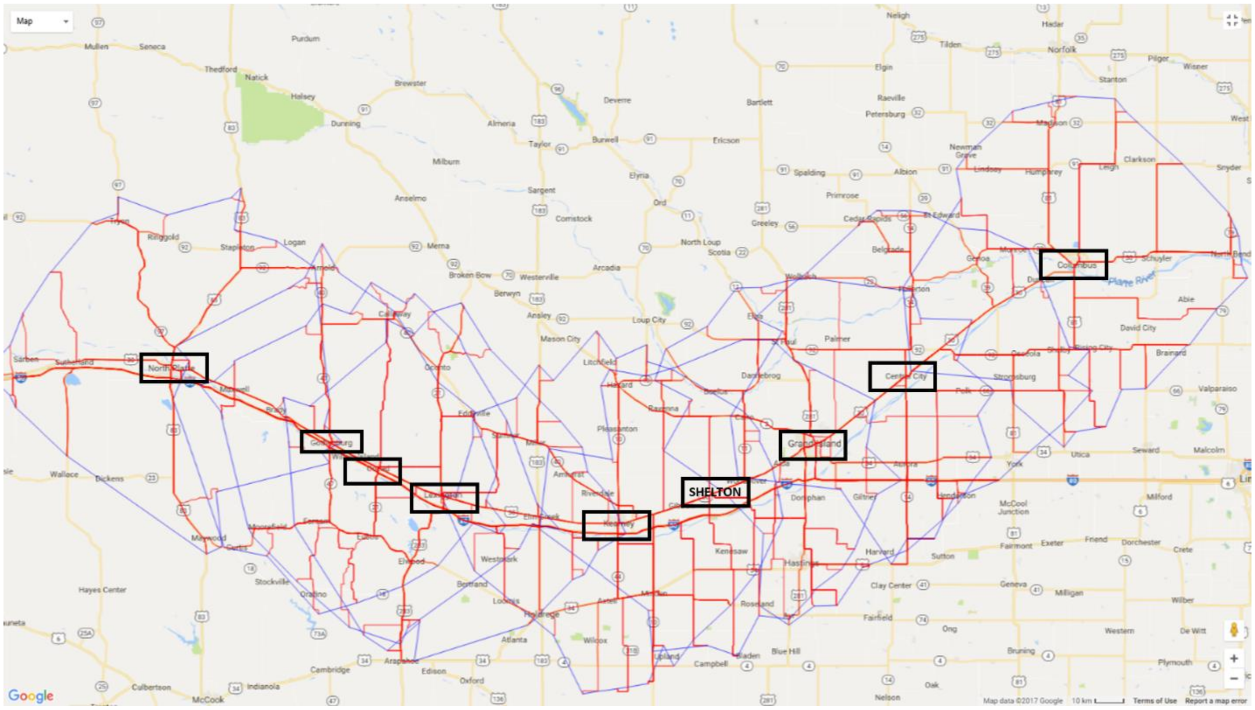


APPENDIX 2.4.4: COVERAGE AREA ON THE INTERSTATE OR THE US-HIGHWAYS IN ZONE 2

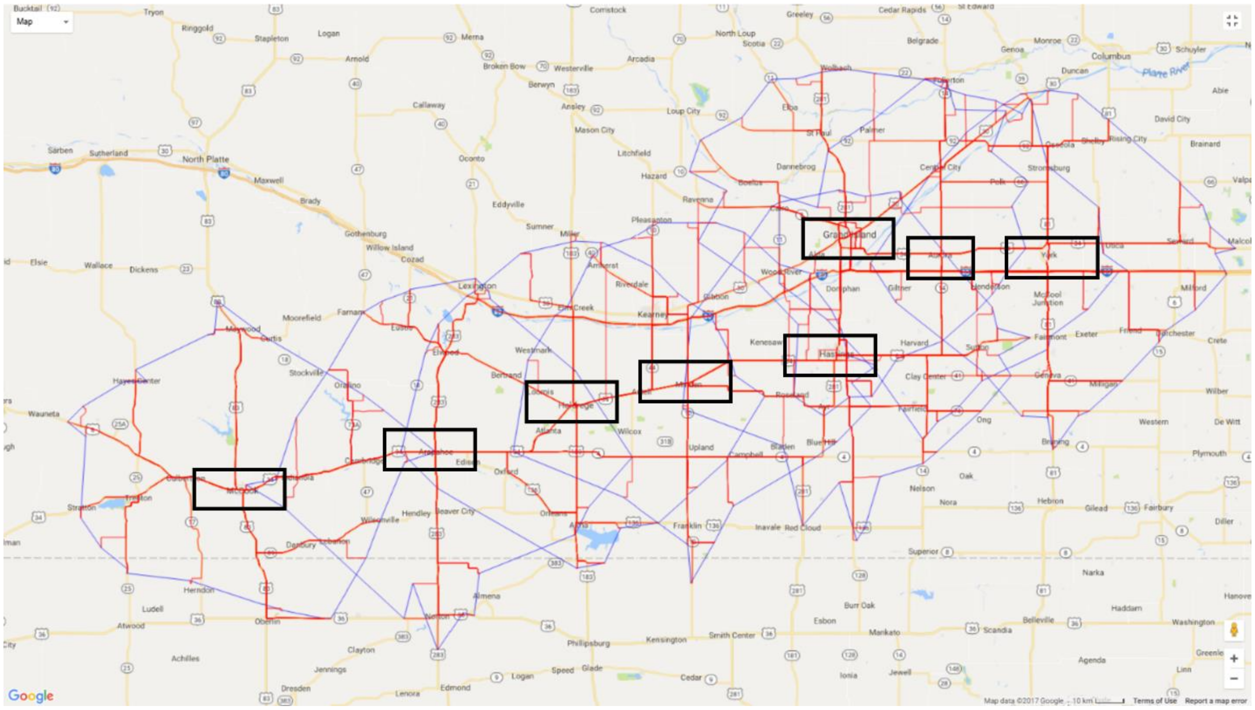
Coverage area of the EV in I-80



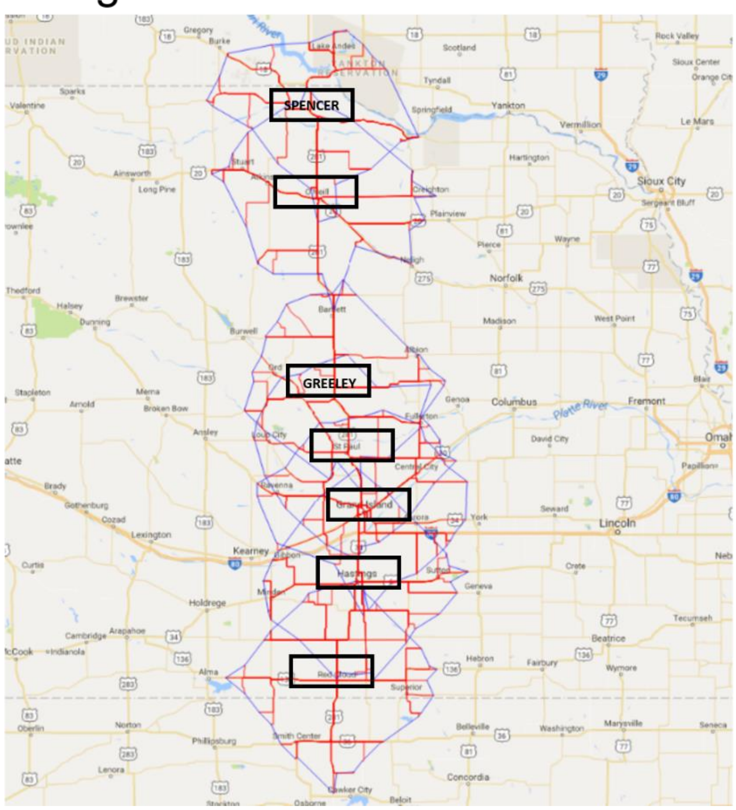
Coverage area of the EV in US-HWY-30



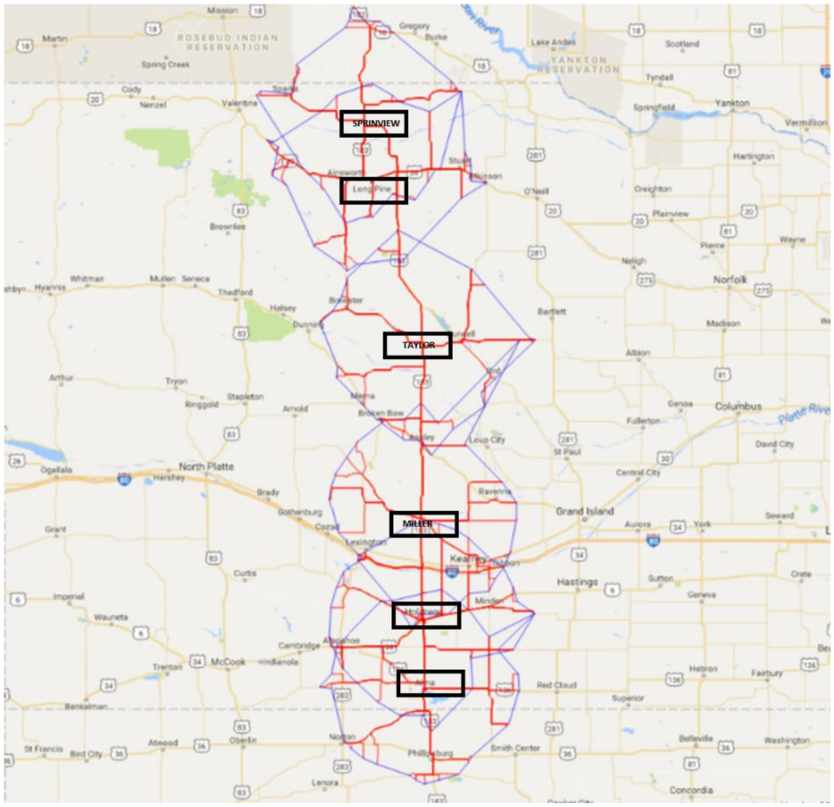
Coverage area of the EV in US-HWY-34



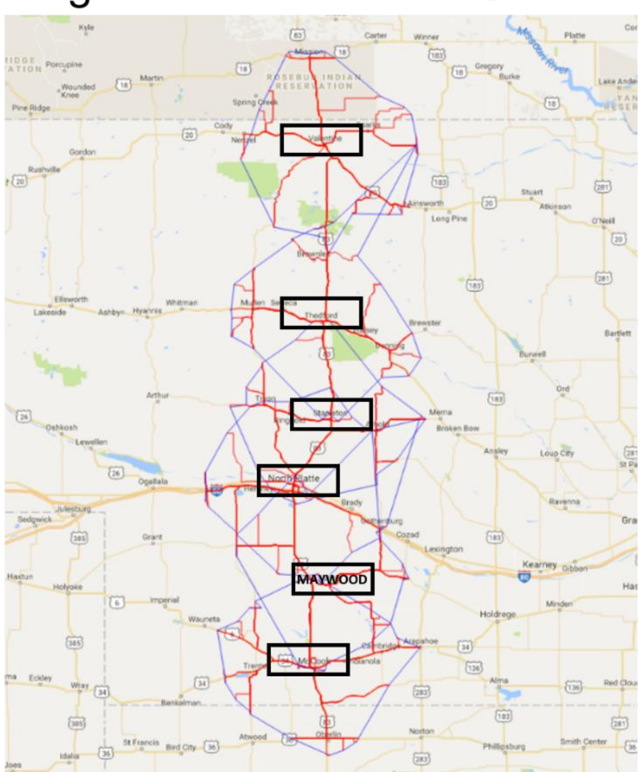
Coverage area of the EV in US-HWY-281



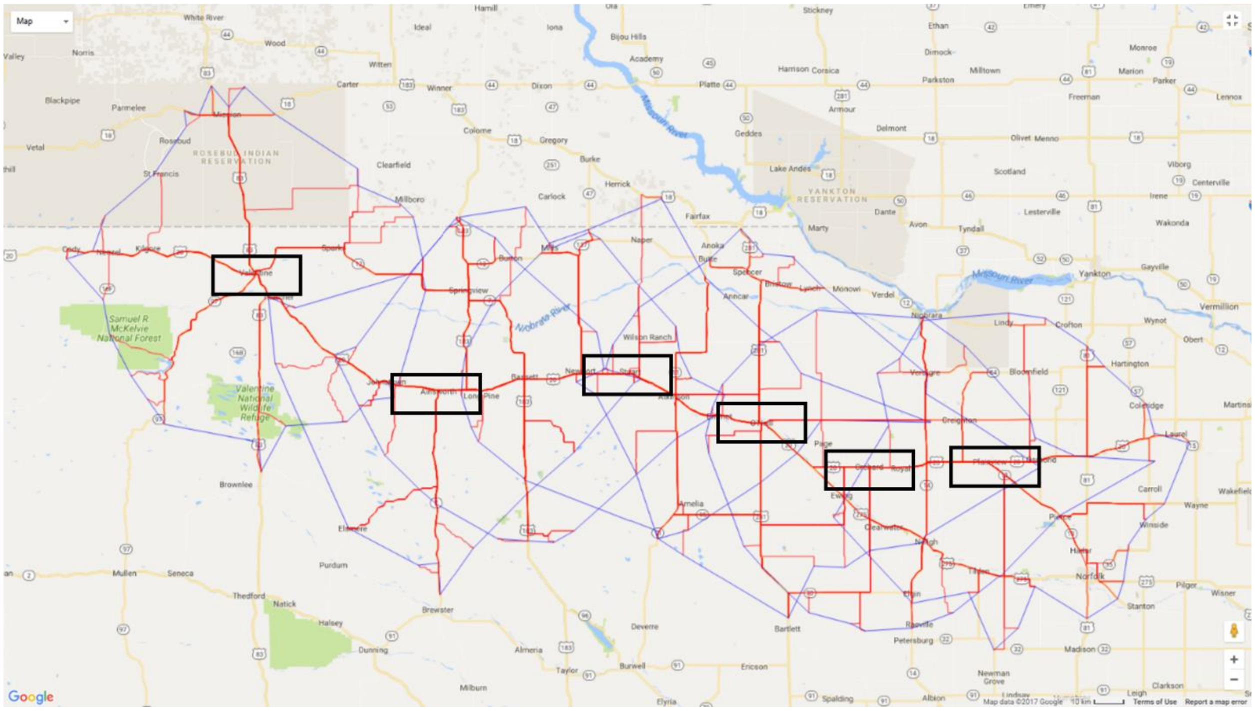
Coverage area of the EV in US-HWY-183



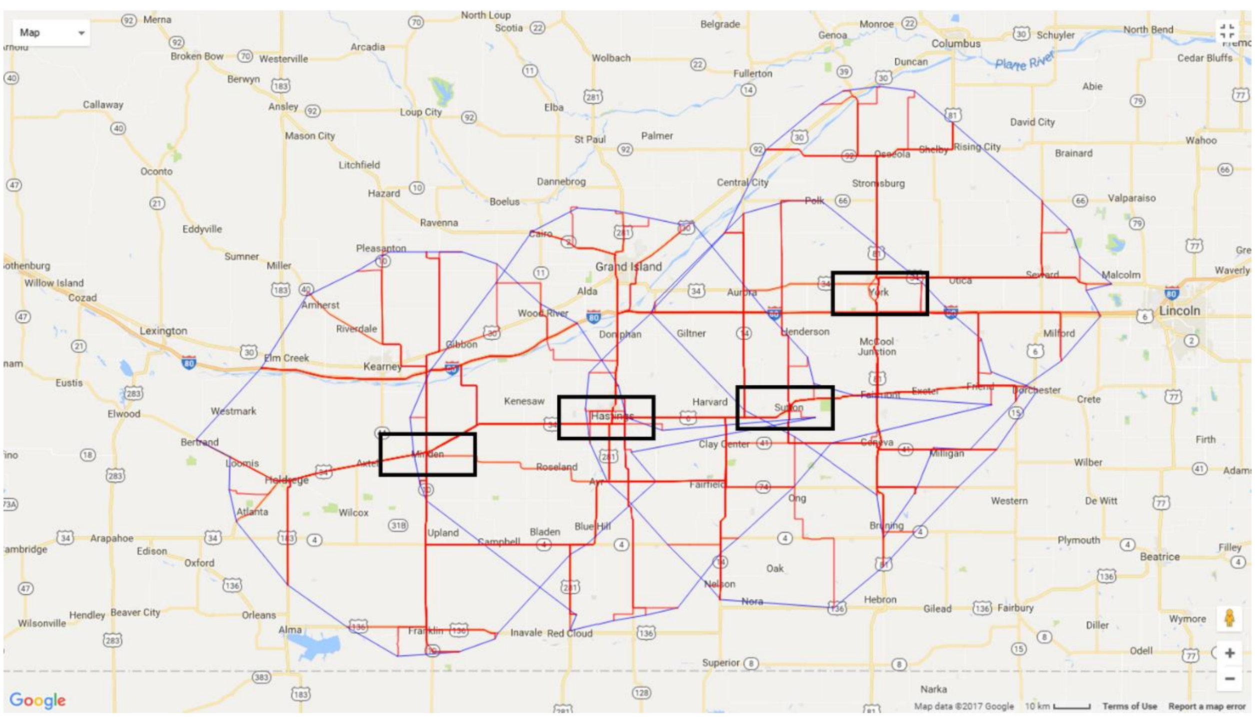
Coverage area of the EV in US-HWY-83



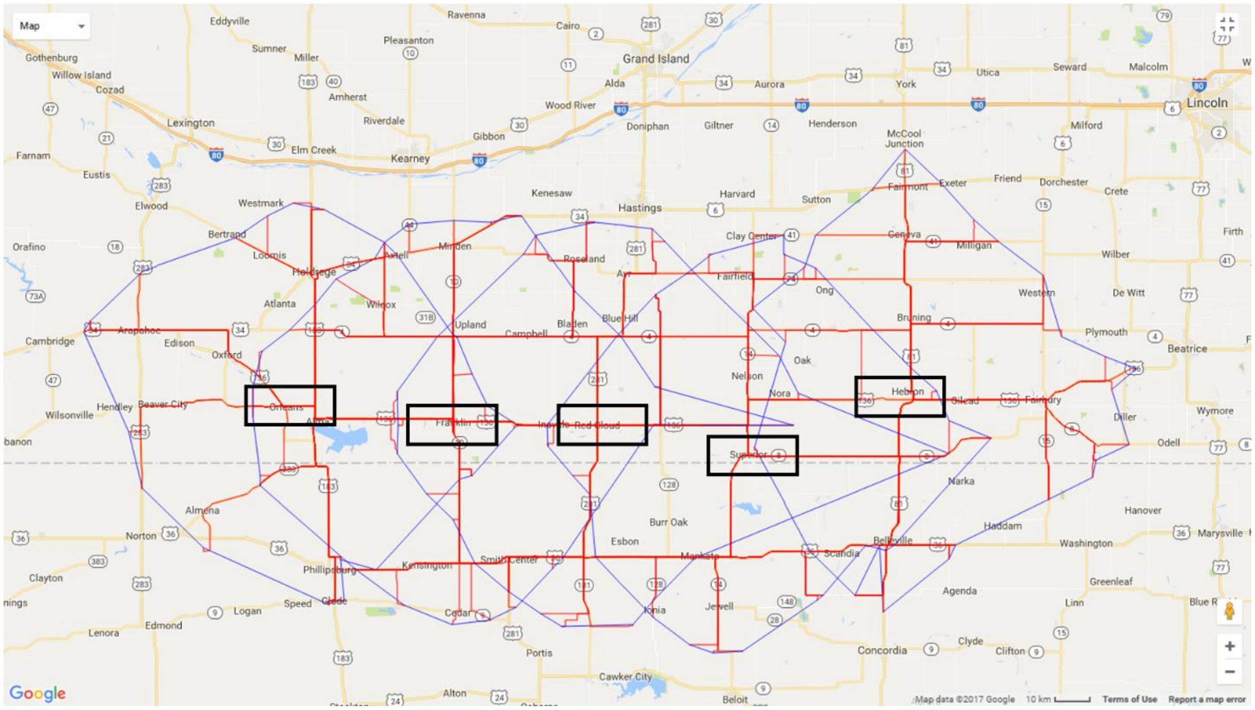
Coverage area of the EV in US-HWY-20



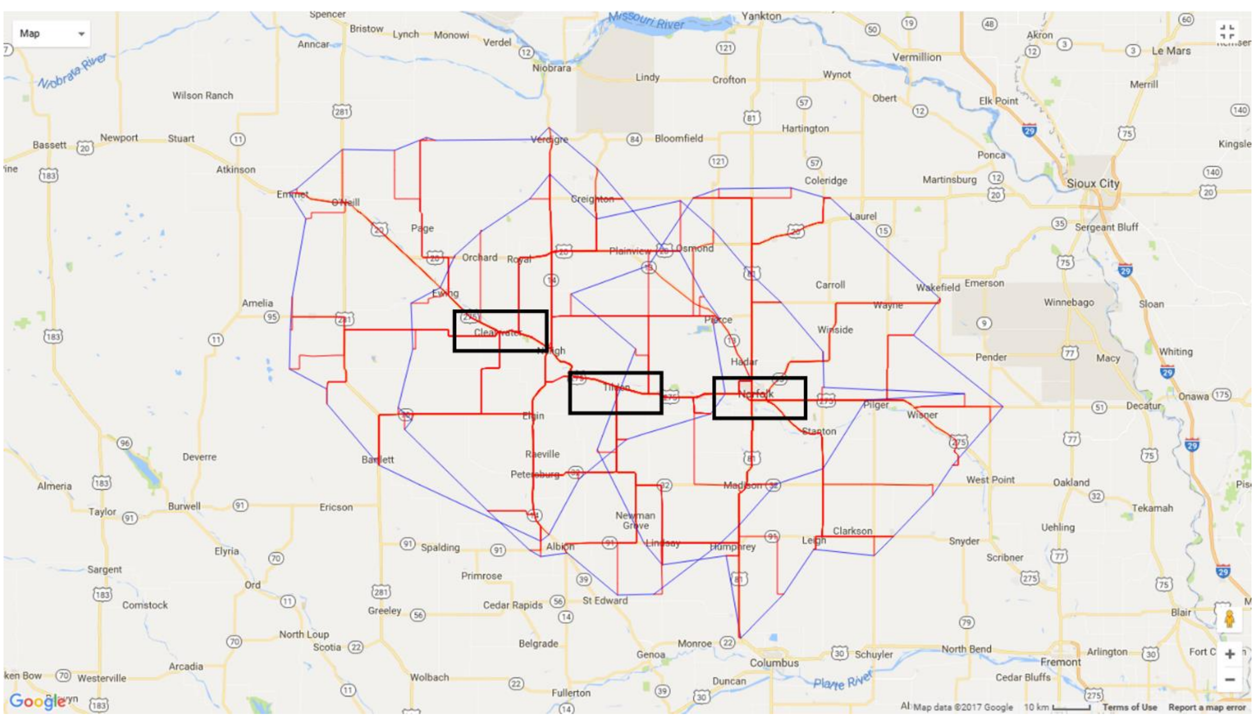
Coverage area of the EV in US-HWY-6



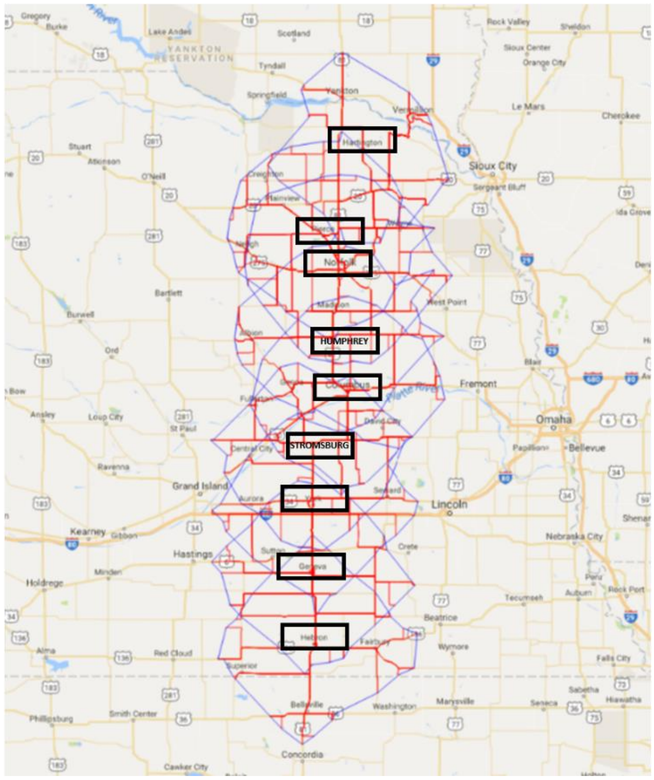
Coverage area of the EV in US-HWY-136



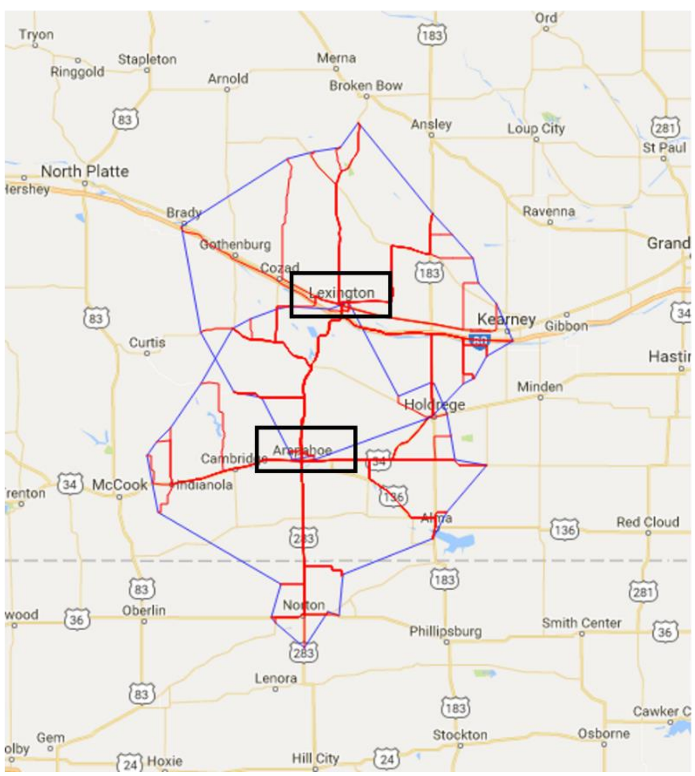
Coverage area of the EV in US-HWY-275



Coverage area of the EV in US-HWY-81

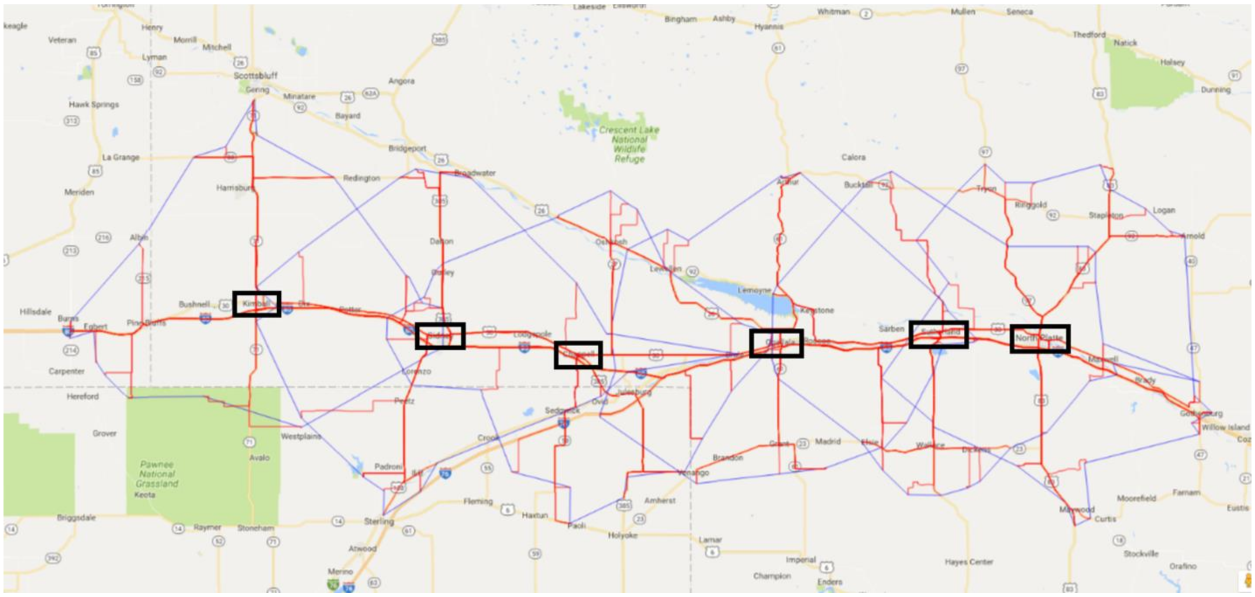


Coverage area of the EV in US-HWY-283

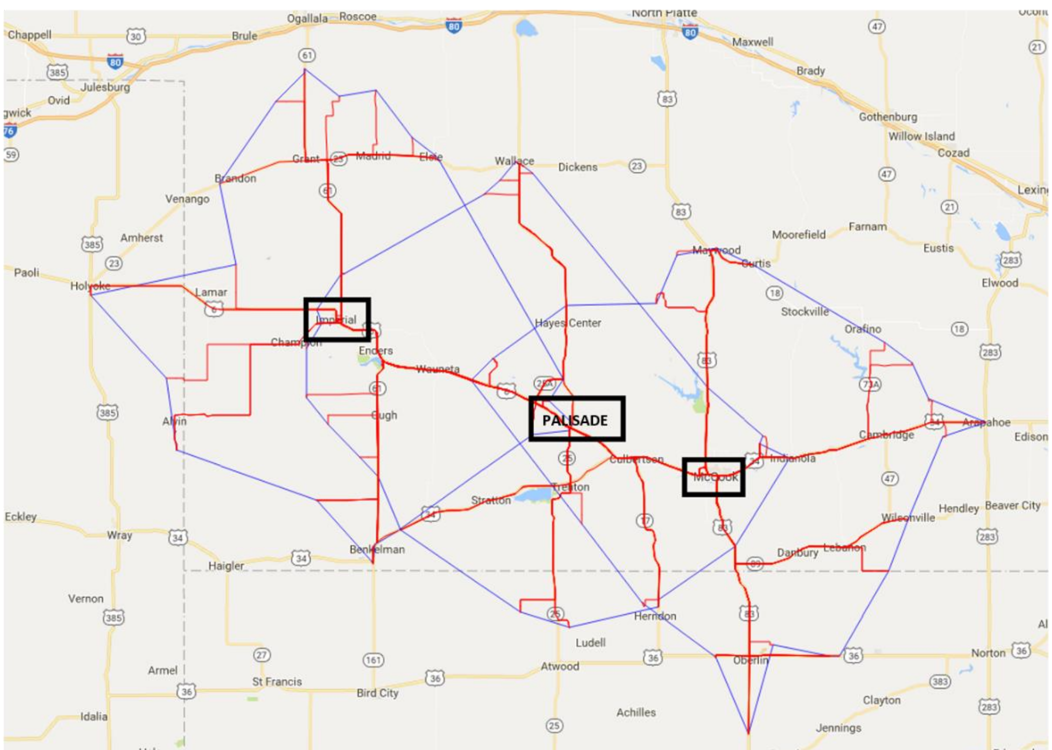


APPENDIX 2.4.5: COVERAGE AREA ON THE INTERSTATE OR THE US-HIGHWAYS IN ZONE 3

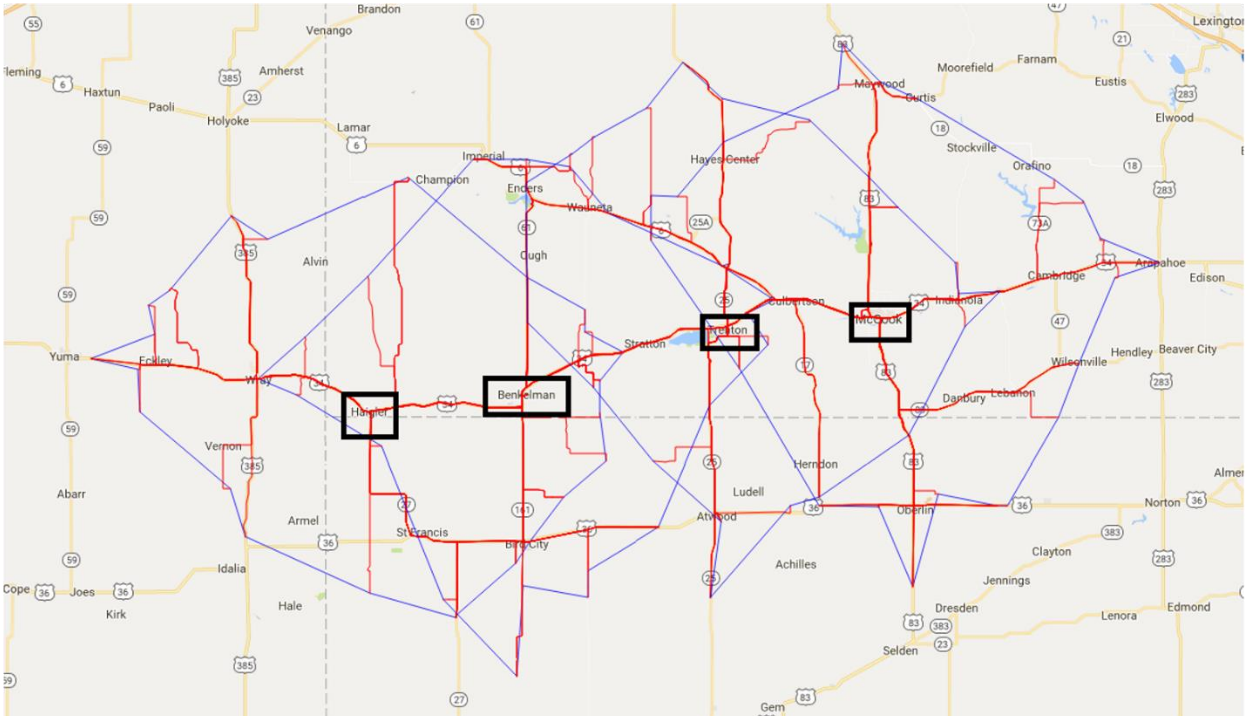
Coverage area of the EV in I-80 and US-HWY-30



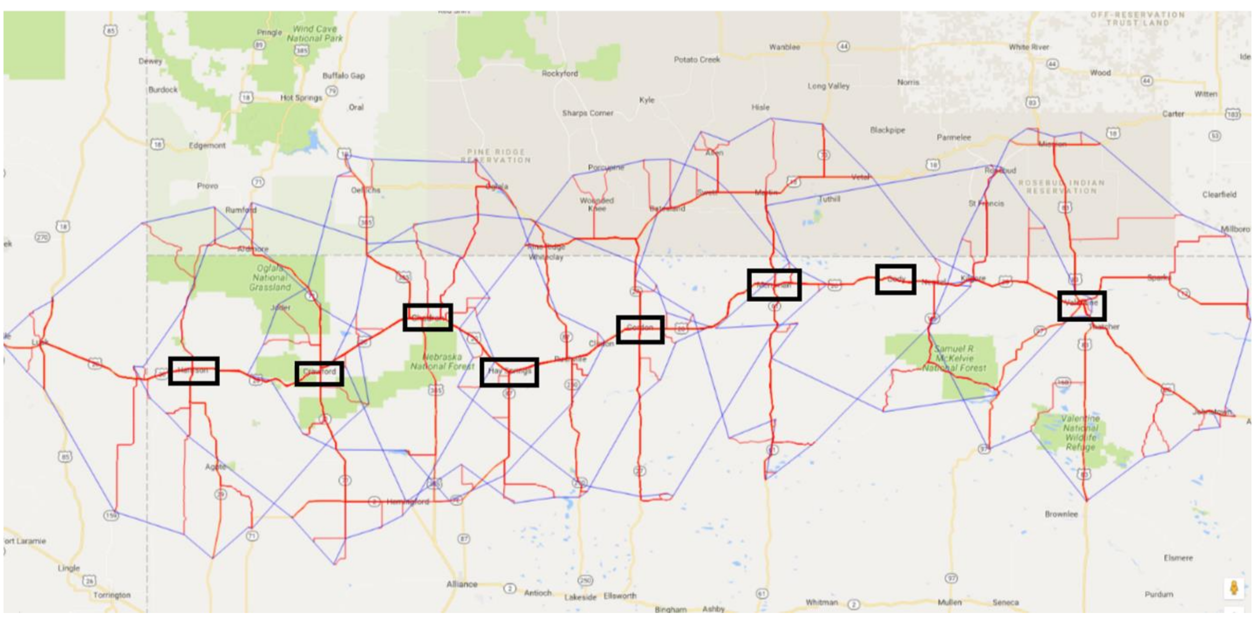
Coverage area of the EV in US-HWY-6



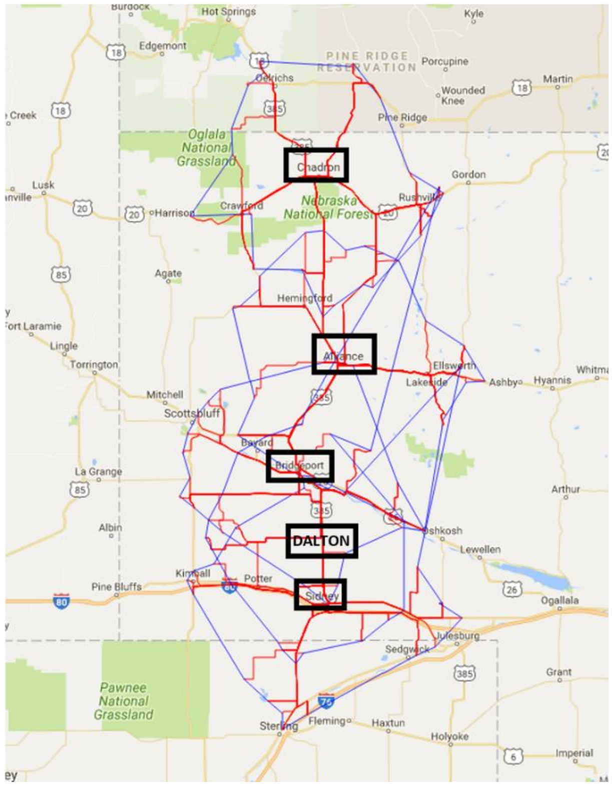
Coverage area of the EV in US-HWY-34



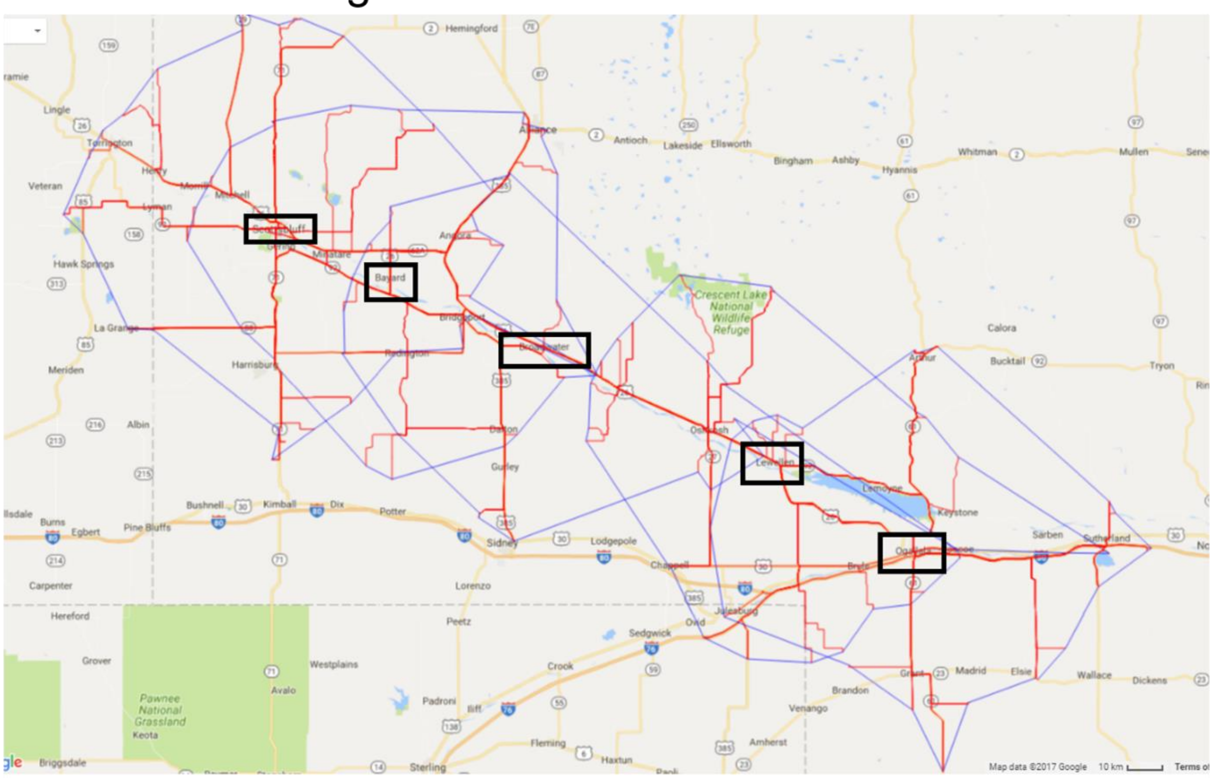
Coverage area of the EV in US-HWY-20



Coverage area of the EV in US-HWY-385



Coverage area of the EV in US-HWY-26



<u>APPENDIX 6.1</u>

KEY TERMS USED IN THE SURVEY REPORT

Table 6.1.1 Key Terms

Key Terms	
Standard Error	The standard error of the sample mean is an estimate of how far the sample mean is likely to be from the population mean. The standard error is calculated by dividing the standard deviation by the square root of number of measurements that make up the mean (often represented by N). By dividing the standard deviation by the square root of N, the standard error grows smaller as the number of measurements (N) grows larger. This reflects the greater confidence one has in their mean value as they make more measurements.
Standard Deviation	Standard Deviation is a measure of the dispersion of a set of data from its mean
Confidence Interval	Confidence interval provides a range of values around the estimate, within which the true value can be expected to fall. The smaller the confidence interval is for a particular estimate, the more precise the estimate is.
Conventional Vehicle	A vehicle that is not an electric-vehicle; a vehicle that uses conventional fuel (gasoline) for its operation for the purpose of this questionnaire
Battery Electric Vehicle (BEV)	A vehicle that is powered completely by a battery system and is recharged using electricity via charging infrastructure
Hybrid Electric Vehicle (HEV)	A vehicle that is powered by a battery and conventional fuel. The battery is charged directly by the conventional Internal Combustion Engine (ICE) powertrain
Plug-in Hybrid Electric Vehicle (PHEV)	An extended range vehicle: a vehicle that is powered by a battery and conventional fuel. The battery is charged using electricity via charging infrastructure
Electric Vehicle (EV)	Is defined as a Battery Electric Vehicle (BEV) or a Plug-in Hybrid Electric Vehicle (PHEV).
Public Electric Vehicle Charging Infrastructure	Any venue open to the public other than at a private residence in which electric vehicle charging can occur

APPENDIX 6.2

GRAPHICAL REPRESENTATION OF SURVEY PART I DATA

Question: Would you consider purchasing an electric vehicle?

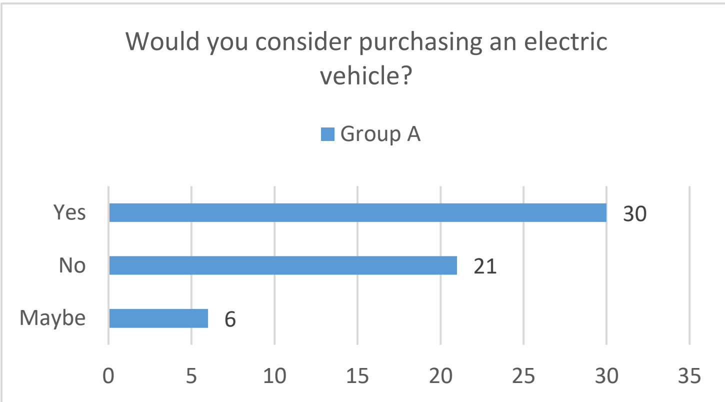


Figure 6.2.1

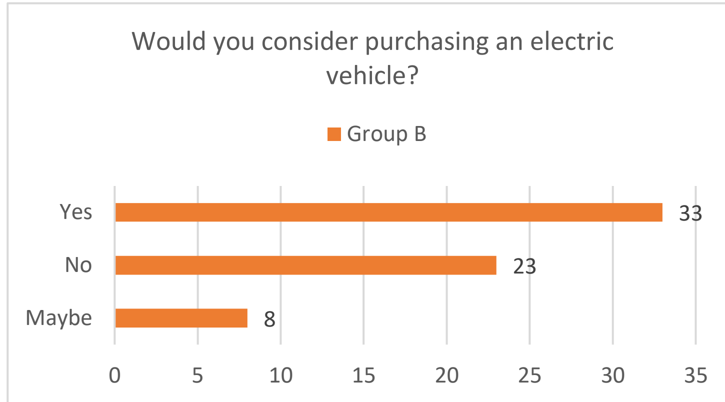


Figure 6.2.2

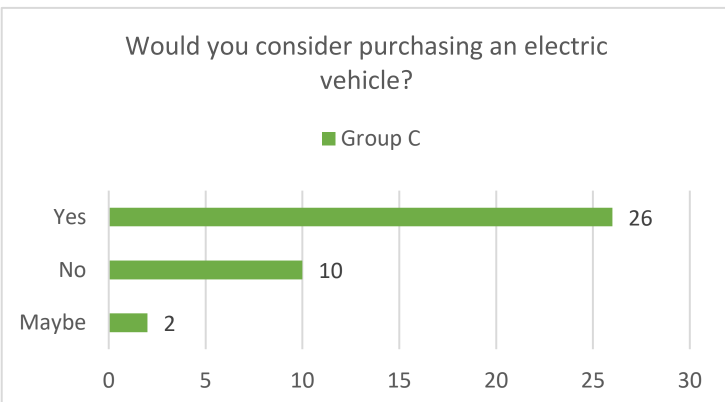


Figure 6.2.3

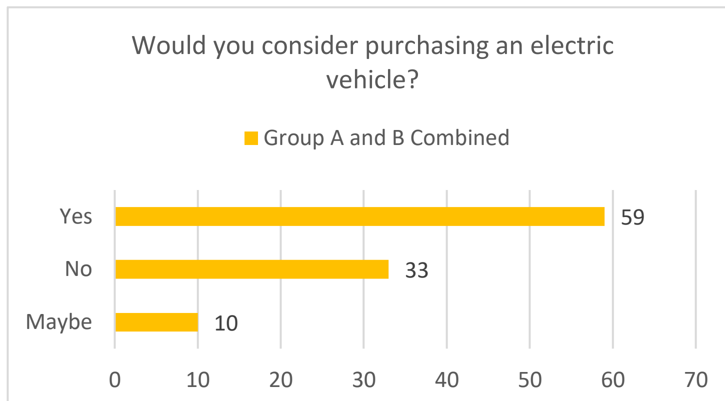


Figure 6.2.4

Question: "Would you be willing to use public charging infrastructure if it were available to you? Why or why not?"

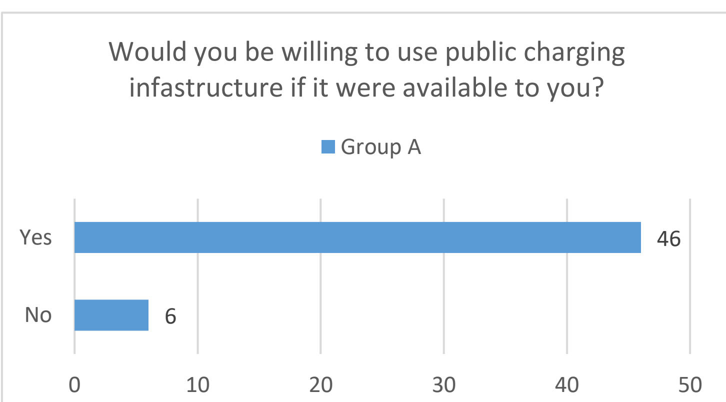


Figure 6.2.

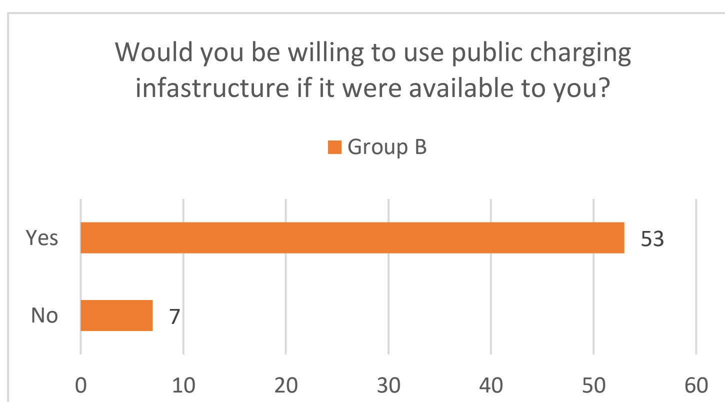


Figure 6.2.

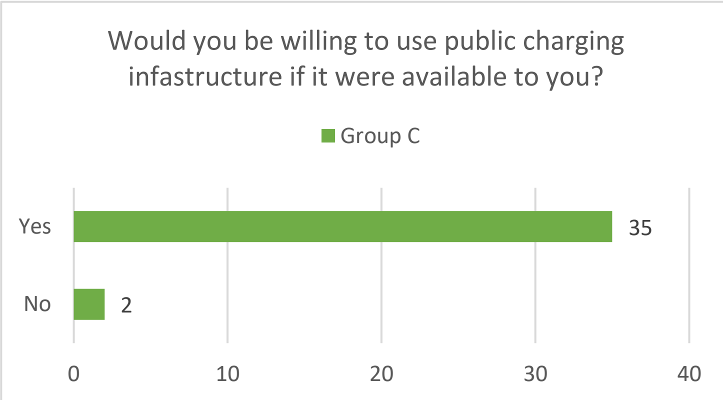


Figure 6.2.

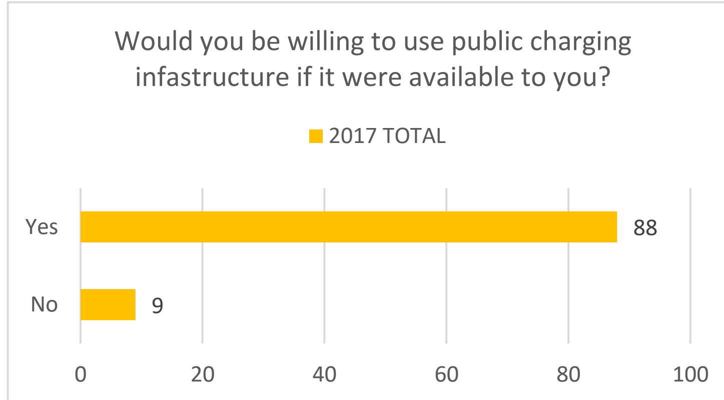


Figure 6.2.

Question: Which of the following factors would be more likely to motivate you to purchase an electric vehicle for use in Nebraska?

	2016	2017			**TOTAL**
Response	Group A	Group B	Group C	TOTAL	
A	24	35	17	52	76
B	0	0	0	0	0
C	15	19	15	34	49
D	13	10	6	16	29

Table 6.2.

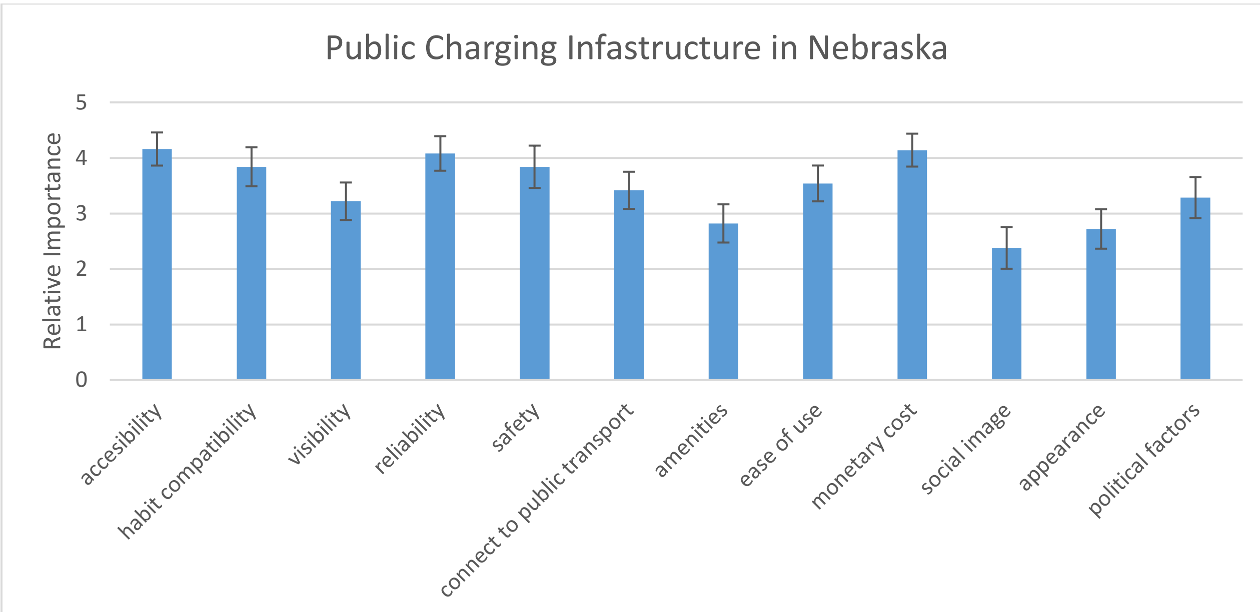
APPENDIX 6.3

GRAPHICAL REPRESENTATION OF SURVEY PART II DATA

Appendix 6.3.1 - Group A

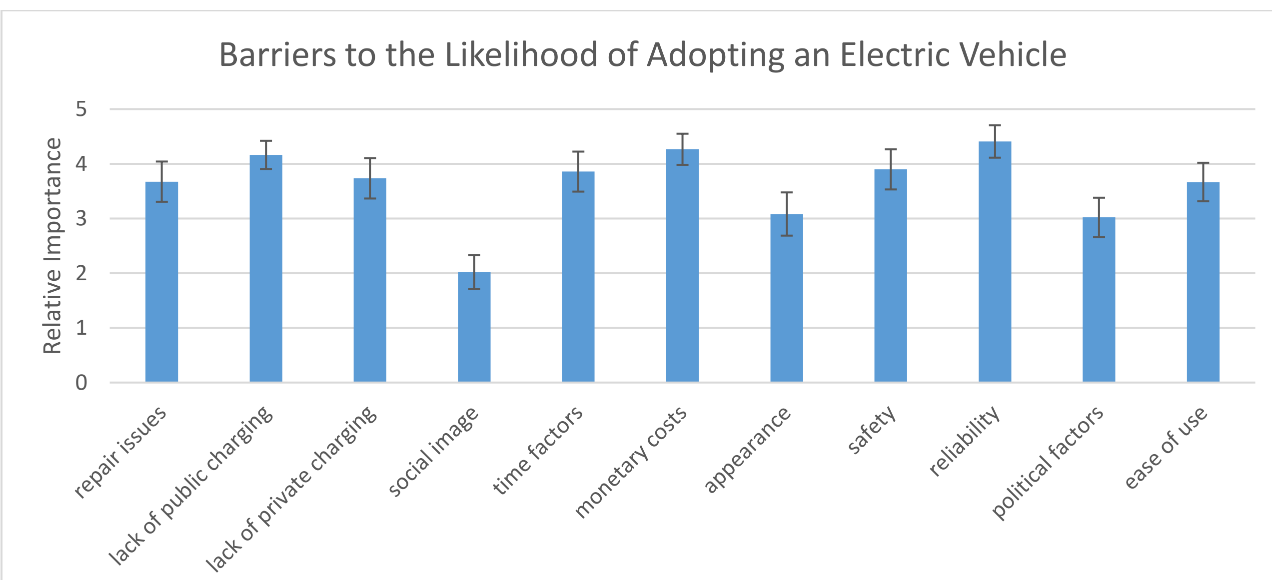
5-Very Important 4-Important 3-Moderately Important 2-Little Importance 1-Unimportant

Factor 1: Which of the following do you consider concerns with regards to public charging infrastructure in Nebraska?



Average response with standard error

Factor 2: Do you consider any of the following a barrier to the likelihood that you will adopt an Electric Vehicle?



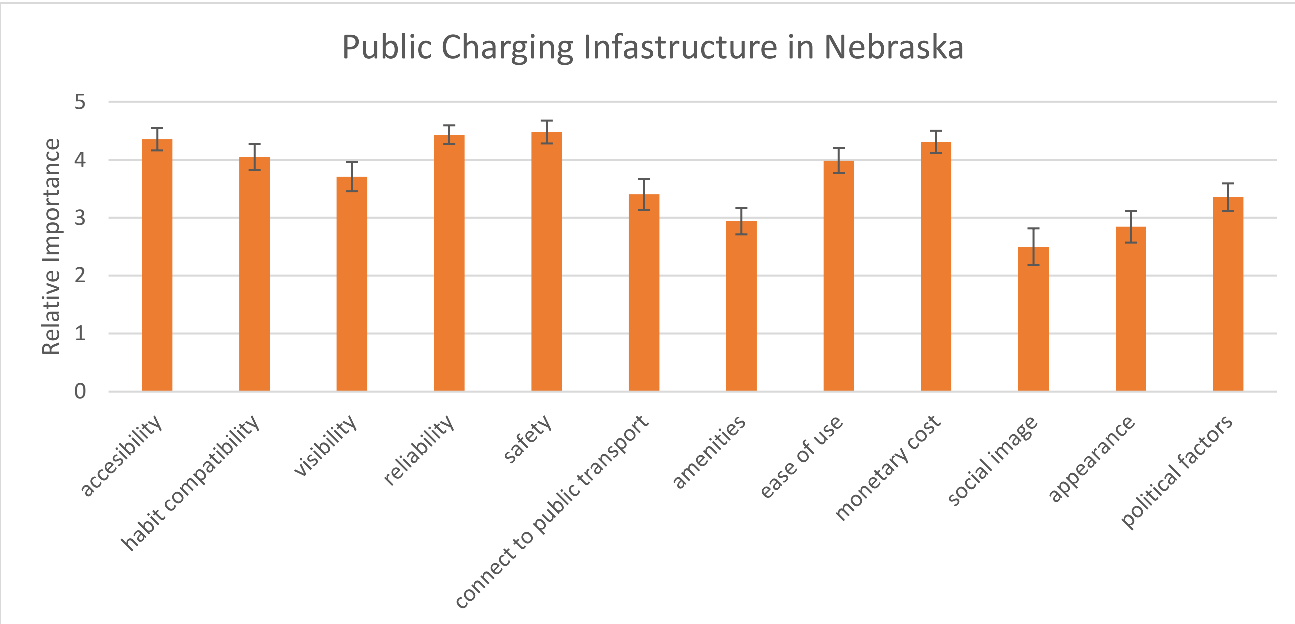
Average response with standard error

Appendix 6.3.2 - Group B

Please rate the following factors based on their importance to you with regards to your likelihood to adopt the technology using the following scale.

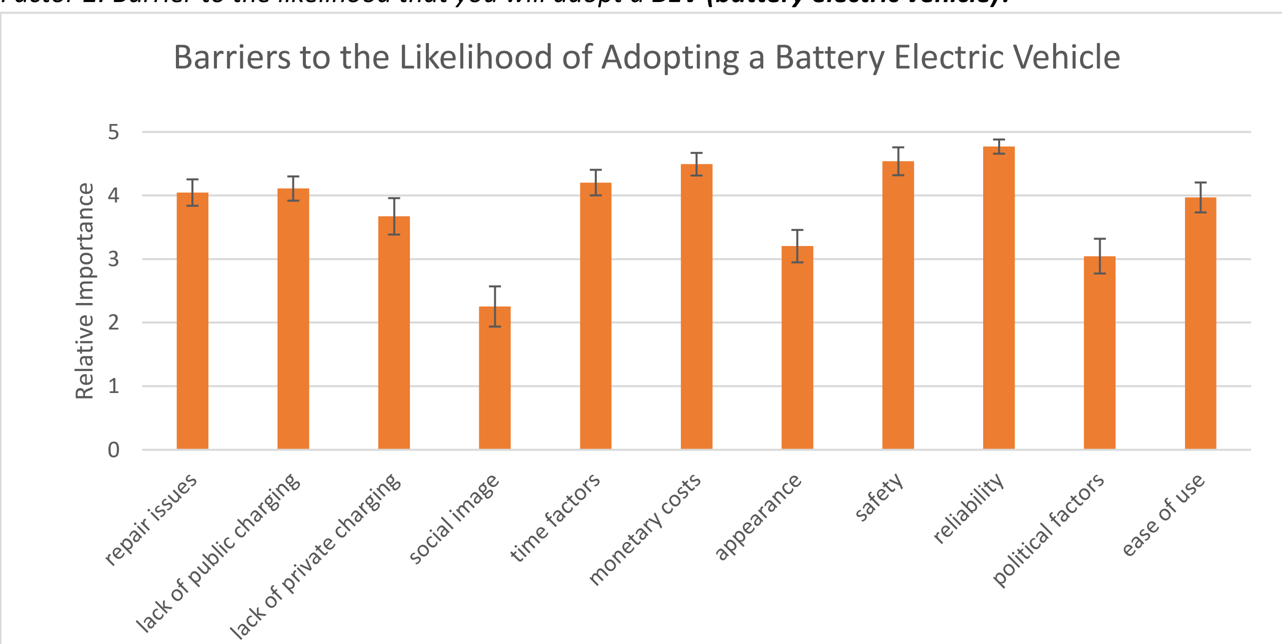
5-Very Important 4-Important 3-Moderately Important 2-Little Importance 1-Unimportant

Factor 1: Public charging infrastructure in Nebraska?



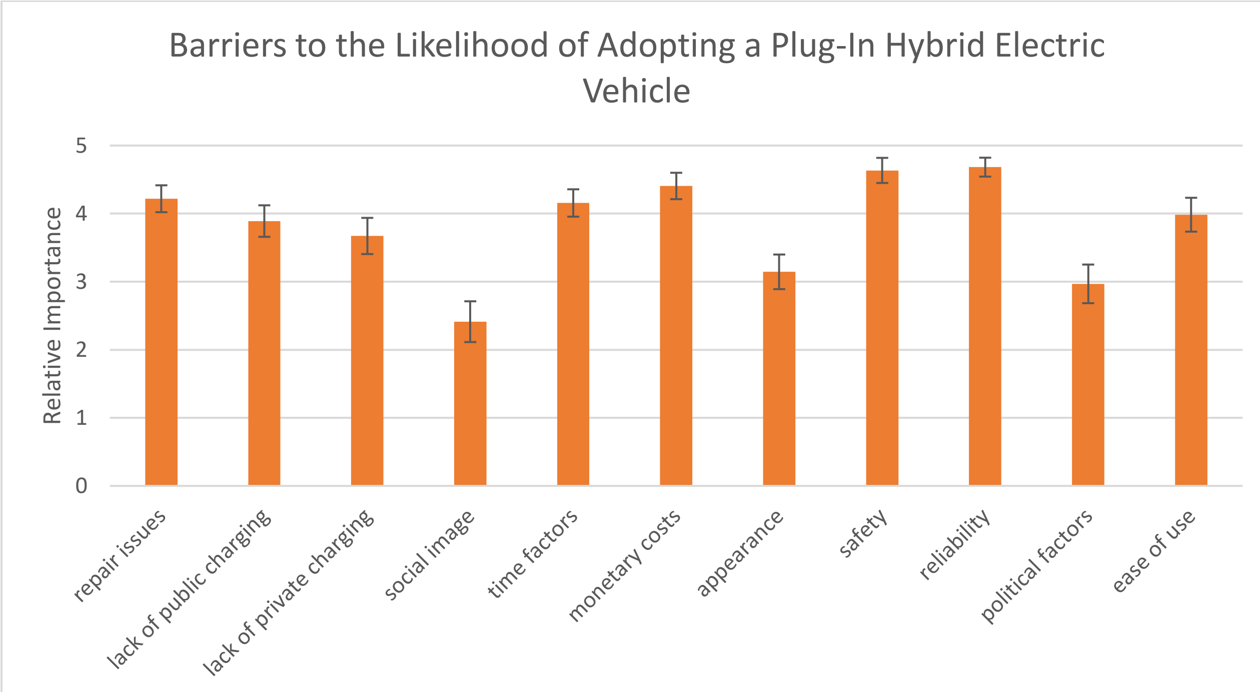
Average response with standard error

Factor 2: Barrier to the likelihood that you will adopt a ***BEV (battery electric vehicle)?***



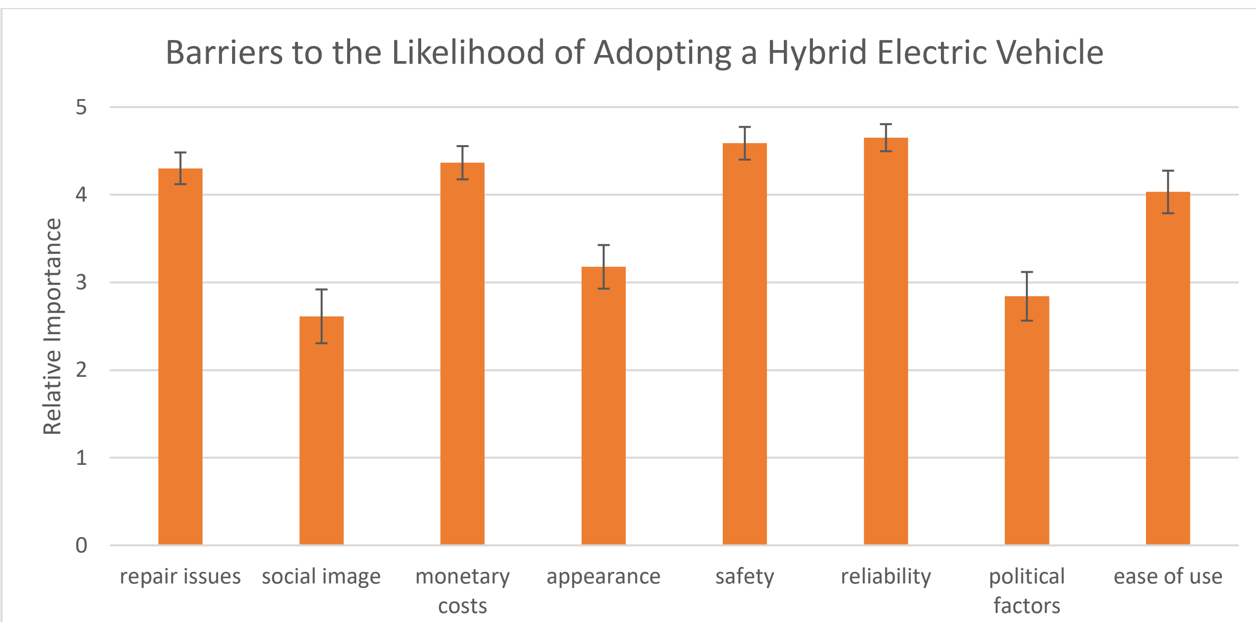
Average response with standard error

Factor 3: Barrier to the likelihood that you will adopt a ***PHEV (plug-in hybrid electric vehicle)?***



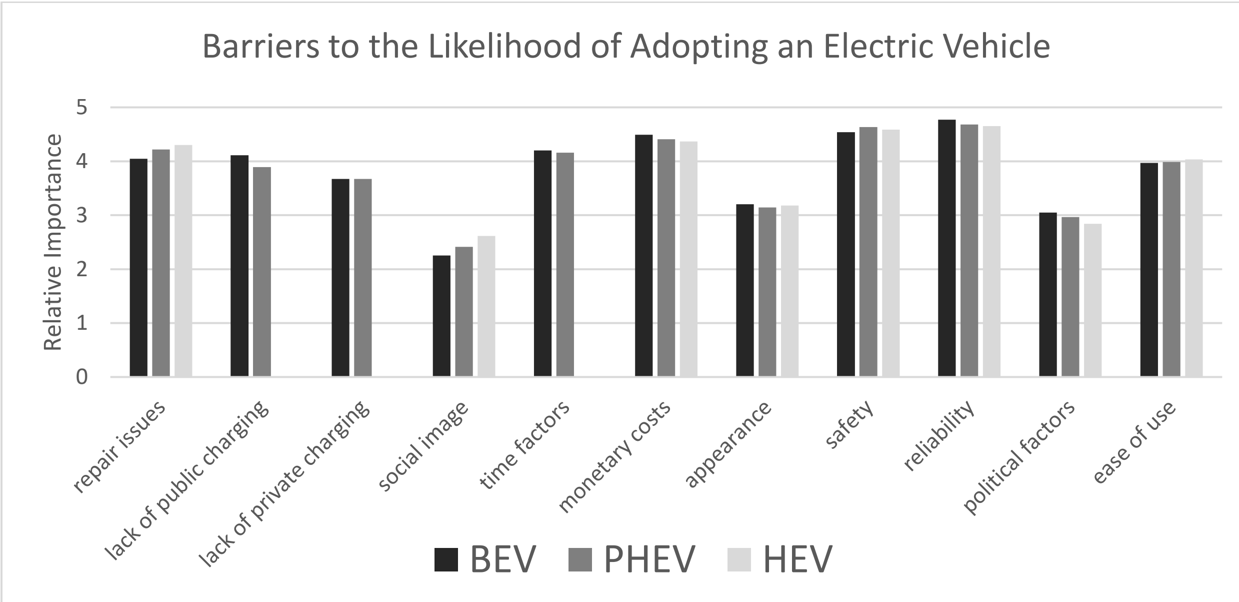
Average response with standard error

Factor 4: Barrier to the likelihood that you will adopt a ***HEV (hybrid electric vehicle)?***



Average response with standard error

Factor 2,3,4: Barrier to the likelihood that you will adopt an Electric Vehicle?

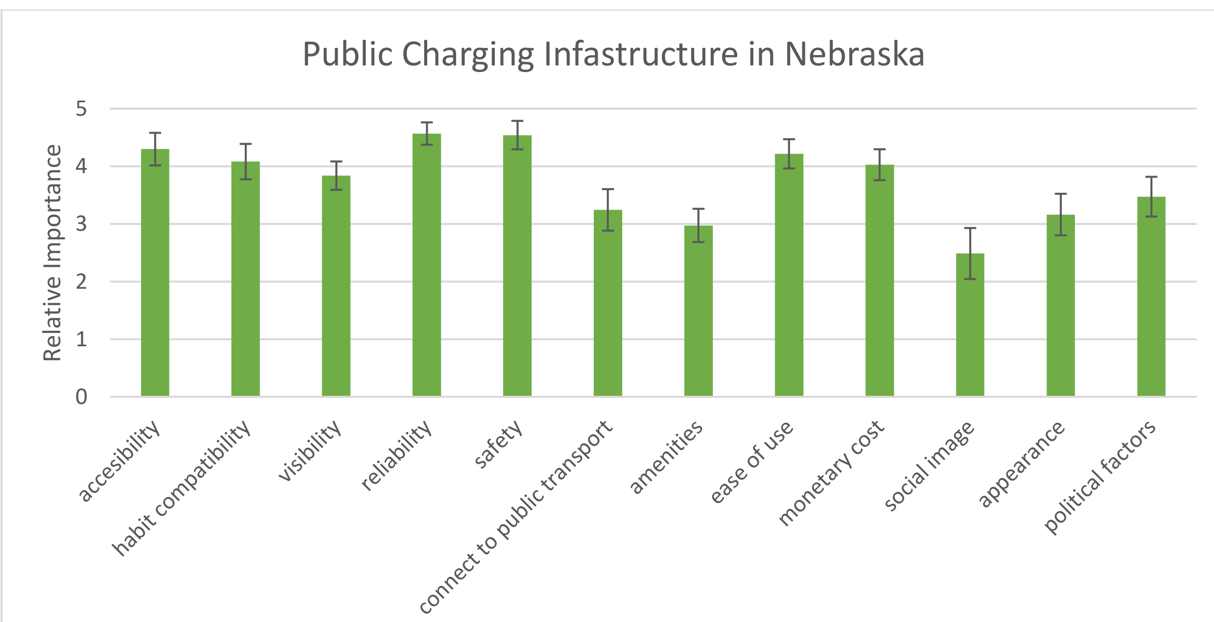


Appendix 6.3.3 - Group C

Please rate the following factors based on their importance to you with regards to your likelihood to adopt the technology using the following scale.

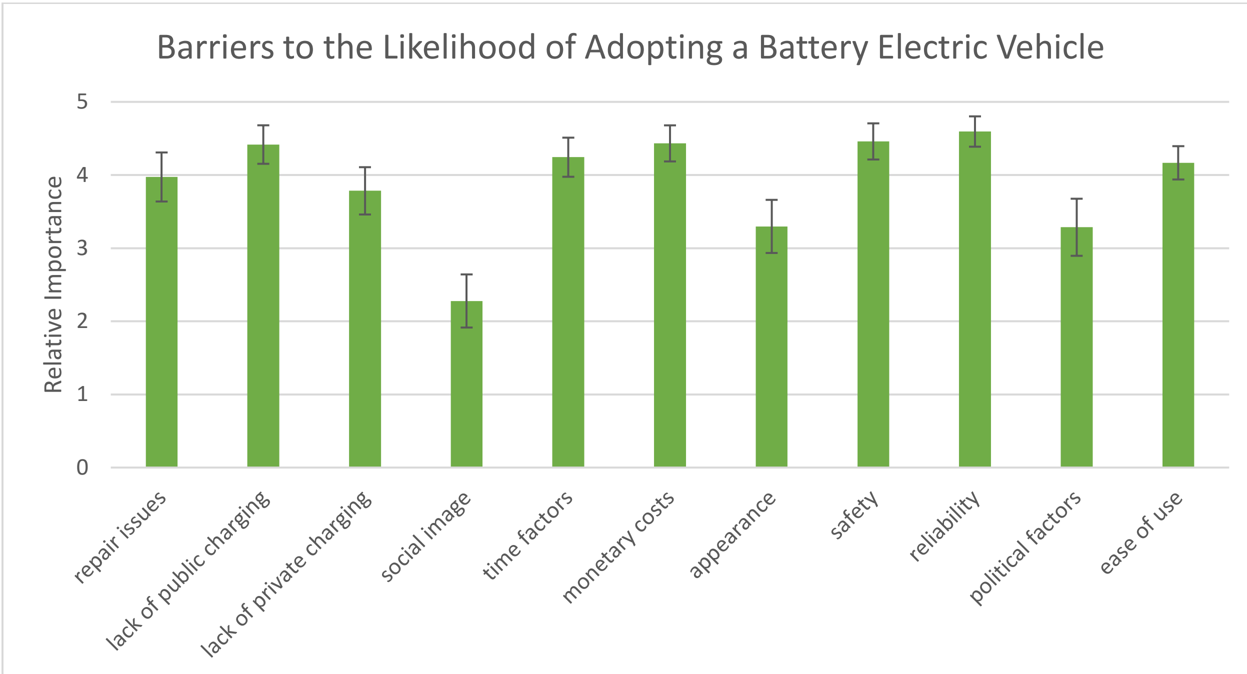
5-Very Important 4-Important 3-Moderately Important 2-Little Importance 1-Unimportant

Factor 1: Public charging infrastructure in Nebraska?



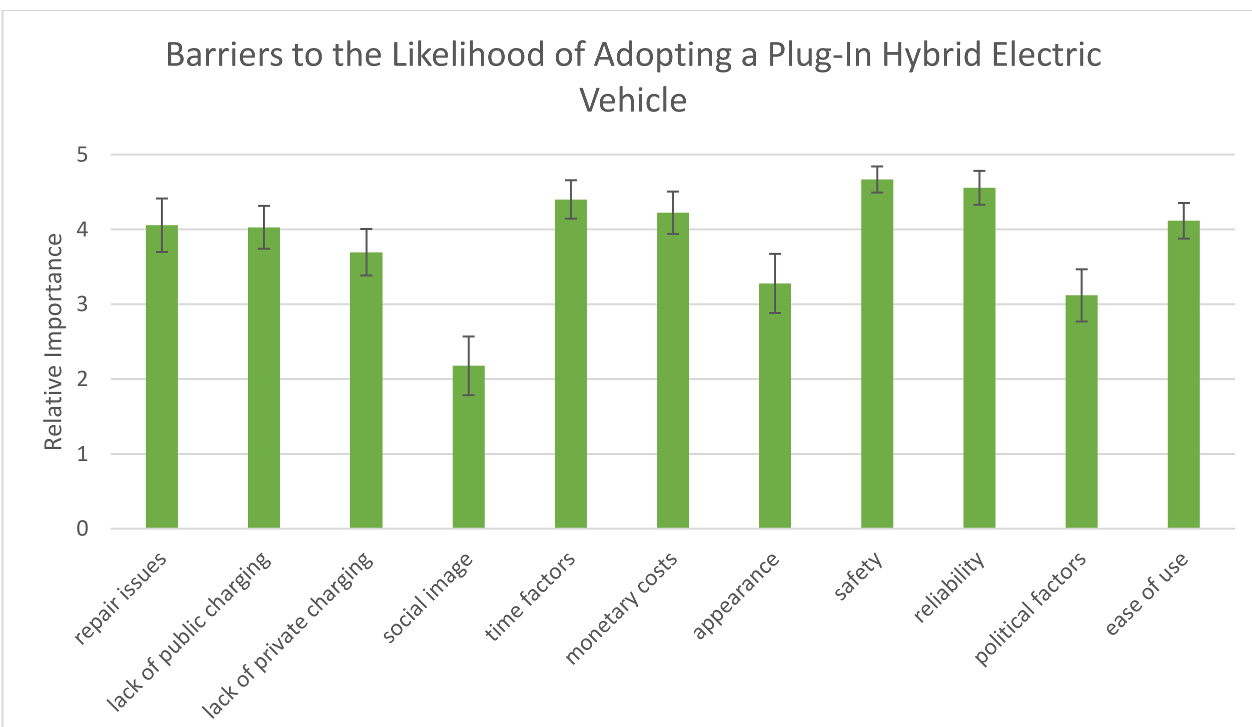
Average response with standard error

Factor 2: Barrier to the likelihood that you will adopt a ***BEV (battery electric vehicle)?***



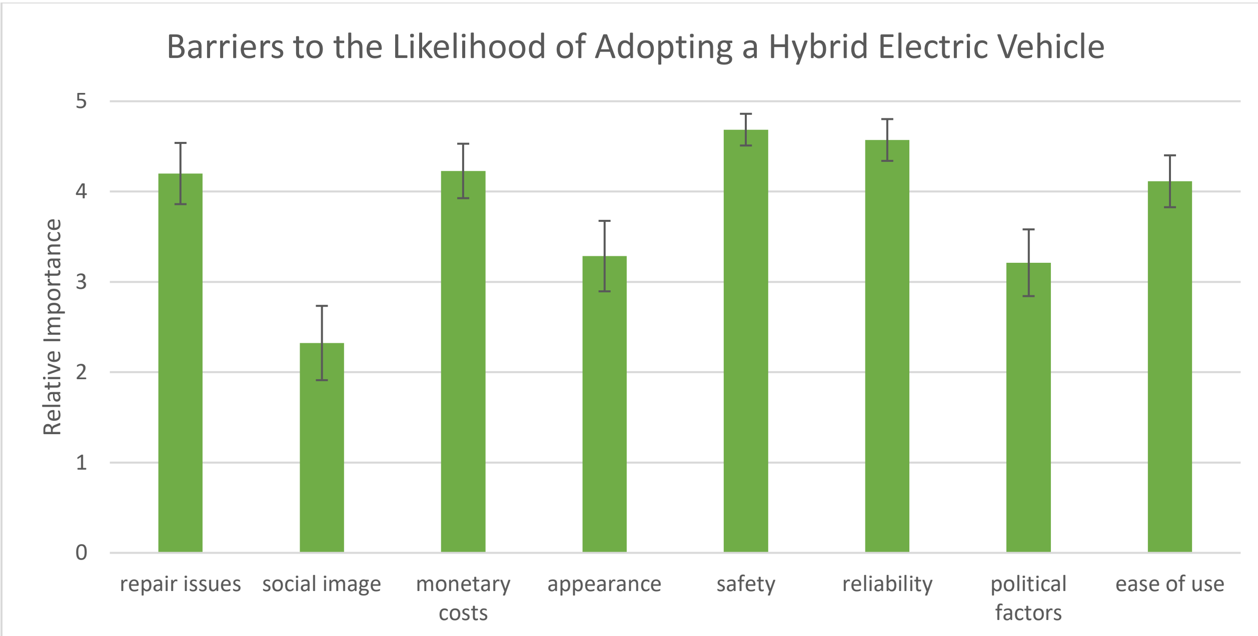
Average response with standard error

Factor 3: Barrier to the likelihood that you will adopt a ***PHEV (plug-in hybrid electric vehicle)?***



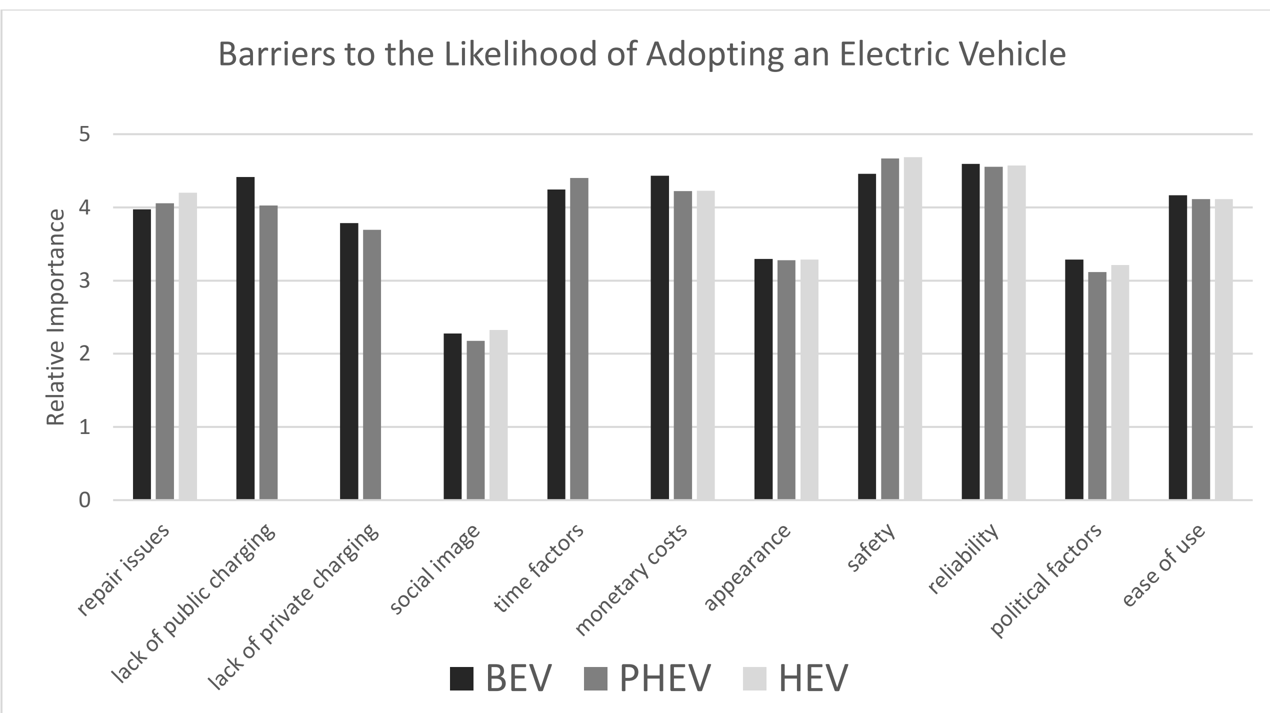
Average response with standard error

Factor 4: Barrier to the likelihood that you will adopt a ***HEV (hybrid electric vehicle)?***



Average response with standard error

Factor 2,3,4: Barrier to the likelihood that you will adopt an Electric Vehicle?



APPENDIX 6.4

ELECTRIC VEHICLE SURVEY

ELECTRIC VEHICLE SURVEY

Instructions:

- This survey consists of two parts: **Part I** and **Part II**.
- There are 16 questions in Part I and 4 factors in Part II
- You will be given Part I with **a letter indicator located** at the upper right corner of the first page. Please remember this letter and provide it on Part II of the survey. **This will be used to associate Part I and part II of the survey.**
- When done with Part I, you will be given Part II.
- Once you have received Part II, you will not be able to change any answers to Part I. Therefore, please make sure that Part I is complete before continuing on to Part II.
- Please fill out this questionnaire as completely as possible.
- Please circle your answer (choice) where necessary

For the purpose of this survey, we have the following ***Definitions:***

- **Conventional Vehicle:** A vehicle that is not an electric vehicle; a vehicle that uses conventional fuel (gasoline) for its operation for the purpose of this questionnaire.

- **Battery Electric Vehicle (BEV): A vehicle that is powered completely by a battery system and is recharged using electricity via charging infrastructure.**

- **Plug-in Hybrid Electric Vehicle (PHEV):** An extended range vehicle: a vehicle that is powered by a battery and conventional fuel. **The battery is recharged using electricity via charging infrastructure**.

- **Hybrid Electric Vehicle (HEV):** A vehicle that is powered by a battery and conventional fuel. **The battery is charged directly by the conventional Internal Combustion Engine (ICE) powertrain.**

- **Electric Vehicles (EV)** is defined as a **Battery Electric Vehicle (BEV), or a Plug-in Hybrid Electric Vehicle (PHEV) Vehicle)**. If you are able, please specify which electric vehicle type you are referring to in your answer.

- **Public Electric Vehicle (EV) Charging Infrastructure:** Any venue open to the public other than at a private residence in which electric vehicle charging can occur.

Thank you for your time and participation in this study.

SURVEY PART I:

Participant Information (**optional**)

1. Age: Gender: Ethnic Identity:

Questions:

1. Are you a conventional vehicle owner?
   Yes
   No
   Unsure (Please explain)

2. Are you a conventional vehicle driver?
   Yes - If yes, how often do your drive:

   No
   Unsure (Please explain)

3. Are you an electric vehicle owner?
   Yes
   No
   Unsure (Please explain)

4. Are you an electric vehicle driver?
   Yes - If yes, how often do your drive:

   No
   Unsure (Please explain)

5. If you drive and/or own a vehicle, does your vehicle say anything about you?
   When people see your vehicle, what do they think?
   Electric Vehicle:

   Conventional Vehicle:

6. Would you consider purchasing an electric vehicle?
   Please explain your reasoning for **Why** or **Why Not?**

7. What do you see the advantages to using an electric vehicle?

8. What do you see the disadvantages to using an electric vehicle?

9. **Which of the following factors would be more likely to motivate you to purchase an electric vehicle for use in Nebraska?**
   A. The availability of more public EV charging infrastructure in Nebraska (including more users) **OR**
   B. The presence and use of more electric vehicles in Nebraska
   C. Options **A and B** would need to be in place before I would be motivated to purchase an EV.
   D. I do not consider either of options **A or B** to be a motivator.

   I choose My answer because:
   (If you feel that your answer would differ depending on the type of electric vehicle (BEV, PHEV), please mention that in your response as well.)

10. Have you seen or visited a place with any type of public EV charging infrastructure?
    Yes - If yes, where did you see it and/or at what location did you visit it?

    No
    Unsure - Please explain your reasoning.

11. Have you ever used public EV charging infrastructure to charge a vehicle before?
    Yes - If you select Yes, would you consider the charging experience to be a positive experience, a negative experience, or a neutral experience? Explain.

    No
    Unsure - please explain your reasoning.

12. Would you be willing to use public charging infrastructure if it was available to you?
    Why or Why not?

13. In your opinion, where should **EV public charging infrastructure** ideally be located?

14. Describe how you envision what an **EV charging infrastructure might look like**? What should and/or should not be included at such a place? (For example, what amenities should be included? Where do cars park? How many charging units should there be? Would it be mostly or completely indoor or outdoor? If possible, explain the reasoning for your preferences.

    What items are necessary and what are not for a viable public EV charging station in Nebraska?

    What items are not necessary for a viable public EV charging station in Nebraska?

15. What are your major concerns, if you have any, about the construction of EV charging stations in Nebraska? (include social and technical concerns)

16. Do you support the idea of erecting more electrical vehicle charging infrastructure in Nebraska?
    Yes - If you select Yes, would you support using public funds to build this infrastructure?
    Why or Why Not?

    No
    Unsure - please explain your reasoning.

SURVEY PART II:

Instructions: Please rate the following **factors** based on their importance to you with regards to your likelihood to adopt the technology using the following scale:

- **Very Important**: This factor is of GREAT CONCERN to me
- **Important:** This factor is of CONCERN to me
- **Moderately Important**: This factor is SOMEWHAT OF A CONCERN to me
- **Little Importance**: This factor is of LITTLE CONCERN to me
- **Unimportant**: This factor is of NO CONCERN to me
- **Not Applicable:** This factor is unlikely to occur or is not present

If you feel that an important issue is not addressed under the selected categories, please add where appropriate. Also feel free to add a new category as you see fit. (A category is a topic header such as "vehicle repair issues"):

For the purpose of this survey, we have the following ***Definitions:***

- **Conventional Vehicle:** A vehicle that is not an electric vehicle; a vehicle that uses conventional fuel (gasoline) for its operation for the purpose of this questionnaire.

- **Battery Electric Vehicle (BEV): A vehicle that is powered completely by a battery system and is recharged using electricity via charging infrastructure.**

- **Plug-in Hybrid Electric Vehicle (PHEV):** An extended range vehicle: a vehicle that is powered by a battery and conventional fuel. **The battery is recharged using electricity via charging infrastructure.**

- **Hybrid Electric Vehicle (HEV):** A vehicle that is powered by a battery and conventional fuel. **The battery is charged directly by the conventional Internal Combustion Engine (ICE) powertrain.**

- **Electric Vehicles (EV)** is defined as a **Battery Electric Vehicle (BEV), or a Plug-in Hybrid Electric Vehicle (PHEV) Vehicle)**. If you are able, please specify which electric vehicle type you are referring to in your answer.

- **Public Electric Vehicle (EV) Charging Infrastructure:** Any venue open to the public other than at a private residence in which electric vehicle charging can occur.

Thank you for your time and participation in this study.

<u>FACTOR #1</u>:

Public charging infrastructure in Nebraska?

- **"Accessibility" (ease of access to the charging infrastructure by the user)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **"Habit Compatibility" (ease in which the charging infrastructure fits into familiar routines …aka..whether or not the location of the charging infrastructure is in a familiar location such as on a route often used)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **"Visibility" (ease of visibility of the infrastructure and signage to users)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **"Reliability"(time in which the charging station is available for use, availability of parking spots and charging stations that might reduce wait times)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **"Safety" (safety of the driver and passengers at the charging infrastructure)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **"Connection to the public transportation network" (proximity of charging station to public transport)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **"Amenities" (the types of amenities provided in proximity to the EV charging infrastructure)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **"Ease of Use" (ease with which the charging station can be used/simplicity of the technology)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **"Monetary Cost" (Monetary cost of using the infrastructure)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **"Social Image" (What your peers think about you as a public charging infrastructure user, for example)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **"Appearance" (Appearance of the public charging infrastructure)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- "**Political Factors" (Risk that policy may affect funding or affect access to infrastructure, as an example)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Other Factors: Please describe**

FACTOR #2:

Barrier to the likelihood that you will adopt a **BEV (Battery Electric Vehicle)**

- **Vehicle Repair Issues (accessibility to resources for repairs such as parts and vehicle experts)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Lack of Public EV Charging Infrastructure (accessibility to public EV charging infrastructure for charging the battery)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Lack of Private EV Charging Infrastructure (ability to charge vehicle in private due to lack of resources or space)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Social Image (how your peers see you-for example, perhaps seeing you as an "environmentalist" for owning an electric vehicle or as someone who is not reliant on foreign oil)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Time Factors (Time needed to charge the vehicle/ Time spent caring for the vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Monetary Costs (Cost of vehicle and resources to maintain the vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Appearance (Appearance of vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Safety (safety of vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Reliability (reliability of vehicle-for example, how long it will last)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Political Factors (for example risk of defunding infrastructure or vehicle resources due to policy changes)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Ease of Use (how easy it is to use the vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Other Factors: Please describe**

FACTOR #3:

Barrier to the likelihood that you will adopt a **PHEV (Plug-in Hybrid Electric Vehicle)**

- **Vehicle Repair Issues (accessibility to resources for repairs such as parts and vehicle experts)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Lack of Public EV Charging Infrastructure (accessibility to public EV charging infrastructure for charging the battery)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Lack of Private EV Charging Infrastructure (ability to charge vehicle in private due to lack of resources or space)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Social Image (how your peers see you-for example, perhaps seeing you as an "environmentalist" for owning an electric vehicle or as someone who is not reliant on foreign oil)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Time Factors (Time needed to charge the vehicle/ Time spent caring for the vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Monetary Costs (Cost of vehicle and resources to maintain the vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Appearance (Appearance of vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Safety (safety of vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Reliability (reliability of vehicle-for example, how long it will last)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Political Factors (for example risk of defunding infrastructure or vehicle resources due to policy changes)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Ease of Use (how easy it is to use the vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Other Factors: Please describe**

FACTOR #4:

Barrier to the likelihood that you will adopt a **HEV (Hybrid Electric Vehicle)**

- **Vehicle Repair Issues (accessibility to resources for repairs such as parts and vehicle experts)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Social Image (how your peers see you-for example, perhaps seeing you as an "environmentalist" for owning an electric vehicle or as someone who is not reliant on foreign oil)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Monetary Costs (Cost of vehicle and resources to maintain the vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Appearance (Appearance of vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Safety (safety of vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Reliability (reliability of vehicle-for example, how long it will last)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Political Factors (for example risk of defunding infrastructure or vehicle resources due to policy changes)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Ease of Use (how easy it is to use the vehicle)**

Very Important Important Moderately Important Little Importance Unimportant Not Applicable

- **Other Factors: Please describe**

APPENDIX 6.5

DETAILED BENEFITS AND NEEDS ANALYSIS IN EACH STATE

The following is a state-by-state analysis of the needs and feasibility

ALABAMA

AL.1. Alabama drivers finding happiness in electric cars

• Alabama Clean Fuels Coalition (ACFC) (a nonprofit that serves as a coordinating point for clean, alternative fueling options for vehicles including, EV) discovered that people are shunning gas pumps and patronizing electric vehicles due to a discount on electric bills by people who use electric vehicles. Since 2013, in Alabama, all EV sales thus, hybrid, plug-in hybrid and battery electric have seen a tremendous increase by 13.7 percent and the sale of pure battery electric have also increase by 55.6 percent. Electric vehicle drivers are offered discounts by Alabama Power if they charge their cars between 9pm and 5am each day. And this discounts applies to the electric bill in total.

• **Source**: Bentley, M. (2016). Alabama drivers finding happiness in electric cars. Retrieved from: http://www.al.com/opinion/index.ssf/2016/07/alabama_drivers_find_happiness.html.

AL.2. Making a case for Electric Vehicle (EV) charging stations

• The market of charging stations is growing since people are now patronizing EV's. There is therefore a need to offer EV owners the same convenience in addressing charging needs as compared to anyone using a fuel vehicle. In making a case for charging stations, ACFC has been promoting to increase the number of EVs on the road mentioning environmental benefits and cost benefits as a key motivation. Also, there is Corporate Average Fuel Economy (CAFE) standards that car manufactures need to meet by 2025 ("requires doubling the overall fleet average in current fuel efficiency, from 27.5 miles per gallon to 54.5 gallon"). In order to meet that, car manufacturers need to expand their current contribution to the plug in technology or by into EV idea. Nationally, Sierra Club's Electric Vehicles (a non-profit environmental organization) Initiative have put together various initiatives with the aim of getting more EV's on the road. If there is a need for more vehicles then, there should be charging stations availability. As an incentive, Alabama Power Company's (an investor-owned, tax-paying utility company) Electric transportation offers residential users discount for using EV. Currently, AeroVironment Inc. (based in California) is among the numerous manufacturers of charging stations in the country.

• **Source:** Baumer, J. (2017). Making the case for Electric Vehicle charging stations. Retrieved from: https://noln.net/2017/01/30/making-the-case-for-electric-vehicle-ev-charging-stations/

AL.3. How to save money with Green Driver State Incentives in Alabama

• There is Alabama auto insurance discounts for hybrid vehicles as well as Alternate fuel vehicles. Also, there is an Alabama resident's tax break eligible for federal tax credits for pollution control equipment through IRS. According to Alabama code (section 40-9-1) all devices or facilities or structures used to reduce air pollution are exempted from property tax. There are also federal tax credits for EV, hybrids, PHEV and AFV. Alabama Power offers charging rate incentive for PEV's (business (Business Electric Vehicle Time of Use (BETVs)) or residential)

- **Source:** DMV.org (2017). Retrieved from: http://www.dmv.org/al-alabama/green-driver-state-incentives.php

AL.4. Auburn University generating solar power to charge electric vehicles.

- 10 EV's are being charged with solar power on the campus of Auburn University. The project on installing 24 solar panels was funded by office of sustainability. The solar panel produces 6.6 kilowatts of power per day which is 13250 kilowatt-hours of electrical energy per year. These 10 EV charging stations are installed on the lower levels of the parking deck. The school is considering to add more charging stations if the demand EV's increase

- **Source:** Auburn University (2012). Auburn University generating solar power to charge electric vehicles. Retrieved from: http://wireeagle.auburn.edu/news/4423

AL.5. Downtown Huntsville Rolls Out Welcome Mat for Electric Vehicles with New Rapid Charging Station

- Huntsville, Alabama installed a DC Fast charger to support residents. Huntsville installed the first rapid EV charger with a $10,000 donation from the Nissan Corporation. The charger was placed directly across from city hall. The station was installed to support the 50 PEVs that were registered as well as future vehicles. Charging is free, though parking is $2 an hour, which is designed to pay for the electricity the station uses. EV's can stay plugged for maximum of 2hrs this is to give others a turn. This is the only locally owned DC Fast station in the state of Alabama (up until 6/17/15). The city plans to install 5 more DC fast stations in downtown parking garages over the next year and will add more as demand drives it.

- **Source:** Doyle, S. (2014). Retrieved from: Downtown Huntsville Rolls Out Welcome Mat for Electric Vehicles with New Rapid Charging Station http://blog.al.com/breaking/2014/03/downtown_huntsville_rolls_out.html

AL.6. Alabama laws and incentives

- A complete list of laws, regulations, public and private incentives for electric vehicles and charging infrastructure in the state of Alabama. Laws and regulations include a Green Fleet Policy that outlines a procedure for procuring state vehicles based on fuel economy and life cycle costing. The plan is for fleets to annually increase fuel economy by 4% for light-duty vehicles, 3% for medium-duty vehicles, and 2% annually for heavy-duty vehicles. Also the DOT appointed a fleet manager to develop a statewide fleet management program that will propose fleet management policies, procedures and guidelines for all state agency, board, commission and department fleets. Utility and Private Incentives include: PEV and Charging Infrastructure Incentive from Alabama Power Commercial customers can receive up to $500 per port for qualified EVSEs, Alabama Power offers a Business Electric Vehicle Time-of-Use (BEVT) charging rate incentive for fleet charging.

- **Source:** Retrieved from: http://www.afdc.energy.gov/laws/all?state=AL

ALASKA

AK.1. Five sites decided for electric car chargers

- Juneau, the Capital of Alaska received $25,000 by the city, Borough of Juneau and the Community foundation and this fund is being used to purchase charging stations. Alaska Electric Light and Power (Private utility company) energy management is championing the project. The five charging station locations were chosen due to the amount of traffic they receive. Each charging station will have connectors. Charging station cost between $500 -$5000 according to director of Canadian transportation electrification company Sun Country Highway Ltd. There is AEL&P discount for owners of EV's. Also, there are Electric Vehicle initiative meeting in Juneau.

- **Source:** Moritz, K. (2014). Five sites decided for electric car chargers. Retrieved from: http://juneauempire.com/local/2014-02-05/five-sites-decided-electric-car-chargers

AK. 2. Alaska Laws and Incentives for Electricity

- A complete list of laws, regulations, public and private incentives for electric vehicles and charging infrastructure in the state of Alaska. The Alaskan DOT and Public Facilities must evaluate cost, efficiency, and commercial availability of alternative fuels for automotive purposes every five years, and purchase or convert to vehicles that operate using alternative fuels whenever practical. The state does not have any specific laws, regulations or incentives for electric vehicle or charging station deployment. There are no Utility or Private incentives for electric vehicle or charging station deployment.

- **Source:** US Department of Energy. Retrieved from: http://www.afdc.energy.gov/fuels/laws/ELEC/AK

AK.3. How to save money with Alaska Green Driver Incentives

- IRS offers sizeable federal tax credits for using EV's, PHEV's, Hybrids and AFV's.

- **Source:** US Department of Energy Retrieved from: http://www.afdc.energy.gov/fuels/laws/ELEC/AK

AK.4. Electric cars spark Juneau's interest

- The city of Borough of Juneau is using a $50000 grant received on September 2014 to set up charging stations across the city. A new station has been opened in December 2014 at Marine view parking garage downtown. It costs $0.75 to charge for hourly parking. There are four other parking stations at Eagle beach, Alaska Electric and Power company, University of Alaska

Southeast and NOAA which are free to use. Alaska Electric and Power (ALE&P) implemented an incentive program for the first 10 electric vehicle owners in 2012 which covered $1000 cost for home charger and installation. In addition to the incentive, participants received a discount of about half of their electric cost charged on a meter installed by AEL&P

• **Source:** Shor, S. (2015). Electric cars spark Juneau's interest. Retrieved from: http://juneauempire.com/local/2015-01-15/electric-cars-spark-juneaus-interest

ARIZONA

AZ.1. Arizona Laws and Incentives for Electricity

• There is PEV incentive from Salt River Project (SRP). SRP is a state-owned enterprise. SRP offers an experimental TOU electricity rate for 10000 PEV qualified customers. The rate is free for 11am to 5am. There is also a state tax credit up to $75 for the installation of Residential Electric Vehicle Supply Equipment (EVSE) in the house or housing unit. Vehicles with an AFV or Energy efficient number plate are allowed to use HOV lanes. AFV's may park without penalty in parking areas that are designated for carpool operators. DOT offers special license plate for AFV's as well.

• With respect to Laws and regulations, at least 75% of the total municipal fleet in Maricopa, Pinal and counties must operate on AFV's. Local governments in counties with populations of more than 500,000 people with bus fleets must purchase or convert buses to operate on alternative fuels. An individual is not supposed to park, stand or stop within a parking space designated tor EV's. The person would be fined $350. Arizona state agencies, boards, and commissions must purchase HEV's, AFV's, or vehicles that meet set greenhouse gas emissions standards; or use alternative fuels; with the goal that all state vehicles be HEVs, meet low emissions standards, or be AFVs by January 2012

• **Source:** US Department of Energy. Retrieved from: http://www.afdc.energy.gov/fuels/laws/ELEC/AZ

AZ.2. Green Driver State Incentives in Arizona

• There are insurance discounts by Arizona auto insurance providers for driving FEV's or having green driving habits. Drivers of AFV's can use Arizona HOV lanes. Arizona DOT offers special licensed plate for AFV's. If you are an owner of AFV's you can park in a carpool operators parking space without a fine.

• **Source:** US Department of Energy. Retrieved from: http://www.dmv.org/az-arizona/green-driver-state-incentives.php

AZ.3. Incentives for Plug-in Hybrids and Electric cars

- There is reduced license fees available for EV's and hybrids. Arizona allows EV's and hybrids to use carpool lanes but that program was limited to 10,000 vehicles and has reached its capacity. Also, the state allows AFV's to park in carpool designated areas. Reduced vehicle licensed tax for hybrids and EV's.

- **Source:** Berman, B. (2016). Retrieved from: http://www.plugincars.com/federal-and-local-incentives-plug-hybrids-and-electric-cars.html

AZ.4. Incentives

- There is Reduced Vehicle License Tax, Carpool lane access and reduced rates for electric vehicle charging

- **Source:** Tesla.com Retrieved from https://www.tesla.com/support/incentives

ARKANSAS

AR.1. Arkansas Laws and Incentives for Electricity

- The Arkansas Department of Finance and Administration (DFA) and the Arkansas State Highways and Transportation Department must prepare an annual report with the number of alternative fuel vehicles licensed in the state and the tax revenue generated

- **Source:** US Department of Energy. Retrieved from: http://www.afdc.energy.gov/fuels/laws/ELEC/AR

AR.2. Green Driver state incentives in Arkansas

- IRS gives tax breaks for fuel-efficient vehicles including EV's. Also, some Arkansas auto insurers providers offer insurance discounts for having green driving habits or using fuel-efficient vehicle.

- **Source:** dmv.org Retrieved from: http://www.dmv.org/ar-arkansas/green-driver-state-incentives.php

CALIFORNIA

CA.1. Public and Workplace charging

- Drive clean an initiative by California Air resources Board has made public charging stations available at public parking lots, retail chains, tourist destinations, entertainment venues, and airports. Many are free or available through free programs such as "No Charge to Charge" or are offered at affordable prices, usually much less than the cost of gasoline.
- **Source:**https://driveclean.arb.ca.gov/pev/Charging/Public_and_Workplace_Charging.php

CA.2. Businesses

- According to Drive clean an initiative by California Air resources Board, A growing number of employers such as Google, SAP and 3M are installing charging for their employees. A few, like Sony, are going even further by offering employees buy down incentives for PEVs.
- **Source:** https://driveclean.arb.ca.gov/pev/Resources_For_Businesses.php

CA.3. Financing program – EV charging stations at small Businesses

- The state of California gives Loans in the Electric Vehicle Charging Station Financing Program (EVCS) can be used for the design, development, purchase, and installation of qualified electric vehicle charging stations in the State of California. The charging station must be accessible to the business owner's employees, the general public, or to the tenants of a multi-unit dwelling.
- **Source:** https://driveclean.arb.ca.gov/pev/Incentives.php?submit=submit&bev=1

CA.4. Financing program – Residential EV charging

- In the state of California Property-Assessed Clean Energy (PACE) financing allows property owners to borrow funds to pay for energy improvements, including purchasing and installing EVSE. Local governments in California are authorized to establish PACE programs.
- **Source:** https://driveclean.arb.ca.gov/pev/Incentives.php?submit=submit&bev=1

CA.5. Free EVSE wiring – at businesses and apartments

- For a limited time, NRG EVgo (an energy company) is wiring eligible apartment buildings and workplaces with up to ten charge-ready parking spaces free. They will also manage the charging stations and cover the electricity costs through each driver's usage fee.
- **Source:** https://driveclean.arb.ca.gov/pev/Incentives.php?submit=submit&bev=1

CA.6. Grant-up to $20,000 for charging stations for California

- The Santa Barbara County Air Pollution Control District is providing grant funding to public entities, nonprofit and private entities to help cover all or a portion of the purchase and / or installation costs of EV charging stations located in Santa Barbara county.
- **Source:** https://driveclean.arb.ca.gov/pev/Incentives.php?submit=submit&bev=1

CA.7. Grant-up to $3,000 for charging at Public agencies

- The Transportation Authority of Marin (TAM) EVSE Grant Program assists public agencies that install employee-only or publicly accessible electric vehicle charging stations. Based on a first-come first-serve basis until funds are depleted for the year, the program will provide matching funds, whichever amount is higher, of 75 percent of the complete installation up to $1,500 for one Level 1 charger (per charging head) or up to $3,000 for one Level 2 charger (per charging head).Eligible agencies include Marin County's government entities and public districts, including school districts, colleges, and universities.
- **Source:** https://driveclean.arb.ca.gov/pev/Incentives.php?submit=submit&bev=1

CA.8. Grant-up to $50,000 for charging at Public charging at public agencies and businesses

- Businesses and public agencies can receive up to $6,000 per electric vehicle charger through the San Joaquin Valley Air Pollution Control District’s new Charge Up! grants program. Charge Up! awards up to $5,000 for a single-port, Level 2 charger and up to $6,000 for a two-port charger that will be available for public use. There is an annual funding cap of $50,000 per applicant, and grants will be awarded on a first-come, first-served basis until funds are exhausted. Eligible projects not selected for initial funding will be placed on hold pending additional funding. The first round of funding is $2 million
- **Source:** https://driveclean.arb.ca.gov/pev/Incentives.php?submit=submit&bev=1

CA.9. Rebate- $1,000 for residential EVSE (Sonoma County)

- 3-2-1 Go Green! Offers rebates for home chargers and EVs to residents of the Northern Sonoma County Air Pollution Control District (NSCAPCD).Residents within the NSCAPCD's boundaries can receive up to $1,000 for the purchase of in-home charging units. Chargers are only eligible for the rebate when paired with purchase/rebate of an eligible vehicle through the District's EV rebate program
- **Source:** https://driveclean.arb.ca.gov/pev/Incentives.php?submit=submit&bev=1

CA.10. Rebate- $400 for EV charging infrastructure (Pasadena Water and power)

- PWP provided a rebate of up to $400.00 to customers who purchase and install a qualifying PEV charger.
- **Source:** https://driveclean.arb.ca.gov/pev/Incentives.php?submit=submit&bev=1

COLORADO

CO.1. State incentives for Wheego liFe

- Tax credit of up to 45% of price between EV and gas car.
- **Source:** http://wheego.net/more/vehicles/federal-and-state-incentives/

CO.2. Electric vehicles and charging stations

- There is Boulder SmartGrid plug-in Electric/ Hybrid vehicles project in Colorado to install charging stations. There is free public charging stations available for use for 24 hrs a day for a week. There is 4 additional parking stations in east boulder community centre, north and south boulder recreation center for $1 per hour. At the end of February 2017, there will be 10 level 2 charging stations in Boulder junction garage, open space and mountain parks annex and public safety building
- **Source:** https://bouldercolorado.gov/public-works/electric-vehicles-and-charging-stations

CO.3. Denver makes electric vehicle charging easy

- Charge ahead Colorado aims to provide free pubic parking statewide. There are 2 new public charging stations at the Denver performing Arts center. There is charging stations at the east terminal at the Denver International Airport. There is also a charging station in Lakewood's, local city hall and charging is free.
- **Source:** https://blog.allstate.com/denver-makes-electric-vehicle-charging-easy/

CO.4. Colorado first high-speed charging station opens

- There is a level 3 charging station is located at the Fort Collins Museum of Discovery on mason court, Fort Collins. It was a $50000 donation from Nissan. it cost $3 per charging session. There is a level 2 charger available at the museum too. 2 level 2 chargers at the civic center parking structure.
- **Source:** http://kdvr.com/2013/08/12/colorados-first-high-speed-electric-charging-vehicle-station-opens/

CO.5. Get charged up! Electric vehicles coming to a neighborhood near you

- There is a law by the governor that allows associations to apply for grants to assist EV charging stations

- **Source:** http://www.cohoalaw.com/from-capitol-hilllegislation-get-charged-up-electric-vehicles-coming-to-a-neighborhood-near-you.html

CO.6. Charge ahead Colorado

- Regional Air Quality Council (RAQC)(a state company) and Colorado Energy Office (CEO) are teaming up to provide financial support for EV and EVSE. RAQC and CEO will fund 80% of the cost of an EVSE up to the following set maximums: Level 2, Single Port Station: $3,260. Level 2, Dual Port Station: $6,260. Level 3, Single Connection Standard Station: $13,000. Level 3, Multiple Connection Standard Station: $16,000

- **Source:** http://cleanairfleets.org/programs/charge-ahead-colorado, https://www.clippercreek.com/evse-rebates-and-tax-credits-by-state/

CO.7. Green driver state incentives in Colorado

- Emission test exemptions for EVs, HEVs. HOV lane exemption for HEVs as permitted by CDOT. Federal tax credits for AFV, EVs, HEVs and PHEVs. Auto insurance discounts for Hybrids and AFVs.

- **Source:** http://www.dmv.org/co-colorado/green-driver-state-incentives.php

<u>CONNECTICUT</u>

CT.1. Department of Energy and environmental protection: Incentives

- Connecticut's Electric Vehicle Charger Incentive Program awards up to $10,000 to businesses, municipalities or other agencies for each EV charging station installed that is publicly accessible. The Department of Energy and Environmental Protection (DEEP), s Government Company sponsored the program. The program offers awards on two tiers.

1. The higher-level award covers up to half of the cost of installing one dual-head or two single-head charging stations, up to a maximum of $10,000, and is available to stations that will be open to the public 24 hours a day, seven days a week, and located at a site that is considered a major traffic generator such as a downtown location.

2. The lower tier awards up to $4,000 toward installation of one dual-head or two single-head charging stations. Preferred proposals include those that are open to the public 24 hours a

day, 7 days a week, that are located in areas underserved by EV charging stations, or that will be open to the public for no fee for the next 3 years.

- **Source:**http://www.ct.gov/deep/cwp/view.asp?a=2684&q=527866&deepNav_GID=1619

CT.2. Green driver state incentives in Connecticut

- New haven offers free metered parking for hybrids and AFV's for only cars registered in New haven. Tax break for FEV's by the IRS. There is also green auto discount by Connecticut auto insurance provider.
- **Source:** http://www.dmv.org/ct-connecticut/green-driver-state-incentives.php

CT.3 Gov. Mallory Announces Funding for Electric Vehicle Charging Stations across Connecticut

- Connecticut's Department of Energy and Environmental Protection will administer a grant program that gives awards ranging from $1,000 to $5,000, depending on technologies and overall project, to 36 municipalities, businesses and organizations to build and deploy EVSE equipment. This is part of the 8 state coalition to get 3.3 million zero-emissions vehicles on the road in the next 12 years.
- **Source:** http://www.ct.gov/deep/cwp/view.asp?A=4380&Q=534564\

CT.4 Governor Malloy Announces Second Round of Funding Available to Build Additional Electric Vehicle Charging Stations around State

- Connecticut Governor announced a second round of the DOE funding. This time, they are supporting the installation of 56 electric chargers, and grants range from $2,000 to $5,000.
- Source: http://www.ct.gov/deep/cwp/view.asp?A=4380&Q=535582

DELAWARE

DE.1. Electric vehicle Charging stations- Retail primer update

- Delaware offers a rebate program for the purchase of charging equipment of a Level 1 (provides charging through a 120-volt AC plug) or Level 2 (provides charging through a 240-volt AC or a 208-volt electrical service). The rebate is for up to $500 and is available to businesses as well as residents, nonprofit organizations, and state, county and local government entities. Delaware has allotted $50,000 to this rebate program.

- **Source:**http://www.icsc.org/newsletters/article/electric-vehicle-charging-stationsretail-primer-update

DE.2. Green Driver state incentives in Delaware

- There is green vehicle discounts for EV's, AFV's and hybrids. There is waive on taxes on AFV's when used to operate official vehicles for the government, state or volunteer, fire or rescue companies. Grid-integrated electric vehicle (EV) users are eligible to receive kilowatt-hour energy credits as a retail electricity customer.

- **Source:** http://www.dmv.org/de-delaware/green-driver-state-incentives.php

DE.3. Delaware Laws and Incentives for Electricity

- As part of the Delaware Clean Transportation Incentive Program, the Delaware Department of Natural Resources and Environmental Control offers rebates for new, leased, or converted AFVs. The following rebate amounts are applicable for vehicles purchased between November 1, 2016, and June 30, 2018: All EV's $3500, PEV's $1500.

- **Source:** http://www.afdc.energy.gov/fuels/laws/NG/DE

DE.4. Delaware: State of Delaware and University of Delaware partner to create electric vehicle charging station network

- Charging stations for EV's will be strategically placed at key locations in Delaware to enable long trips in the state by next year (2015), through a new collaborative research agreement between the University of Delaware (UD) and the Delaware Department of Natural Resources and Environmental Control (DNREC).The State of Delaware (Department of Natural Resources and Environmental Control, Division of Energy and Climates) and Delaware University (College of Ocean, Earth and Environment) are teaming up to provide DC Fast charging stations to its citizens and those traveling though the state.

- **Source:** http://www.dnrec.delaware.gov/News/Pages/State-of-Delaware-and-University-of-Delaware-partner-to-create-electric-vehicle-charging-station-network.aspx

DE.5. Delaware: State of Delaware and University of Delaware partner to create electric vehicle charging station network

- The Delaware Department of Natural Resources and Environmental Control (DNREC) and the University of Delaware (UD) say they are teaming up to help create a larger electric vehicle

(EV) charging station network in the state by next year (2015). These charging stations are no more than 50 miles apart and are being implemented to increase not only convenience, but also the number of cars being purchased.

- **Source:** http://ngtnews.com/university-of-delaware-state-agency-partner-on-ev-charging-station-network

FLORIDA

FL.1. Some utilities are making it cheaper to drive EVs

- JEA, a utility company offers a rebate of $1000 for the purchase and lease of a PEV.
- **Source:** https://content.sierraclub.org/evguide/blog/2014/11/some-utilities-are-making-it-cheaper-drive-electric-vehicles

FL.2. Green driver state incentives in Florida

- Emission test exemptions for EVs, HEVs. HOV lane exemption for HEVs as permitted by CDOT. Federal tax credits for AFV, EVs, HEVs and PHEVs. Auto insurance discounts for Hybrids and AFVs.
- **Source:** http://www.dmv.org/fl-florida/green-driver-state-incentives.php

FL.3. Sarasota County, Florida, unveils new EV charging incentives for Businesses & Nonprofits.

- Nonprofits and government organizations in Sarasota county can get rebates of up to 50% of the cost of a charging station (up to a $4,000 maximum), and businesses can save up to 25% of the cost (up to a $2,000 maximum).
- **Source:** https://evobsession.com/sarasota-county-florida-unveils-new-ev-charging-incentives-businesses-nonprofits-act-quickly/

FL.4. Electric Vehicle Charging stations

- University of South Florida has 4 electric charging stations as part of the Charge Point network.
- **Source:** http://www.usf.edu/administrative-services/parking/parking/ev-charging-stations.aspx

GEORGIA

GA. 1 Solar-powered EV charging station comes to west Georgia

- Kia Motors manufacturing Georgia and several other agencies (the Ray C. Anderson foundation, Georgia Department of Transportation (GADOT), Georgia Department of Economic Development, and Hannah Solar, LLC collaborated to do this PVE4EV(photovoltaic electric vehicle). This charging station is installed at the state visitor information center in West point. The charger charges a car in 25 minutes (level 3 charger).
- **Source:** http://www.wave3.com/story/30264829/solar-powered-ev-charging-station-comes-to-west-georgia

GA. 2 Green Driver state incentives in Georgia

- High Occupancy Vehicle (HOV) lane exemption for AFV is by Georgia Motor Vehicle Division. Auto insurance discounts hybrids, AFV's. Georgia Tax incentives for individuals who uses AFV's, LEV's, ZEV's, and businesses that uses AFV's. Federal tax credits for hybrids, EV's, AFV's and Plug-in hybrids
- **Source:** http://www.dmv.org/ga-georgia/green-driver-state-incentives.php

GA. 3 Some utilities are making it cheaper to drive EVs

- Georgia Power offers residential customers incentives of $250 and up to $500 for businesses if they install EV charging stations
- **Source:** https://content.sierraclub.org/evguide/blog/2014/11/some-utilities-are-making-it-cheaper-drive-electric-vehicles

HAWAII

HI. 1 Hawaii state energy office

- Hawaii has a mobile app for EV drivers to locate charging stations. The app is free and available for apple, android and other mobile devices.
- **Source:** http://energy.hawaii.gov/testbeds-initiatives/ev-ready-program/resources

HI. 2 Green Driver State Incentives in Hawaii

- There is HOV lane exemption for EV's. EV's, PEV's are exempted from parking fees charged by the state- there is free parking at parking meters. There is also green vehicle discounts for EV's, AFV's and hybrids.

• **Source:** DMV. Retrieved from: http://www.dmv.org/hi-hawaii/green-driver-state-incentives.php

IDAHO

ID 1. Green Driver state incentives in Idaho

• Exempts from emission testing. Federal tax credits for buying EV, Hybrids, PEVs and AFVs. Auto insurance discounts for hybrids and AFVs

• **Source:** http://www.dmv.org/id-idaho/green-driver-state-incentives.php

ID 2. Idaho power to its business customers: Get your electric vehicles charges now!

• Idaho Power (a subsidiary electric generation company of IDACORP Inc (public company)) announced that its businesses can apply for big incentives as offset for the cost of installing EV charging stations. Incentives include a $1,000 incentive for a single port charging station and $1,500 incentive for a dual port charging station up to a maximum of $4,500 per company, per cite. Charging stations must be installed between April 18 and November 11, 2016.

• **Source:** http://snakeriveralliance.org/idaho-power-to-its-business-customers-get-yer-electric-vehicle-charges-now/

ID 3. Charging ahead: Treasure Valley gets more places in your car

• There is a growth of charging stations due to a pilot program from Idaho power, which offers a rebate of $2500 after installing a charging station for employees and customer use. The program dispersed $100000 rebates to nine participants and about 25 stations were installed. Boise State University replaced an old charging station at Bronco Circle near the Student Union building. There are two charging stations in Lincoln and Brady garages. Charging is free you have to pay only for parking cost.

• **Source:** http://snakeriveralliance.org/idaho-power-to-its-business-customers-get-yer-electric-vehicle-charges-now/

ID 4. Sierra Club leads way

• Sierra Club (a non-profit organization) offers free-to-the-public charging stations. The Sierra Club's station cost about $500, plus another $500 or so to install. The city is replacing old vehicles with electric ones and announced in September plans to install more stations at eight locations, including the Library at Cole/Ustick and at Bown Crossing, and at the Boise Airport and City Hall Plaza.

- **Source:** http://snakeriveralliance.org/idaho-power-to-its-business-customers-get-yer-electric-vehicle-charges-now/

ID 5. Utah, Wyoming and Idaho secure funding for electric vehicle infrastructure

- The Department of Energy (DoE) invested $4 million to build electric highway corridors throughout Utah, Wyoming, and Idaho. The DoE selected Rocky Mountain Power to develop 1,500 miles of electric corridors along Interstate 15, I-80, I-70, and I-84. Rocky Mountain Power intended to use the grant to develop smart mobility programs to encourage electric car sharing, and advance the use of electric bikes and buses to create an emission-free community. The grant hopes to double the number of EVs in the region in the next 10 years to more than 50,000. With the grant, Rocky Mountain Power plans to build DC fast chargers every 100 miles along the highway corridors and AC level 2 chargers in every major community in the region; offer incentives for employers to install charging stations at their places of work; help businesses purchase 200 EVs and more than 13,800 electric rental vehicles. The work will take place over the next several years and requires collaboration across multiple states, government agencies, and organizations, including the Utah Governor's Office of Energy Development, the Idaho National Laboratory, the Utah State University Center for Sustainable Electrified Transportation, the University of Utah, and Utah Clean Cities Coalition.

- **Source:** https://www.21centurystate.com/articles/utah-wyoming-and-idaho-secure-funding-for-electric-vehicle-infrastructure/

ID 6. Feds grant Rocky mountain power millions to build electric vehicle corridor

- Rocky mountain power received $4 million grant from US Department of Energy to build EV charging corridor along 1500 miles of major freeways running through Utah, Wyoming and Idaho. Some of the grant dollars will also be used to develop a program encouraging drivers to use electric car-sharing, electric bikes and electric buses. The grant will fund DC fast chargers every 100 miles along Interstate 15, Interstate 80, Interstate 84 and Interstate 80. Funds will also be used to encourage businesses to install EV chargers and purchase 14,000 electric vehicles. The utility company will install AC level 2 chargers in communities throughout the Intermountain Region as well.

- **Source:** http://www.standard.net/Environment/2017/01/18/Feds-grant-Rocky-Mountain-Power-millions-to-build-electric-vehicle-charger-corridor-in-Utah-Wyoming-Idaho

ILLINOIS

IL 1. Transportation- City of Berwyn, Illinois

- The city of Berwyn had a fully funded grant in October 2011 and has now completed three level 2 charging stations. This is part of the city's goal of increasing green transportation and increasing the number of charging stations. The charging stations are located in the city's municipal parking structure and another near the route 66 museum. EV users can charge in 2-6 hrs.

- **Source:** Retrieved form: http://www.berwyn-il.gov/?q=transportation

IL 2. Government Incentives- Illinois

- Fleet user fee exemption, EV registration fee reduction, AFV and alternative fuel rebates, EVSE rebates (50% of cost up to: $3,750 networked single station, $3,000 non-networked single station, $7,500 networked dual station, $6,000 non-networked dual station, $15,000 networked DC Fast, $12,50 non-networked DC Fast, maximum of $50,000). Utility/Private incentives which include PEV financing and charging by Illinois Electric Cooperative

- **Source:** http://pluginchicagometro.org/incentives-for-ev-drivers/

IL.3. Modeling Best Locations for Electric Vehicle Charging Stations

- Associate Professor Diego Klabjan at Northwestern University's McCormick School of Engineering and Applied Science, Illinois has created a model to installing charging infrastructure in the city of Chicago. The main determining factor for places to install infrastructure is where people are going to spend most of their time, and where they will have time to wait for their vehicle to charge.

- **Source:**
https://www.rita.dot.gov/utc/publications/spotlight/2011_04/html/spotlight_1104.html

IL.4. Green Driver State Incentives in Illinois

- Illinois Secretary of State Vehicle Services Department offers discounted vehicle registration fees to residents who drive an electric vehicle. EV fees does not exceed $35 for a 2-year period of $18 per year. There is auto insurance for hybrids, AFV's. Federal tax credits for EV's, PEV's and hybrids.

- Source: http://www.dmv.org/il-illinois/green-driver-state-incentives.php

INDIANA

IN.1. Green Driver State Incentives in Indiana

- Emission testing exemption for EV's. There is auto insurance for hybrids, AFV's. Federal tax credits for EV's, PEV's and hybrids.

- **Source:** http://www.dmv.org/in-indiana/green-driver-state-incentives.php

IN.2. Ricker's opens nation's largest level 3 electric vehicle charger network

- Ricker's oil company (private company) has opened nine level 3 charging stations at Ricker's BP. Nissan supported the network opening by offering two years of free charging
- **Source:** http://greaterindiana.com/rickers-opens-nations-largest-level-3-electric-vehicle-charger-network/

IN.3. Murphy USA opens Indiana's first level 3 quick charger

- Murphy USA opened a level 3 charging station in Plainfield, Indianapolis.
- **Source:** http://www.csnews.com/industry-news-and-trends/corporate-store-operations/murphy-usa-opens-indianas-first-level-3-quick-charger

IOWA

IA 1. Take credit for going green

- The Alliant Energy Level 2 Charging Station Rebate offers rebates of $1,000 for single-port Level 2 charging stations and $1,500 for dual-port Level 2 charging stations (limit 2 stations per commercial location). Rebates are available for Alliant Energy commercial and industrial electric customers in Iowa and Wisconsin. The charging station must be purchased and installed between April 1, 2016 and March 31, 2017. Applications are accepted on a first-come, first-served basis until rebate funds are exhausted.
- **Source:** https://www.chargepoint.com/products/station-incentives/

IA 2. State Incentives for Wheego LiFe

- Reduced EV registration fee
- **Source:** http://wheego.net/more/vehicles/federal-and-state-incentives/

IA 3. Green Driver state incentives in Iowa

- Federal tax credits for buying EV, Hybrids, PEVs and AFVs. Auto insurance discounts for hybrids and AFVs
- **Source:** http://www.dmv.org/ia-iowa/green-driver-state-incentives.php

IA 4. Iowa laws and incentives for electricity

- Alliant Energy (a public utility holding company) offers a $500 rebate to residential customers who purchase and install Level 2 EVSE. It must be purchased and installed between April 1, 2016 and march 31, 2017
- Alliant Energy also offers a rebate to commercial and industrial customers who purchase and install Level 2 EVSE for use by their employees or the public. The rebate is $1,000 for the purchase of a single connector EVSE, and $1,500 for a dual connector EVSE
- **Source:** http://www.afdc.energy.gov/fuels/laws/ELEC/IA

KANSAS

KS. 1. In America's Heartland, A power company leads charge for electric cars

- Kansas City power and light (KCP&L), a public electric utility company installed charging stations with $20 million. The charging stations are installed in workplaces, in apartment garages, at grocery stores, in city parking lots and malls, and near the baseball and football stadiums
- **Source:** http://www.npr.org/sections/alltechconsidered/2017/02/14/514517425/in-americas-heartland-a-power-company-leads-charge-for-electric-cars

KS. 2. State regulators cool to Kansas City utility's electric vehicle plans

- Kansas City power and light (KCP&L) has installed 230 charging stations in Kansas.
- **Source:** http://midwestenergynews.com/2016/10/27/state-regulators-cool-to-kansas-city-utilitys-electric-vehicle-plans/

KS. 3. Green Driver state incentives in Kansas

- KS tax incentives for green drivers. Tax credits for AFVs. Federal tax credits for AFVs, EVs and PEVs and hybrids. Auto insurance discounts for AFV's and hybrids.
- **Source:** http://www.dmv.org/ks-kansas/green-driver-state-incentives.php

KS. 4. KCP&L looking to make Kansas City an electric vehicle hotspot

- KCP&L has a goal of having 1100 charging stations in Kansas City. Most of the charging stations to be installed are level 2. KCP&L are working with Nissan to create a level 3 network.
- **Source:** https://www.forbes.com/sites/peterdetwiler/2015/08/11/kcpl-looking-to-make-kansas-city-an-electric-vehicle-hotspot/#205e9b143b9f

KENTUCKY

KY. 1. Public Service Commission Oks electric-car charging stations

- The Kentucky Public Service Commission approved a proposal by Kentucky Utilities Company (KU) and Louisville & Electric Co. (LG &E) to establish company-operated public EV charging stations and to permit non-residential customers to host charging stations. KU and LG&E plan to install 10 utility operated charging stations in each service territory. The charging stations would be level 2. The utility-operated stations would charge an hourly rate of $2.88 (by KU) or $2.85 (by LG&E. The monthly fee for chargers hosted by non-residential customers would range from $132.49 (LG&E customer paying for the power consumed by a one-vehicle charger) to $302.41 (KU customer hosting a two-vehicle charger, with the cost of estimated electric use reflected in the fee).
- **Source:** http://www.kentucky.com/news/state/article71164757.html

KY. 2. EVolve KY celebrates new electric vehicle charging station at Green Building

- Evolve KY (an organization of owners and enthusiasts of EV's) installed EV charging station in Green Building NuLu. It is free to charge. It cost $7000-$9000 for a two-vehicle charger.
- **Source:**http://insiderlouisville.com/metro/sustainability/evolve-ky-celebrates-new-electric-vehicle-charging-station-green-building/

KY. 3. Green driver state incentives in Kentucky

- Federal tax credit for AFV and hybrids.
- **Source:** http://www.dmv.org/ky-kentucky/green-driver-state-incentives.php

LOUISIANA

LA. 1. Green driver state incentives in Louisiana

- Louisiana offers tax incentives for green drivers. Tax credits for AFVs. Federal tax credits for AFVs, EVs and PEVs and hybrids. Auto insurance discounts for AFV's and hybrids. Emission testing exemption for EV's. There is also emission testing exemptions for EV's.
- **Source:** http://www.dmv.org/me-maine/green-driver-state-incentives.php

MAINE

ME. 1. High-powered electric Vehicle charging now available at Hannaford locations in Maine

- ReVision energy installed a level 3 and level 2 charging stations in Hannaford.
- **Source:** http://www.kentucky.com/news/state/article71164757.html

ME. 2. Fast-charging kiosks for electric cars open at five Hannaford stores

- Level 3 charging stations have been installed in 5 supermarkets in Maine. It was installed by a joint partnership between EVgo and Nissan. The chargers are at the Hannaford stores in Portland on Forest Avenue, South Portland at the Maine Mall, Topsham, York and Augusta. At the Hannaford locations, customers can pay for their vehicle's electricity with a credit card or a monthly EVgo subscription.
- **Source:**http://www.pressherald.com/2016/09/23/hannaford-opens-five-fast-charge-kiosks-for-electric-cars/

ME. 3. Green driver state incentives in Maine

- Maine tax incentives for green drivers. Tax credits for AFVs. Federal tax credits for AFVs, EVs and PEVs and hybrids. Auto insurance discounts for AFV's and hybrids. Emission testing exemption for EV's.
- **Source:** http://www.dmv.org/me-maine/green-driver-state-incentives.php

MARYLAND

MD. 1. City moves to expand electric-vehicle charging in municipal garages

- The Board of Estimates in Baltimore has agreed to let a Baltimore-based company install about 20 new charging outlets in up to six city-owned garages. The agreement calls for Electric Vehicle Institute Inc. to install and maintain the plug-in stations at its own cost for up to three years.
- **Source:**http://www.baltimoresun.com/features/green/blog/bs-md-electric-charging-20150513-story.html

MD. 2. Through December 2015, Pepco's plug-in vehicle pilot program had 154 enrolled participants in Maryland

- Pepco had a pilot program which offered two types of rates:

1. A R-PIV rate: A whole house TOU rate that applies to the entire house demand including the electric vehicle (EV)

2. A PIV rate: Participants signed up for an EV-only TOU charging rate with a separate utility advanced meter infrastructure (AMI) meter. Customers with the PIV rate also had the provision to elect a “Green Power” adder option for an additional $0.0179 per kWh to allow for zero emission charging

- PIV rate and the Green Power adder – had two options:

1. Using their existing 240V Level 2 charging station, which cannot be externally controlled, with Pepco installing a second AMI meter at the customer’s premise

2. Purchasing special 240V Level 2 electric vehicle supply equipment (EVSE) (specified by Pepco) charging station with an embedded revenue-grade metering chip from Itron with communication capabilities. A second AMI utility meter was also installed along with the special Level 2 EVSE with the embedded Itron meter

- **Source:**http://www.transmissionhub.com/articles/2016/02/through-december-2015-pepco-s-plug-in-vehicle-pilot-program-had-154-enrolled-participants-in-maryland.html

MD. 3. How Pepco is finding ways to shift demand through Maryland EV pilot program

- The state of Maryland has passed a legislation to extend tax credit to $125/kwh of OEV capacity. Potomac Electric Power Company, Pepco (a utility company) offered a pilot program that included a whole-house-time use rate for EV’s. Peak charging times were from 12noon to 8pm (Monday to Friday) at a rate of about 23 cents/kWh. Off- peak rates were 5 cents. EV power cost $1/gallon. There was also ‘green rider” that made customers pay extra $0.02/kwh. The aftermath of the pilot program was: Increase in the demand of EV’s.

- **Source:**http://www.utilitydive.com/news/how-pepco-is-finding-ways-to-shift-demand-through-maryland-ev-pilot-program/434156/

MD. 4. Green driver state incentives in Maryland

- Maryland has tax incentives for green drivers. Tax credits for AFVs. Federal tax credits for AFVs, EVs and PEVs and hybrids. Auto insurance discounts for AFV’s and hybrids. Emission testing exemption for EV’s. HOV lane use for EV’s

- **Source:** http://www.dmv.org/md-maryland/green-driver-state-incentives.php

MASSACHUSETTS

MA. 1. Massachusetts Electric Vehicle Incentive Program (MassEVIP): Workplace Charging

- Massachusetts Department of Environmental Protection (MassDEP) offers grant for the acquisition of level 1 and level 2 EV charging stations. MassDEP offers up to $25000 for hardware cost.
- **Source:** http://www.mass.gov/eea/agencies/massdep/air/grants/workplace-charging.html

MA. 2. Massachusetts Electric Vehicle Incentive Program (MassEVIP): Fleet

- Massachusetts Department of Environmental Protection (MassDEP) offers grant for the acquisition of EV's and installation of level 2-dual-port charging stations. This grant is available to Massachusetts cities, towns, state agencies, and public colleges and universities.
- **Source:** http://www.mass.gov/eea/agencies/massdep/air/grants/massevip-municipal.html

MA. 3. Green driver state incentives in Massachusetts

- Massachusetts has tax incentives for green drivers. Tax credits for AFVs. Federal tax credits for AFVs, EVs and PEVs and hybrids. Auto insurance discounts for AFV's and hybrids. Emission testing exemption for EV's.
- **Source:** http://www.dmv.org/md-maryland/green-driver-state-incentives.php

MICHIGAN

MI.1. Some utilities are making it cheaper to drive EVs

- Customers Energy, a utility company in Michigan offers a reimbursement up to $2500 to help customers cover the purchase, installation and wiring of a level 2 Ev charging station.
- **Source:** https://content.sierraclub.org/evguide/blog/2014/11/some-utilities-are-making-it-cheaper-drive-electric-vehicles

MI.2. Consumer energy seeks to put 800 EV charging stations in Michigan

- Customers Energy, a utility company in Michigan seeks to install 800 EV charging stations which involves 60 level 3 along major highways in the lower peninsula and &50 level 2 stations in metropolitan areas.

• **Source:** https://content.sierraclub.org/evguide/blog/2014/11/some-utilities-are-making-it-cheaper-drive-electric-vehicles

MI. 3. Green driver state incentives in Michigan

• Michigan has tax incentives for green drivers. Tax credits for AFVs. Federal tax credits for AFVs, EVs and PEVs and hybrids. Auto insurance discounts for AFV's and hybrids. Emission testing exemption for EV's.

• **Source:** http://www.dmv.org/md-maryland/green-driver-state-incentives.php

MINNESOTA

MN. 1. Green Drivers State Incentives in Minnesota

• Auto insurers discount for hybrids and AFV's.Federal tax credits for EV's, AFV's and PHEV's and hybrids. Dakota Electric Association offers reduced rates for customers with plug-in hybrid electric vehicles through a pilot program called ChargeWise. To be eligible for the discount, members must use a ChargeWise circuit to charge their PHEV batteries during low-demand hours.

• **Source:** http://www.dmv.org/mn-minnesota/green-driver-state-incentives.php

MN. 2. Electric-car boosters offer Minnesotans a rebate

• The nonprofit, Drive Electric Minnesota, does not itself sell electric cars but has teamed up with a local Nissan dealer to offer a steep discount on the Leaf electric-car model. Drive Electric Minnesota offers vouchers for big leaf discount. This discount is to increase the use of EVs.

• **Source:** http://www.twincities.com/2016/03/09/electric-car-boosters-offer-minnesotans-a-rebate/

MN. 3. Green Drivers State Incentives in Minnesota

• Dakota Electric Association offers reduced rates for customers with plug-in hybrid electric vehicles through a pilot program called ChargeWise. To be eligible for the discount, members must use a ChargeWise circuit to charge their PHEV batteries during low-demand hours

• **Source:** http://www.dmv.org/mn-minnesota/green-driver-state-incentives.php

MISSISSIPPI

MS. 1. Green Driver state incentives in Mississippi

- Auto insurance discounts for AFVs and hybrids. Federal tax credits for EVs, PHEVs and EVs
- **Source:** http://www.dmv.org/ms-mississippi/green-driver-state-incentives.php

MS. 2. Electric cars slowly emerging throughout Mississippi

- The University of Mississippi has three charging stations which is opened to the public.
- **Source:** http://thedmonline.com/electric-cars-slowly-emerging-throughout-mississippi/

MISSOURI

MO. 1. Take credit for going green

- The Alternative Fueling Infrastructure Tax Credit is available to Missouri taxpayers for 20% or up to $20,000 for businesses of the cost of a charging station. The tax credit is authorized through January 1, 2018 but is subject to annual funding appropriations. Kansas City Power & Light is also taking applications for businesses to host charging stations through the KCP&L Clean Charge Network Program.
- **Source:** https://www.chargepoint.com/products/station-incentives/

MO. 2. State Incentives for Wheego LiFe

- Exemption for emissions testing.
- **Source:** http://wheego.net/more/vehicles/federal-and-state-incentives/

MO. 3. Green Driver state incentives in Missouri

- Exemption for emissions testing. Auto insurance discounts for AFVs and hybrids. Federal tax credits for EVs, PHEVs and EVs
- **Source:** http://www.dmv.org/mo-missouri/green-driver-state-incentives.php

MO. 4. Ameren plans electric car charging stations in Missouri

- Ameren Missouri is seeking approval from the Missouri Public Service Commission to build six public charging stations for electric vehicles between St. Louis and central Missouri.

Project leader Mark Nealon said five of the stations would be along the 140-mile stretch between St. Louis and Boonville on Interstate 70. Ameren Missouri estimates the cost of the charging stations will be around $600.000

• **Source:** http://stlouis.cbslocal.com/2016/08/15/ameren-plans-electric-car-charging-stations-in-missouri/

MONTANA

MT. 1. Green Driver state incentives in Montana

• Auto insurance discounts for AFVs and hybrids. Federal tax credits for EVs, PHEVs and EVs

• **Source:** http://www.dmv.org/mt-montana/green-driver-state-incentives.php

MT. 2. Missoula to get 2 EV charging stations

• The city of Missoula and Northwestern Energy are introducing 2 level 2 EV stations at the city's park place parking structure.

• **Source:** http://www.abcfoxmontana.com/story/34701019/missoula-to-get-2-electric-vehicle-charging-stations

NEVADA

NV. 1 Nevada Electric Vehicle programs and resources

• Nevada legislation has been implemented (Senate Bill 332) requiring State and local governments in highly populated areas to add EVs and AFVs to their fleets. In addition, EV's and AFV's are exempted from emission testing requirements. There is a bill passed by City of Las Vegas and City of Reno for preferential parking for EV and AFV vehicles. The Governor's Office of Energy (GOE) partnered with NV Energy in 2013 to install a charging station in Carson City. DOT has adopted regulations to allow certain low emission and energy-efficient vehicles to be operated in lane designated for high-occupancy vehicles.

• **Source:** http://energy.nv.gov/Programs/Nevada_Electric_Vehicle_Programs_and_Resources/

NV. 2. Nevada Green Driver State Incentives in Nevada

• Auto insurance discounts for hybrids and AFV's. Federal tax credit for EV's, PHEV's, AFV's and hybrids. Free parking at parking meters for AFV's. An HEV used as a taxicab can exceed the normal rules regarding how long a taxicab can be in operation (as a taxicab) by 24 months. Nevada Energy customers that live in Northern and Southern Service territories get discounts for EV charging from 10pm to 6am.

- **Source:** http://www.dmv.org/nv-nevada/green-driver-state-incentives.php

NEW HAMPSHIRE

NH.1. Green driver incentive for New Hampshire

- AFV income tax credit. Federal tax incentives for EVs, PHEVs and AFVs. Auto insurance Discounts for Hybrids and AFVs and emission test exemptions for EV's
- **Source:** http://www.dmv.org/nh-new-hampshire/green-driver-state-incentives.php

NEW JERSEY

NJ.1. Green driver incentive for New Mexico

- AFV income tax credit. Federal tax incentives for EVs, PHEVs and AFVs. Auto insurance Discounts for Hybrids and AFVs and emission test exemptions for EV's. EV's can use HOV lanes [Northbound (from Interchange 11 to 14)—Between 6 and 9 a.m., Monday through Friday. Southbound (from Interchange 14 to 11)—Between 4 and 7 p.m., Monday through Friday]
- **Source:** http://www.dmv.org/nh-new-hampshire/green-driver-state-incentives.php

NEW MEXICO

NM.1. Green driver incentive for New Mexico

- AFV income tax credit. Federal tax incentives for EVs, PHEVs and AFVs. Auto insurance Discounts for Hybrids and AFVs and emission test exemptions for EV's
- **Source:** http://www.dmv.org/nh-new-hampshire/green-driver-state-incentives.php

NEW YORK

NY. 1

- The New York State Energy Research and Development Authority (NYSERDA) has awarded $3.6 million to 14 organizations to install more than 260 electric vehicle charging stations across the state, from Long Island to Buffalo. Most stations will be dual charging stations.
- City of White Plains had $200,000 to install 10 EV charging stations at multifamily residences around the city.

- **Source**:https://www.governor.ny.gov/news/governor-cuomo-announces-installation-hundreds-electric-vehicle-charging-stations

NY.2. Green driver incentive for New York

- AFV income tax credit. Federal tax incentives for EVs, PHEVs and AFVs. Auto insurance Discounts for Hybrids and AFVs and emission test exemptions for EV's
- **Source:** http://www.dmv.org/ny-new-york/green-driver-state-incentives.php

NORTH CAROLINA

NC.1. Green driver incentive for North Carolina

- AFV income tax credit. Federal tax incentives for EVs, PHEVs and AFVs. Auto insurance Discounts for Hybrids and AFVs and emission test exemptions for EV's. HOV access for AFV's
- **Source:** http://www.dmv.org/nc-north-carolina/green-driver-state-incentives.php

NC.2. Duke Energy's $1.5 million program aims to increase public electric vehicle charging in N.C. by 30 percent

- Duke Energy will provide $1 million to help cities and towns develop public charging stations for residents. Duke Energy will pay 100 percent up to $5,000 per charge port; $20,000 per site, or $50,000 per city
- **Source:** https://news.duke-energy.com/releases/duke-energy-s-1-5-million-program-aims-to-increase-public-electric-vehicle-charging-in-n-c-by-30-percent

NC.3. Biogen Idec installs Electric Vehicle charging stations in RTP

- Biogen Idec purchased ten charging stations and located them at its campus in Research Triangle Park, North Carolina with support from the Carolina Blue Skies Initiative, a project led by Triangle J Council of Governments (TJCOG), with $12 million in American Recovery and Reinvestment Act (ARRA) funding from the U.S. Department of Energy.
- **Source:** https://nccleantech.ncsu.edu/biogen-idec-installs-electric-vehicle-charging-stations-in-rtp/

NORTH DAKOTA

ND.1. Electric Vehicle Charging stations to be installed in North Dakota

- Electric vehicle charging stations are coming to North Dakota. They would be located along I-29 and 94 and Highway 2. They will be paid for by the state’s share of the record settlement in the Volkswagen diesel emissions cheating scandal. That total is about $900,000.
- **Source:** http://www.kvrr.com/2017/04/20/electric-vehicle-charging-stations-installed-north-dakota/

ND.2. Green driver incentive for North Dakota

- Federal tax incentives for EVs, PHEVs and AFVs. Auto insurance Discounts for Hybrids and AFVs
- **Source:** http://www.dmv.org/nd-north-dakota/green-driver-state-incentives.php

OHIO

OH.1. Green driver incentive for Ohio

- AFV income tax credit. Federal tax incentives for EVs, PHEVs and AFVs. Auto insurance Discounts for Hybrids and AFVs and emission test exemptions for EV’s
- **Source:** http://www.dmv.org/ny-new-york/green-driver-state-incentives.php

OH.2. Ohio group pushes for workplace electric vehicle charging

- Melink Corporation, an energy solutions firm near Cincinnati, offers its employees $5,000 to purchase a hybrid or electric vehicle.
- **Source:** http://midwestenergynews.com/2014/08/22/ohio-group-pushes-for-workplace-electric-vehicle-charging/

OKLAHOMA

OK.1. Rebates and tax credits for Electric vehicles

- Tax credits available for alternative Infrastructure tax credit by the state of Oklahoma.
- **Source:** https://www.clippercreek.com/evse-rebates-and-tax-credits-by-state/

OK.2. State Incentives

- AFV income tax credits
- **Source:** http://www.okcleancities.org/state-tax-incentives

OK.3. Oklahoma laws and incentives

- For tax years beginning before January 1, 2020, a one-time income tax credit is available for 45% of the incremental cost of purchasing a new original equipment manufacturer AFV, excluding electric vehicles, or converting a vehicle to operate on an alternative fuel. The state also provides a tax credit in the amount of 10% of the total vehicle cost, up to $1,500, if the incremental cost of a new AFV cannot be determined or when an AFV is resold, as long as a tax credit has not been previously taken on the vehicle
- **Source:** http://www.afdc.energy.gov/laws/all?state=OK

OK.4. Green driver incentive for Oklahoma

- AFV income tax credit. Federal tax incentives for EVs, PHEVs and AFVs. Auto insurance Discounts for Hybrids and AFVs
- **Source:** http://www.dmv.org/ok-oklahoma/green-driver-state-incentives.php

<u>OREGON</u>

OR.1 Electric Vehicles and Infrastructure Program

- On Jan. 2016, a new law went into that makes it punishable by a fine of up to $250 for parking in a spot designated for an electric vehicle if you aren't an electric vehicle/you're not charging your EV.
- ODOT and the Federal Highway Administration, in conjunction with the U.S. Department of Energy's Clean Cities Program, hosted the first workshop under the EV corridor development initiative, titled "EV Infrastructure Corridor Development Workshop: Lessons Learned from the West Coast Experience," on July 28, 2015.
- **Source:** https://www.oregon.gov/ODOT/HWY/OIPP/Pages/inn_ev-charging.aspx

OR.2 Electric Vehicles and Infrastructure Program

- Emission testing exempts by DOT. Federal tax credits and Auto insurance discounts for hybrids, PHEV, EV, AFV.
- **Source:** http://www.dmv.org/or-oregon/green-driver-state-incentives.php

PENNSYLVANIA

PA.1 Green Driver state incentives in Pennsylvania

- Emission testing exempts by DOT. Federal tax credits and Auto insurance discounts for hybrids, PHEV, EV, AFV. HOV lane access by AFV's
- **Source:** http://www.dmv.org/pa-pennsylvania/green-driver-state-incentives.php

PA.2 Turnpike opens electric care charging stations in Western Pennsylvania

- Four EV chargers were opened at service plaza on Pennsylvania turnpike, new Stanton and Oakmont. All four EV chargers are Level 2. Car charging group in Miami installed the chargers.
- **Source:** http://triblive.com/news/westmoreland/6126986-74/charging-stations-car

RHODE ISLAND

RI. 1. Transportation

- Office of Energy in partnership with National grid has implemented the installation of 50 electric vehicle throughout Rhode Island and it is free to charge.
- **Source:** http://www.energy.ri.gov/Transportation/index.php

RI. 2. Green Drivers State Incentives in Rhode Island

- EV's are exempted from emission test. Auto insurers discount for hybrids and AFV's. Taxpayers in Warren have tax exemption and federal tax credits. Federal tax credits for EV's, AFV's and PHEV's and hybrids
- **Source:** http://www.dmv.org/ri-rhode-island/green-driver-state-incentives.php

SOUTH CAROLINA

SC.1. Spinx stores installs level 3 EV charging stations

- Spinx convenience store opened seven level 3 EV charging stations. There was a partnership between Spinx and Nissan. Nissan's "No Charge to Charge" program is offering eligible Nissan Leaf owners 24 months of free public charging at the new Level 3 Spinx stations. Once the introductory program expires, the cost to charge will be $5.95 for a 20-minute charge.
- **Source:**http://www.nacsonline.com/YourBusiness/FuelsCenter/Alternative/News/Pages/ND0411165.aspx#.WNiOyNy1upo

SC.2 Green Driver state incentives in South Carolina

- Federal tax credits and Auto insurance discounts for hybrids, PHEV, EV, AFV.
- **Source:** http://www.dmv.org/sc-south-carolina/green-driver-state-incentives.php

SOUTH DAKOTA

SD. 1. Green Drivers State Incentives in South Dakota

- Auto insurers discount for hybrids and AFV's. Federal tax credits for EV's, AFV's and PHEV's and hybrids
- **Source:** http://www.dmv.org/sd-south-dakota/green-driver-state-incentives.php

SD. 2. Dakota Electric Residential Services

- If you have a plug-in electric vehicle or plug-in hybrid electric vehicle, you can power your EV with 100% renewable wind energy for no additional cost
- Dakota Electric offers a rebate of up to $500 to cover the cost of installing a charger on one of the Charge Wise programs
- **Source:** http://www.dakotaelectric.com/residential/programs/electric-vehicles

SD. 3. Green Drivers State Incentives in Minnesota

- Dakota Electric Association offers reduced rates for customers with plug-in hybrid electric vehicles through a pilot program called ChargeWise. To be eligible for the discount, members must use a ChargeWise circuit to charge their PHEV batteries during low-demand hours
- **Source:** http://www.dmv.org/mn-minnesota/green-driver-state-incentives.php

TENNESSEE

TN. 1. Green Drivers State Incentives in Tennessee

- EV's are exempted from emission test. Auto insurers discount for hybrids and AFV's. Federal tax credits for EV's, AFV's and PHEV's and hybrids. HOV lane access for AFV's
- **Source**: http://www.dmv.org/tn-tennessee/green-driver-state-incentives.php

TN. 2. CARTA plans 20 Electric Vehicle Charging stations in Chattanooga, New Electric Vehicle car-share program

- Chattanooga Area Regional Transportation Authority (CARTA) plans 20 Electric Vehicle Charging stations in Chattanooga, New Electric Vehicle car-share program
- **Source**: http://www.chattanoogan.com/2016/4/21/322600/CARTA-Plans-20-Electric-Vehicle.aspx

TEXAS

TX. 1. Plug-In Austin

- Austin Energy rebates helps you pay for a faster (240v) charging station in your home. Additionally, you can get unlimited charging for your vehicle at any of our public charging stations for $4.17 a month.
- **Source:** http://austinenergy.com/wps/portal/ae/green-power/plug-in-austin/!ut/p/a0/04_Sj9CPykssy0xPLMnMz0vMAfGjzOINjCyMPJwNjDzdzY0sDBzdnZ28TcP8DC09DfWDU4v1C7IdFQF4CNQ8/

TX. 2. Green Drivers State Incentives in Texas

- EV's are exempted from emission test. Auto insurers discount for hybrids and AFV's. Federal tax credits for EV's, AFV's and PHEV's and hybrids.
- **Source:** http://www.dmv.org/tx-texas/green-driver-state-incentives.php

TX. 3. Austin EV Charging

- Austin EV an initiative started by Austin energy has 226 charging stations in parking lots across Austin. Advanced Micro Devices (AMD) has 30 EV charging stations on its campus. AMD not only provides the charging stations, it also pays for electric car owners to have an EV Everywhere monthly subscription. For $4.17, subscribers can plug in at any public station in Austin. The company helps offset costs with an Austin Energy rebate that pays up to $4,000 per charging station on the campus
- **Source:** http://kut.org/post/texas-stalls-electric-car-infrastructure-austin-prepares-surge-drivers

UTAH

UT. 1. Green Drivers State Incentives in Utah

- EV's are exempted from emission test. Auto insurers discount for hybrids and AFV's. Federal tax credits for EV's, AFV's and PHEV's and hybrids. HOV lane access for AFV's

- **Source**: http://www.dmv.org/ut-utah/green-driver-state-incentives.php

UT. 2. Salt Lake City debuts 28 new electric vehicle charging stations

- New level 2 chargers are located at 12 sites across Salt Lake City. Locations include the International Peace Gardens in Jordan Park, Sorenson Multicultural Center, Sunnyside Avenue near Hogle Zoo, Pioneer Park, the Forest Dale Golf Course. The Utah Division of Air Quality (DAQ) grant went toward hard costs, including purchasing the new stations. This money was combined with City funding to help pay for the overall investment.

- **Source:** http://www.dmv.org/ut-utah/green-driver-state-incentives.php

VERMONT

VT. 1. Green Drivers State Incentives in Vermont

- EV's are exempted from emission test. Auto insurers discount for hybrids and AFV's. Federal tax credits for EV's, AFV's and PHEV's and hybrids.

- **Source:** http: http://www.dmv.org/vt-vermont/green-driver-state-incentives.php

VIRGINIA

VA. 1. With downtown charging station, Roanoke empowers electric vehicle owners

- Installation of an advanced EV charging station by the Roanoke city market building which took the number of charging stations to seven.

- The Virginia Museum of transportation has also installed an EV charging station and it is billed at ordinary rates.

- The river house complex which contains a restaurant, offices, apartments and gym offers free charging to the public.

- There is also a veteran affairs Medical Center in Salem which has also installed an EV charging station but it is used for federal agency vehicles used by hospital staff.

- Virginia Western Community College offers free use of an electrical outlet outside its college services building near Overland Road, equipment that can fill up a battery overnight. Use is free.

- There are also charging stations at the Inn at Virginia Tech. Virgina Clean cities gave an EV charger worth $30000 to the Roanoke city.

- **Source:** Retrieved from: http://www.roanoke.com/news/local/roanoke/with-downtown-charging-station-roanoke-empowers-electric-vehicle-owners/article_db2e9b8e-c985-51e8-b04b-68b0f2726a00.html

VA. 2. Green Drivers State Incentives in Virginia

- EV's are exempted from emission test. Auto insurers discount for hybrids and AFV's. Federal tax credits for EV's, AFV's and PHEV's and hybrids. HOV lane access for AFV's
- **Source:** http://www.dmv.org/va-virginia/green-driver-state-incentives.php

WASHINGTON

WA. 1. If you build it, will they charge?

- Avista Utilities plan to spend $3 million to install, own, and operate 272 grid-integrated electric vehicle (EV) chargers at about 200 residential, workplace, and public charging sites in its Eastern Washington state service territory.
- **Source:** http://www.utilitydive.com/news/if-you-build-it-will-they-charge-utilities-cautious-in-plans-to-spur-elec/423982/

WA. 2. Green Drivers State Incentives in Washington

- EV's are exempted from emission test. Auto insurers discount for hybrids and AFV's. Federal tax credits for EV's, AFV's and PHEV's and hybrids.
- **Source**: http: http://www.dmv.org/wa-washington/green-driver-state-incentives.php

WEST VIRGINIA

WV. 1. Green Drivers State Incentives in Vermont

- EV's are exempted from emission test. Auto insurers discount for hybrids and AFV's. Federal tax credits for EV's, AFV's and PHEV's and hybrids.
- **Source**: http://www.dmv.org/wv-west-virginia/green-driver-state-incentives.php

WISCONSIN

WI.1. Rebates and tax credits for Electric vehicles

- Alliant Energy (Public utility Company) offers a rebate to commercial and industrial customers who purchase and install level 2 EVSE. The rebate is $1,000 for the purchase of a single connector EVSE, and $1,500 for a dual connector EVSE. There is also up to $500 for purchase of a level 2 home charging station.
- **Source:** https://www.clippercreek.com/evse-rebates-and-tax-credits-by-state/

WI.2. Green driver incentive for Wisconsin

- Exempt of vehicle emission testing by DOT but hybrids must undergo testing. If you use alternative fuel to operate a taxi for the purpose of transporting passengers, you will get a reimbursement for the amount you used. There is tax exemption for alternative fuel.
- **Source:** http://www.dmv.org/wi-wisconsin/green-driver-state-incentives.php

WYOMING

WY.1. Rebates and tax credits for Electric vehicles

- Yellowstone-Teton Clean Cities (YTCC) (functions as Department of Energy's on-the-ground advocate focused on petroleum displacement activities in the Greater Yellowstone Region) offers a $5000 rebate for the purchase of a public accessible EVSE
- **Source:** https://www.clippercreek.com/evse-rebates-and-tax-credits-by-state/

WY.2. Green driver incentives for Wyoming

- Federal tax credits and Auto insurance discounts for hybrids, PHEV, EV, AFV.
- **Source:** http://www.dmv.org/wy-wyoming/green-driver-state-incentives.php

DISTRICT OF COLUMBIA

DC.1. Utility wants to offer discount to D.C. electricity vehicle owners willing to plug in during off-hours

- Pepco (a utility company) wants to offer a lower rate to D.C. residents who own electric vehicles to see if it can help ease potential strains on the power grid by getting them to charge up during off-peak times. The owners will pay a lower rate for plugging in between 8pm and noon.
- **Source:** https://www.washingtonpost.com/local/trafficandcommuting/utility-wants-to-offer-discount-to-dc-electric-vehicle-owners-willing-to-plug-in-during-off-

hours/2017/04/25/c64c3038-29e0-11e7-b605-33413c691853_story.html?utm_term=.d477b2d5fe9d

DC.2. EV charging on the National Mall in Washington, DC

- The National Park Service has installed two curbside electric vehicle charging stations on the National Mall in Washington, DC. One is on Madison Drive by the Air and Space Museum, the other is on Jefferson Drive near the National Museum of American History. NPS received a grant from the Department of Energy Clean Cities program to install the stations. Each of the two charging stations serve one vehicle and are available to the public. The cost to use the charging stations is $2.00 per hour
- **Source:** http://pluginsites.org/ev-charging-on-the-national-mall-in-washington-dc/

APPENDIX 8.1

SMART ENERGY TALK 2017
PRESENTATION

Our Research Shows the Benefits are Real

Moe Alahmad & Ala'a Rayyan

October 28, 2017

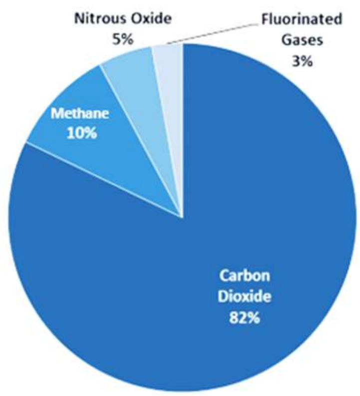
1

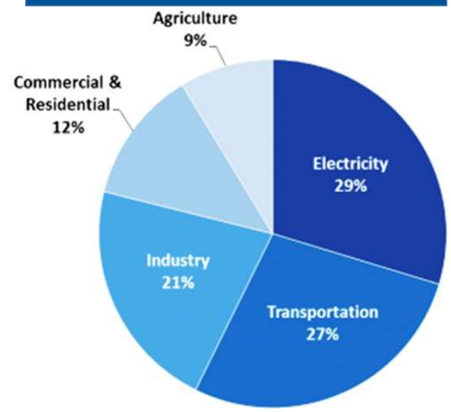
Outline

- Motivation
- NCEA & Members
- NCEA Projects
- The Benefits are Real
- Moving Ahead
- Perfect Match
  - Electrified Transportation
  - +
  - Solar Energy

2

Overview of Greenhouse Gas Emissions in 2015	Sources of Greenhouse Gas Emissions in 2015





"**In 2015, U.S. greenhouse gas emissions totaled 6,587 million metric tons of carbon dioxide equivalents**, or 5,828 million metric tons of carbon dioxide equivalents after accounting for sequestration from the land sector."

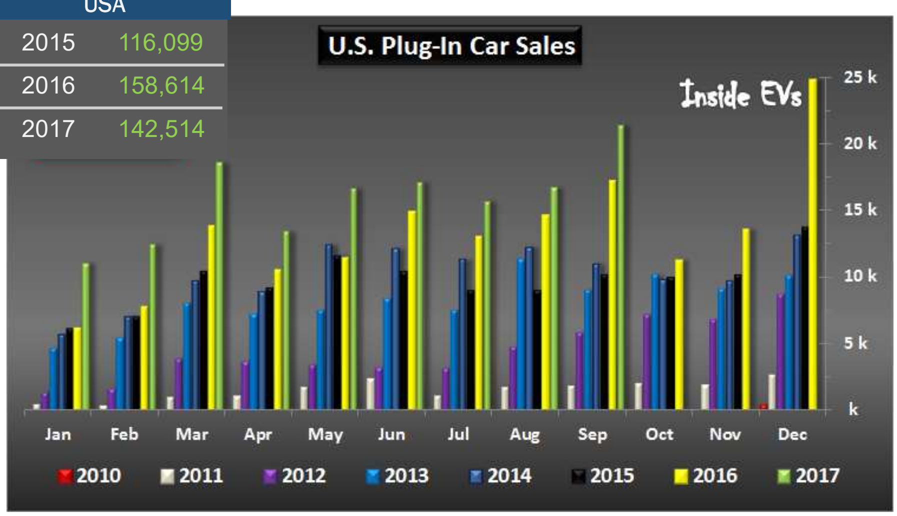
U.S. Environmental Protection Agency (2017). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015

3

https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

Trends

# of EV CARS SOLD in USA	
2015	116,099
2016	158,614
2017	142,514



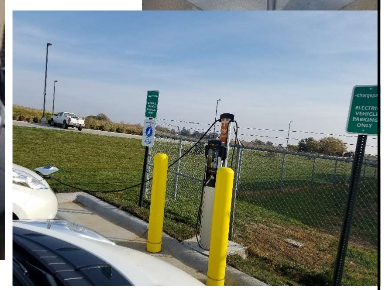
4

Trends

EVSE CHARGING INFRASTRUCTURE

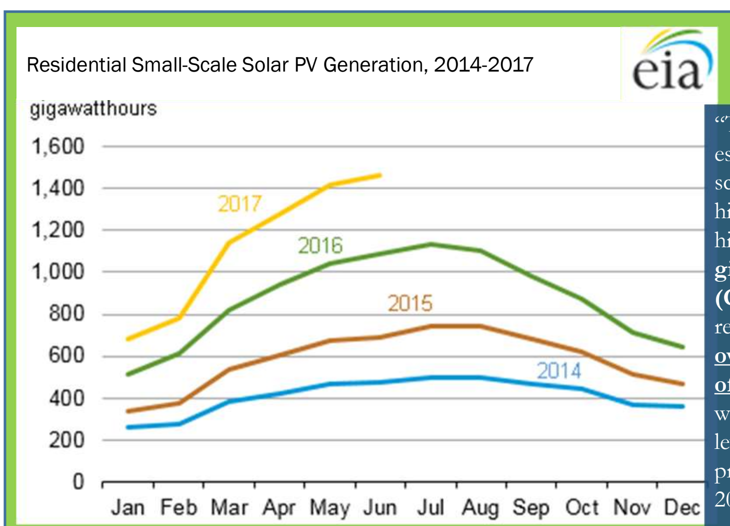
	USA	NE
LEVEL 2 EVSE	14846	52
LEVEL 3 (DC) EVSE		
DC FAST CHARGERS	1827	1
TESLA DC FAST CHARGERS	358	4
TOTAL DC FAST CHARGERS	2185	5





5

Community Solar: Trends



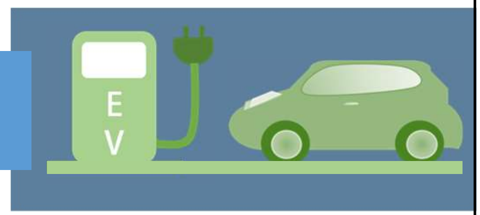
"The June 2017 estimate for small-scale solar PV output hit a monthly record high of **1,460 gigawatt-hours (GWh).** This value represents a **year-over-year increase of 34.4%** compared with the June 2016 level, according to preliminary 2016 and 2017 EIA data."

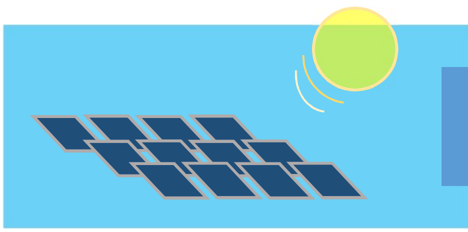
6

https://www.eia.gov/electricity/monthly/update/archive/august2017/

NCEA Member Participation

Electrified Transportations





Community Solar

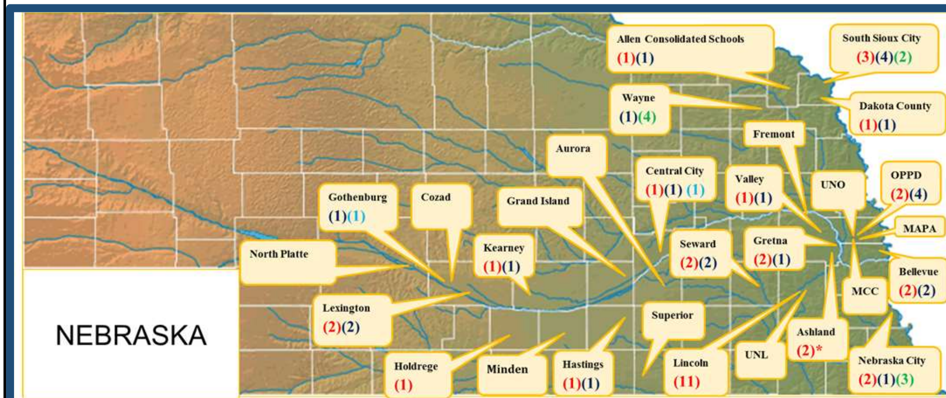
7

NCEA Members (29)

- Allen Consolidated Schools
- Ashland
- Aurora
- Bellevue
- Central City
- Cozad
- Dakota County
- Fremont
- Gothenburg
- Grand Island
- Gretna
- Hastings
- Holdrege
- Kearney
- Lexington
- Lincoln
- Metropolitan Area Planning Agency (MAPA) (includes cities and counties in Washington, Douglas, and Sarpy counties, including the City of Omaha)
- Metropolitan Community College
- Minden
- Nebraska City
- North Platte
- Omaha Public Power District (OPPD)
- Seward
- South Sioux City
- Superior
- University of Nebraska at Omaha
- University of Nebraska-Lincoln
- Valley
- Wayne

8

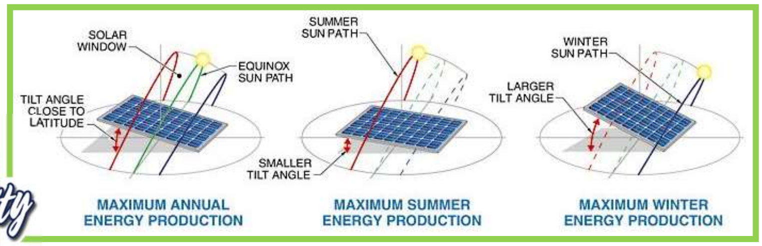
Deployment of AFVs and EV Smart Charging Infrastructure in Participating Communities



- (X) Number of Available Charging Stations in each NCEA community
- 35 TOTAL Stations
  * (1) DC Fast Charging Station
- (X) Number of Electric Vehicles (EVs) in each NCEA community
- 24 TOTAL EVs
- (X) Number of CNG Vehicles in each NCEA community
- 9 TOTAL CNGs
- (X) Number of Solar projects in each NCEA community
- 2 TOTAL Installations

Deployment of AFVs and EV Smart Charging Infrastructure in Participating Communities

Central City



Single-axis Tracking

11

Central City

Aerial Video

https://www.dropbox.com/s/ctpo72a1i6p3axy/CC%20Drone%20%20Out.avi?dl=0

12

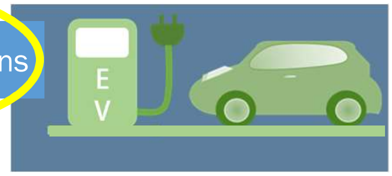
Gothenburg

Gothenburg nebraska

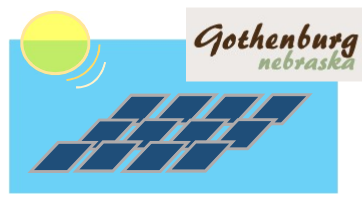
Our Research Shows the Benefits are Real

NCEA Member Participation

Electrified Transportations



Community Solar



15

Economic and Environmental Benefits

Car Types

Electricity Provider

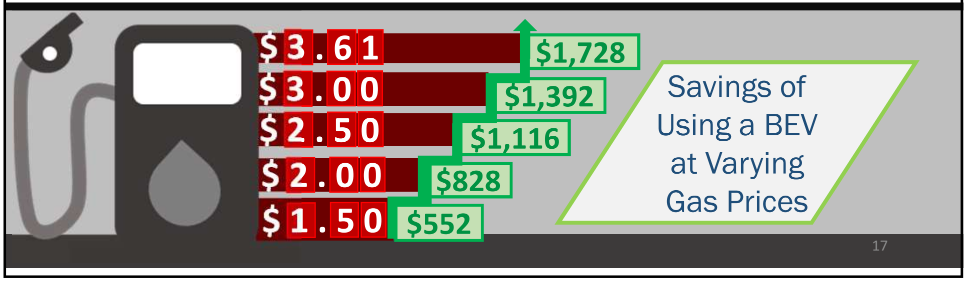
- EV: Electric Vehicle — OPPD, NPPD, NeNPPD, LES
- CV: Conventional Vehicle — G
- DV: Diesel Vehicle — D
- CNG: Compressed Natural Gas — CNG

16

Economic Benefits

Cost of Fuel (per gallon)	$2.43	$2.71	$1.97
Fuel Efficiency	21.6 mpg	27 mpg	21 mpg
Cost of Driving One Mile	$0.11	$0.10	$0.09
Savings over CV per year (12,000 miles)		$120	$240

	Electricity Provider			
	OPPD	NPPD	NeNPPD	LES
Cost of Fuel (per kWh)	$0.092	$0.091	$0.065	$0.0706
Fuel Efficiency	3.4 miles/kWh			
Cost of Driving One Mile	$0.027	$0.027	$0.019	$0.021
Savings over CV per year (12,000 miles)	$996	$1,000	$1,092	$1,070



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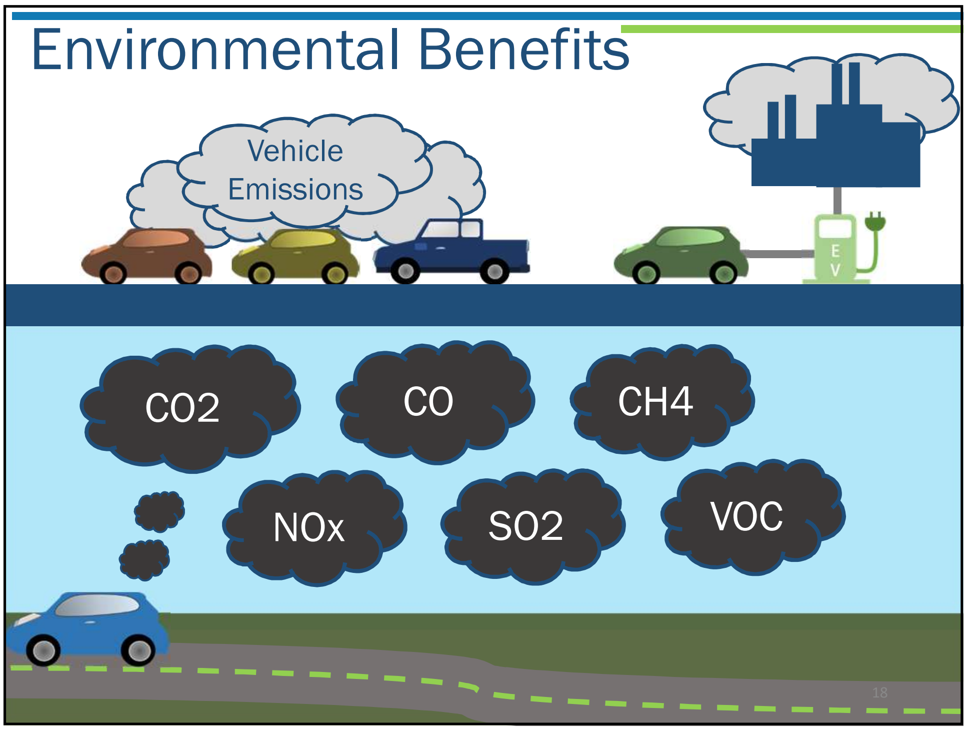
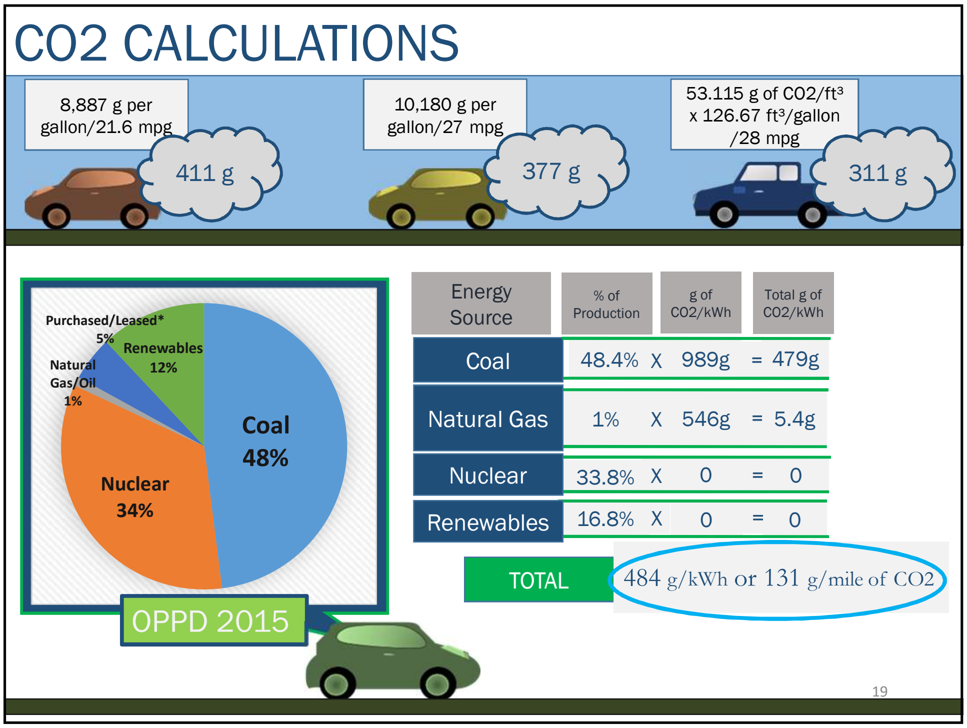
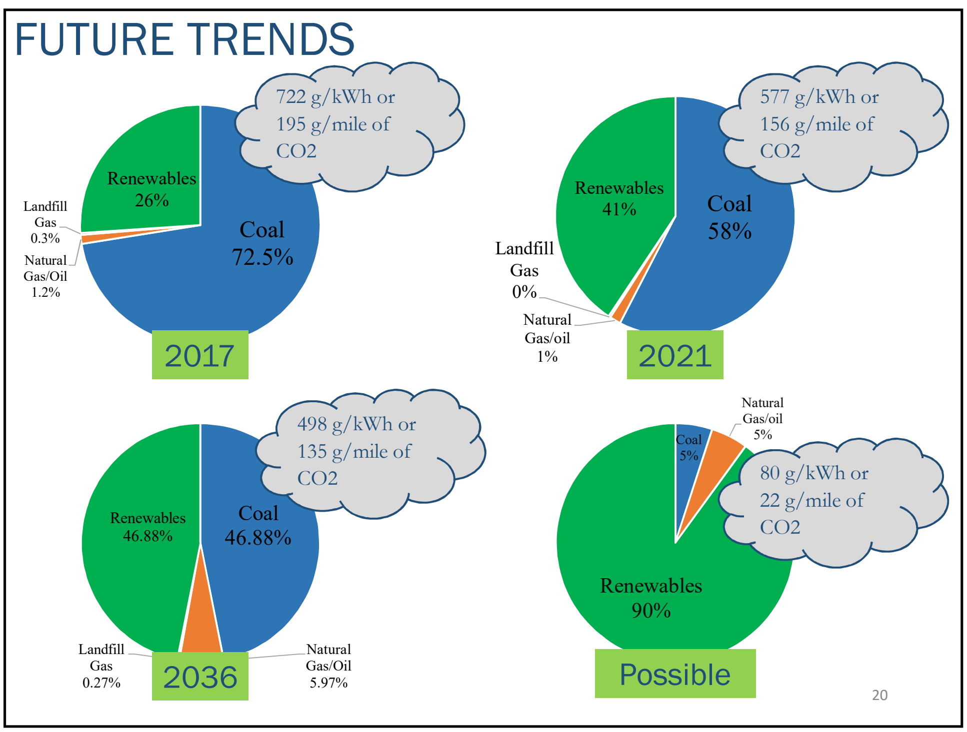



CO2 CALCULATIONS
8,887 g per gallon/21.6 mpg
411 g
10,180 g per gallon/27 mpg
377 g
53.115 g of CO2/ft³ x 126.67 ft³/gallon /28 mpg
311 g
Purchased/Leased* 5%
Renewables 12%
Natural Gas/Oil 1%
Coal 48%
Nuclear 34%
OPPD 2015
Energy Source
% of Production
g of CO2/kWh
Total g of CO2/kWh
Coal 48.4% X 989g = 479g
Natural Gas 1% X 546g = 5.4g
Nuclear 33.8% X 0 = 0
Renewables 16.8% X 0 = 0
TOTAL
484 g/kWh or 131 g/mile of CO2
19


FUTURE TRENDS
722 g/kWh or 195 g/mile of CO2
Renewables 26%
Coal 72.5%
Landfill Gas 0.3%
Natural Gas/Oil 1.2%
2017
577 g/kWh or 156 g/mile of CO2
Renewables 41%
Coal 58%
Landfill Gas 0%
Natural Gas/oil 1%
2021
498 g/kWh or 135 g/mile of CO2
Renewables 46.88%
Coal 46.88%
Landfill Gas 0.27%
Natural Gas/Oil 5.97%
2036
Natural Gas/oil 5%
Coal 5%
80 g/kWh or 22 g/mile of CO2
Renewables 90%
Possible
20

Total Economic and Environmental Benefits for the Cities Participating in this Project

Participating Cities	BEV	CNG	CP	Economic Benefits	CO2 Reductions (lbs.)
Allen Consolidated Schools	1 Volt	-	1	$1,713.09	12,947.33
Ashland	-	-	2*	$169.80	1,486.52
Bellevue	2 Leaf	-	2	$2,028.21	18,468.38
Central City	1 Leaf	-	1	$131.39	1,113.51
Dakota County	1 Leaf	-	1	$282.76	2,137.12
Ferguson House	-	-	1	$505.16	4,337.94
Gothenburg	1 Leaf	-	-	$682.92	5,830.56
Gretna	1 Leaf	-	2	$571.53	5,069.03
Hastings	1 Fusion	-	1	$34.64	303.80
Holdrege	-	-	1	$70.77	592.15
Kearney	1 Fusion	-	1	$846.34	7,132.69
LES	-	-	2	$1,445.88	11,411.84
Lexington	2 Fusion Volt	-	2	$752.33	6,244.30
Lincoln	1 Leaf	-	10	$1,501.79	11,853.14
Nebraska City	1 Leaf	3	3	$3,611.12	24,204.20
OPPD	3 Leaf Volt	-	3	$3,916.76	34,928.21
Seward	2 Leaf	-	5	$1,138.99	9,719.07
South Sioux City	4 Leaf	2	3	$3,887.97	33,173.18
Valley	1 Volt	-	1	$137.86	1,269.08
Wayne	1 Fusion	4	1	$1,295.33	6,134.69
Total				**$24,725**	**198,357**

* (1) CP & (1) ChargePoint DC Fast charger

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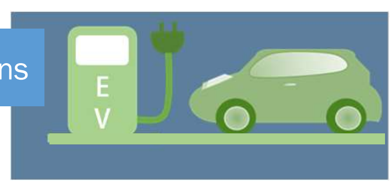
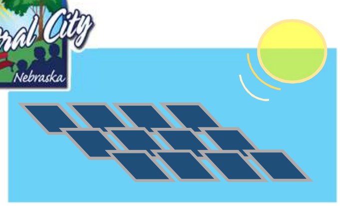
NCEA Member Participation

Electrified Transportations

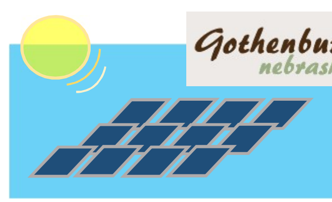


Community Solar

Central City Nebraska



Gothenburg nebraska

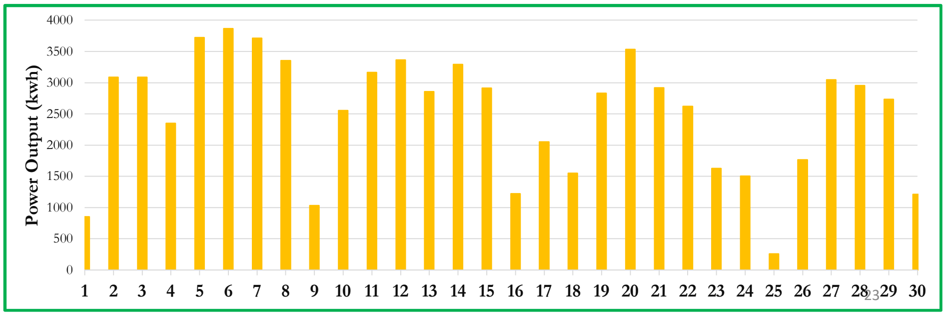


22

SEPTEMBER 2017 PERFORMANCE

500 kW PV System

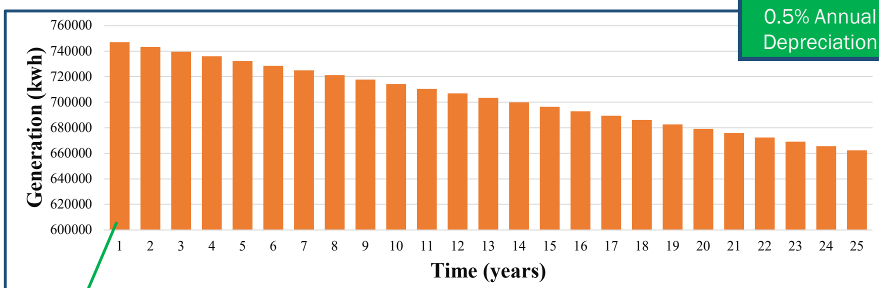
	September (kWh)	All Time (MWh)
Power Output	74,964	94.537
Energy Savings (Based of NPPD $0.0903/kWh)	$6,769	$8,537
	79,722.55 lbs.	50.27 tons



23

Gothenburg: FUTURE ESTIMATES

0.5% Annual Depreciation



62,241.83 kWh (Monthly)

746,902 kWh (First Year)

Savings

$59,752.16 Annually

795,178 lbs. of CO2 — **Annually**

9,366 tons of CO2 — **Lifetime**

500 kW PV System

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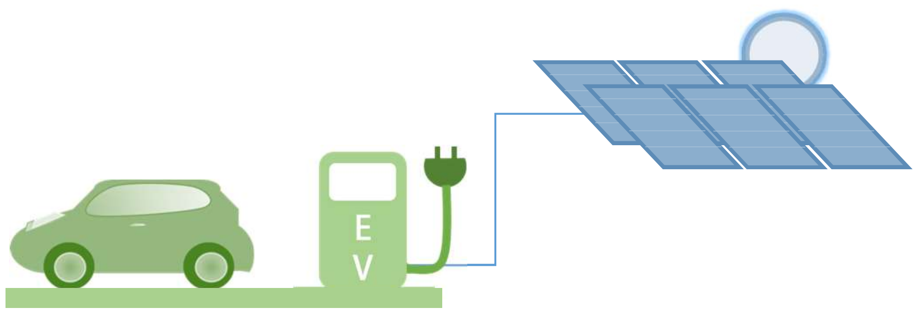
THE PERFECT MATCH ELECTRIFIED TRANSPORTATION & SOLAR



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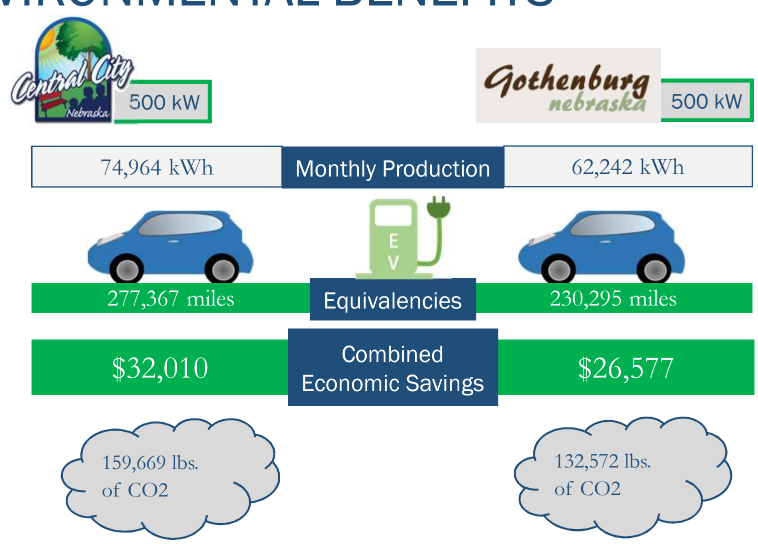
COMBINED ECONOMIC AND ENVIRONMENTAL BENEFITS



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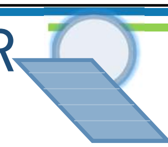
Developing an Electrified Transportation Vision for Nebraska

COMMUNITY SOLAR



	Allen (6 kWh)	Fremont (1 MW)	Superior (1 MW)
Annual Output (kWh)	8,953	1,289,348	1,427,806
Energy Savings	$859	$141,313	$160,057
CO2 Emission Savings	9,532 lbs.	2,446,990 lbs.	1,520,092 lbs.

MOVING AHEAD: ELECTRIFIED TRANSPORTATION

2018 NCEA-NET Grant

Participating communities	EV	CNG	Charging Station
Allen Consolidated Schools	1	0	1
Ashland	0	0	2
Bellevue	4	0	4
Central City	1	0	1
Dakota County	1	0	1
Ferguson House (Lincoln)	0	0	1
Fremont	3	0	2
Gothenburg	1	0	0
Gretna	1	0	2
Hastings	3	0	1
Holdrege	0	0	1
Kearney	1	0	1
Lexington	2	0	2
Lincoln	0	0	10
Metro Community College	1	0	2
Nebraska City	1	4	2
OPPD	4	0	2
Seward	2	0	2
South Sioux City	4	2	3
Valley	1	0	1
Wayne	1	4	0
Total	32	10	41

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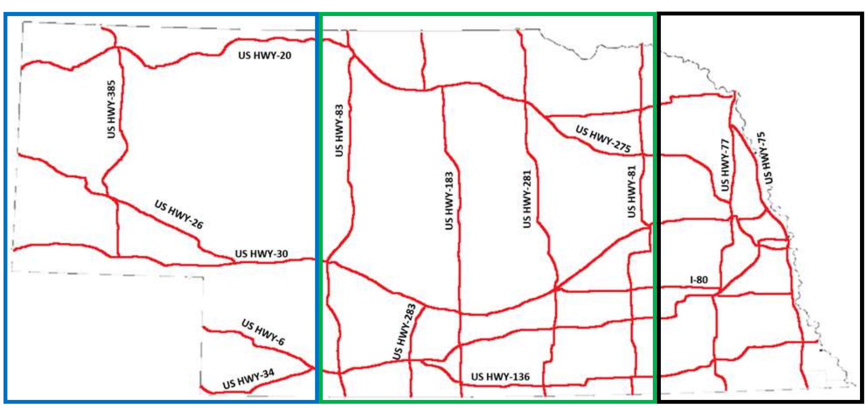
ON-GOING RESEARCH

STATE OF NEBRASKA



ZONE 3
(Area left of US-HWY 83)

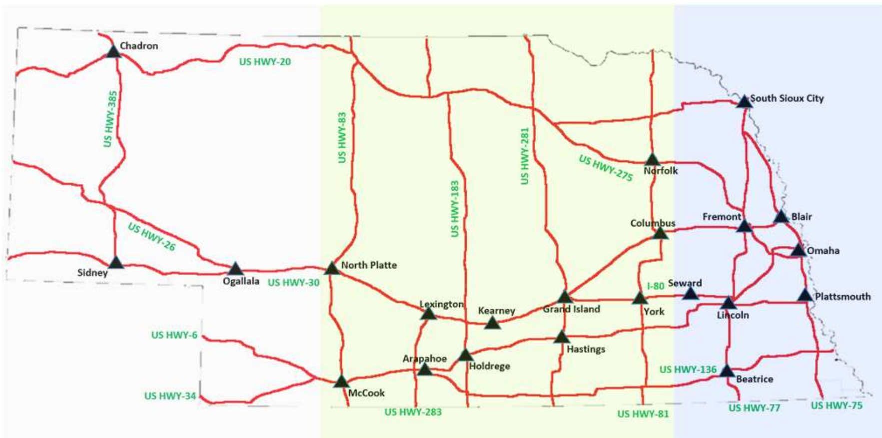
ZONE 2
(Area between US-HWY 83 and US HWY 81)

ZONE 1
(Area right of US HWY 81)

30

PRIORITY 1 LOCATIONS

ZONE 3 *ZONE 2* *ZONE 1*

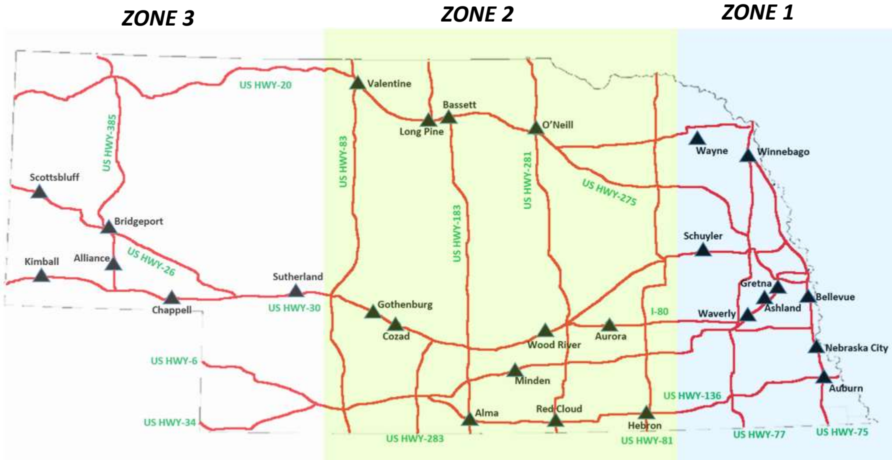


PRIORITY 1 SUMMARY		
ZONE 1	ZONE 2	ZONE 3
8	11	3

31

PRIORITY 2 LOCATIONS

ZONE 3 *ZONE 2* *ZONE 1*

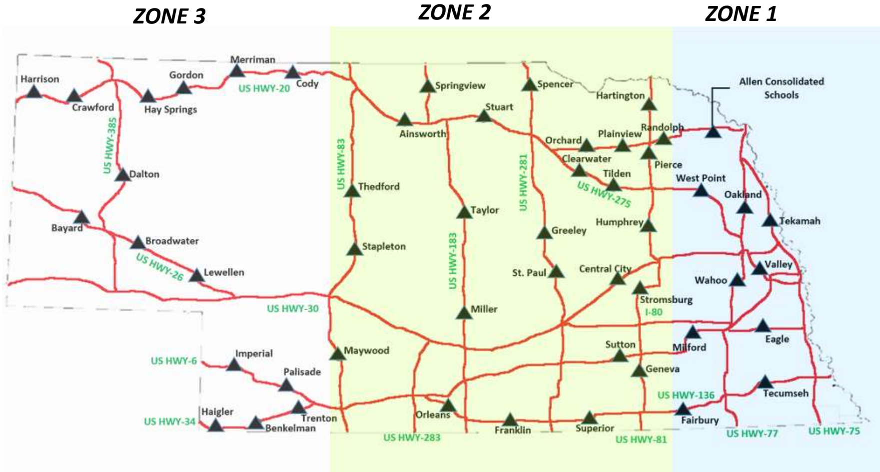


PRIORITY 2 SUMMARY		
ZONE 1	ZONE 2	ZONE 3
9	13	6

32

PRIORITY 3 LOCATIONS

ZONE 3 *ZONE 2* *ZONE 1*



PRIORITY 3 SUMMARY		
ZONE 1	ZONE 2	ZONE 3
11	25	15

ELECTRIFIED TRANSPORTATION

https://engineering.unl.edu/e-vehicle/

COMMUNITY SOLAR

https://engineering.unl.edu/photovoltaics/

THANK YOU!

- Nebraska Environmental Trust (NET)
- Nebraska Department of Transportation (NDOT)
- Nebraska Community Energy Alliance (NCEA)
- Durham School of Architectural Engineering and Construction-University of Nebraska-Lincoln.

NEBRASKA DEPARTMENT OF TRANSPORTATION

The Nebraska Environmental Trust

NCEA Nebraska Community Energy Alliance

UNIVERSITY OF Nebraska Lincoln THE DURHAM SCHOOL OF ARCHITECTURAL ENGINEERING AND CONSTRUCTION

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APPENDIX 8.2

CONFERENCE PAPER - DETERMINING OPTIMAL LOCATIONS OF ELECTRIFIED TRANSPORTATION INFRASTRUCTURE ON INTERSTATE/US-HIGHWAYS

Determining Optimal Locations of Electrified Transportation Infrastructure on Interstate/ US-Highways

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***Abstract*- Determining electric vehicle charging infrastructure locations within a particular city or state is a key factor for a successful electrified transportation deployment. In this paper, a search algorithm is developed to calculate the number of charging infrastructure locations for a particular model of an electric vehicle when traveling between two points on a particular Interstate or US-Highway. The algorithm determines the actual mileage a given electric vehicle will travel, which in turn is used to determine the number of charging infrastructure locations. This algorithm is applied as a case study to determine the number of locations needed for a given electric vehicle model in Nebraska state, USA. Detailed analysis are conducted to identify gaps in the coverage area. Then, a prioritization method is applied to the selected locations and cities. This is done to insure key cities and highly visible Interstates and US-Highway corridors are selected for advancement of the State's economy and planning for deployment and penetrations of electric vehicle expansion.**

I. INTRODUCTION

A key factor to increase market penetration of battery electric vehicles (EVs) and support the electrification of transportation at scale is to increase the number and output capabilities of Electric Vehicle Charging Stations (EVSE) deployed in public spaces; in other words, an adequate public charging infrastructure is needed to effectively extend EVs' battery ranges when it is away from home charging access. Currently, there are three types of EVSE stations: Level 1 (110 V) for home charging, Level 2 (240 V) for workplace and commercial charging, and Level 3 (480 V) DC fast charging for commercial and highway travel. DC fast charging can recharge a dead battery to 80% of its full capacity in 30 minutes or less. In contrast, Level 2 charging can take between four and six hours, depending on the size of the vehicle's onboard charger and Level 1 takes 8-12 hours. As technology advances to make EVs more convenient, as technology such as DC fast charging becomes more available, and as production costs continue to decrease, the improved economic and environmental benefits will make it more practical for consumers to purchase electric vehicles. As of December 2016, a total of 14,750 battery electric vehicles (320 EVs and 14,430 hybrid EVs) were registered in Nebraska [1]. Following national-level trends, this number is expected to grow in Nebraska; the market share of electrified vehicle sales is expected to reach eight percent nationwide by 2020. Nationwide, 159,139 EVs were sold in 2016 [2].

One of the greatest factor that is hindering this growth is range anxiety, the fact that there are not enough charging infrastructures, in our cities and communities. Due to range anxiety, electric vehicle users are not confident enough to travel a long distance, and it is one of the main reasons, users do not use their electric vehicles as their primary car. Previous research has been done to tackle the range anxiety problem. In [3], techniques to minimize range anxiety are discussed, in which the battery capacity is analyzed which will be required to reach a charging station and the users are not left stranded.

Research has also been conducted on the placement of charging stations for electric vehicles. In [4], planning model of electric vehicle charging stations in an urban area is discussed. It takes into consideration road network structure, information on vehicle flow, structure of distribution system capacity constraints. In [5] an optimized algorithm is proposed to find the optimal number and placement of charging station which minimizes loss on the way to the charging station. It also takes the economic constraint into account. A city in Germany, Cologne is considered to validate their findings. In [6] [7], the calculation of actual percentage of the battery that is being utilized under real conditions is discussed. A real time range indicator is developed which will alert the EV user about the actual State of Charge (SoC) of the battery and will mitigate range anxiety. This might vary from place to place if the weather of the place, geographical conditions of the place are taken into account. Also, the driving styles of different electric vehicle users will have an impact on the percentage of mileage being utilized.

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In [8], a city readiness system is discussed which is based on 5 major factors and 13 observation indicators. The five major factors incorporate government policies and investment, charging infrastructure construction and operation, business models and related maintenance service system, public awareness education, operation scope and environmental benefits. In [9], an index is formulated such that it indicates the readiness of the cities for market adoption of plug-in electric vehicles. The index reflects the incorporation of various types of policy instruments, infrastructure development, municipal investments in plug-in electric vehicles technology, and participation in relevant stakeholder coalitions.

In this paper, an algorithm is developed to calculate the total number of charging stations along an Interstate and a US-Highway running across the whole state of Nebraska, USA for a specific electric vehicle model. To do so, the state of Nebraska is divided into 3 zones. The charging infrastructure considered is the Level 3 DC fast chargers, as charging time on a Highway is a major concern for the EV user. It is assumed that the electric vehicle will be fully charged when leaving from the city of origin to a final destination. The total number of charging stations once calculated is then prioritized for effective planning.

The rest of the paper is organized as follows. Section II discusses the charging station locator algorithm and prioritization method. The simulation results are discussed in Section III and conclusion and future scope of work is discussed in Section IV.

II. CHARGING STATION LOCATOR ALGORITHM & PRIORITIZATION METHOD

An average U.S. driver drives around 29 miles per day [10]. This daily commute is mainly for work purposes. With the range in the Electric Vehicles nowadays, daily commute is not that much of a problem. A person can charge their EVs in their workplace or once they are back at their homes. However, the problem magnifies during inter-city or inter-state travel. If there is no charging stations in the right locations, people are discouraged to take their Electric Vehicles for long distance travels. This restricts potential EV buyers, as they cannot make their EV as their primary car. From a financial perspective, at this moment a lot of people are not willing to have two cars, an electric car for city driving and a conventional car for long distance travel due to lack of public charging infrastructure. This is a major problem for potential electric vehicle owners in many states in the country as they are demotivated by the lack of charging infrastructure network. From recent data, in the U.S. there are 16,269 electric vehicle charging stations and 44,528 charging outlets [11]. Figure 1 shows the locations of these charging stations. It is observed that the locations of these charging stations are unevenly distributed concentrating mainly in the east coast and the west coast. In Nebraska, there are 55 electric vehicle charging stations and 141 charging outlets [11]. Figure 2 shows the locations of these charging stations in Nebraska. It is observed that the locations of these charging stations are again unevenly distributed such that an EV owner cannot move about freely without range anxiety.

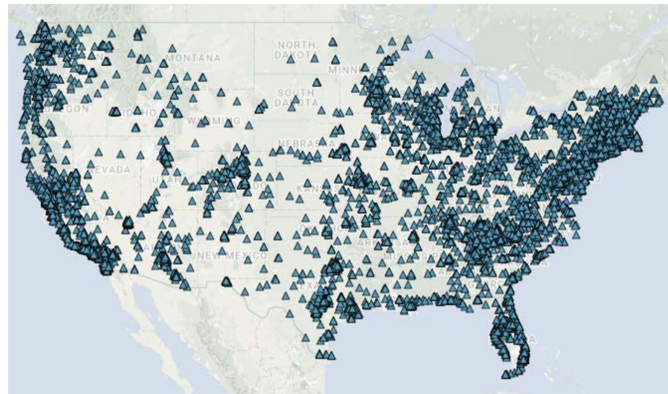

Figure 1: Locations of charging stations in the U.S. [11].

Figure 2: Locations of charging stations in the state of Nebraska [11].

To address this issue in Nebraska, a charging station locator algorithm is developed to determine the number of charging stations required between a city of origin and a final destination for a given electric vehicle. This algorithm incorporates many constraints in its formulation, namely: range anxiety, rated mileage of the electric vehicle, population of the cities near the Interstate or US-Highway, and distance between origin city and final destination city. The charging infrastructure considered is the Level 3 DC fast charger because charging time in an Interstate or US-Highway will be a major concern for the electric vehicle user. In addition, if a fast charger infrastructure is used then the battery capacity that an electric vehicle user is able to utilize is different from charging the electric car in Level I and Level II infrastructure. This will provide a different numerical value for battery utilization percentage used for the calculation of real mileage. It is also assumed that the electric vehicle leaving the city to its destination will be fully charged. As the algorithm is used to determine the location of charging infrastructure required to travel from one particular point to another, it is very important that this assumption is made so to ensure the electric car does

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not run out of charge in any unexpected location. This assumption allow us to locate an electric charging station in the origin city.

Two population factors are used to determine the optimal charging infrastructure location between two cities. The first population factor is referenced as the 'x' factor. The charging station locator algorithm searches a database for all the cities in the state whose population is greater than x. The database is a lookup table that contain all relevant information such as city population, and Interstate/ US-Highway intersections, routes and so forth. The x parameter will decide how the database will be checked by the algorithm for cities in an Interstate/ US-Highway. The value of x is so chosen that it exclude very small cities along the Interstate/ US-Highway, due to lack of sufficient electrical system to supply the needs of the Level 3 chargers. This value of x will differ from state to state, depending on the population per city of the state. For the state of Nebraska, USA the value of x is chosen as 1,000. It can be seen from the consensus report of Nebraska [12] for the year 2015/2016 that out of the 451 cities nearly 117 cities (about 25.94%) have a population which is greater than 1,000. The cities having population greater than 1,000 in Nebraska is well distributed along the Interstate or US-Highway and the utility companies supplying these cities have enough generation as of now as well as in the near future to cope up with the additional consumption of energy due to charging of the electric cars.

The second population factor is the 'y' factor. Cities with population greater than y will be identified as locations where charging infrastructure to be provided. This assumption is made in order to promote the growth of electric vehicle market and encouraging more and more people to drive electric cars. Furthermore, cities with population above y will have the electrical system infrastructure to support the charging infrastructure. For the state of Nebraska, USA the value of y is chosen as 10,000. The value of y will also be different in different states. The values of x and y will depend on the state and utility companies of the cities, and it is to be determined before running the algorithm for each state.

For the selected electric vehicle, the real mileage of the electric vehicle m_r is calculated using [13]

$$m_r = 0.8*(0.6m_a) = 0.48m_a$$

where m_a, is the rated mileage of the electric car and is published by the vehicle manufacturer. With the value of m_r calculated, the total number of charging stations S_t, is calculated using the database created when the origin city of travel and destination city are specified. The algorithm will continue until the destination city specified is reached on the database. The charging infrastructure is then added to find the total number of locations between the source city and destination city for a specific model of the electric vehicle. A flowchart of the charging station locator algorithm is shown in Figure 3.

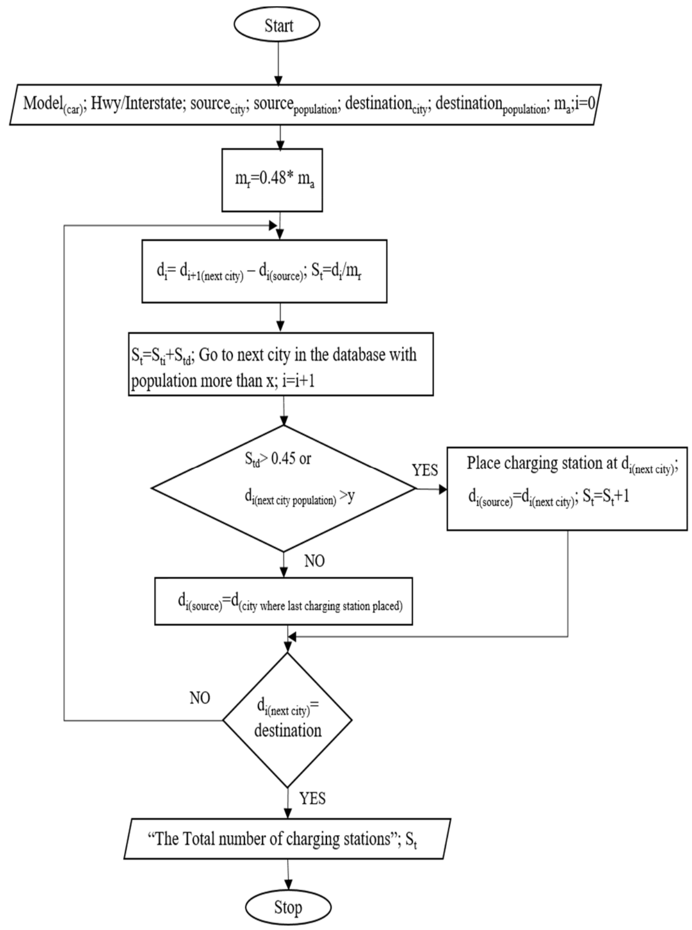

Figure 3: Flow chart of the charging station locator algorithm to determine best charging infrastructure location on a given Interstate or US-Highway

a) Nebraska State case study

Databases for all the prominent US-Highways and the Interstates in the state of Nebraska are documented. The databases includes city names on the Interstate or the US-Highway, their population and the distance between them. Next, the model of the electric car was chosen, which in this case was the Nissan Leaf 2016 model. The rated mileage of the car (m_a) is found out to be 84 miles [14] and the actual mileage (m_r) was calculated to be 40.32 miles. For the sake of simplicity, the state of Nebraska is divided into three zones. Zone 1 is the area east of US-Highway 81. Zone 2 is the area between US-Highway 81 and US-Highway 83. Zone 3 is the area west of US-Highway 83. Then the databases containing the information of all Interstate and the US-Highways are created. Then they were subjected to the charging station locator algorithm and simulated to find out the total number of charging stations required along with their locations for each zones. Figure 4 shows the state of Nebraska divided into three

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zones. Figure 5, 6, and 7 shows the three zones separately with all the Interstates and US-Highways showing.

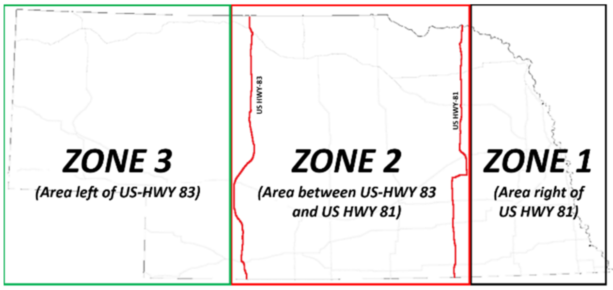

Figure 4: State of Nebraska divided into 3 zones

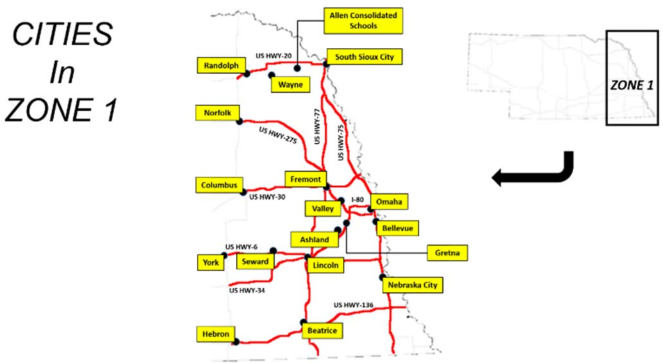

Figure 5: State map of Nebraska showing Zone 1 with all the Interstates and US-Highways with few cities on them

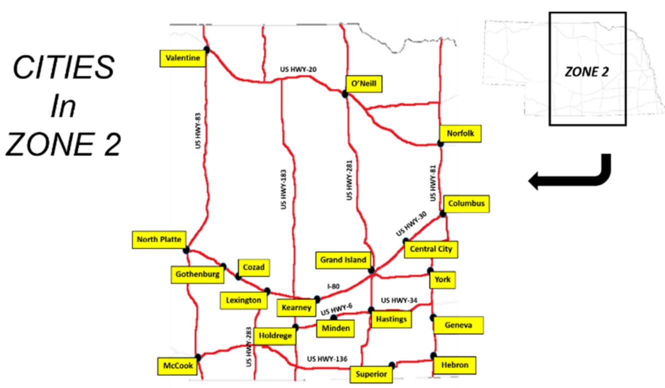

Figure 6: State map of Nebraska showing Zone 2 with all the Interstates and US-Highways with few cities on them

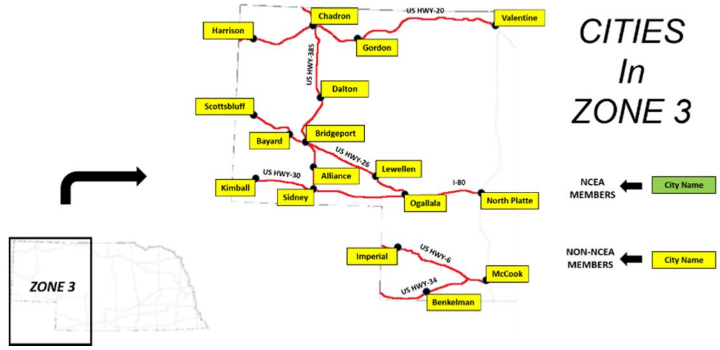

Figure 7: State map of Nebraska showing Zone 3 with all the Interstates and US-Highways with few cities on them

b) Prioritization method

After identifying the charging infrastructure's location, a prioritization method is applied as it would be very difficult to install all the proposed Electric Vehicle chargers at the same time, considering the financial budget of the respective state. In order to prioritize the locations the following preliminary factors are considered:

- Population of the city
- Number of Interstate(s)/ US-Highways that can be accessed from that location

As per the algorithm developed, any city that has a population greater than 10,000 will be installed with a charging infrastructure, in Nebraska. So, a ranking is designed accordingly and is shown in Table 1.

Table 1: Population and their weight factor

Population Range	**Weight Factor(W)**
> 10,000	10
5,000-10,000	9
1,000-5,000	8
< 1,000	7

The number of Interstate(s)/ US-Highways (n) are documented for each locations and the number n is multiplied by a factor of 10. Total score of each location is determined by the equation below:

$$TS= (n*10) + W$$

Where W is the weight factor from Table 1.

With the TS calculated for each location in each zone, priority 1, 2 and 3 are assigned as per Table 2.

Table 2: Priority schedules

Priority conditions	TS	Priority scenario

2 Interstate/ US-Highways & population greater than 5,000	29 & more	1
1 Interstate/ US-Highway & population greater than 5,000	19 – 28	2
1 Interstate/ US-Highways & population less than 5,000	18 & less	3

III. SIMULATION & RESULTS

Calculations show that a total of 101 charging station locations are required (three zones combined) in the state of Nebraska for the Electric Vehicle owners and the potential EV buyers to move in and about the state without any range anxiety. Figure 8 shows the locations where charging infrastructures need to be installed in the state map of Nebraska.

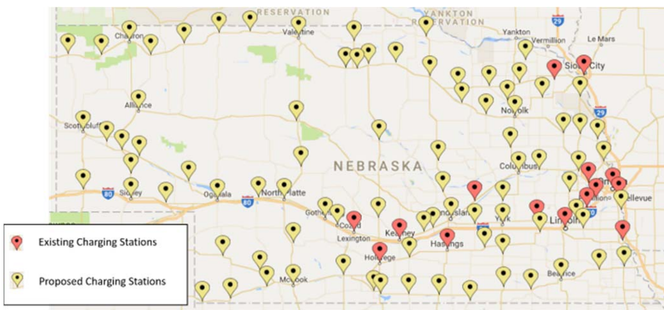

Figure 8: State map of Nebraska showing the possible locations for EV charging infrastructures

Prioritizing of these 101 locations are made. In Table 3 the results are shown as a sample, for Zone 1.

Table 3: Priority of the city's location in Zone 1

CITY NAME	POPULATION [12]	INTERSTATES/ US-HIGHWAYS ACCESSED	n	TS	PRIORITY
OMAHA	408258	I-80 and US-HWY-6, 34, 75, 275	5	60	**1**
LINCOLN	258379	I-80 and US-HWY-6, 34, 77	4	50	**1**
FREMONT	26397	US-HWY-30, 75, 275	3	40	**1**
BEATRICE	12459	US-HWY-77, 136	2	30	**1**
SOUTH SIOUX CITY	13353	US-HWY-20, 75	2	30	**1**
PLATTSMOUTH	6502	US-HWY-34, 75	2	29	**1**
SEWARD	6964	I-80 and US-HWY-34	2	29	**1**
BLAIR	7990	US-HWY-30, 75	2	29	**1**
ASHLAND	2453	I-80 and US-HWY-6	2	28	**2**
WAVERLY	3277	I-80 and US-HWY-6	2	28	**2**
AUBURN	3460	US-HWY-136, 75	2	28	**2**
GRETNA	4441	I-80 and US-HWY-6	2	28	**2**
WINNEBAGO	774	US-HWY-75, 77	2	27	**2**
BELLEVUE	50137	US-HWY-75	1	20	**2**
WAYNE	5660	US-HWY-20	1	19	**2**
SCHUYLER	6211	US-HWY-30	1	19	**2**
NEBRASKA CITY	7289	US-HWY-75	1	19	**2**
EAGLE	1024	US-HWY-34	1	18	**3**
OAKLAND	1244	US-HWY-77	1	18	**3**
TECUMSEH	1677	US-HWY-136	1	18	**3**
TEKAMAH	1736	US-HWY-75	1	18	**3**
VALLEY	1875	US-HWY-275	1	18	**3**
MILFORD	2090	US-HWY-6	1	18	**3**
WEST POINT	3364	US-HWY-275	1	18	**3**
FAIRBURY	3942	US-HWY-136	1	18	**3**
WAHOO	4508	US-HWY-77	1	18	**3**
ALLEN CONSOLIDATE D SCHOOLS	377	US-HWY-20	1	17	**3**
RANDOLPH	944	US-HWY-20	1	17	**3**

Table 4 gives us a summary of how many city locations fall in the three different priority categories in each of the zones. Figure 9, 10 and 11 shows the state map of Nebraska showing the city locations in each of the priority category. Different color schemes are used for the different priority category. Priority category 1 is depicted by color green. Priority category 2 is depicted by color red and Priority category 3 is depicted by color sky blue.

Table 4: Number of charging infrastructures in each priority category in each zone

Priority Category	**Zone 1**	**Zone 2**	**Zone 3**	Total
1	8	11	3	**22**
2	9	13	6	**28**
3	11	25	15	**51**
Total	**28**	**49**	**24**	**101**

Figure 9: Charging Infrastructures to be installed in Priority Category 1

Figure 10: Charging Infrastructures to be installed in Priority Category 2

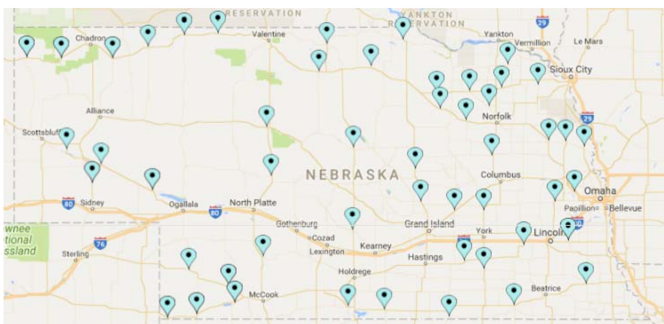

Figure 11: Charging Infrastructures to be installed in Priority Category 3

For the state of Nebraska, charging infrastructure locations in each priority category are so designed that in each phase of the installation, EV owners would benefit in each individual zones.

IV. CONCLUSION AND FUTURE SCOPE

A search algorithm is developed to identify the locations of electric vehicle charging infrastructure for a given state along its Interstate and US-Highways. For the state of Nebraska, 101 locations are identified when using the Nissan LEAF. The locations are then prioritized based on set criteria for future planning and deployment.

As for future work, each location will be further analyzed to determine the required number of charging ports to allow electric vehicle owners to move in and about the city without having any range anxiety. Factors in the determination will include key driving patterns, vehicle specifications, driving routes and forecasted data among others. An optimization technique will then be used to minimize waiting time for charging, idle rate of ports and cost. A city-readiness index will be formulated for each city in the state to determine whether a selected city location is market ready for electrified transportation and charging infrastructure. If a city is not ready, this index will aid in providing the necessary requirements and changes to make that city electric vehicle market ready.

ACKNOWLEDGEMENT

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APPENDIX 8.3

CONFERENCE PAPER - CHARACTERIZATION OF A SEARCH ALGORITHM TO DETERMINE NUMBER OF ELECTRIC VEHICLE CHARGING STATIONS BETWEEN TWO POINTS ON AN INTERSTATE OR US-HIGHWAY

Characterization of a Search Algorithm to Determine Number of Electric Vehicle Charging Stations between Two Points on an Interstate or US- Highway

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***Abstract*- An algorithm has been developed to calculate the number of charging infrastructures for a particular model of an electric vehicle when traveling between two points in a particular Interstate or US- Highway. The algorithm developed is essentially a search algorithm, incorporating many constraints in its formulation, including: range anxiety, rated mileage of the electric vehicle, population of the cities near the Interstate or US-Highway, and distance between origin city and destination city. A mathematical formula is modeled which calculates the real mileage of the electric vehicle which in turn is used in the search algorithm to determine the number of charging infrastructures to be installed.**

I. INTRODUCTION

Electric cars are the next big thing in the transportation industry, as an environmentally friendly way of getting around. With a lot of advancement in the field of battery technology, there has been a substantial growth in the total number of electric cars. It is seen that U.S. electric vehicle sales has seen a rise of 37% in 2016. With a 32% compound annual growth rate (CAGR) over the past four years, U.S. electric vehicles have made a great impact in the market. Globally, electric vehicles have seen a 72% rise in 2015 and a 41% rise in 2016 [1]. Having virtually no direct emissions, electric cars also have the advantage of using electric motors over the use of internal combustion engines, namely utilization of regenerative braking, where it recovers some of the energy lost as heat and friction. [2]

Though there are many advantages of using electric vehicles, one of the primary factors restricting the growth of the electric vehicle market is the lack of well distributed charging infrastructure network. In order to be market ready for electric vehicles, there need to be charging stations installed at strategic locations so that the electric vehicle users could go to their destination city without any range anxiety. Because of the range anxiety problem, electric vehicle users are not being able to travel a long distance, mainly along the Interstates or US Highways, and it is one of many reasons why electric cars are still not used as the primary car by their owners. The accessibility of the charging stations will ensure the electric vehicle users to adopt and use their electric vehicles as their primary vehicle [3]. In one of the research papers [4], the authors discussed the techniques to tackle range anxiety and also evaluate the capacity of battery required by the electric vehicle to reach a charging station.

There has been a lot of research work on location and placement of charging infrastructures for electric vehicles and their feasibility options. In paper [5], the authors discussed the charging locations to be installed in urban areas considering traffic density, limited space and other factors like the distribution of power grids. In paper [6], the author discussed developing of a model to determine the placement of electric vehicle charging stations in urban area, considering road network structure, traffic flow data, and distribution system capacity limitations. In paper [7], the authors analyzed the requirements for charging infrastructure requirements for plug in hybrid electric vehicles (PHEVs) under different situations including single-family residential, multi-family residential, and commercial situations. They also provided a cost analysis of the infrastructure in association with the deployment of PHEVs.

In paper [8], the authors developed an algorithm which determines the optimal number and placement of charging stations. This algorithm includes the economic constraint and minimizes the loss on the way to the charging station. Cologne, a city in Germany is used to validate their work. In paper [9], the authors incorporated the power systems constraints in determining the charging stations of the electric vehicles. The electric vehicles are voltage dependent and may cause voltage instabilities in the power system at peak loads. In [10], the authors presented a model which estimates the minimum number of charging infrastructures required along highway corridors and then optimizing these charging infrastructure's deployment. They consider a highway corridor in Texas, US to exhibit their findings. In [11], the authors discussed the charger location problems of electric vehicle and also evaluated the effect of public charging infrastructure deployment and increase in electric miles traveled. They develop an activity-based assessment method which determines the feasibility of BEVs in actual driving conditions, and then using a genetic algorithm to determine the optimal locations of public charging stations.

There are three levels of charging: Level 1 (slow) charging, Level 2 (semi-fast) charging and Level 3 (fast) charging. Residential charging is typically a Level 1 charging. Level 2 charging requires a 240 V outlet and can both be used as a private and public facilities charging. Level 3 and DC fast charging are typically used as commercial and public applications [19][20]. In this paper, as only Interstates and US Highways are considered for this algorithm, the charging infrastructure considered is the DC fast charging type when the time of recharging the battery is a major constraint.

An algorithm is developed to calculate the total number of charging stations along an Interstate or a US-Highway for a particular model of an electric car. It has been assumed that when the electric vehicle is leaving the origin city to the destination city, the car will be fully charged. Once the number of charging stations have been calculated, this number will help not only the electric vehicle users to check the maximum number of times they must stop to re-charge the battery, but also it will give an estimate to the manufacturing car companies about the number and location of the charging stations that needs to be installed in that particular corridor. This will in turn enhance the electric vehicle market.

The paper is organized as follows. Section II explains the search algorithm. A flowchart is shown for visualizing the plan of action. Section III shows the simulation and results for a particular section in Interstate-80 in Nebraska, US. Section IV discusses future scope of work and conclusion.

II. SEARCH ALGORITHM TO DETERMINE CHARGING STATION LOCATIONS

The algorithm is so modeled that when the city of origin of the travel and the destination is specified, the algorithm calculates the number of charging stations required in between for the electric vehicle to complete the trip. The type of charging station considered in this algorithm is Level-3 charging, i.e., DC fast charging. However, this algorithm will also work in similar manner for Level-2 charging. The reason for considering DC fast charging is because we are considering Interstates and US-Highways, and electric vehicle users will not be willing to wait for a longer period of time.

For calculation purposes of the algorithm, two databases are created for this process. The first database contains the required information for a specific U.S. state, including the interstates/ US-highways in it, the cities on the interstate/ US-Highway with their population, and the distance between each city based on a reference city for a specific U.S. state. This reference city is generally the origin city of travel. The second database lists all the electric vehicle manufacturers, with the model and rated mileage of the vehicle (m_a). Based on the value of m_a, a mathematical formula is formulated to calculate the real mileage of the electric vehicle m_r. The constraints, assumptions, and calculations in each database are defined to describe the process of the search algorithm.

The assumptions in the model developed to find the best charging infrastructure location between two cities are discussed as follows. The search algorithm looks in the database for cities in a state whose population is greater than *x*. The database would contain all the cities in or near the Interstate/ US-Highway. The *x* parameter will decide how the database will be checked by the algorithm for cities in an Interstate/ US-Highway. The value of *x* is so chosen that it excludes very small cities along the Interstate/ US-Highway, the reason being the utility company supplying these cities will have limited generation and sufficient infrastructure to provide for the electrical needs of the DC fast charging. This value of *x* will differ in different states, depending on the population per city of the state.

The second assumption has been made, that the cities with population greater than *y* will be installed with charging stations. This assumption is made because cities with population above *y* will have utility companies, which will have the potential to generate more power for the charging infrastructure. Also, cities having a population greater than *y*, will be installed with charging station in order to promote the growth of electric vehicle market and encouraging more and more people to drive electric cars. The value of *y* will also be different in different states. Both the values of *x* and *y* will depend on the state and utility companies of the cities, and it is to be determined before running the algorithm.

The electric vehicle model is selected first and the information is given as an input to the algorithm. The calculated mileage m_c, is then calculated using rated mileage m_a of the electric vehicle with added assumptions of the battery life, heating, ventilation and air conditioning (HVAC) system usage, and range anxiety. A critical component to an electric vehicle is the durability of the battery, which is greatly affected by how it is charged over time. A battery should not be depleted past 20% of its charge to maintain a good battery life. Also, for DC fast charging, 80% of the battery is recharged very quickly and the remaining 20% takes a very long time [12]. So, it can be calculated that we will be able to utilize 60% of the battery where the battery constraint accounts for 40% of m_a. The ambient temperature outside would also affect the battery and hence the mileage of the car. This is included in the 40% battery constraint, in our model.

Next, we consider that the electric vehicle uses the heating or air-conditioning when driving. If the windows are rolled down when driving on an interstate or U.S. highway, the drag force due to the speed will decrease the mileage of the electric vehicle to a greater extent. The usage of HVAC in the car will account for 10% of the calculated mileage m_c.

Also, the range anxiety of the driver will also affect the mileage of the electric car. The range anxiety [13] is the concern of the Electric Vehicle user of not having enough charge in the car to make it to the nearest charging station or destination. The range anxiety factor varies from individual to individual. In our model, we have considered that the range anxiety will account for 10% of the calculated mileage m_c.

First step will be to find the calculated mileage of the car m_c and is defined as,

$$m_c = m_a - 0.4m_a = 0.6m_a \qquad (1)$$

The second step will be to find the real mileage m_r of the car. The HVAC constraint and the range anxiety together account for 20% of the calculated mileage m_c. The real mileage of the car m_r becomes,

$$m_r = m_c - 0.2m_c = 0.8m_c \qquad (2)$$

The third step will be to substitute the calculated mileage m_c from Equation 1 into Equation 2, and we get

$$m_r = 0.8*(0.6m_a) = 0.48m_a \qquad (3)$$

The real mileage of the electric vehicle m_r is calculated using Equation 3. The distance d_i is defined as the distance between two cities on the Interstate or the US Highway whose population is greater than *x*. The total number of charging stations S_t, is calculated using the database created when origin city of travel and destination is specified. S_t is calculated using the two components S_i and S_d. The values of S_i and S_d are explained as follows. S_i is defined as,

$$S_i = \lfloor d_i/m_r \rfloor \qquad (4)$$

where $\lfloor\ \rfloor$ returns the integer value of d_i/m_r which gives us the value of the number of charging stations between two cities that needs to be implemented along the way. Sd is defined as,

$$S_d = d_i/m_r - S_i \qquad (5)$$

The value of S_d returns a decimal number and this value is used to decide whether there needs to be a charging station in the next city. In this paper, it has been considered that if the decimal part S_d is more than 0.45, a charging station needs to be installed in the next city. If the decimal part is less than 0.45 then a charging station is not required in the next city. This assumption has been made based on the fact that if the electric vehicle user decides to return from the next city, one will have enough charge to the nearest charging station. 0.45 signifies the percentage of miles utilized by the electric car.

The search algorithm checks whether the next city is the destination city or not. If the next is the destination city, then the algorithm stops, and the final number of charging stations are calculated. If the next city is not the destination city, then two cases can be studied.

CASE I: The next city does not require a charging infrastructure to be installed. In this scenario, the last city where a charging station has been assigned by the algorithm, is marked as the source city and the next city on the database, whose population is greater than *x* is used to calculate the distance (d_i) between these two cities. The calculations are repeated to check the number of charging infrastructures in between the two cities.

CASE II: The next city do require a charging infrastructure to be installed. In this case, the next city is marked as the source city and the next city on the database, whose population is greater than *x* is used to calculate the distance (d_i) between these two cities. The calculations are repeated to calculate the number of charging infrastructures in between these two cities.

The algorithm continues until the destination city specified is reached on the database. The charging infrastructures are then added to find the total number of charging infrastructures in between the source city and destination city for a specific model of the electric vehicle. A flowchart of the search algorithm is shown in Figure 1.

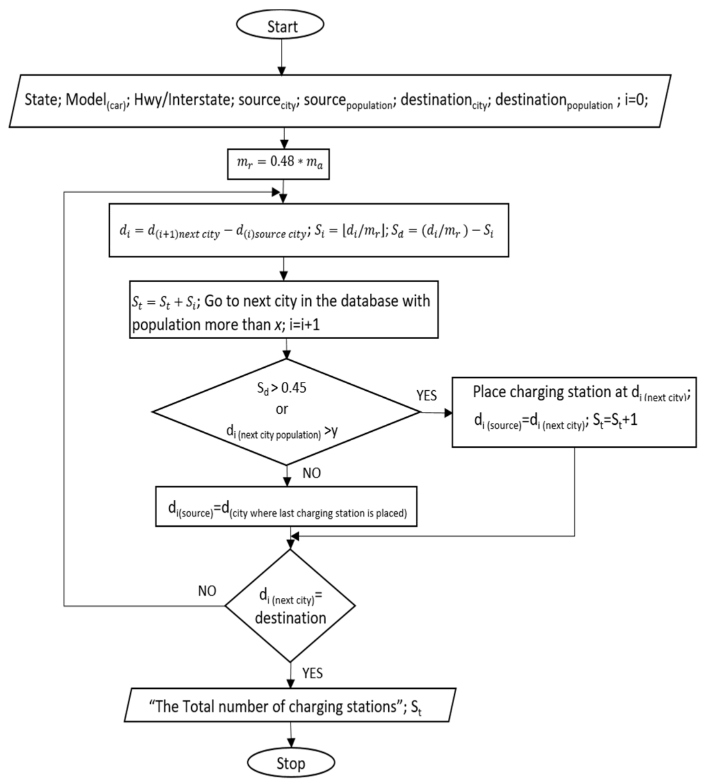

Figure 1: Flow chart of the search algorithm to determine best charging infrastructure location on a given Interstate or US-Highway

III. SIMULATION & RESULTS

In this section, simulation and results are shown. The algorithm was realized in MATLAB platform. Two databases were created and imported to the MATLAB program. The model of the electric car is specified to the program. The information on the source city and the destination is also put in the algorithm. The algorithm then calculates the number of charging stations. The number of charging stations suggests the electric vehicle user as to how many times they must stop to recharge their car and also they get an idea in which cities the charging infrastructures are located. This algorithm helps to build a private charging station network specific to a particular model of the electric car.

In order to validate the algorithm, a test case is shown. The state of Nebraska in US is considered and Interstate-80 is selected. A corridor is selected in Interstate 80 from the city of Lexington to Sutherland city. 2016 Nissan Leaf Model S24 is chosen from the electric car database. The value of x and y in Nebraska is set to be 1,000 and 10,000 respectively. Database showing the number of cities located in between Lexington and Sutherland, along with their population is provided in Table 1. Subsequently, the calculations and explanations for each iteration is described next.

Table 1: Database containing all the city names on Interstate-80 in Nebraska, USA with their population and the distance from the reference city which is Lexington

City Name	**Population** [14]	**Distance (cumulative) (miles)**
Lexington	10,230	0
Cozad	3,977	16.9
Gothenburg	3,574	24.8
Brady	428	39.8
Maxwell	312	48.3
North Platte	24,733	61.6
Hershey	665	73.6
Sutherland	1,286	80.0

The rated mileage m_a of Nissan Leaf 2016 Model S24 is **84** miles [15]. In the algorithm m_r will be calculated as **40.32** miles.

One assumption that is made while making the calculations is that the electric car is fully charged when leaving the origin city which is Lexington in this case. The values of x and y are already set.

Table 2, 3, 4 and 5 shows the different iteration processes to find the number of charging station locations.

On the first iteration, Table 2 is generated.

Table 2: Information provided from the first iteration

i	0
$d_0 = d_{1(\text{next city})} - d_{0(\text{source})}$	16.9 miles
m_r	40.32
$S=d_0/m_r$	0.419
$S_i = \lfloor S \rfloor$	0
S_d=0.419	<0.450, so S_t=0

From the first iteration in Table 2, there will be no charging station placed in between Lexington and Cozad. The source city will remain Lexington. So, the algorithm checks for the next city which has population more than x i.e., 1,000. So, the next city from the database will be Gothenburg.

On the second iteration, Table 3 is generated.

Table 3: Information provided from the second iteration

i	1
$d_1 = d_{2(\text{next city})} - d_{1(\text{source})}$	24.8 miles
m_r	40.32
$S=d_1/m_r$	0.615
$S_i = \lfloor S \rfloor$	0
S_d=0.615	>0.450, so S_t=1

In the second iteration, one charging station is required to be installed in Gothenburg. In the next iteration, the source city will be Gothenburg and the algorithm checks for the next city which have population more than x i.e., 1,000. The next city from the database will be North Platte.

On the third iteration, Table 4 is generated.

Table 4: Information provided from the third iteration

i	2
$d_2 = d_{3(\text{next city})} - d_{2(\text{source})}$	36.8 miles
m_r	40.32
$S=d_2/m_r$	0.91
$S_i = \lfloor S \rfloor$	0
S_d=0.910	>0.450, so S_t=2

North Platte has a population greater than y, i.e., 10,000. So, North Platte will be installed with a charging infrastructure irrespective of the value of S_d i.e., 0.91. In this case, though the value of S_d is greater than 0.45, however, if the value had been less than 0.45, then also North Platte would have been installed with a charging station. In the next iteration, the source city will be North Platte and the algorithm checks for the next city which have population more than x i.e., 1,000. The next city from the database will be Sutherland.

On the fourth iteration, Table 5 is generated.

Table 5: Information provided from the fourth iteration

i	3
$d_3 = d_{4(\text{next city})} - d_{3(\text{source})}$	18.4 miles
m_r	40.32
$S=d_3/m_r$	0.456
$S_i = \lfloor S \rfloor$	0
S_d=0.456	>0.450, so S_t=3

From Table 5, Sutherland must be installed with a charging station. The value of S_d is slightly over 0.45. After Sutherland has been assigned with a charging station, it is also observed that the destination city is reached. The algorithm stops and displays the total number of charging stations required to travel from Lexington to Sutherland covering a length of 80 miles. It is observed that the algorithm does not include cities like Brady, Maxwell and Hershey on account of their population.

Once the number of stations have been determined, this model allows travel in either directions. In this case, it is determined that three charging stations in Interstate-80, Nebraska corridor from Lexington to Sutherland are required. Once the charging stations are installed in their respective places, the electric car can travel from any place in this corridor and the location of the charging stations would be the same.

Figure 2 gives the locations where the charging stations would be placed and Figure 3 shows the result from the MATLAB program. Figure 4 shows the coverage area of the electric vehicle from the location of the charging station which are proposed.

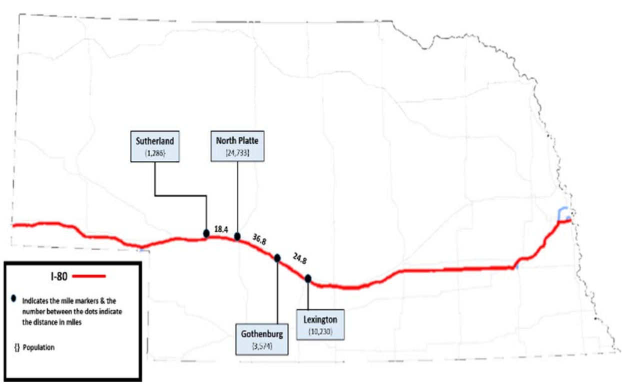

Figure 2: A map of Nebraska, USA showing the corridor in Interstate-80 with cities having a population greater than 1,000 installed with a charging infrastructure

```
number of stations: 3
City: Lexington, Population: 10230, distance: 0.000000
City: Gothenburg, Population: 3574, distance: 24.800000
City: North Platte, Population: 24733, distance: 36.800000
City: Sutherland, Population: 1286, distance: 18.400000
>>
```

Figure 3: The results from the MATLAB program.

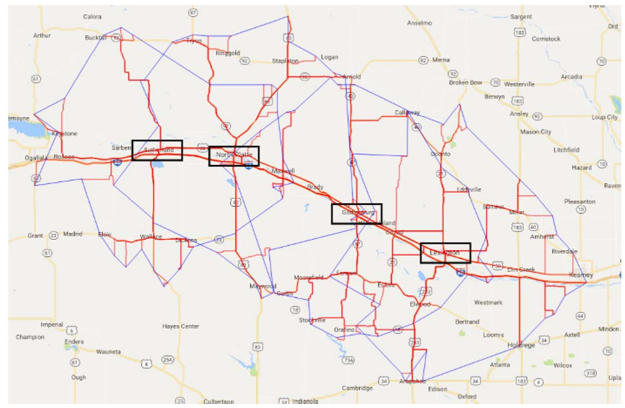

Figure 4: Coverage area of the electric vehicle from the charging station proposed and the origin city.

IV. CONCLUSION AND FUTURE SCOPE

In this paper an algorithm has been modeled and then simulated using the MATLAB software for determining the location of the electric vehicles charging stations along an Interstate or US Highway. Various constraints such as range anxiety, good battery life, actual mileage of the electric car and population of the cities in consideration, are incorporated within the algorithm. The algorithm then determines the total number of required charging stations in a corridor of Interstate or US-Highway when driving a specific model of the electric car. This algorithm has many advantages. Once the number of charging stations and their locations are determined, the travel can be bi-directional. Also the algorithm is flexible, i.e., it can include the existing charging stations and then propose the new charging station locations. The information on the location of the charging infrastructures will help to plan to incorporate the charging stations in these cities.

As for future work, a city-readiness index [16] needs to be modeled to validate the location of the electric car charging stations that the algorithm determines. The city readiness index will also help to validate the values of x and y. This index can also help to determine whether the city where the charging stations need to be installed is ready for electric vehicles in all aspects. If the city is not adequate enough, this index will help the city to make the necessary changes to get itself electric vehicle market ready.Also, the algorithm that is modeled in this paper is very conservative. It uses only 48% of the actual mileage of the electric car. This gives us the total number of charging stations under the worst case scenario. Future scope of work may include the calculation of actual percentage of the battery that is being utilized under real conditions. A real time range indicator once developed, will alert the driver about the actual State of Charge (SoC) of the battery and will mitigate range anxiety [17][18]. This might vary from place to place if the weather of the place, geographical conditions of the place are taken into account. Also, the driving styles of different electric vehicle users will have an impact on the percentage of mileage being utilized.

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APPENDIX 8.4

CONFERENCE PAPER - CASE STUDIES VALIDATING ALGORITHM TO DETERMINE THE NUMBER OF CHARGING STATION PLACED IN AN INTERSTATE AND US-HIGHWAY

Case Studies validating algorithm to determine the number of charging station placed in an Interstate and US-Highway

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***Abstract-* Determining the location for electric vehicles charging stations within a particular area of interest can be a key factor for a successful deployment. In this paper, an algorithm is developed which calculates the total number of charging stations for a particular model of electric vehicle in an Interstate and US-Highway in between two point cities. The algorithm takes into account design factors such as range anxiety, rated mileage of the electric vehicle, population of the cities near the Interstate and US-Highway, and distance between start-point and end-point. Two case studies have been shown for the state of Nebraska, USA with two different models of electric vehicles, to validate the algorithm.**

I. INTRODUCTION

In the recent past, there has been a considerable growth of total electric vehicles, taken into the fact that there has been a rapid development in the production of advanced batteries. Electric vehicles produce no direct emissions which is a great benefit to the environment. Electric motors are more advantageous than internal combustion engines, which benefits from the energy-saving techniques, such as regenerative braking where some of the energy, lost as heat and friction, is recovered [1].

Electric vehicles market is set to see a rapid growth and mass acceptance, which is driven by the willingness to reduce environmental impacts and establish energy independence. Due to primary three reasons, mainly the price of an electric vehicle, recharging time and lack of information about battery and distance to charging stations, people are not inclined towards buying electric vehicles. One of the greatest factor that is hindering this growth, is the fact that there are not enough charging infrastructures, spread out over the country. This is causing range anxiety among the electric vehicle users and potential future users. Previous research has been done to tackle the range anxiety problem. Mahmoud Faraj and Otman Basir in their paper discusses about techniques to minimize range anxiety, which analyzes the battery capacity the electric vehicle will require to reach a charging station and the users are not left stranded [2]. Due to range anxiety, electric vehicle users are not confident enough to travel a long distance, and it is one of the main reasons, users do not use their electric vehicles as their primary car.

Recently, research has been conducted on the placement of charging stations for electric vehicles. In [3], the authors discuss the planning model of electric vehicle charging stations in an urban area, taking into consideration road network structure, information on vehicle flow, structure of distribution system capacity constraints [3]. The authors in [4] proposes an optimized algorithm to find the optimal number and placement of charging station, minimizing loss on the way to the charging station, and taking the economic constraint into account. They consider a city in Germany, Cologne to validate their findings. On the other hand, the work in [5] discusses the planning of electric vehicle charging stations based on power systems constraints. The voltage dependent nature of the electric vehicle may lead to voltage instabilities in the power system. Sathaye, Nakul, and Scott Kelley, in their paper presents an approach which gives an estimation of minimum charging infrastructure needed and optimization of these infrastructure's deployment along highway corridors [6]. The highway corridor they considered is for the state of Texas, and it does not run through the whole of the state.

In this paper, we develop and apply an algorithm to calculate the total number of charging stations along an Interstate and a US-Highway running across the whole state of Nebraska, USA. The charging infrastructures considered are the DC fast chargers because charging time in a Highway will be a major concern for the electric vehicle user. Assumption has been made that when the electric vehicle leaving the city to its destination will be fully charged. This algorithm helps to calculate the total number of charging stations required for a specific model of an electric vehicle. This information will not only help the users to check the maximum number of times they must stop to charge, but also help the manufacturing car companies to estimate the position of the placement of the charging stations for their model of the car. This will be helpful to boost the electric vehicle market. The total number of charging stations calculated in this paper gives the maximum value, and the user may boost the range of their cars, depending on their driving style.

The rest of the paper is organized as follows. Section II introduces the search algorithm. The simulation results of selected cases are presented in Section III and conclusion and future scope of work is discussed in Section IV.

II. CHARGING STATION PLACEMENT ALGORITHM

In developing the proposed algorithm, databases were created for a particular Interstate or US-Highway in a particular state in USA. It contains information about the number of cities on the Interstate or US-Highway with their population, and the distance between each city based on a reference city. Next specific car model was chosen. The value of rated mileage m_a, is known for the specific model of the electric car. A mathematical formula is then developed, to calculate the real mileage of the electric vehicle m_r.

To facilitate better battery life, a battery should not be deep discharged or fully charged. For calculation purposes, it is proposed that the battery is not allowed to be depleted past 20% of its charge, and should not be charged more than 80% at one time [7]. Assumption has been made that the electric vehicle will have its heating, ventilation and air conditioning (HVAC) on while driving on Interstate or US Highway, otherwise, the drag force due to the speed will decrease the mileage of the electric vehicle greatly. This will account for 10% of the remaining mileage, along with range anxiety which will account for 10% as well. This will give us the real mileage of the car which is:

$$m_r = 0.48 \times m_a \qquad (1)$$

After the calculation of m_r, the algorithm will search the databases for the cities located within its range. Assumption has been made that the algorithm will only consider cities which have a population greater than x. The x value will vary in different states, depending on the utility regulations, state policies and other factors.

Another population parameter y is proposed. The value of y is so chosen that it promotes electric vehicle market in a populated city in a particular state, and this value will be based on city regulations and utility companies. Any city which has a population more than y, the city will be installed with a charging infrastructure.

The distance d_i will be calculated next after the cities are selected. d_i is the distance between two cities on the Interstate or the US Highway whose population is greater than x. The number of charging stations S_t are then calculated by the formula,

$$S_t = d_i/m_r \qquad (2)$$

Next, the integer value of S, i.e., $S_{ti} = \lfloor S_t \rfloor$ and the decimal part of S_t, i.e., $S_{td} = S_t - S_{ti}$ are calculated for further investigations. The value of S_{ti} gives the number of charging stations in between two cities and the value of S_{td} decides whether charging station will be placed in the next city or not. If the value of S_{td} is greater than 0.45 or the population of the next city is greater than y, then charging infrastructure will be installed in that city. Then the algorithm will check if the next city is the destination or not. If it is not, then the reference city will be changed depending on the location of the charging station, and the algorithm will continue with the iterations.

After all the iterations are done, the sum of S_{ti} and S_{td} will give the total number of charging stations that will allow an electric vehicle user to move from the source city to the destination city in an Interstate/ US-Highway without having range anxiety. A flow chart of the search algorithm is shown in Figure 1.

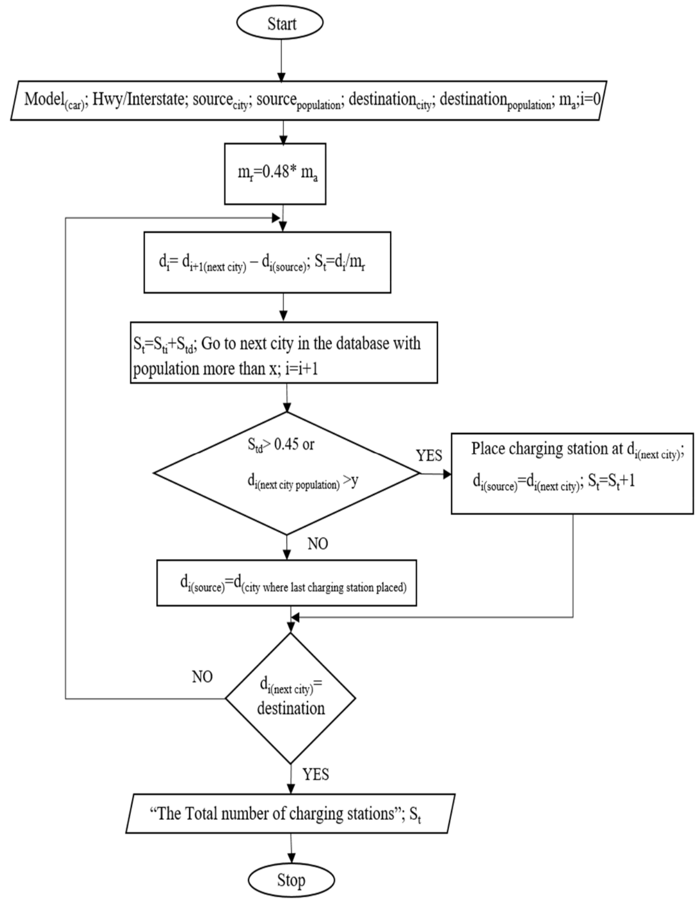

Figure 1: Flow chart of the search algorithm to determine best charging infrastructure location on a given Interstate or US-Highway

III. SIMULATION & RESULTS

In this section, simulation and results are shown. In order to show these simulations, the state of Nebraska is considered and two of the most used Interstate and US-Highway is considered. To achieve the number of charging infrastructures required for an electric car of a specific model to travel from initial point to the final point, two databases are created which are shown in Table 1 and Table 4. Maps showing Interstate-80 and US-Highway 34, Nebraska, USA, with all the cities on it having population more than the x-parameter which is 1,000 is given in Figure 2 and Figure 3.

Then a specific model of the car is considered and with the help of the search algorithm, charging infrastructures are placed at the desired points and finally the total number of charging infrastructures in the particular Interstate/ US-Highway are calculated and shown.

Two case studies are made. Case Study 1 is for Interstate-80, Nebraska and Case study II is for US-Highway34. Two makes of the electric car are considered, Nissan Leaf 2016 Model S24 and Tesla Model S60 2016. The reason for considering these two particular model of electric car is because the Nissan Leaf is affordable with a good range and Tesla, though expensive has exceptionally well range.

CASE STUDY I: INTERSTATE-80, NEBRASKA, USA

Start Point City: Omaha, NE; Destination City: Kimball, NE; x parameter: 1,000; y parameter: 10,000 (Assumptions)

Table 1: Database I containing all the city names on Interstate-80 in Nebraska, USA with their population and the distance from the reference city which is Omaha

City Names	Population [8]	Distance (cumulative) (in miles)	City Names	Population [8]	Distance (cumulative) (in miles)
Omaha	408,958	0	Cozad	3,977	230
Gretna	4,441	19.6	Gothenburg	3,574	240
Ashland	2,453	26.5	Brady	428	253
Greenwood	568	31.6	Maxwell	312	262
Waverly	3,277	40.1	North Platte	24,733	275
Lincoln	258,379	51.4	Hershey	665	287
Seward	6,964	73.3	Sutherland	1,286	294
York	7,766	99.2	Paxton	523	306
Henderson	991	110	Ogallala	4,737	325
Aurora	4,479	120	Brule	326	335
Doniphan	829	140	Big Springs	400	344
Wood River	1,325	152	Chappell	929	366
Shelton	1,059	161	Lodgepole	318	382
Gibbon	1,833	167	Sidney	6,757	392
Kearney	30,787	180	Potter	337	413
Elm Creek	901	195	Dix	255	422
Overton	594	204	Kimball	2,496	431
Lexington	10,230	215			

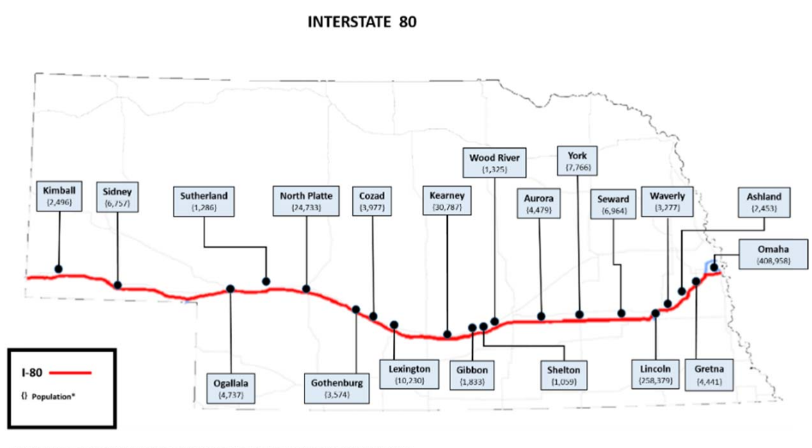

Figure 2: A map of Nebraska, USA showing Interstate-80 with cities having a population greater than 1,000

With the help of the database I and the search algorithm, the charging infrastructures are calculated and are shown in Table 2 and Table 3. First the distance d_i is calculated and m_r is calculated for the specific model of the electric car. Next S_t is calculated. S_{ti} and S_{td} found accordingly. The arguments are checked and decision on the placement of charging infrastructure is made.

(a) Nissan Leaf 2016 Model S24 (Rated mileage [9] (m_a): 84 miles; Actual mileage (m_r): 0.48*m_a=40.32 miles)

Table 2: Simulations for Nissan Leaf using Database I

i^{th} iteration	Distance (in miles) $d_i = d_{i+1(next\ city)} - d_{i(source)}$	m_r	$S_t=d_i/m_r$	S_{ti}=Integer part of S_t	Decimal part of S_t	S_{td} (cumulative)
1	19.6-0=19.6	40.32	0.486	0	>0.45	1
2	26.5-19.6=6.9	40.32	0.171	0	<0.45	1
3	40.1-19.6=20.5	40.32	0.508	0	>0.45	2
4	51.4-40.1=11.3	40.32	0.280	0	<0.45 but y>10,000	3
5	73.3-51.4=21.9	40.32	0.543	0	>0.45	4
6	99.2-73.3=25.9	40.32	0.642	0	>0.45	5
7	120-99.2=20.8	40.32	0.516	0	>0.45	6
8	152-120=32	40.32	0.794	0	>0.45	7
9	161-152=9	40.32	0.223	0	<0.45	7
10	167-152=15	40.32	0.372	0	<0.45	7
11	180-152=28	40.32	0.694	0	>0.45 also y>10,000	8
12	215-180=35	40.32	0.868	0	>0.45 also y>10,000	9
13	230-215=15	40.32	0.372	0	<0.45	9
14	240-215=25	40.32	0.620	0	>0.45	10
15	275-240=35	40.32	0.868	0	>0.45 also y>10,000	11
16	294-275=19	40.32	0.471	0	>0.45	12
17	325-294=31	40.32	0.769	0	>0.45	13
18	392-325=67	40.32	1.662	1	>0.45	14
19	431-392=39	40.32	0.967	0	>0.45	15
				$\sum S_{ti}=1$		$\sum S_{td}=15$

$\sum S_t = \sum S_{ti} + \sum S_{td} = 1+15=16$; It can be seen that while driving a Nissan leaf 2016 S24, from Omaha to Kimball using Interstate-80, Nebraska, USA, a total number of 16 charging stations will be needed.

(b) Tesla Model S60 2016 (Rated mileage [10] (m_a): 219 miles; Actual mileage (m_r): 0.48*m_a=105.12 miles)

Table 3: Simulations for Tesla using Database I

i^{th} iteration	Distance (in miles) $d_i = d_{i+1(next\ city)} - d_{i(source)}$	m_r	$S_t=d_i/m_r$	S_{ti}=Integer part of S_t	Decimal part of S_t	S_{td} (cumulative)
1	19.6-0=19.6	105.12	0.186	0	<0.45	0
2	26.5-0=26.5	105.12	0.252	0	<0.45	0
3	40.1-0=40.1	105.12	0.381	0	<0.45	0
4	51.4-0=51.4	105.12	0.489	0	>0.45 also y>10,000	1
5	73.3-51.4=21.9	105.12	0.208	0	<0.45	1
6	99.2-51.4=47.8	105.12	0.454	0	>0.45	2
7	120-99.2=20.8	105.12	0.198	0	<0.45	2
8	152-99.2=52.8	105.12	0.502	0	>0.45	3
9	161-152=9	105.12	0.086	0	<0.45	3
10	167-152=15	105.12	0.143	0	<0.45	3
11	180-152=28	105.12	0.266	0	<0.45 but y>10,000	4
12	215-180=35	105.12	0.333	0	<0.45 but y>10,000	5
13	230-215=15	105.12	0.143	0	<0.45	5
14	240-215=25	105.12	0.238	0	<0.45	5
15	275-215=60	105.12	0.571	0	>0.45 also y>10,000	6
16	294-275=19	105.12	0.181	0	<0.45	6
17	325-275=50	105.12	0.476	0	>0.45	7
18	392-325=67	105.12	0.637	0	>0.45	8
19	431-392=39	105.12	0.371	0	<0.45	8
				$\sum S_{ti}=0$		$\sum S_{td}=8$

$\sum S_t = \sum S_{ti} + \sum S_{td} = 0+8=8$; It is seen that driving a Tesla Model S60 2016 from Omaha to Kimball using Interstate-80, Nebraska, USA, a total number of 8 charging stations will be needed.

CASE STUDY II: US-HIGHWAY 34, NEBRASKA, USA

Start Point City: Plattsmouth, NE; Destination City: McCook, NE; x parameter: 1,000; y parameter: 10,000 (Assumptions)

Table 4: Database II containing all the city names on US-Highway 34 in NE, USA with their population and the distance from the reference city which is Plattsmouth

City Names	Population [8]	Distance (cumulative)(in miles)	City Names	Population [8]	Distance (cumulative)(in miles)
Plattsmouth	6,502	0	Heartwell	71	192
Weeping Water	1,050	26.5	Minden	2,923	202
Eagle	1,024	41	Axtell	726	211
Lincoln	258,379	55.8	Funk	194	218
Malcolm	382	68.4	Holdrege	5,495	225
Seward	6,964	80.7	Atlanta	131	232
Utica	861	94.7	Edison	133	251
York	7,766	108	Arapahoe	1,026	257
Hampton	423	123	Holbrook	207	264
Aurora	4,479	128	Cambridge	1,063	271
Grand Island	48,520	150	Bartley	283	279
Doniphan	829	157	Indianola	584	284
Hastings	24,907	171	McCook	7,698	297
Juniata	755	177			

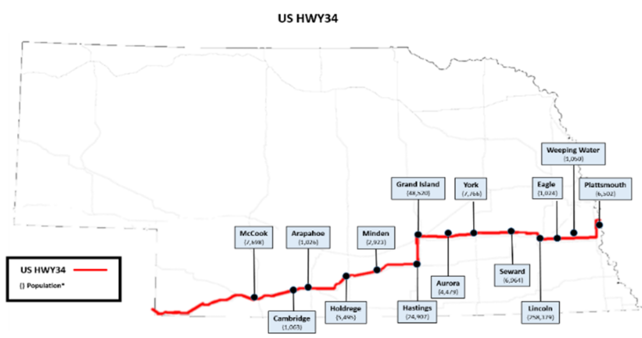

Figure 3: A map of Nebraska, USA showing US-Highway 34 with cities having population greater than 1,000

Similarly like Interstate-80 calculations, with the help of the database II and the search algorithm, the charging infrastructures are calculated for US-Highway 34 and are shown in Table 5 and Table 6.

(a) Nissan Leaf 2016 Model S24 (Rated mileage [9] (m_a): 84 miles; Actual mileage (m_r): 0.48*m_a=40.32 miles)

Table 5: Simulations for Nissan Leaf using Database II

i^{th} iteration	**Distance (in miles) $d_i = d_{i+1(next\ city)} - d_{i(source)}$**	**m_r**	**$S_t = d_i/m_r$**	**S_{ti}=Integer part of S_t**	**Decimal part of S_t**	**S_{td} (cumulative)**
1	26.5-0=26.5	40.32	0.657	0	>0.45	1
2	41-26.5=14.5	40.32	0.359	0	<0.45	0
3	55.8-26.5=29.3	40.32	0.727	0	>0.45 also y>10,000	2
4	80.7-55.8=24.9	40.32	0.618	0	>0.45	3
5	108-80.7=27.3	40.32	0.677	0	>0.45	4
6	128-108=20	40.32	0.496	0	>0.45	5
7	150-128=22	40.32	0.546	0	>0.45 also y>10,000	6
8	171-150=21	40.32	0.521	0	>0.45 also y>10,000	7
9	202-171=31	40.32	0.768	0	>0.45	8
10	225-202=23	40.32	0.570	0	>0.45	9
11	257-225=32	40.32	0.794	0	>0.45	10

12	271-257=14	40.32	0.347	0	<0.45	10
13	297-257=40	40.32	0.992	0	>0.45	11
				$\sum S_{ti}=0$		$\sum S_{td}=11$

$\sum S_t=\sum S_{ti}+\sum S_{td}=0+11=11$; It is seen that driving a Nissan leaf 2016 S24, from Plattsmouth to McCook using US-Highway34, Nebraska, USA, a total number of 11 charging stations will be needed.

(b) Tesla Model S60 2016 (Rated mileage [10] (m_a): 219 miles; Actual mileage (m_r): $0.48*m_a$=105.12 miles)

Table 6: Simulations for Tesla using Database II

i^{th} iteration	Distance (in miles) $d_i = d_{i+1(next\ city)} - d_{i(source)}$	m_r	$S_t=d_i/m_r$	S_{ti}=Integer part of S_t	Decimal part of S_t	S_{td} (cumulative)
1	26.5-0=26.5	105.12	0.252	0	<0.45	0
2	41-0=41	105.12	0.39	0	<0.45	0
3	55.8-0=55.8	105.12	0.531	0	>0.45 also y>10,000	1
4	80.7-55.8=24.9	105.12	0.237	0	<0.45	1
5	108-55.8=52.2	105.12	0.497	0	>0.45	2
6	128-108=20	105.12	0.190	0	<0.45	2
7	150-108=42	105.12	0.399	0	<0.45 but y>10,000	3
8	171-150=21	105.12	0.199	0	<0.45 but y>10,000	4
9	202-171=31	105.12	0.295	0	<0.45	4
10	225-171=54	105.12	0.514	0	>0.45	5
11	257-225=32	105.12	0.304	0	<0.45	5
12	271-225=46	105.12	0.438	0	<0.45	5
13	297-225=72	105.12	0.685	0	>0.45	6
				$\sum S_{ti}=0$		$\sum S_{td}=6$

$\sum S_t=\sum S_{ti}+\sum S_{td}=0+6=6$; It is seen that driving a Tesla Model S60 2016, from Plattsmouth to McCook using US-Highway34, Nebraska, USA, a total number of 6 charging stations will be needed.

IV. CONCLUSION AND FUTURE SCOPE

In this paper an algorithm has been designed and simulated for the placement of electric vehicles charging stations along an Interstate US Highway. In doing so, various factors have been considered such as range anxiety, betterment of battery life, distance between start point and end point, mileage of the car in consideration and population of the cities in consideration. The search algorithm gives us an estimate of the number of charging stations required in a particular corridor of Interstate or US-Highway when driving a specific make of the electric car. With this knowledge, planning can be made ahead so as to prepare with the installation of the charging infrastructures.

As for future work, a city-readiness index [11] can be formulated to validate the positioning of the electric car charging stations that is determined by the use of this algorithm. The city readiness index will determine whether the city where the charging stations need to be placed is market ready for electric vehicles. If not, the index will help to make the necessary changes to make the city electric vehicle market ready.

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