

MA615 Final Project

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Introduction

Background

Nowadays, we can see more and more electric vehicles in the streets than we used to do. Electric cars have many obvious advantages comparing to gasoline cars. For instance, Tesla, as one of the largest electric vehicle manufacturer, has earned a reputation from customers. It is also important to know that all the models that Tesla has sold were electric vehicles. This means that electric vehicle business has started to get prosper.

By this notion, I would like to check the distribution of electric vehicle charging station to get a better understanding on how convenient it would be for electric vehicle owner to recharge.

Task

In this report, I would like to use the data of eletric vehicle charging stations in the U.S. and Canada to see if there is a trend in the distribution of electric vehicle charging stations on this continent. Moreover, I will construct maps and a ShinyApp to better examine the data.

Data

The data I obtained was from the U.S. Department of Energy, and their website is https://afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC. From the description, there are 28,347 charging stations and 79,853 chargin outlets in the U.S. and Canada. Hence it would be less effective to process this amount of data through API.

```
## Extract the data and check for the number of variables
data_raw<- read.csv("~/Desktop/BU/MA615/FinalProj/alt_fuel_stations.csv")
length(data_raw)

## [1] 64
```

Variables

As we can see, there are 64 variables in this dataset but many of them has missing values or even missing columns. Thus we need to clean the data before we carry out any further study.

```
## Remove the empty columns
data_0<- remove_empty(data_raw, c("cols"))
length(data_0)

## [1] 40
```

We first removed 24 empty columns. Then we should remove those columns with variables which are vague and not useful to our study. For example, “expected_date” represent “the date the station is expected to open or start carrying alternative fuel”.

However, this step could be subjective and we should be careful with it.

Exploratory Data Analysis

Cross Country Comparison

```
##      CA      US  
##  4843 23504
```

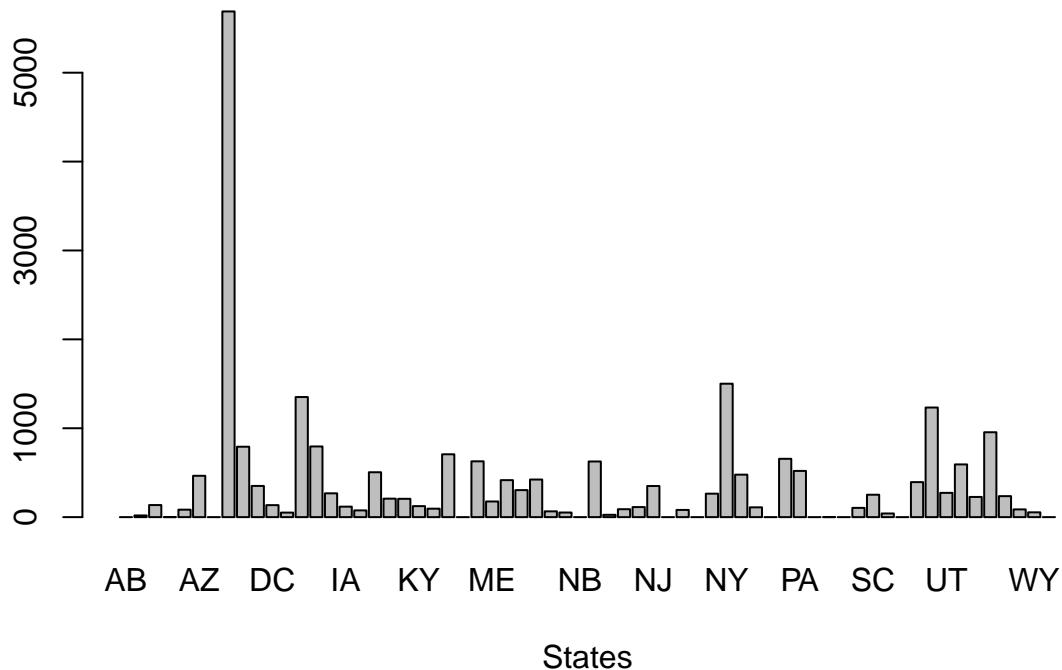
We can see that in 28,347 charging stations, 23,504 are in the United States and only 4,843 are in Canada. This can be due to several reasons. First reason could be that Tesla, one of the largest electric vehicle manufacturer is an American corporation. The second reason might be that electric vehicles tend to perform better in lower latitude area because cold weather might lower the performance of the battery.

Inside U.S.

By States

##	AB	AK	AL	American Samoa	AR
##	0	19	136	1	84
##	AZ	BC	CA	CO	CT
##	465	0	5689	792	351
##	DC	DE	FL	GA	HI
##	135	51	1351	795	268
##	IA	ID	IL	IN	KS
##	118	76	505	208	206
##	KY	LA	MA	MB	MD
##	124	95	707	0	628
##	ME	MI	MN	MO	MS
##	176	416	304	423	65
##	MT	NB	NC	ND	NE
##	52	0	626	26	89
##	NH	NJ	NL	NM	NS
##	113	350	0	81	0
##	NV	NY	OH	OK	ON
##	264	1501	478	110	0
##	OR	PA	PE	Puerto Rico	QC
##	656	520	0	1	0
##	RI	SC	SD	SK	TN
##	104	252	41	0	394
##	TX	UT	VA	VT	WA
##	1233	273	593	227	955
##	WI	WV	WY	YT	
##	236	87	54	0	

Charging stations in U.S.



As we could see that inside U.S., California has the most charging stations. This might be due to the weather and the location of headquarter of Tesla, or it might be due to the large size of California.

By Cities

##	Los Angeles	New York	San Diego	Atlanta	Austin
##	517	317	290	272	264
##	Seattle	San Francisco	Baltimore	Kansas City	Irvine
##	191	187	168	168	166

As we can see, 10 cities in the U.S. with the most charging stations are listed above. Four our of ten, which are Los Angeles, San Diego, San Francisco and Irvine, are located in California. This would meet up with my notion above.

By ZIP Codes(Counties)

##	92618	94025	92101	98004	95054	95814	93446	80202	94538	21201
##	74	60	50	50	46	46	43	42	42	41

Furthermore, let's check on the ZIP code in U.S. The 10 areas/counties with the most charging stations are Orange County/92618(Irvine, California), San Mateo County/94025(Menlo Park, California), San Diego/92101(California), King County/98004(Bellevue, Washington), Santa Clara County/95054(California), Sacramento/95814(California), San Luis Obispo County/93446(Paso Robles, California), Denver/80202(Colorado), Fremont/94538(California), Baltimore/21201(Maryland).

We can clearly see that, with more detailed locations, 7 out of ten zip code areas with the most charging stations are in California.

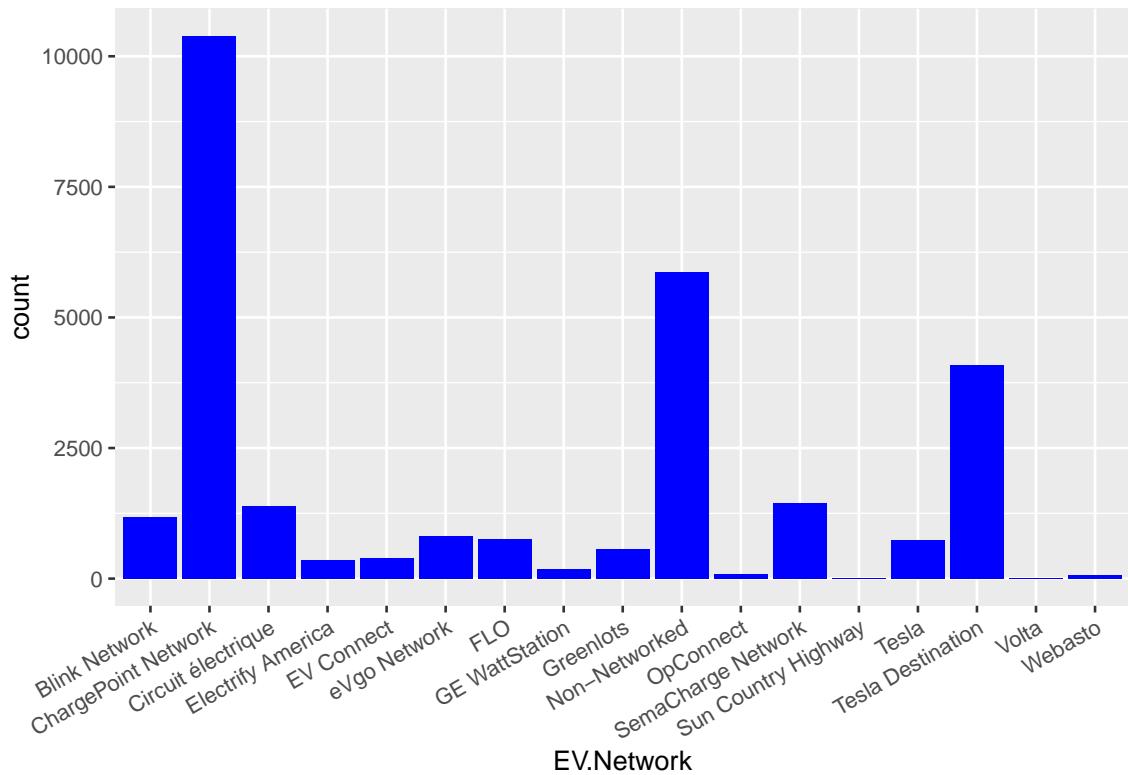
By Network

##	Blink Network	ChargePoint Network	Circuit électrique
##	1186	10392	1385
##	Electrify America	EV Connect	eVgo Network

```

##          359          396          807
##          FLO        GE WattStation      Greenlots
##          758          185          572
## Non-Networked      OpConnect    SemaCharge Network
##          5872          88          1452
## Sun Country Highway      Tesla    Tesla Destination
##          2          744          4086
##          Volta      Webasto
##          3          60

```



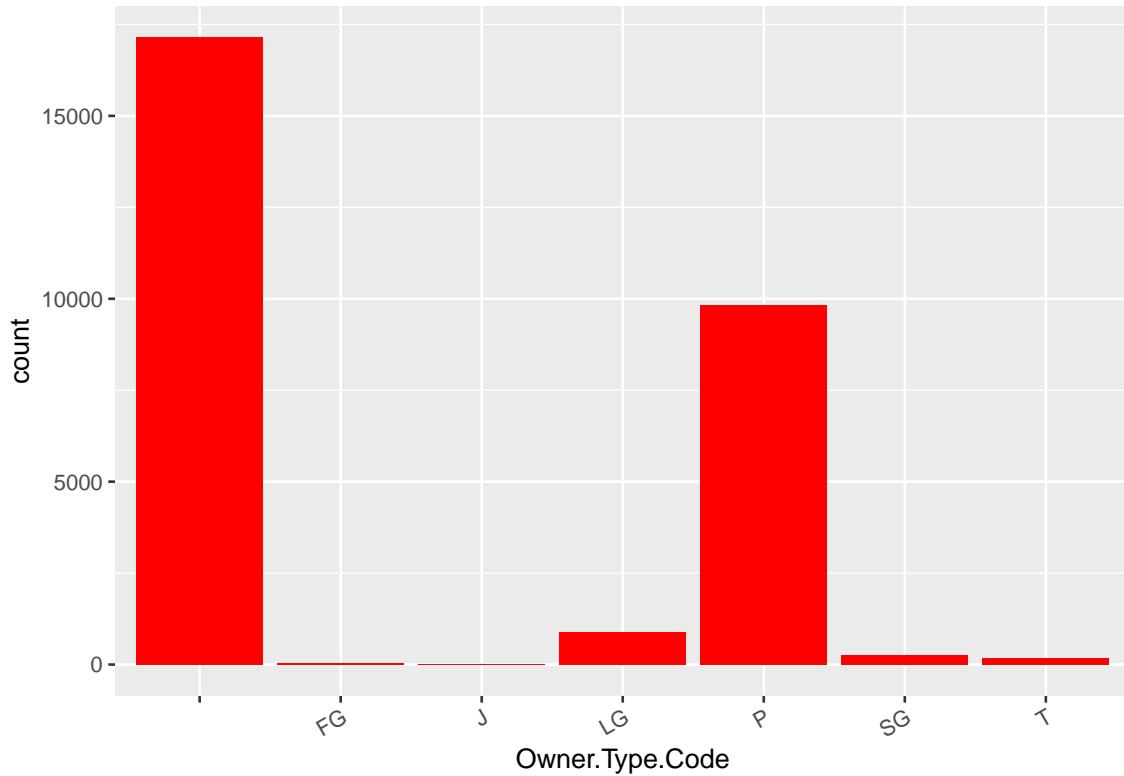
Most of the electric charging stations belong to some network(franchise). ChargePoint Network is the largest network among those. There are also 5,872 charging stations that are Non-Networked. This might be the result of misrecording or some small independent charging stations.

By Ownerships

```

##          FG          J          LG          P          SG          T
## 17142     36         5       879     9837      258       190

```

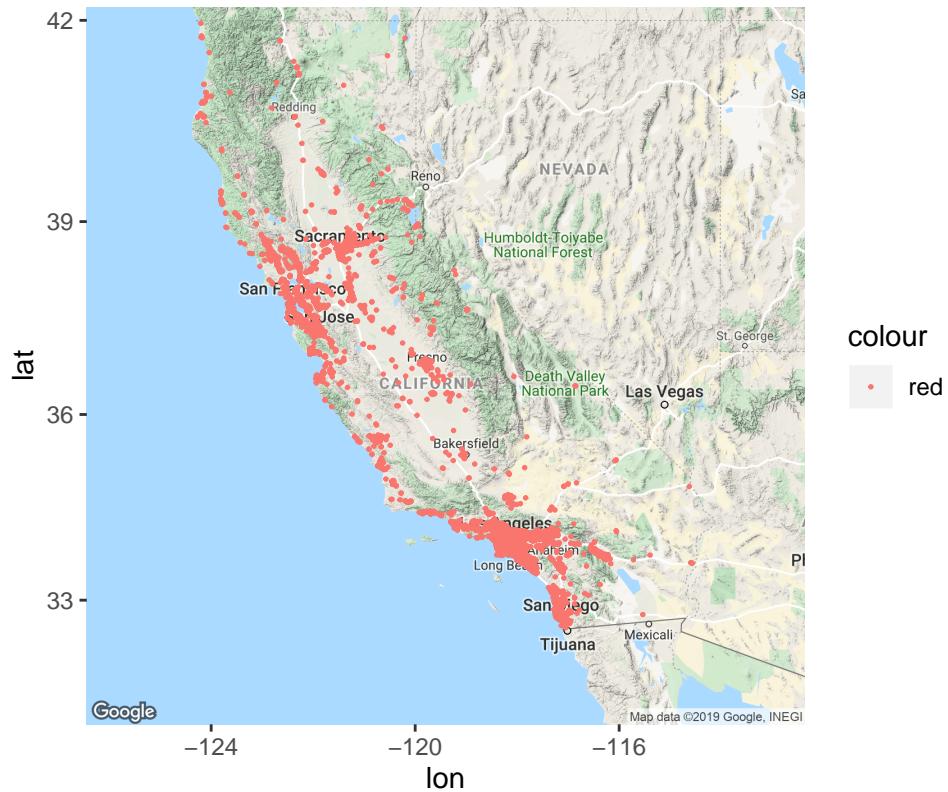


From the variable explanation website, we can acquire the information that variable “Owner.Type.Code” represents the owner’s identity of the infrastructure. The one without a header is the variable that was not mentioned from the dataset. Among the explanations, there was not such thing as corporation owned charging station, which might actually be the largest owner of the charging stations nationwide. Besides that, as the second largest category, private owner charging station(P) is all over the country. This might be private commercial charging stations or the owner of electric vehicles.

Mapping

Zoom down to California

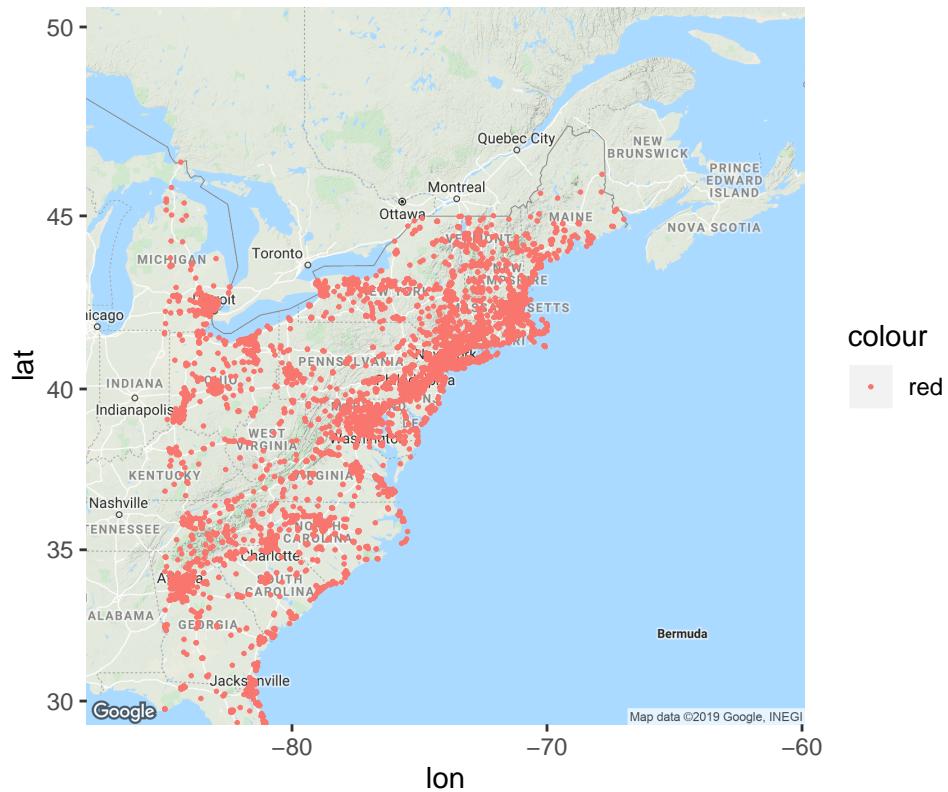
Charging Stations in California



From the map, we get an even clearer view on how the electric vehicle charging stations distributed in California. They have two heavy centers at South(Los Angeles and San Diego) and North(San Francisco). And there are more charging stations when it gets closer to the coastal area.

U.S. East Coast

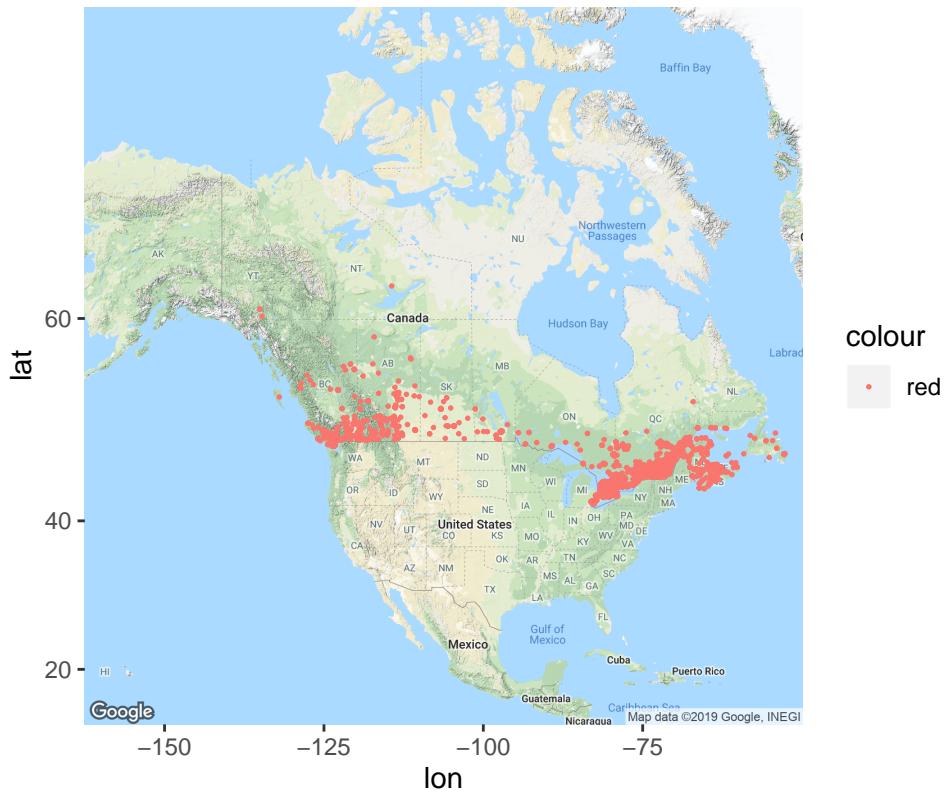
Charging Stations in East Coast



From this map we can see that electric vehicle charging stations on the east coast(east of 85 west longitude in U.S.) are actually more than the number of charging stations in California. However, none of those eastern states has charging station as half of the number in California. From my point of view, this is the result of the sizes of the states. States on the east coast are generally smaller than California. On the other hand, we can see that the charging stations on the east coast are distributed more average along the coastal area. Still, the stations get denser when it gets closer to the coast.

Canada Charging Stations

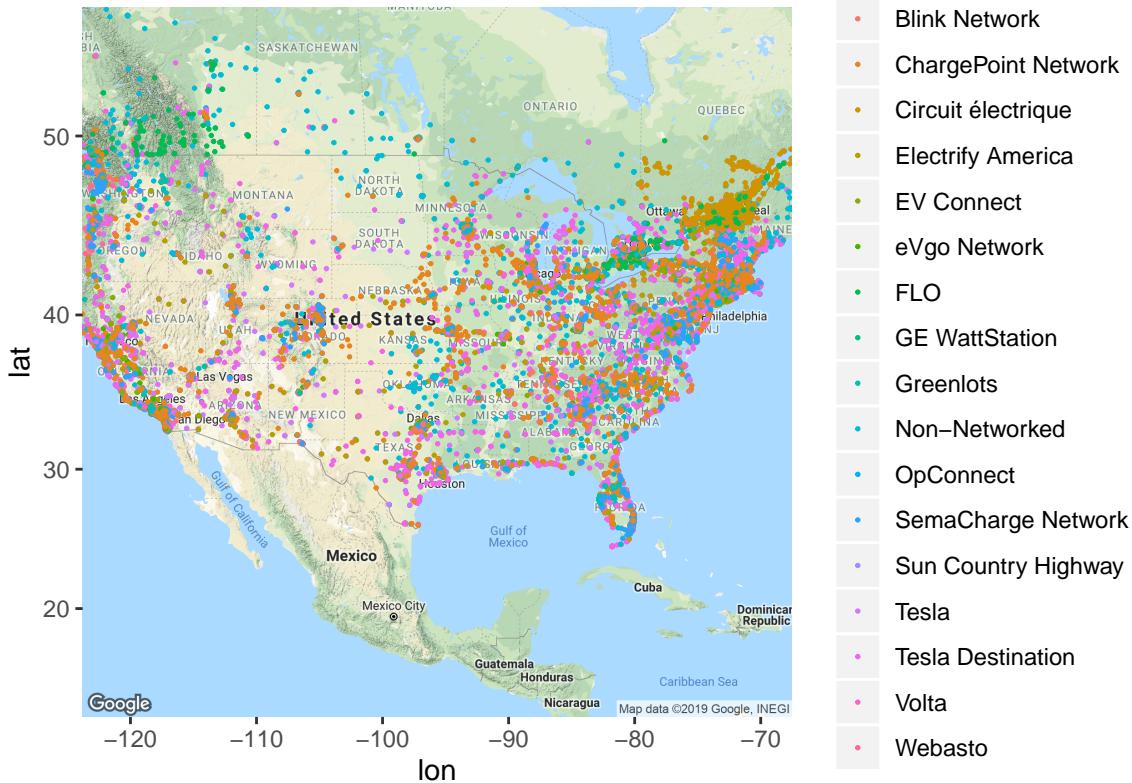
Charging Stations in Canada



It was not hard to find that the electric vehicle charging stations in Canada also have two centers on East and West coasts respectively. And the stations in Canada are more densed when it gets closer to the U.S. border.

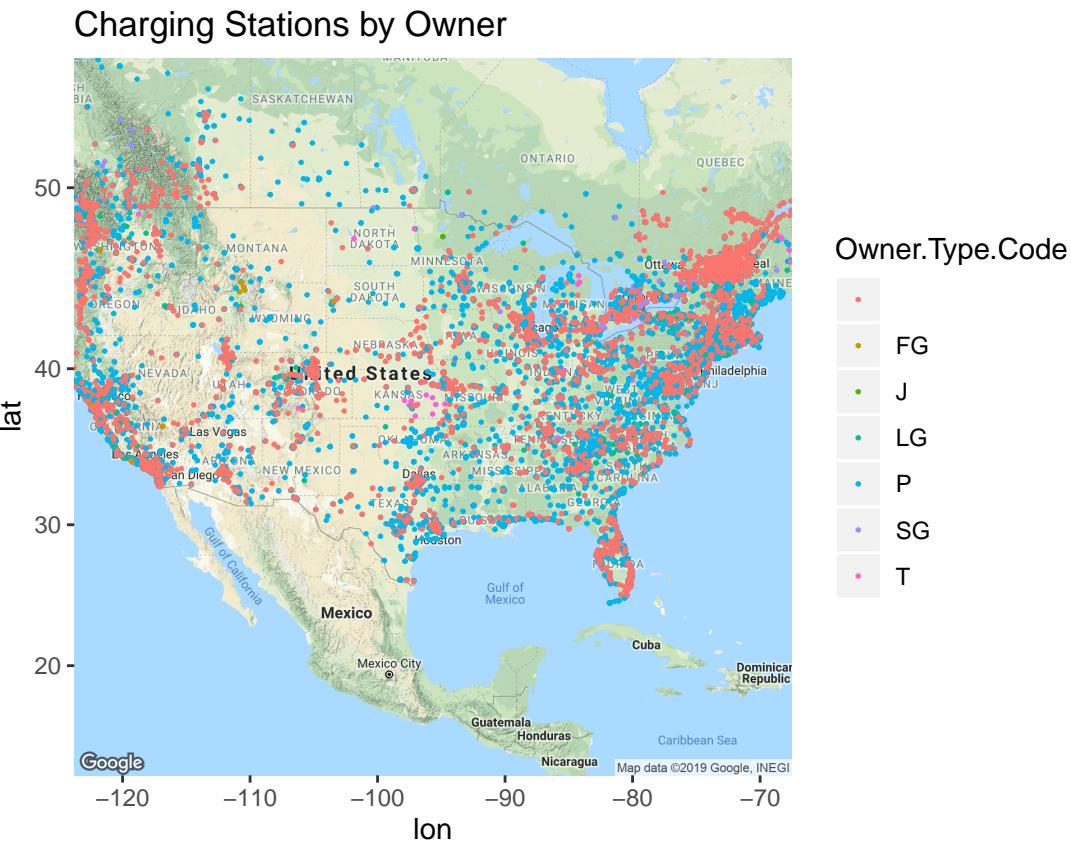
Network of a Charging Station

Charging Stations by Network



From the map we can see that Non-Networked charging stations are more likely to be distributed in the east coast area than the west coast.

Charging Stations by Owners



In this map, most of the owner-unrecorded charging stations are densed in coastal areas and big cities. On the other hand, the rest of the charging stations, which are more likely to be owned by the government would sit in the areas between the commercial charging stations.

Summary

Implication

This project mainly discussed the distribution of the electric vehicle charging stations' locations and its relationship with other intuitive aspects. We have a clear view that the charging stations are more likely to be distributed closer to the coastal area. Different kinds of charging stations in terms of ownership or network have different patterns of distributions. The reason could be due to economics, road conditions and local sales of electric vehicles. However, there is no proof in the dataset, so we cannot make such conclusion by now.

Limitation

The dataset was extracted from the government fuel energy website, which would be accurate but might lack some insightful or interesting variables. The prices of charging stations could be an important subject to study but the dataset only contains "Free", "Pay to Park" and etc. If we could have specific pricing information on charging stations, then it would make this study more practical.

Future Direction

It will be more practical to relate the locations of charging stations to many different kinds of outside resources. If I decided a topic(sales of electric vehicles, road coditions), I would search for outside resources and highly relate them to the dataframe we have right now.

Appendix

This is the data I intended to add into the study. This website(referred at last) provides numeric values of ranges of different models of electric vehicles. I feel like it would be interesting to add it into the study. However, I did not find a good place to fit in this idea.

On the other hand, they do not provide any csv download portal or url to extract. Thus I manually picked ten popular models just for fun.

Reference

[1]Data source: https://afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC.

[2]Variable Explanation: <https://developer.nrel.gov/docs/transportation/alt-fuel-stations-v1/all/>.

[3]EV Range data: <https://ev-database.org/cheatsheet/range-electric-car>.