Statement of Purpose

Typically, the deployment of electric vehicle charging infrastructure in a country lags behind the purchase of electric vehicles[1]. The same holds in the United States. This set of choropleth maps shows that as time went by, the electric vehicle (EV) to charger ratios were decreasing during 2018 – 2021. That indicates more charger points were built as time went by compared to the purchase of electric vehicles in the US states.

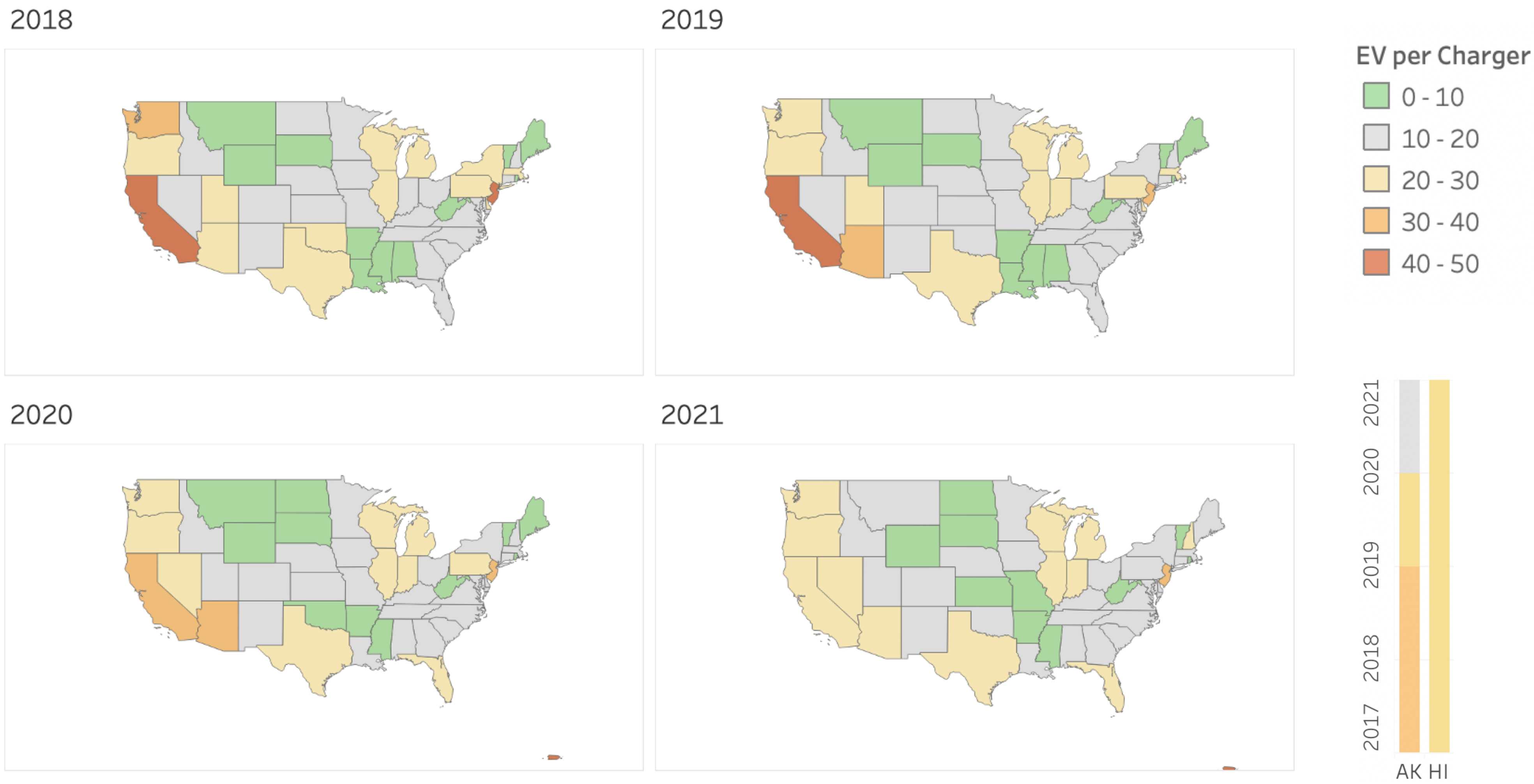
However, the deployment of EV charging infrastructure is still insufficient according to the most recent data. In 2014, the Alternative Fuel Infrastructure Directive (AFID) recommended that countries reach 10 electric light-duty vehicles (LDVs) per public charger by 2020. This set of maps marks the US states with warm tones (yellow, orange, and dark orange) while the EV-to-charger ratios are no less than 20, which is a threshold even higher than the recommendation, to indicate the US states that are still urgent for EV charging infrastructures. On the contrary, the US states marked as green or gray indicate their sufficient or mediocre deployment level of EV charging infrastructures compared to the numbers of registered EVs in the states.

Note: There is no R code for data visualization since this set of choropleth maps is created by Tableau. The R code here only includes the data wrangling process.

[1] IEA. (2022). Global EV Outlook 2022. https://www.iea.org/reports/global-ev-outlook-2022

U.S. Commits to Deploy Electric Vehicle Charging Infrastructure

the EV to Charger Ratio is decreasing in U.S. states, 2018 - 2021



According to Alternative Fuel Infrastructure Directive (AFID), countries were recommended to reach 10 electric light-duty vehicles (LDVs) per public charger by 2020. The US states did not meet the standard and EV-to-charger ratios larger than 20 are marked with warm tone (yellow, orange, and dark orange). Although the EV-to-charger ratios were decreasing, there were still plenty of states that were insufficient of electric vehicle charging infrastructures.

Data Source: Alternative Fuels Data Center: Vehicle Registration Counts by State, Alternative Fueling Station Counts by State.

```
# Load packages ------------------------------------------------------------

library(tidyverse)
library(readxl)
library(writexl)

# Load data ----------------------------------------------------------------

# Stations

stations <-
  read_csv('assignment5/alt_fuel_stations.csv')

# EV registration

LDV_2021 <-
  read_excel('assignment5/2021_LDV_registration.xlsx')

LDV_2020 <-
  read_excel('assignment5/2020_LDV_registration.xlsx')

LDV_2019 <-
  read_excel('assignment5/2019_LDV_registration.xlsx')

LDV_2018 <-
  read_excel('assignment5/2018_LDV_registration.xlsx')

# State name and code

state <-
  read_csv('assignment5/state.csv') %>%
  select(-'abbrev') %>%
  rename('State' = 'state')

# Data for 2021 -----------------------------------------------------------

# Electric vehicle supply equipment (EVSE, charging points) in 2021 by state

charger_2021 <-
  stations %>%

  # the open date is ealier than 2022, so this is the existence of chargers in
  # 2021

  filter(year(`Open Date`) < 2022) %>%

  # 'ON' is in Canada

  filter(State != 'ON') %>%
  select(`Station Name`, `EV Level1 EVSE Num`, `EV Level2 EVSE Num`,
         `EV DC Fast Count`, State) %>%
```

```
  # 'NA' indicates that there is no this type of EVSE in the station, so there
  # is 0 this type of EVSE in the station

  replace(is.na(.), 0) %>%

  # the total number of charging points in a charging station is the sum of
  # 3 types of EVSEs

  mutate(EVSE = `EV Level1 EVSE Num` + `EV Level2 EVSE Num` +
           `EV DC Fast Count`) %>%

  # calculate the total number of EVSE in each state in 2021

  group_by(State) %>%
  summarise(EVSE_state = sum(EVSE))

# the Plug-in Electric Vehicles in 2021 by state

PEV_2021 <-
  LDV_2021 %>%

  # exclude the total amount

  filter(State != 'United States') %>%

  # only calculate the types of EV that needed chargers

  mutate(PEV = `Electric (EV)` + `Plug-In Hybrid Electric (PHEV)`) %>%
  select(State, PEV)

# Merge the needed data for 2021

merge_2021 <-
  full_join(state, PEV_2021) %>%
  select(code, PEV) %>%
  rename(State = code) %>%
  full_join(charger_2021) %>%
  mutate(EV_per_charger = PEV / EVSE_state) %>%
  select(State, EV_per_charger) %>%
  mutate(year = 2021)

# Data for 2020 -----------------------------------------------------------

# Electric vehicle supply equipment (EVSE, charging points) in 2020 by state

charger_2020 <-
  stations %>%
  filter(year(`Open Date`) < 2021) %>%
  filter(State != 'ON') %>%
  select(`Station Name`, `EV Level1 EVSE Num`, `EV Level2 EVSE Num`,
         `EV DC Fast Count`, State) %>%
  replace(is.na(.), 0) %>%
```

```r
  mutate(EVSE = `EV Level1 EVSE Num` + `EV Level2 EVSE Num` +
           `EV DC Fast Count`) %>%
  group_by(State) %>%
  summarise(EVSE_state = sum(EVSE))

# the Plug-in Electric Vehicles in 2020 by state

PEV_2020 <-
  LDV_2020 %>%
  filter(State != 'United States') %>%
  mutate(PEV = `Electric (EV)` + `Plug-In Hybrid Electric (PHEV)`) %>%
  select(State, PEV)

# Merge the needed data for 2020

merge_2020 <-
  full_join(state, PEV_2020) %>%
  select(code, PEV) %>%
  rename(State = code) %>%
  full_join(charger_2020) %>%
  mutate(EV_per_charger = PEV / EVSE_state)%>%
  select(State, EV_per_charger) %>%
  mutate(year = 2020)

# Data for 2019 -----------------------------------------------------------

# Electric vehicle supply equipment (EVSE, charging points) in 2019 by state

charger_2019 <-
  stations %>%
  filter(year(`Open Date`) < 2020) %>%
  filter(State != 'ON') %>%
  select(`Station Name`, `EV Level1 EVSE Num`, `EV Level2 EVSE Num`,
         `EV DC Fast Count`, State) %>%
  replace(is.na(.), 0) %>%
  mutate(EVSE = `EV Level1 EVSE Num` + `EV Level2 EVSE Num` +
           `EV DC Fast Count`) %>%
  group_by(State) %>%
  summarise(EVSE_state = sum(EVSE))

# the Plug-in Electric Vehicles in 2019 by state

PEV_2019 <-
  LDV_2019 %>%
  filter(State != 'United States') %>%
  mutate(PEV = `Electric (EV)` + `Plug-In Hybrid Electric (PHEV)`) %>%
  select(State, PEV)

# Merge the needed data for 2019

merge_2019 <-
  full_join(state, PEV_2019) %>%
```

```
  select(code, PEV) %>%
  rename(State = code) %>%
  full_join(charger_2019) %>%
  mutate(EV_per_charger = PEV / EVSE_state)%>%
  select(State, EV_per_charger) %>%
  mutate(year = 2019)

# Data for 2018 ---------------------------------------------------------

# Electric vehicle supply equipment (EVSE, charging points) in 2018 by state

charger_2018 <-
  stations %>%
  filter(year(`Open Date`) < 2019) %>%
  filter(State != 'ON') %>%
  select(`Station Name`, `EV Level1 EVSE Num`, `EV Level2 EVSE Num`,
         `EV DC Fast Count`, State) %>%
  replace(is.na(.), 0) %>%
  mutate(EVSE = `EV Level1 EVSE Num` + `EV Level2 EVSE Num` +
           `EV DC Fast Count`) %>%
  group_by(State) %>%
  summarise(EVSE_state = sum(EVSE))

# the Plug-in Electric Vehicles in 2018 by state

PEV_2018 <-
  LDV_2018 %>%
  filter(State != 'United States') %>%
  mutate(PEV = `Electric (EV)` + `Plug-In Hybrid Electric (PHEV)`) %>%
  select(State, PEV)

# Merge the needed data for 2018

merge_2018 <-
  full_join(state, PEV_2018) %>%
  select(code, PEV) %>%
  rename(State = code) %>%
  full_join(charger_2018) %>%
  mutate(EV_per_charger = PEV / EVSE_state)%>%
  select(State, EV_per_charger) %>%
  mutate(year = 2018)

# Merge the data in different years ---------------------------------------

All_years <-
  rbind(merge_2018,
        merge_2019) %>%
  rbind(merge_2020) %>%
  rbind(merge_2021) %>%
  mutate(EV_per_Charger =
           case_when(EV_per_charger <= 10 ~ '0 - 10',
                     EV_per_charger <= 20 ~ '10 - 20',
```

```
                   EV_per_charger <= 30 ~ '20 - 30',
                   EV_per_charger <= 40 ~ '30 - 40',
                   .default = '40 - 50'))

# Export an excel file for Tableau

write_xlsx(All_years, 'assignment5/merge_all.xlsx')
```

02

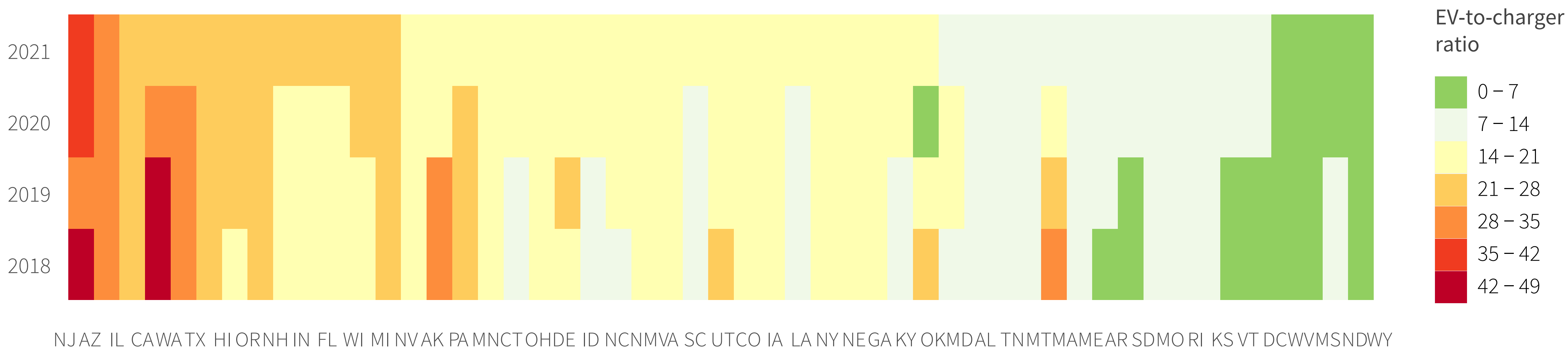
Statement of Purpose

This data set is almost identical to the one generated in the previous section, demonstrating the change in electric vehicle (EV) to charger ratios across U.S. states from 2018 to 2021, with only a few adjustments to fit the graph type better.

However, while a set of choropleth maps are mainly indicating to readers the general trend of the decrease of EV-to-charger ratio across U.S. states, the heat map here focuses on the spectrum of different levels of EV charging infrastructure deployment across U.S. states. On the most left there is New Jersey, with the highest EV-to-charger ratio in 2021, while on the most right there is Wyoming with the lowest ratio. From this aspect, readers could see that New Jersey, Arizona, Illinois, and California are among the states that need EV charging infrastructure the most, while Wyoming, North Dakota, and Mississippi are the states that need the infrastructure the least.

Electric Vehicle Charging Point Deployment by State in the U.S., 2018 – 2021

From left to right: the state with the least (NJ) to most (WY) adequate deployment of EV charging points



From left to right are the states with the least (NJ) to most (WY) adequate deployment of EV charging points.
From 2018 to 2021, every state in the U.S. was committed to deploying electric vehicle charging infrastructure.
The EV-to-charger ratio decreases in most states.
However, most states still do not meet the Alternative Fuel Infrastructure Directive's (AFID) recommendation to reduce the EV-to-charger ratio to 10 by 2020 (white and green tiles in the chart).

Data Source:
Alternative Fuels Data Center:
Vehicle Registration Counts by State
Alternative Fueling Station Counts by State

```r
# Load packages -----------------------------------------------------------

library(tidyverse)
library(ggplot2)
library(readxl)

# Load data ---------------------------------------------------------------

# Stations

stations <-
  read_csv('assignment5/alt_fuel_stations.csv') %>%

  # ON is a Canada state, exclude non-US states.

  filter(State != 'ON')

# EV registration

LDV_2021 <-
  read_excel('assignment5/2021_LDV_registration.xlsx')

LDV_2020 <-
  read_excel('assignment5/2020_LDV_registration.xlsx')

LDV_2019 <-
  read_excel('assignment5/2019_LDV_registration.xlsx')

LDV_2018 <-
  read_excel('assignment5/2018_LDV_registration.xlsx')

# State name and code

state <-
  read_csv('assignment5/state.csv') %>%
  select(-'abbrev') %>%
  rename('State' = 'state')

# Data wrangling ----------------------------------------------------------

# 1. Repeat the process to generate the 'All_years' data frame as same as
# the first graph

# Electric vehicle supply equipment (EVSE, charging points) in 2021 by state

charger_2021 <-
  stations %>%
  filter(year(`Open Date`) < 2022) %>%
  filter(State != 'ON') %>%
  select(`Station Name`, `EV Level1 EVSE Num`, `EV Level2 EVSE Num`,
         `EV DC Fast Count`, State) %>%
  replace(is.na(.), 0) %>%
```

```r
  mutate(EVSE = `EV Level1 EVSE Num` + `EV Level2 EVSE Num` +
           `EV DC Fast Count`) %>%
  group_by(State) %>%
  summarise(EVSE_state = sum(EVSE))

# the Plug-in Electric Vehicles in 2021 by state

PEV_2021 <-
  LDV_2021 %>%
  filter(State != 'United States') %>%
  mutate(PEV = `Electric (EV)` + `Plug-In Hybrid Electric (PHEV)`) %>%
  select(State, PEV)

# Merge the needed data for 2021

merge_2021 <-
  full_join(state, PEV_2021) %>%
  select(code, PEV) %>%
  rename(State = code) %>%
  full_join(charger_2021) %>%
  mutate(EV_per_charger = PEV / EVSE_state) %>%
  select(State, EV_per_charger) %>%
  mutate(year = 2021)

# Electric vehicle supply equipment (EVSE, charging points) in 2020 by state

charger_2020 <-
  stations %>%
  filter(year(`Open Date`) < 2021) %>%
  filter(State != 'ON') %>%
  select(`Station Name`, `EV Level1 EVSE Num`, `EV Level2 EVSE Num`,
         `EV DC Fast Count`, State) %>%
  replace(is.na(.), 0) %>%
  mutate(EVSE = `EV Level1 EVSE Num` + `EV Level2 EVSE Num` +
           `EV DC Fast Count`) %>%
  group_by(State) %>%
  summarise(EVSE_state = sum(EVSE))

# the Plug-in Electric Vehicles in 2020 by state

PEV_2020 <-
  LDV_2020 %>%
  filter(State != 'United States') %>%
  mutate(PEV = `Electric (EV)` + `Plug-In Hybrid Electric (PHEV)`) %>%
  select(State, PEV)

# Merge the needed data for 2020

merge_2020 <-
  full_join(state, PEV_2020) %>%
  select(code, PEV) %>%
  rename(State = code) %>%
```

```
  full_join(charger_2020) %>%
  mutate(EV_per_charger = PEV / EVSE_state)%>%
  select(State, EV_per_charger) %>%
  mutate(year = 2020)

# Electric vehicle supply equipment (EVSE, charging points) in 2019 by state

charger_2019 <-
  stations %>%
  filter(year(`Open Date`) < 2020) %>%
  filter(State != 'ON') %>%
  select(`Station Name`, `EV Level1 EVSE Num`, `EV Level2 EVSE Num`,
         `EV DC Fast Count`, State) %>%
  replace(is.na(.), 0) %>%
  mutate(EVSE = `EV Level1 EVSE Num` + `EV Level2 EVSE Num` +
           `EV DC Fast Count`) %>%
  group_by(State) %>%
  summarise(EVSE_state = sum(EVSE))

# the Plug-in Electric Vehicles in 2019 by state

PEV_2019 <-
  LDV_2019 %>%
  filter(State != 'United States') %>%
  mutate(PEV = `Electric (EV)` + `Plug-In Hybrid Electric (PHEV)`) %>%
  select(State, PEV)

# Merge the needed data for 2019

merge_2019 <-
  full_join(state, PEV_2019) %>%
  select(code, PEV) %>%
  rename(State = code) %>%
  full_join(charger_2019) %>%
  mutate(EV_per_charger = PEV / EVSE_state)%>%
  select(State, EV_per_charger) %>%
  mutate(year = 2019)

# Electric vehicle supply equipment (EVSE, charging points) in 2018 by state

charger_2018 <-
  stations %>%
  filter(year(`Open Date`) < 2019) %>%
  filter(State != 'ON') %>%
  select(`Station Name`, `EV Level1 EVSE Num`, `EV Level2 EVSE Num`,
         `EV DC Fast Count`, State) %>%
  replace(is.na(.), 0) %>%
  mutate(EVSE = `EV Level1 EVSE Num` + `EV Level2 EVSE Num` +
           `EV DC Fast Count`) %>%
  group_by(State) %>%
  summarise(EVSE_state = sum(EVSE))
```

```r
# the Plug-in Electric Vehicles in 2018 by state

PEV_2018 <-
  LDV_2018 %>%
  filter(State != 'United States') %>%
  mutate(PEV = `Electric (EV)` + `Plug-In Hybrid Electric (PHEV)`) %>%
  select(State, PEV)

# Merge the needed data for 2018

merge_2018 <-
  full_join(state, PEV_2018) %>%
  select(code, PEV) %>%
  rename(State = code) %>%
  full_join(charger_2018) %>%
  mutate(EV_per_charger = PEV / EVSE_state)%>%
  select(State, EV_per_charger) %>%
  mutate(year = 2018)

# Merge the data of different years

All_years <-
  rbind(merge_2018,
        merge_2019) %>%
  rbind(merge_2020) %>%
  rbind(merge_2021)

# 2. Minor adjustments

All_years_heat <-
  All_years %>%
  filter(!is.na(EV_per_charger))

# factorize the state vector

level <-
  All_years_heat %>%
  filter(year == 2021) %>%
  arrange(desc(EV_per_charger)) %>%
  pull(State)

All_years_heat$State <-
  factor(All_years_heat$State, levels = level)

# Reset the discrete intervals that suit heat map better

All_years_heat <-
  All_years_heat %>%
  mutate(EV_per_Charger =
           case_when(EV_per_charger <= 7 ~ '0 - 7',
                     EV_per_charger <= 14 ~ '7 - 14',
                     EV_per_charger <= 21 ~ '14 - 21',
```

```
                     EV_per_charger <= 28 ~ '21 - 28',
                     EV_per_charger <= 35 ~ '28 - 35',
                     EV_per_charger <= 42 ~ '35 - 42',
                     .default = '42 - 49'))

All_years_heat$EV_per_Charger <-
  factor(All_years_heat$EV_per_Charger,
         levels = c('0 - 7', '7 - 14', '14 - 21', '21 - 28', '28 - 35',
                    '35 - 42', '42 - 49'))

# Heat map -------------------------------------------------------------------

heat_map <-
  All_years_heat %>%
  ggplot(mapping =
           aes(x = State,
               y = year)) +
  geom_tile(
    aes(fill = EV_per_Charger)) +

  # the mid point is EV-to-charger ratio equals to 10, which is the recommended
  # level of EV charger deployment by the Alternative Fuel Infrastructure
  # Directive (AFID).

  scale_fill_manual(values =
                      c('#91cf60', '#f0f9e8', '#ffffb2',
                        '#fecc5c', '#fd8d3c', '#f03b20', '#bd0026')) +
  labs(title = paste('Electric Vehicle Charging Point Deployment by State in',
                     'the U.S., 2018 - 2021'),
       subtitle = paste('From left to right: the state with the least (NJ) to',
                        'most (WY) adequate deployment of EV charging points'),
       caption = 'Data Source: Alternative Fuels Data Center') +
  theme(axis.title = element_blank(),
        axis.ticks = element_blank(),
        panel.background = element_blank())
```