Final Group Project: 19-706: Air Quality Modeling: Using Data to Explore the links between PM2.5 with Electricity generation and Transportation, individually

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#Data Preparation and Cleaning, along with Exploratory Data Analysis #PM2.5 Data

```
library(dplyr)
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
library(knitr)
library(conflicted)
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v forcats   1.0.0     v readr     2.1.5
## v ggplot2   3.4.4     v stringr   1.5.1
## v lubridate 1.9.3     v tibble    3.2.1
## v purrr     1.0.2     v tidyr     1.3.1
```

```
conflict_prefer("filter", "dplyr")
```

```
## [conflicted] Will prefer dplyr::filter over any other package.
```

```
conflict_prefer("lag", "dplyr")
```

```
## [conflicted] Will prefer dplyr::lag over any other package.
```

```r
knitr::opts_chunk$set(echo = TRUE, warning = FALSE, message = FALSE)

#Store all PM2.5 Data for all counties

PM2.5_2016 <- read.csv("C:/Users/Harsh Vaibhav/Desktop/Data Science Data Sets/Final/PM2.5
↪  and egrid Data/daily_88101_2016.csv")
PM2.5_2018 <- read.csv("C:/Users/Harsh Vaibhav/Desktop/Data Science Data Sets/Final/PM2.5
↪  and egrid Data/daily_88101_2018.csv")
PM2.5_2019 <- read.csv("C:/Users/Harsh Vaibhav/Desktop/Data Science Data Sets/Final/PM2.5
↪  and egrid Data/daily_88101_2019.csv")
PM2.5_2020 <- read.csv("C:/Users/Harsh Vaibhav/Desktop/Data Science Data Sets/Final/PM2.5
↪  and egrid Data/daily_88101_2020.csv")
PM2.5_2021 <- read.csv("C:/Users/Harsh Vaibhav/Desktop/Data Science Data Sets/Final/PM2.5
↪  and egrid Data/daily_88101_2021.csv")
PM2.5_2022 <- read.csv("C:/Users/Harsh Vaibhav/Desktop/Data Science Data Sets/Final/PM2.5
↪  and egrid Data/daily_88101_2022.csv")

#Extract year from date format in the CSV (MM/DD/YYYY) and group by year

#2016
date_2016 <- PM2.5_2016$Date.Local
date_2016_asDate <- substr(date_2016, start = 0, stop = 4)
PM2.5_2016$Year <- as.integer(date_2016_asDate)

PM2.5_2016 <- PM2.5_2016 %>%
  group_by(County.Name,Year, State.Name) %>%
  summarise(PM2.5_Avg = mean(Arithmetic.Mean))
```

```
## `summarise()` has grouped output by 'County.Name', 'Year'. You can override
## using the `.groups` argument.
```

```r
#2018
date_2018 <- PM2.5_2018$Date.Local
date_2018_asDate <- substr(date_2018, start = 0, stop = 4)
PM2.5_2018$Year <- as.integer(date_2018_asDate)

PM2.5_2018 <- PM2.5_2018 %>%
  group_by(County.Name,Year, State.Name) %>%
  summarise(PM2.5_Avg = mean(Arithmetic.Mean))
```

```
## `summarise()` has grouped output by 'County.Name', 'Year'. You can override
## using the `.groups` argument.
```

```r
#2019
date_2019 <- PM2.5_2019$Date.Local
date_2019_asDate <- substr(date_2019, start = 0, stop = 4)
PM2.5_2019$Year <- as.integer(date_2019_asDate)

PM2.5_2019 <- PM2.5_2019 %>%
  group_by(County.Name,Year, State.Name) %>%
  summarise(PM2.5_Avg = mean(Arithmetic.Mean))
```

```
## `summarise()` has grouped output by 'County.Name', 'Year'. You can override
## using the `.groups` argument.
```

```
#2020
date_2020 <- PM2.5_2020$Date.Local
date_2020_asDate <- substr(date_2020, start = 0, stop = 4)
PM2.5_2020$Year <- as.integer(date_2020_asDate)

PM2.5_2020 <- PM2.5_2020 %>%
  group_by(County.Name,Year, State.Name) %>%
  summarise(PM2.5_Avg = mean(Arithmetic.Mean))
```

```
## `summarise()` has grouped output by 'County.Name', 'Year'. You can override
## using the `.groups` argument.
```

```
#2021
date_2021 <- PM2.5_2021$Date.Local
date_2021_asDate <- substr(date_2021, start = 0, stop = 4)
PM2.5_2021$Year <- as.integer(date_2021_asDate)

PM2.5_2021 <- PM2.5_2021 %>%
  group_by(County.Name,Year, State.Name) %>%
  summarise(PM2.5_Avg = mean(Arithmetic.Mean))
```

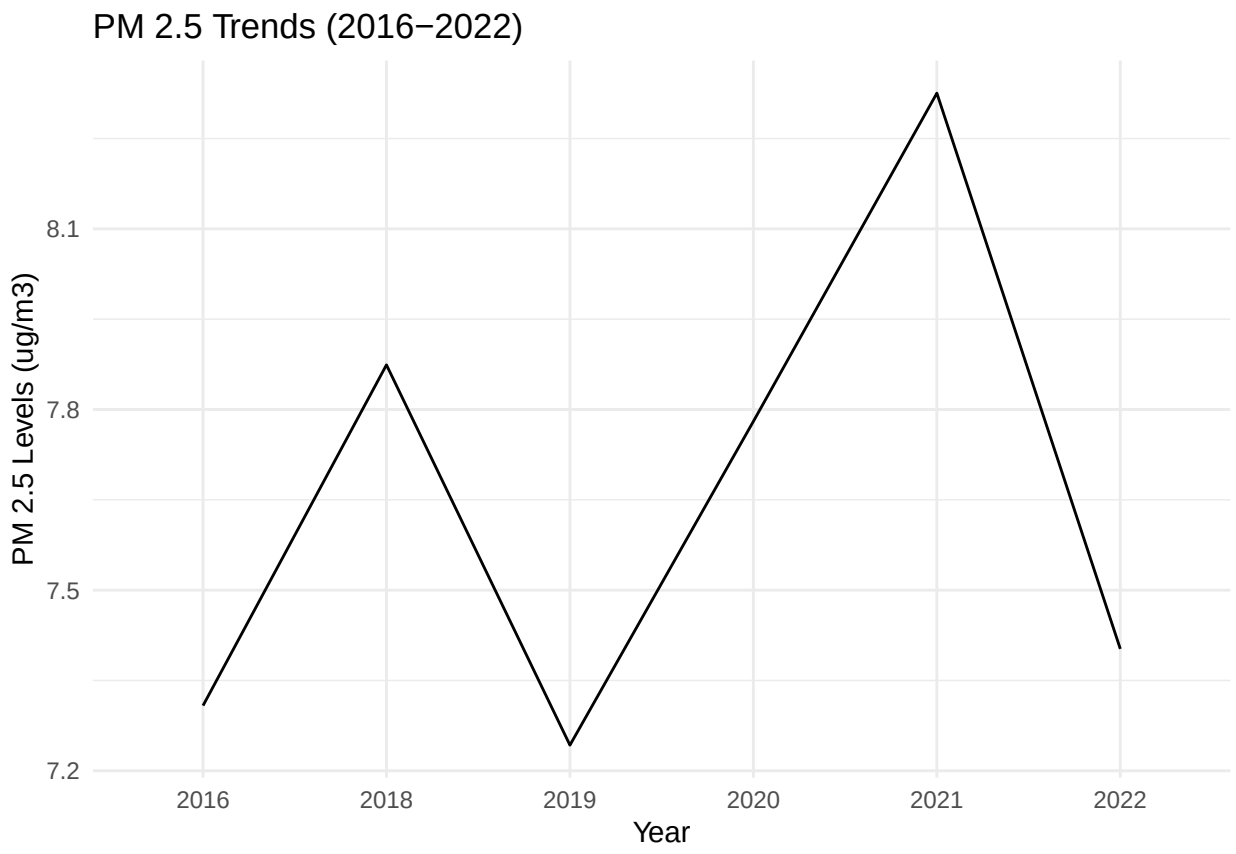
```
## `summarise()` has grouped output by 'County.Name', 'Year'. You can override
## using the `.groups` argument.
```

```
#2022
date_2022 <- PM2.5_2022$Date.Local
date_2022_asDate <- substr(date_2022, start = 0, stop = 4)
PM2.5_2022$Year <- as.integer(date_2022_asDate)

PM2.5_2022 <- PM2.5_2022 %>%
  group_by(County.Name,Year, State.Name) %>%
  summarise(PM2.5_Avg = mean(Arithmetic.Mean))
```

```
## `summarise()` has grouped output by 'County.Name', 'Year'. You can override
## using the `.groups` argument.
```

```
# Visualizing PM2.5 Trends
TotalAvg_PM2.5 <- data.frame(
  Year = c("2016", "2018", "2019", "2020", "2021", "2022"),
  PM2.5_Avg = c(
    mean(PM2.5_2016$PM2.5_Avg),
    mean(PM2.5_2018$PM2.5_Avg),
    mean(PM2.5_2019$PM2.5_Avg),
    mean(PM2.5_2020$PM2.5_Avg),
    mean(PM2.5_2021$PM2.5_Avg),
    mean(PM2.5_2022$PM2.5_Avg)
  )
```

```
)

ggplot(data = TotalAvg_PM2.5) +
  geom_line(aes(x = Year, y = PM2.5_Avg, group = 1), colour = "black") +
  labs(title = "PM 2.5 Trends (2016-2022)",
       x = "Year",
       y = "PM 2.5 Levels (ug/m3)") +
  theme_minimal()
```

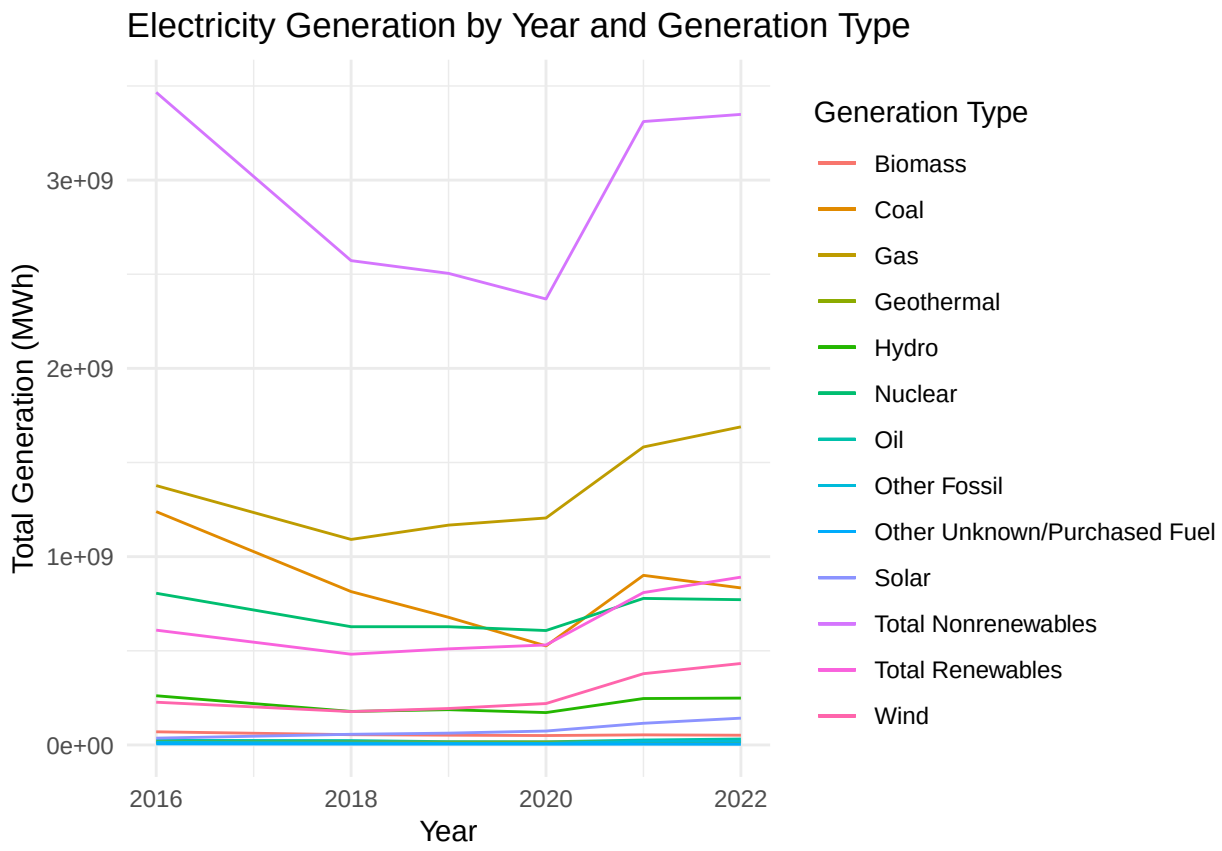


#eGRID Data

```
library(tidyverse)
df <- "C:/Users/Harsh Vaibhav/Desktop/Data Science Data Sets/Final/PM2.5 and egrid
↪  Data/egrid_total_data.xlsx"

egrid_data <- readxl::read_excel(df)

egrid_data <- egrid_data %>% rename(Year = `Data Year`)

energy_data <- egrid_data %>%
  group_by(`Plant county name`, Year) %>%
  summarise(
    `Plant annual coal net generation (MWh)` = sum(`Plant annual coal net generation
    ↪  (MWh)`, na.rm = TRUE),
    `Plant annual oil net generation (MWh)` = sum(`Plant annual oil net generation
    ↪  (MWh)`, na.rm = TRUE),
```

```
    `Plant annual gas net generation (MWh)` = sum(`Plant annual gas net generation
    ↪  (MWh)`, na.rm = TRUE),
    `Plant annual nuclear net generation (MWh)` = sum(`Plant annual nuclear net
    ↪  generation (MWh)`, na.rm = TRUE),
    `Plant annual hydro net generation (MWh)` = sum(`Plant annual hydro net generation
    ↪  (MWh)`, na.rm = TRUE),
    `Plant annual biomass net generation (MWh)` = sum(`Plant annual biomass net
    ↪  generation (MWh)`, na.rm = TRUE),
    `Plant annual wind net generation (MWh)` = sum(`Plant annual wind net generation
    ↪  (MWh)`, na.rm = TRUE),
    `Plant annual solar net generation (MWh)` = sum(`Plant annual solar net generation
    ↪  (MWh)`, na.rm = TRUE),
    `Plant annual geothermal net generation (MWh)` = sum(`Plant annual geothermal net
    ↪  generation (MWh)`, na.rm = TRUE),
    `Plant annual other fossil net generation (MWh)` = sum(`Plant annual other fossil net
    ↪  generation (MWh)`, na.rm = TRUE),
    `Plant annual other unknown/ purchased fuel net generation (MWh)` = sum(`Plant annual
    ↪  other unknown/ purchased fuel net generation (MWh)`, na.rm = TRUE),
    `Plant annual total nonrenewables net generation (MWh)` = sum(`Plant annual total
    ↪  nonrenewables net generation (MWh)`, na.rm = TRUE),
    `Plant annual total renewables net generation (MWh)` = sum(`Plant annual total
    ↪  renewables net generation (MWh)`, na.rm = TRUE)
  )

#Visualizing the Generation
summarized_data <- energy_data %>%
  group_by(Year) %>%
  summarise(
    `Plant annual coal net generation (MWh)` = sum(`Plant annual coal net generation
    ↪  (MWh)`, na.rm = TRUE),
    `Plant annual oil net generation (MWh)` = sum(`Plant annual oil net generation
    ↪  (MWh)`, na.rm = TRUE),
    `Plant annual gas net generation (MWh)` = sum(`Plant annual gas net generation
    ↪  (MWh)`, na.rm = TRUE),
    `Plant annual nuclear net generation (MWh)` = sum(`Plant annual nuclear net
    ↪  generation (MWh)`, na.rm = TRUE),
    `Plant annual hydro net generation (MWh)` = sum(`Plant annual hydro net generation
    ↪  (MWh)`, na.rm = TRUE),
    `Plant annual biomass net generation (MWh)` = sum(`Plant annual biomass net
    ↪  generation (MWh)`, na.rm = TRUE),
    `Plant annual wind net generation (MWh)` = sum(`Plant annual wind net generation
    ↪  (MWh)`, na.rm = TRUE),
    `Plant annual solar net generation (MWh)` = sum(`Plant annual solar net generation
    ↪  (MWh)`, na.rm = TRUE),
    `Plant annual geothermal net generation (MWh)` = sum(`Plant annual geothermal net
    ↪  generation (MWh)`, na.rm = TRUE),
    `Plant annual other fossil net generation (MWh)` = sum(`Plant annual other fossil net
    ↪  generation (MWh)`, na.rm = TRUE),
    `Plant annual other unknown/ purchased fuel net generation (MWh)` = sum(`Plant annual
    ↪  other unknown/ purchased fuel net generation (MWh)`, na.rm = TRUE),
    `Plant annual total nonrenewables net generation (MWh)` = sum(`Plant annual total
    ↪  nonrenewables net generation (MWh)`, na.rm = TRUE),
    `Plant annual total renewables net generation (MWh)` = sum(`Plant annual total
    ↪  renewables net generation (MWh)`, na.rm = TRUE)
```

```
  )

ggplot(summarized_data, aes(x = Year)) +
  geom_line(aes(y = `Plant annual coal net generation (MWh)`, color = "Coal")) +
  geom_line(aes(y = `Plant annual oil net generation (MWh)`, color = "Oil")) +
  geom_line(aes(y = `Plant annual gas net generation (MWh)`, color = "Gas")) +
  geom_line(aes(y = `Plant annual nuclear net generation (MWh)`, color = "Nuclear")) +
  geom_line(aes(y = `Plant annual hydro net generation (MWh)`, color = "Hydro")) +
  geom_line(aes(y = `Plant annual biomass net generation (MWh)`, color = "Biomass")) +
  geom_line(aes(y = `Plant annual wind net generation (MWh)`, color = "Wind")) +
  geom_line(aes(y = `Plant annual solar net generation (MWh)`, color = "Solar")) +
  geom_line(aes(y = `Plant annual geothermal net generation (MWh)`, color =
  ↪  "Geothermal")) +
  geom_line(aes(y = `Plant annual other fossil net generation (MWh)`, color = "Other
  ↪  Fossil")) +
  geom_line(aes(y = `Plant annual other unknown/ purchased fuel net generation (MWh)`,
  ↪  color = "Other Unknown/Purchased Fuel")) +
  geom_line(aes(y = `Plant annual total nonrenewables net generation (MWh)`, color =
  ↪  "Total Nonrenewables")) +
  geom_line(aes(y = `Plant annual total renewables net generation (MWh)`, color = "Total
  ↪  Renewables")) +
  labs(title = "Electricity Generation by Year and Generation Type",
       x = "Year",
       y = "Total Generation (MWh)",
       color = "Generation Type") +
  theme_minimal()
```




```
#Filter for counties that have data for all 6 years
energy_data <- energy_data %>%
  group_by(`Plant county name`) %>%
  filter(n_distinct(Year) == 6)

#We have different number of counties for each year in this data set, this is a problem.
↪  Lets find the common counties so it is easier to map trends for equal amount of time
↪  duration.

common_county_names <- Reduce(intersect, list(PM2.5_2016$County.Name,
↪  PM2.5_2018$County.Name, PM2.5_2019$County.Name, PM2.5_2020$County.Name,
↪  PM2.5_2021$County.Name, PM2.5_2022$County.Name))

Filtered_county_2016 <- PM2.5_2016 %>% filter(County.Name %in% common_county_names)
Filtered_county_2018 <- PM2.5_2018 %>% filter(County.Name %in% common_county_names)
Filtered_county_2019 <- PM2.5_2019 %>% filter(County.Name %in% common_county_names)
Filtered_county_2020 <- PM2.5_2020 %>% filter(County.Name %in% common_county_names)
Filtered_county_2021 <- PM2.5_2021 %>% filter(County.Name %in% common_county_names)
Filtered_county_2022 <- PM2.5_2022 %>% filter(County.Name %in% common_county_names)
Filtered_county_energy <- energy_data %>% filter(`Plant county name` %in%
↪  common_county_names)

Filtered_county_energy <- Filtered_county_energy %>%
  rename(County.Name = `Plant county name`)

combined_df <- bind_rows(Filtered_county_2016, Filtered_county_2018,
↪  Filtered_county_2019, Filtered_county_2020, Filtered_county_2021,
↪  Filtered_county_2022) %>%
```

```
  arrange(County.Name, Year)

County_PM2.5_Energy_Data <- merge(combined_df, Filtered_county_energy, by =
↪  c("County.Name", "Year"))
```

Model Building

#Electricity Model 1: Linear Regression

```
PM2.5 <- County_PM2.5_Energy_Data$PM2.5_Avg
NonRenewableEnergy <- County_PM2.5_Energy_Data$`Plant annual total nonrenewables net
↪  generation (MWh)`/10^6
RenewableEnergy <- County_PM2.5_Energy_Data$`Plant annual total renewables net generation
↪  (MWh)`/10^6
CountyName <- County_PM2.5_Energy_Data$County.Name
Geothermal <- County_PM2.5_Energy_Data$`Plant annual geothermal net generation (MWh)`
Year <- County_PM2.5_Energy_Data$Year

Total_Energy <- lm(PM2.5 ~ NonRenewableEnergy + RenewableEnergy + factor(Year) +
↪  factor(CountyName))
summary(Total_Energy)
```

```
##
## Call:
## lm(formula = PM2.5 ~ NonRenewableEnergy + RenewableEnergy + factor(Year) +
##     factor(CountyName))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.0889 -0.6684 -0.0352  0.6174 11.2806
##
## Coefficients:
##                                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)                           6.96354    0.60566  11.498  < 2e-16 ***
## NonRenewableEnergy                    0.01791    0.01248   1.435 0.151516
## RenewableEnergy                      -0.01559    0.02690  -0.579 0.562417
## factor(Year)2018                      0.61379    0.09802   6.262 4.49e-10 ***
## factor(Year)2019                     -0.03946    0.09865  -0.400 0.689166
## factor(Year)2020                      0.51581    0.09954   5.182 2.38e-07 ***
## factor(Year)2021                      1.01249    0.09737  10.399  < 2e-16 ***
## factor(Year)2022                      0.05738    0.09745   0.589 0.556058
## factor(CountyName)Adams               1.23112    0.75843   1.623 0.104667
## factor(CountyName)Alachua            -0.62163    0.85185  -0.730 0.465621
## factor(CountyName)Alameda             1.93168    0.85170   2.268 0.023416 *
## factor(CountyName)Albany             -1.57345    0.74033  -2.125 0.033661 *
## factor(CountyName)Allegan            -0.41567    0.85170  -0.488 0.625565
## factor(CountyName)Allegheny           2.80643    0.85502   3.282 0.001044 **
## factor(CountyName)Allen               0.40812    0.74861   0.545 0.585688
## factor(CountyName)Androscoggin       -2.01236    0.85157  -2.363 0.018201 *
## factor(CountyName)Apache             -4.91157    0.86392  -5.685 1.46e-08 ***
## factor(CountyName)Arapahoe           -1.32493    0.85166  -1.556 0.119909
```

```
## factor(CountyName)Arkansas              0.52607    0.85164   0.618 0.536825
## factor(CountyName)Armstrong             1.29797    0.86058   1.508 0.131619
## factor(CountyName)Aroostook            -2.10153    0.85157  -2.468 0.013662 *
## factor(CountyName)Ashley                0.63857    0.85164   0.750 0.453439
## factor(CountyName)Atlantic             -0.73247    0.85167  -0.860 0.389856
## factor(CountyName)Baldwin               0.07325    0.85165   0.086 0.931470
## factor(CountyName)Baltimore             0.22628    0.85169   0.266 0.790508
## factor(CountyName)Bay                  -1.08140    0.85585  -1.264 0.206519
## factor(CountyName)Beaver                1.70825    0.88192   1.937 0.052866 .
## factor(CountyName)Becker               -1.30689    0.85170  -1.534 0.125052
## factor(CountyName)Belknap              -2.81763    0.85170  -3.308 0.000953 ***
## factor(CountyName)Bell                  0.94737    0.76283   1.242 0.214390
## factor(CountyName)Beltrami             -1.33983    0.85171  -1.573 0.115824
## factor(CountyName)Benewah               2.42857    0.85169   2.851 0.004389 **
## factor(CountyName)Bergen                1.89357    0.85249   2.221 0.026429 *
## factor(CountyName)Berks                 1.29873    0.85520   1.519 0.128987
## factor(CountyName)Berkshire            -0.68575    0.85166  -0.805 0.420792
## factor(CountyName)Bernalillo           -0.27520    0.85167  -0.323 0.746622
## factor(CountyName)Bibb                  1.18644    0.85157   1.393 0.163674
## factor(CountyName)Black Hawk            0.55003    0.85170   0.646 0.518472
## factor(CountyName)Blair                 1.02854    0.85158   1.208 0.227243
## factor(CountyName)Boulder               0.65578    0.85169   0.770 0.441390
## factor(CountyName)Bradford             -0.18583    0.85411  -0.218 0.827777
## factor(CountyName)Brevard              -0.55974    0.85563  -0.654 0.513054
## factor(CountyName)Bristol              -0.96928    0.85169  -1.138 0.255205
## factor(CountyName)Bronx                 0.48859    0.85171   0.574 0.566253
## factor(CountyName)Broward              -0.06556    0.85855  -0.076 0.939136
## factor(CountyName)Brown                -0.75830    0.73753  -1.028 0.303982
## factor(CountyName)Buchanan              0.58722    0.85170   0.689 0.490598
## factor(CountyName)Buncombe             -0.80275    0.85233  -0.942 0.346375
## factor(CountyName)Burke                -3.14291    0.88606  -3.547 0.000397 ***
## factor(CountyName)Burleigh             -0.72539    0.85158  -0.852 0.394396
## factor(CountyName)Butler                2.57374    0.85274   3.018 0.002569 **
## factor(CountyName)Butte                 3.33122    0.85327   3.904 9.72e-05 ***
## factor(CountyName)Caddo                 2.57438    0.85383   3.015 0.002596 **
## factor(CountyName)Calaveras             1.93540    0.85157   2.273 0.023128 *
## factor(CountyName)Calcasieu             0.19632    0.86275   0.228 0.820013
## factor(CountyName)Cambria               1.75915    0.85392   2.060 0.039498 *
## factor(CountyName)Camden                1.96602    0.85161   2.309 0.021051 *
## factor(CountyName)Canyon                1.79624    0.85170   2.109 0.035048 *
## factor(CountyName)Carlton              -4.07240    0.85158  -4.782 1.84e-06 ***
## factor(CountyName)Carson City          -0.31069    0.85170  -0.365 0.715304
## factor(CountyName)Cass                 -0.53414    0.70163  -0.761 0.446561
## factor(CountyName)Catawba               0.73050    0.85700   0.852 0.394084
## factor(CountyName)Cecil                -0.25882    0.85271  -0.304 0.761517
## factor(CountyName)Cedar                -0.34377    0.85158  -0.404 0.686477
## factor(CountyName)Centre                1.04696    0.85170   1.229 0.219095
## factor(CountyName)Champaign             0.45517    0.85170   0.534 0.593095
## factor(CountyName)Charles              -1.09254    0.85443  -1.279 0.201136
## factor(CountyName)Chatham               1.64958    0.85163   1.937 0.052865 .
## factor(CountyName)Chautauqua           -1.35203    0.85160  -1.588 0.112502
## factor(CountyName)Chester               1.50043    0.85164   1.762 0.078229 .
## factor(CountyName)Christian             1.56331    0.85286   1.833 0.066922 .
## factor(CountyName)Clark                 0.74199    0.76080   0.975 0.329521
```

```
## factor(CountyName)Clarke                1.61554    0.85167   1.897 0.057958 .
## factor(CountyName)Clay                 -0.71873    0.72874  -0.986 0.324104
## factor(CountyName)Clayton               1.23524    0.85170   1.450 0.147101
## factor(CountyName)Cleveland             2.29773    0.85779   2.679 0.007442 **
## factor(CountyName)Clinton               1.03788    0.85183   1.218 0.223184
## factor(CountyName)Cobb                  0.83564    0.88128   0.948 0.343116
## factor(CountyName)Colusa                2.97011    0.85236   3.485 0.000502 ***
## factor(CountyName)Comanche              0.39897    0.85163   0.468 0.639490
## factor(CountyName)Contra Costa          1.66492    0.86973   1.914 0.055700 .
## factor(CountyName)Cook                 -0.97861    0.73765  -1.327 0.184749
## factor(CountyName)Crook                 1.90340    0.85163   2.235 0.025508 *
## factor(CountyName)Crow Wing            -1.92064    0.85170  -2.255 0.024218 *
## factor(CountyName)Cumberland            0.36370    0.67373   0.540 0.589367
## factor(CountyName)Custer               -3.57216    0.82129  -4.349 1.42e-05 ***
## factor(CountyName)Cuyahoga              2.07149    0.85170   2.432 0.015081 *
## factor(CountyName)Dakota               -0.29930    0.85184  -0.351 0.725349
## factor(CountyName)Dallas                1.41688    0.85169   1.664 0.096320 .
## factor(CountyName)Dauphin               1.77039    0.85268   2.076 0.037976 *
## factor(CountyName)Davidson              1.58151    0.73755   2.144 0.032111 *
## factor(CountyName)Daviess               1.50048    0.85181   1.762 0.078277 .
## factor(CountyName)Davis                 0.32681    0.85170   0.384 0.701220
## factor(CountyName)DeKalb                1.08629    0.73830   1.471 0.141326
## factor(CountyName)Delaware              1.31276    0.73694   1.781 0.074977 .
## factor(CountyName)Denver                0.81307    0.85168   0.955 0.339845
## factor(CountyName)DeSoto                1.15144    0.85216   1.351 0.176760
## factor(CountyName)Dewey                 0.23656    0.85425   0.277 0.781859
## factor(CountyName)District of Columbia  0.93863    0.85168   1.102 0.270527
## factor(CountyName)Dodge                 0.30765    0.85160   0.361 0.717936
## factor(CountyName)Dona Ana             -0.39815    0.85188  -0.467 0.640273
## factor(CountyName)Dorchester           -1.06569    0.85166  -1.251 0.210943
## factor(CountyName)Dougherty             1.84192    0.85157   2.163 0.030641 *
## factor(CountyName)Douglas              -0.12105    0.73366  -0.165 0.868965
## factor(CountyName)Dubois                1.42793    0.85170   1.677 0.093758 .
## factor(CountyName)DuPage                2.18855    0.85173   2.570 0.010243 *
## factor(CountyName)Durham                0.57649    0.85169   0.677 0.498549
## factor(CountyName)Duval                 0.64491    0.86099   0.749 0.453909
## factor(CountyName)East Baton Rouge      1.56253    0.85332   1.831 0.067207 .
## factor(CountyName)El Paso              -0.07079    0.74159  -0.095 0.923959
## factor(CountyName)Elkhart               1.13379    0.85167   1.331 0.183231
## factor(CountyName)Ellis                 0.84498    0.85296   0.991 0.321959
## factor(CountyName)Erie                 -0.21771    0.73754  -0.295 0.767881
## factor(CountyName)Escambia              1.39940    0.85240   1.642 0.100780
## factor(CountyName)Essex                -1.48465    0.69906  -2.124 0.033790 *
## factor(CountyName)Etowah                0.80071    0.85171   0.940 0.347249
## factor(CountyName)Fairfield             0.45919    0.85947   0.534 0.593206
## factor(CountyName)Fayette               0.67114    0.75810   0.885 0.376091
## factor(CountyName)Flathead              0.30474    0.85163   0.358 0.720498
## factor(CountyName)Forrest               2.10421    0.85167   2.471 0.013554 *
## factor(CountyName)Forsyth               0.82141    0.85159   0.965 0.334863
## factor(CountyName)Franklin             -0.19621    0.72469  -0.271 0.786608
## factor(CountyName)Frederick             0.32384    0.85168   0.380 0.703799
## factor(CountyName)Fremont              -3.58091    0.85165  -4.205 2.71e-05 ***
## factor(CountyName)Fresno                5.50977    0.85959   6.410 1.75e-10 ***
## factor(CountyName)Fulton                1.87234    0.85177   2.198 0.028032 *
```

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## factor(CountyName)Garland              1.23125    0.85159   1.446 0.148356
## factor(CountyName)Garrett             -1.90381    0.85158  -2.236 0.025468 *
## factor(CountyName)Genesee             -0.02903    0.85160  -0.034 0.972813
## factor(CountyName)Gloucester          -0.36048    0.85354  -0.422 0.672823
## factor(CountyName)Glynn                0.56687    0.85157   0.666 0.505682
## factor(CountyName)Grafton             -1.92169    0.85162  -2.257 0.024128 *
## factor(CountyName)Grant                1.16696    0.95503   1.222 0.221863
## factor(CountyName)Greene              -0.17553    0.69348  -0.253 0.800202
## factor(CountyName)Guilford             0.16080    0.85169   0.189 0.850261
## factor(CountyName)Gwinnett             1.98218    0.85168   2.327 0.020027 *
## factor(CountyName)Hall                -0.03701    0.73767  -0.050 0.959985
## factor(CountyName)Hamilton             1.04522    0.70645   1.480 0.139127
## factor(CountyName)Hampden             -0.55305    0.85169  -0.649 0.516165
## factor(CountyName)Hampshire           -1.44409    0.85167  -1.696 0.090092 .
## factor(CountyName)Hancock             -0.79510    0.69732  -1.140 0.254307
## factor(CountyName)Hardin               0.59755    0.85193   0.701 0.483113
## factor(CountyName)Harford             -0.30956    0.85245  -0.363 0.716533
## factor(CountyName)Harris               1.96666    0.88181   2.230 0.025823 *
## factor(CountyName)Harrison             0.52384    0.69231   0.757 0.449331
## factor(CountyName)Hartford             0.04921    0.85160   0.058 0.953921
## factor(CountyName)Hawaii              -2.46358    0.85165  -2.893 0.003853 **
## factor(CountyName)Hennepin             0.46476    0.85211   0.545 0.585513
## factor(CountyName)Henry                0.25784    0.85176   0.303 0.762134
## factor(CountyName)Hidalgo              2.87953    0.85259   3.377 0.000743 ***
## factor(CountyName)Hillsborough        -1.75403    0.75294  -2.330 0.019910 *
## factor(CountyName)Hinds                2.12711    0.85272   2.495 0.012679 *
## factor(CountyName)Honolulu            -4.08633    0.85489  -4.780 1.86e-06 ***
## factor(CountyName)Houston              1.13439    0.79811   1.421 0.155347
## factor(CountyName)Howard               0.51155    0.73764   0.693 0.488067
## factor(CountyName)Hudson               0.78983    0.85182   0.927 0.353902
## factor(CountyName)Humboldt            -0.54751    0.85186  -0.643 0.520470
## factor(CountyName)Hunterdon            0.45454    0.85167   0.534 0.593594
## factor(CountyName)Iberville            0.57864    0.86269   0.671 0.502453
## factor(CountyName)Imperial             3.27901    0.87565   3.745 0.000185 ***
## factor(CountyName)Ingham               0.51578    0.85181   0.606 0.544897
## factor(CountyName)Inyo                 1.07943    0.85181   1.267 0.205199
## factor(CountyName)Jackson              0.13688    0.68729   0.199 0.842158
## factor(CountyName)Jefferson            0.17193    1.18348   0.145 0.884505
## factor(CountyName)Johnson              0.72235    0.73767   0.979 0.327567
## factor(CountyName)Johnston             0.42850    0.85157   0.503 0.614878
## factor(CountyName)Kalamazoo            1.32730    0.85170   1.558 0.119270
## factor(CountyName)Kane                 1.41135    0.85169   1.657 0.097625 .
## factor(CountyName)Kauai               -4.34682    0.85163  -5.104 3.58e-07 ***
## factor(CountyName)Kay                  1.56884    0.85305   1.839 0.066023 .
## factor(CountyName)Kennebec            -1.85848    0.85165  -2.182 0.029189 *
## factor(CountyName)Kent                -0.80544    0.67366  -1.196 0.231967
## factor(CountyName)Kern                 3.01628    0.96229   3.134 0.001742 **
## factor(CountyName)Kings                4.31113    0.73847   5.838 6.00e-09 ***
## factor(CountyName)Klamath              6.21436    0.85232   7.291 4.15e-13 ***
## factor(CountyName)Knox                 1.69450    0.85304   1.986 0.047099 *
## factor(CountyName)La Paz              -3.50157    0.85166  -4.111 4.06e-05 ***
## factor(CountyName)Lackawanna           0.12818    0.85633   0.150 0.881022
## factor(CountyName)Lafayette            0.53184    0.85165   0.624 0.532373
## factor(CountyName)Lake                -0.51637    0.69691  -0.741 0.458802
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## factor(CountyName)Lancaster             0.96982    0.73894   1.312 0.189490
## factor(CountyName)Lane                  2.01918    0.85158   2.371 0.017814 *
## factor(CountyName)LaPorte               0.56634    0.85192   0.665 0.506252
## factor(CountyName)Larimer              -0.09130    0.85194  -0.107 0.914670
## factor(CountyName)Lawrence             -0.57710    0.75969  -0.760 0.447532
## factor(CountyName)Lea                  -0.64036    0.85425  -0.750 0.453558
## factor(CountyName)Lebanon               1.83831    0.85400   2.153 0.031450 *
## factor(CountyName)Lee                  -0.02266    0.80129  -0.028 0.977440
## factor(CountyName)Lehigh                1.70625    0.85170   2.003 0.045253 *
## factor(CountyName)Lemhi                 3.22966    0.85170   3.792 0.000153 ***
## factor(CountyName)Lenawee               1.09984    0.85170   1.291 0.196706
## factor(CountyName)Leon                 -0.13972    0.85191  -0.164 0.869736
## factor(CountyName)Lewis and Clark      -1.05895    0.85157  -1.244 0.213796
## factor(CountyName)Lincoln               3.49989    0.84003   4.166 3.20e-05 ***
## factor(CountyName)Linn                  0.73946    0.86155   0.858 0.390816
## factor(CountyName)Litchfield           -2.26048    0.85167  -2.654 0.008002 **
## factor(CountyName)Los Angeles           3.95700    0.88767   4.458 8.66e-06 ***
## factor(CountyName)Lowndes               0.67950    0.85383   0.796 0.426212
## factor(CountyName)Lucas                 0.80857    0.85452   0.946 0.344125
## factor(CountyName)Lyon                 -1.37335    0.85180  -1.612 0.107027
## factor(CountyName)Macomb                0.55816    0.85164   0.655 0.512278
## factor(CountyName)Macon                 1.86787    0.85178   2.193 0.028410 *
## factor(CountyName)Madera                5.30327    0.85163   6.227 5.58e-10 ***
## factor(CountyName)Madison               0.92334    0.67062   1.377 0.168692
## factor(CountyName)Mahoning              0.82303    0.85164   0.966 0.333940
## factor(CountyName)Manistee             -2.10665    0.85169  -2.473 0.013449 *
## factor(CountyName)Maricopa             -0.23565    1.18067  -0.200 0.841818
## factor(CountyName)Marin                 0.45010    0.85169   0.528 0.597213
## factor(CountyName)Marion                1.81220    0.74026   2.448 0.014434 *
## factor(CountyName)Marshall              2.18029    0.85716   2.544 0.011033 *
## factor(CountyName)Maui                 -3.70855    0.85167  -4.354 1.39e-05 ***
## factor(CountyName)McCracken             1.73700    0.85476   2.032 0.042248 *
## factor(CountyName)McHenry               1.11377    0.85159   1.308 0.191042
## factor(CountyName)McKenzie             -2.84034    0.85176  -3.335 0.000867 ***
## factor(CountyName)McLean                1.45349    0.85874   1.693 0.090664 .
## factor(CountyName)Mecklenburg           0.74217    0.88620   0.837 0.402404
## factor(CountyName)Medina               -0.16833    0.85170  -0.198 0.843339
## factor(CountyName)Mendocino             1.63775    0.85170   1.923 0.054607 .
## factor(CountyName)Merced                4.75781    0.85157   5.587 2.57e-08 ***
## factor(CountyName)Mercer               -0.55793    0.71758  -0.778 0.436932
## factor(CountyName)Mesa                 -1.52445    0.85168  -1.790 0.073590 .
## factor(CountyName)Middlesex            -0.31283    0.78391  -0.399 0.689886
## factor(CountyName)Missaukee            -0.32992    0.85161  -0.387 0.698490
## factor(CountyName)Mitchell             -1.14193    0.85224  -1.340 0.180395
## factor(CountyName)Mobile                0.42907    0.87182   0.492 0.622656
## factor(CountyName)Monroe               -0.93257    0.83020  -1.123 0.261418
## factor(CountyName)Monterey             -1.64824    0.85417  -1.930 0.053770 .
## factor(CountyName)Montgomery           -0.02525    0.72099  -0.035 0.972065
## factor(CountyName)Morgan                0.58804    0.86606   0.679 0.497218
## factor(CountyName)Morris               -1.59897    0.85169  -1.877 0.060584 .
## factor(CountyName)Multnomah             0.11932    0.85828   0.139 0.889444
## factor(CountyName)Muscatine             0.72530    0.85177   0.852 0.394565
## factor(CountyName)Muscogee              1.33967    0.85159   1.573 0.115814
## factor(CountyName)Neosho                1.65118    0.85163   1.939 0.052637 .
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## factor(CountyName)Nevada                0.20823    0.85160   0.245 0.806849
## factor(CountyName)New Castle            0.59455    0.85310   0.697 0.485917
## factor(CountyName)New Hanover          -2.57328    0.85335  -3.016 0.002592 **
## factor(CountyName)New Haven             0.28994    0.85687   0.338 0.735116
## factor(CountyName)New London           -1.17436    0.87775  -1.338 0.181048
## factor(CountyName)New York              0.44054    0.85270   0.517 0.605450
## factor(CountyName)Northampton           0.60446    0.77002   0.785 0.432538
## factor(CountyName)Oakland               0.39662    0.85169   0.466 0.641487
## factor(CountyName)Ocean                -0.80356    0.85206  -0.943 0.345738
## factor(CountyName)Ohio                  0.37080    0.85236   0.435 0.663583
## factor(CountyName)Oklahoma              1.85737    0.85580   2.170 0.030078 *
## factor(CountyName)Oliver               -1.38247    0.85349  -1.620 0.105409
## factor(CountyName)Olmsted              -0.61620    0.85169  -0.724 0.469439
## factor(CountyName)Onondaga             -1.47010    0.85163  -1.726 0.084436 .
## factor(CountyName)Orange                0.49863    0.71999   0.693 0.488654
## factor(CountyName)Orleans               0.49947    0.85164   0.586 0.557611
## factor(CountyName)Ouachita              0.24455    0.85606   0.286 0.775152
## factor(CountyName)Oxford               -1.86533    0.85161  -2.190 0.028594 *
## factor(CountyName)Palm Beach           -1.20399    0.91479  -1.316 0.188251
## factor(CountyName)Palo Alto            -0.41914    0.85158  -0.492 0.622627
## factor(CountyName)Park                 -3.77592    0.79673  -4.739 2.27e-06 ***
## factor(CountyName)Pennington           -0.55667    0.85170  -0.654 0.513434
## factor(CountyName)Penobscot            -2.17384    0.85179  -2.552 0.010769 *
## factor(CountyName)Peoria                1.40471    0.85260   1.648 0.099570 .
## factor(CountyName)Perry                 0.75771    0.85157   0.890 0.373669
## factor(CountyName)Philadelphia          1.47812    0.85181   1.735 0.082820 .
## factor(CountyName)Phillips             -2.00103    0.85170  -2.349 0.018882 *
## factor(CountyName)Pierce                0.32774    0.85163   0.385 0.700388
## factor(CountyName)Pike                 -0.21530    0.85806  -0.251 0.801898
## factor(CountyName)Pima                 -2.27126    0.85173  -2.667 0.007712 **
## factor(CountyName)Pinal                 2.14661    0.85215   2.519 0.011831 *
## factor(CountyName)Pinellas             -0.11811    0.85543  -0.138 0.890197
## factor(CountyName)Pitt                 -0.95625    0.85168  -1.123 0.261643
## factor(CountyName)Pittsburg             1.25369    0.85357   1.469 0.142030
## factor(CountyName)Placer                1.55666    0.85197   1.827 0.067805 .
## factor(CountyName)Plumas                5.89063    0.85184   6.915 5.96e-12 ***
## factor(CountyName)Plymouth             -0.26511    0.85199  -0.311 0.755697
## factor(CountyName)Polk                 -0.18531    0.77787  -0.238 0.811726
## factor(CountyName)Portage              -0.18376    0.85168  -0.216 0.829190
## factor(CountyName)Porter                0.76078    0.85189   0.893 0.371919
## factor(CountyName)Pottawattamie         0.57368    0.85662   0.670 0.503111
## factor(CountyName)Pueblo               -1.67699    0.85864  -1.953 0.050926 .
## factor(CountyName)Pulaski               1.27480    0.73764   1.728 0.084079 .
## factor(CountyName)Putnam               -0.75313    0.86788  -0.868 0.385603
## factor(CountyName)Queens               -0.51504    0.86720  -0.594 0.552626
## factor(CountyName)Ramsey               -0.01928    0.85227  -0.023 0.981951
## factor(CountyName)Randolph              0.51977    0.87006   0.597 0.550297
## factor(CountyName)Rapides               0.22423    0.85480   0.262 0.793101
## factor(CountyName)Richland             -1.05815    0.73773  -1.434 0.151605
## factor(CountyName)Richmond              1.35844    0.75025   1.811 0.070318 .
## factor(CountyName)Rio Blanco            0.86403    0.85170   1.014 0.310456
## factor(CountyName)Riverside             2.92806    0.86615   3.381 0.000735 ***
## factor(CountyName)Rock Island           0.95893    0.87666   1.094 0.274131
## factor(CountyName)Rockingham           -1.38526    0.77977  -1.776 0.075777 .
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## factor(CountyName)Russell              1.88453    0.85206   2.212 0.027079 *
## factor(CountyName)Sacramento           1.77938    0.85371   2.084 0.037238 *
## factor(CountyName)San Benito          -1.32814    0.85160  -1.560 0.118990
## factor(CountyName)San Bernardino       3.99687    0.86156   4.639 3.69e-06 ***
## factor(CountyName)San Diego            2.81327    0.85400   3.294 0.001001 **
## factor(CountyName)San Francisco        1.27599    0.85170   1.498 0.134222
## factor(CountyName)San Joaquin          4.77748    0.85187   5.608 2.28e-08 ***
## factor(CountyName)San Luis Obispo     -0.48059    0.87941  -0.546 0.584780
## factor(CountyName)San Mateo            0.79242    0.85166   0.930 0.352236
## factor(CountyName)Sangamon             1.08583    0.85185   1.275 0.202550
## factor(CountyName)Santa Barbara       -0.63864    0.85165  -0.750 0.453395
## factor(CountyName)Santa Clara          1.71426    0.85309   2.009 0.044599 *
## factor(CountyName)Santa Cruz           0.67059    0.73762   0.909 0.363371
## factor(CountyName)Sarasota            -0.03878    0.85169  -0.046 0.963684
## factor(CountyName)Sarpy                0.70052    0.85170   0.822 0.410877
## factor(CountyName)Scioto              -0.19185    0.85161  -0.225 0.821783
## factor(CountyName)Scott                0.22022    0.73795   0.298 0.765414
## factor(CountyName)Scotts Bluff        -1.83199    0.85170  -2.151 0.031577 *
## factor(CountyName)Sedgwick             0.48526    0.85171   0.570 0.568905
## factor(CountyName)Seminole            -0.42584    0.85200  -0.500 0.617254
## factor(CountyName)Sequoyah             0.61486    0.85157   0.722 0.470341
## factor(CountyName)Shasta               1.70957    0.86392   1.979 0.047947 *
## factor(CountyName)Shawnee              1.95852    0.85168   2.300 0.021556 *
## factor(CountyName)Shelby               1.02476    0.85864   1.193 0.232806
## factor(CountyName)Silver Bow          -0.23739    0.85171  -0.279 0.780486
## factor(CountyName)Siskiyou             3.91287    0.85159   4.595 4.56e-06 ***
## factor(CountyName)Solano               2.35170    0.85357   2.755 0.005911 **
## factor(CountyName)Sonoma              -0.50317    0.86184  -0.584 0.559384
## factor(CountyName)Spencer              0.79240    0.85686   0.925 0.355181
## factor(CountyName)Stanislaus           5.73723    0.85195   6.734 2.05e-11 ***
## factor(CountyName)Stark                2.09399    0.85172   2.459 0.014020 *
## factor(CountyName)Stearns             -0.75979    0.85158  -0.892 0.372366
## factor(CountyName)Steuben             -1.81774    0.85158  -2.135 0.032898 *
## factor(CountyName)Suffolk             -0.54074    0.74329  -0.727 0.466994
## factor(CountyName)Sullivan            -0.14329    0.78020  -0.184 0.854294
## factor(CountyName)Summit               1.43390    0.85167   1.684 0.092384 .
## factor(CountyName)Sumner               0.54555    0.73809   0.739 0.459891
## factor(CountyName)Sussex               0.24802    0.85167   0.291 0.770909
## factor(CountyName)Sutter               4.12469    0.85189   4.842 1.37e-06 ***
## factor(CountyName)Swain               -0.20106    0.85174  -0.236 0.813408
## factor(CountyName)Taylor              -0.91322    0.85329  -1.070 0.284623
## factor(CountyName)Tehama               1.18201    0.85169   1.388 0.165312
## factor(CountyName)Terrebonne          -0.11203    0.85170  -0.132 0.895361
## factor(CountyName)Teton               -3.23565    0.85164  -3.799 0.000149 ***
## factor(CountyName)Tioga               -1.08102    0.85160  -1.269 0.204423
## factor(CountyName)Tippecanoe           0.99346    0.85171   1.166 0.243559
## factor(CountyName)Trumbull            -0.16181    0.85356  -0.190 0.849658
## factor(CountyName)Tulare               7.68232    0.85157   9.021  < 2e-16 ***
## factor(CountyName)Tulsa                1.99294    0.85378   2.334 0.019664 *
## factor(CountyName)Tuscaloosa           0.36022    0.85161   0.423 0.672342
## factor(CountyName)Union                0.47496    0.74850   0.635 0.525789
## factor(CountyName)Van Buren           -0.43602    0.86648  -0.503 0.614870
## factor(CountyName)Vanderburgh          1.52010    0.85170   1.785 0.074422 .
## factor(CountyName)Ventura              0.33762    0.85186   0.396 0.691897
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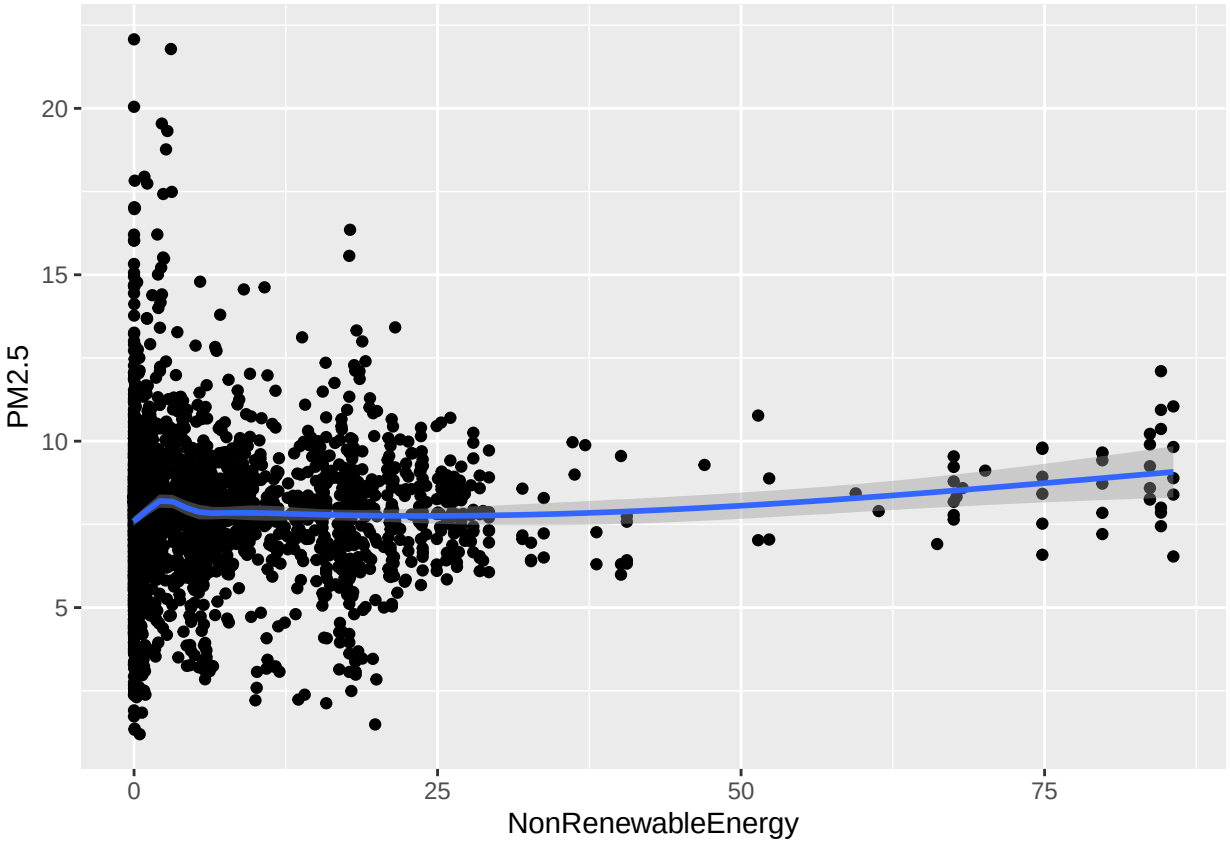
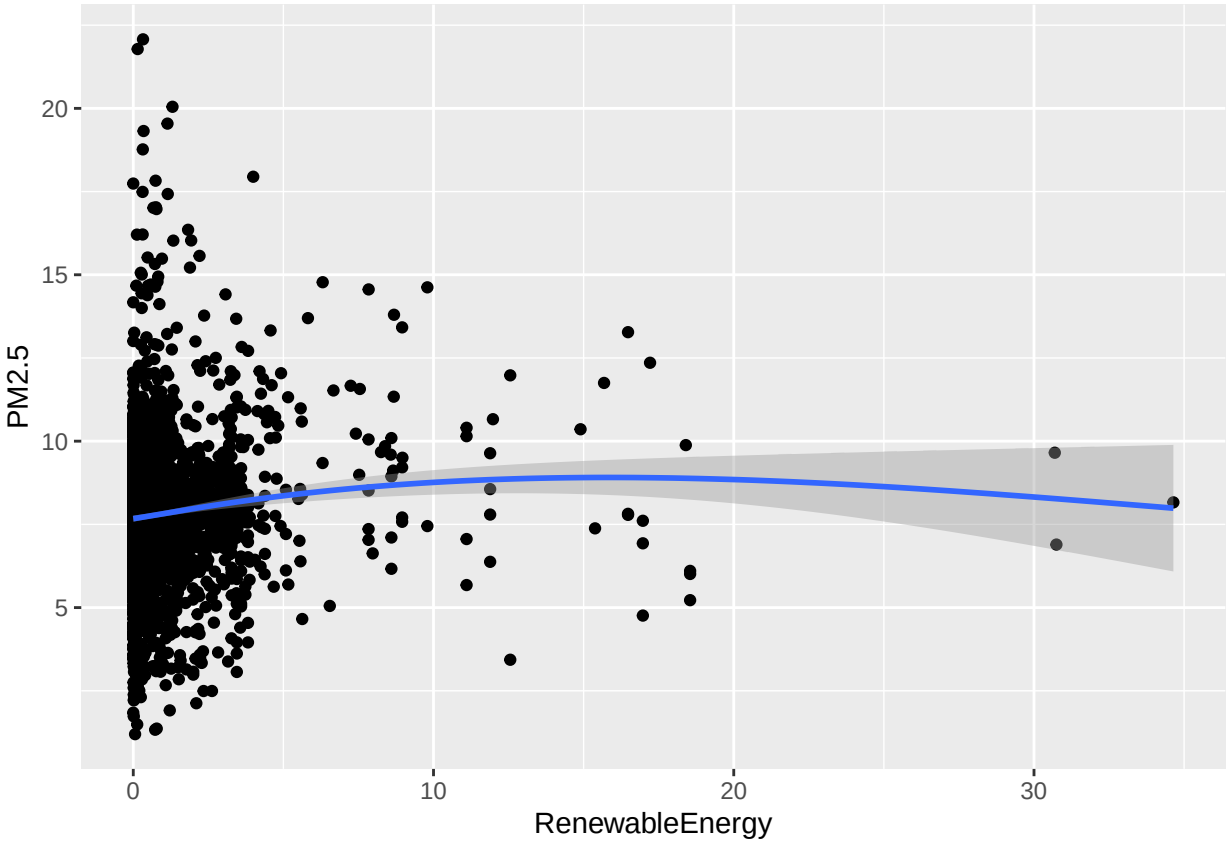
## factor(CountyName)Vigo                  1.44647    0.85292   1.696 0.090032 .
## factor(CountyName)Volusia                0.08015    0.85952   0.093 0.925715
## factor(CountyName)Wake                   0.97772    0.85739   1.140 0.254260
## factor(CountyName)Walker                 2.20063    0.85193   2.583 0.009850 **
## factor(CountyName)Warren                 0.69819    0.74007   0.943 0.345565
## factor(CountyName)Washington            -0.38741    0.67426  -0.575 0.565637
## factor(CountyName)Washoe                 0.81822    0.85159   0.961 0.336742
## factor(CountyName)Washtenaw              1.19003    0.85166   1.397 0.162451
## factor(CountyName)Wayne                  2.55114    0.88308   2.889 0.003900 **
## factor(CountyName)Weld                   1.41042    0.85616   1.647 0.099608 .
## factor(CountyName)West Baton Rouge       1.63929    0.85168   1.925 0.054376 .
## factor(CountyName)Westmoreland           0.33795    0.85337   0.396 0.692126
## factor(CountyName)Whitley                0.92477    0.85170   1.086 0.277681
## factor(CountyName)Will                   1.28536    0.90410   1.422 0.155241
## factor(CountyName)Winnebago              1.32114    0.85159   1.551 0.120942
## factor(CountyName)Wood                   0.30663    0.85166   0.360 0.718852
## factor(CountyName)Woodbury               0.40131    0.85269   0.471 0.637945
## factor(CountyName)Worcester              0.29840    0.85264   0.350 0.726391
## factor(CountyName)Wright                -0.79404    0.85435  -0.929 0.352771
## factor(CountyName)Wyandotte              2.49482    0.85182   2.929 0.003434 **
## factor(CountyName)Yellowstone            0.12363    0.85173   0.145 0.884601
## factor(CountyName)Yolo                   2.14759    0.85162   2.522 0.011741 *
## factor(CountyName)York                   0.44215    0.87553   0.505 0.613597
## factor(CountyName)Yuma                   1.30135    0.85163   1.528 0.126624
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.475 on 2412 degrees of freedom
## Multiple R-squared:   0.57,  Adjusted R-squared:  0.5049
## F-statistic: 8.759 on 365 and 2412 DF,  p-value: < 2.2e-16
```

```
ggplot()+
  geom_point(aes(x= NonRenewableEnergy, y= PM2.5))+
  geom_smooth(aes(x= NonRenewableEnergy, y= PM2.5))
```




```
ggplot()+
  geom_point(aes(x= RenewableEnergy, y= PM2.5))+
  geom_smooth(aes(x= RenewableEnergy, y= PM2.5))
```




```
PM2.5 <- County_PM2.5_Energy_Data$PM2.5_Avg
Coal <- County_PM2.5_Energy_Data$`Plant annual coal net generation (MWh)`/10^6
Oil <- County_PM2.5_Energy_Data$`Plant annual oil net generation (MWh)`/10^6
NGas <- County_PM2.5_Energy_Data$`Plant annual gas net generation (MWh)`/10^6
Nuclear <- County_PM2.5_Energy_Data$`Plant annual nuclear net generation (MWh)`/10^6
Hydro <- County_PM2.5_Energy_Data$`Plant annual biomass net generation (MWh)`/10^6
Wind <- County_PM2.5_Energy_Data$`Plant annual wind net generation (MWh)`/10^6
Biomass <- County_PM2.5_Energy_Data$`Plant annual biomass net generation (MWh)`/10^6
Solar <- County_PM2.5_Energy_Data$`Plant annual solar net generation (MWh)`/10^6
Geothermal <- County_PM2.5_Energy_Data$`Plant annual geothermal net generation
↪  (MWh)`/10^6
CountyName <- County_PM2.5_Energy_Data$County.Name

Source_Energy <- lm(PM2.5 ~ Geothermal + factor(Year)+ factor(CountyName))
summary(Source_Energy)
```

```
##
## Call:
## lm(formula = PM2.5 ~ Geothermal + factor(Year) + factor(CountyName))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.1279 -0.6668 -0.0327  0.6118 11.2999
##
## Coefficients:
```

```
##                                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)                      6.965501   0.605022  11.513  < 2e-16
## Geothermal                       3.593537   1.698714   2.115 0.034494
## factor(Year)2018                 0.595857   0.096973   6.145 9.35e-10
## factor(Year)2019                -0.050524   0.097268  -0.519 0.603508
## factor(Year)2020                 0.490557   0.097232   5.045 4.87e-07
## factor(Year)2021                 1.005252   0.097061  10.357  < 2e-16
## factor(Year)2022                 0.053551   0.097040   0.552 0.581110
## factor(CountyName)Adams          1.472918   0.736998   1.999 0.045770
## factor(CountyName)Alachua       -0.589272   0.851012  -0.692 0.488729
## factor(CountyName)Alameda        1.951796   0.851012   2.294 0.021905
## factor(CountyName)Albany        -1.480091   0.736998  -2.008 0.044726
## factor(CountyName)Allegan       -0.403461   0.851012  -0.474 0.635475
## factor(CountyName)Allegheny      2.922386   0.851012   3.434 0.000605
## factor(CountyName)Allen          0.412381   0.748102   0.551 0.581523
## factor(CountyName)Androscoggin  -2.014397   0.851012  -2.367 0.018008
## factor(CountyName)Apache        -4.695996   0.851012  -5.518 3.79e-08
## factor(CountyName)Arapahoe      -1.317663   0.851012  -1.548 0.121669
## factor(CountyName)Arkansas       0.532601   0.851012   0.626 0.531476
## factor(CountyName)Armstrong      1.479869   0.851012   1.739 0.082171
## factor(CountyName)Aroostook     -2.101077   0.851012  -2.469 0.013621
## factor(CountyName)Ashley         0.647046   0.851012   0.760 0.447134
## factor(CountyName)Atlantic      -0.723437   0.851012  -0.850 0.395359
## factor(CountyName)Baldwin        0.080238   0.851012   0.094 0.924890
## factor(CountyName)Baltimore      0.236842   0.851012   0.278 0.780801
## factor(CountyName)Bay           -0.954065   0.851012  -1.121 0.262359
## factor(CountyName)Beaver         1.169477   0.934988   1.251 0.211131
## factor(CountyName)Becker        -1.297969   0.851012  -1.525 0.127338
## factor(CountyName)Belknap       -2.808886   0.851012  -3.301 0.000979
## factor(CountyName)Bell           1.009875   0.761209   1.327 0.184743
## factor(CountyName)Beltrami      -1.329684   0.851012  -1.562 0.118307
## factor(CountyName)Benewah        2.437000   0.851012   2.864 0.004224
## factor(CountyName)Bergen         1.954196   0.851012   2.296 0.021743
## factor(CountyName)Berks          1.417104   0.851012   1.665 0.096003
## factor(CountyName)Berkshire     -0.676510   0.851012  -0.795 0.426722
## factor(CountyName)Bernalillo    -0.260682   0.851012  -0.306 0.759387
## factor(CountyName)Bibb           1.187490   0.851012   1.395 0.163028
## factor(CountyName)Black Hawk     0.559425   0.851012   0.657 0.511009
## factor(CountyName)Blair          1.031704   0.851012   1.212 0.225506
## factor(CountyName)Boulder        0.667200   0.851012   0.784 0.433112
## factor(CountyName)Bradford      -0.085881   0.851012  -0.101 0.919625
## factor(CountyName)Brevard       -0.436551   0.851012  -0.513 0.608013
## factor(CountyName)Bristol       -0.949619   0.851012  -1.116 0.264589
## factor(CountyName)Bronx          0.502802   0.851012   0.591 0.554690
## factor(CountyName)Broward        0.093637   0.851012   0.110 0.912394
## factor(CountyName)Brown         -0.747119   0.736998  -1.014 0.310812
## factor(CountyName)Buchanan       0.599300   0.851012   0.704 0.481363
## factor(CountyName)Buncombe      -0.747700   0.851012  -0.879 0.379705
## factor(CountyName)Burke         -2.790964   0.851012  -3.280 0.001054
## factor(CountyName)Burleigh      -0.727912   0.851012  -0.855 0.392443
## factor(CountyName)Butler         2.640236   0.851012   3.102 0.001941
## factor(CountyName)Butte          3.300188   0.851012   3.878 0.000108
## factor(CountyName)Caddo          2.648156   0.851012   3.112 0.001881
## factor(CountyName)Calaveras      1.936021   0.851012   2.275 0.022995
```

```
## factor(CountyName)Calcasieu              0.401063   0.851012   0.471 0.637485
## factor(CountyName)Cambria                1.849544   0.851012   2.173 0.029851
## factor(CountyName)Camden                 1.973732   0.851012   2.319 0.020463
## factor(CountyName)Canyon                 1.805898   0.851012   2.122 0.033934
## factor(CountyName)Carlton               -4.074839   0.851012  -4.788 1.78e-06
## factor(CountyName)Carson City           -0.301767   0.851012  -0.355 0.722922
## factor(CountyName)Cass                  -0.495796   0.699948  -0.708 0.478807
## factor(CountyName)Catawba                0.870963   0.851012   1.023 0.306200
## factor(CountyName)Cecil                 -0.191410   0.851012  -0.225 0.822060
## factor(CountyName)Cedar                 -0.346892   0.851012  -0.408 0.683586
## factor(CountyName)Centre                 1.056951   0.851012   1.242 0.214359
## factor(CountyName)Champaign              0.467550   0.851012   0.549 0.582778
## factor(CountyName)Charles               -0.986715   0.851012  -1.159 0.246383
## factor(CountyName)Chatham                1.648218   0.851012   1.937 0.052889
## factor(CountyName)Chautauqua            -1.345428   0.851012  -1.581 0.114015
## factor(CountyName)Chester                1.507202   0.851012   1.771 0.076675
## factor(CountyName)Christian              1.635033   0.851012   1.921 0.054814
## factor(CountyName)Clark                  1.023351   0.672784   1.521 0.128373
## factor(CountyName)Clarke                 1.623782   0.851012   1.908 0.056502
## factor(CountyName)Clay                  -0.738140   0.727503  -1.015 0.310388
## factor(CountyName)Clayton                1.244132   0.851012   1.462 0.143887
## factor(CountyName)Cleveland              2.450706   0.851012   2.880 0.004015
## factor(CountyName)Clinton                1.040524   0.851012   1.223 0.221566
## factor(CountyName)Cobb                   1.168530   0.851012   1.373 0.169847
## factor(CountyName)Colusa                 3.026233   0.851012   3.556 0.000384
## factor(CountyName)Comanche               0.396825   0.851012   0.466 0.641044
## factor(CountyName)Contra Costa           1.920611   0.851012   2.257 0.024106
## factor(CountyName)Cook                  -0.959523   0.736998  -1.302 0.193063
## factor(CountyName)Crook                  1.909576   0.851012   2.244 0.024930
## factor(CountyName)Crow Wing             -1.911989   0.851012  -2.247 0.024748
## factor(CountyName)Cumberland             0.400689   0.672784   0.596 0.551520
## factor(CountyName)Custer                -3.592674   0.820104  -4.381 1.23e-05
## factor(CountyName)Cuyahoga               2.082865   0.851012   2.448 0.014455
## factor(CountyName)Dakota                -0.266989   0.851012  -0.314 0.753753
## factor(CountyName)Dallas                 1.437197   0.851012   1.689 0.091385
## factor(CountyName)Dauphin                1.837052   0.851012   2.159 0.030974
## factor(CountyName)Davidson               1.588756   0.736998   2.156 0.031205
## factor(CountyName)Daviess                1.527903   0.851012   1.795 0.072716
## factor(CountyName)Davis                  0.335796   0.851012   0.395 0.693184
## factor(CountyName)DeKalb                 1.066124   0.736998   1.447 0.148145
## factor(CountyName)Delaware               1.476064   0.727504   2.029 0.042574
## factor(CountyName)Denver                 0.824526   0.851012   0.969 0.332703
## factor(CountyName)DeSoto                 1.194886   0.851012   1.404 0.160424
## factor(CountyName)Dewey                  0.197391   0.851012   0.232 0.816597
## factor(CountyName)District of Columbia   0.947873   0.851012   1.114 0.265467
## factor(CountyName)Dodge                  0.318923   0.851012   0.375 0.707874
## factor(CountyName)Dona Ana               -0.363114   0.851012  -0.427 0.669647
## factor(CountyName)Dorchester            -1.058211   0.851012  -1.243 0.213814
## factor(CountyName)Dougherty              1.843763   0.851012   2.167 0.030366
## factor(CountyName)Douglas               -0.181051   0.694848  -0.261 0.794453
## factor(CountyName)Dubois                 1.436819   0.851012   1.688 0.091470
## factor(CountyName)DuPage                 2.209348   0.851012   2.596 0.009485
## factor(CountyName)Durham                 0.584790   0.851012   0.687 0.492041
## factor(CountyName)Duval                  0.832875   0.851012   0.979 0.327832
```

```
## factor(CountyName)East Baton Rouge       1.645431   0.851012   1.934 0.053291
## factor(CountyName)El Paso                0.032098   0.736998   0.044 0.965265
## factor(CountyName)Elkhart                1.141675   0.851012   1.342 0.179868
## factor(CountyName)Ellis                  0.885076   0.851012   1.040 0.298431
## factor(CountyName)Erie                  -0.210544   0.736998  -0.286 0.775149
## factor(CountyName)Escambia               1.451354   0.851012   1.705 0.088240
## factor(CountyName)Essex                 -1.395472   0.694848  -2.008 0.044721
## factor(CountyName)Etowah                 0.811392   0.851012   0.953 0.340461
## factor(CountyName)Fairfield              0.627916   0.851012   0.738 0.460679
## factor(CountyName)Fayette                0.844315   0.748103   1.129 0.259175
## factor(CountyName)Flathead               0.298857   0.851012   0.351 0.725485
## factor(CountyName)Forrest                2.111944   0.851012   2.482 0.013144
## factor(CountyName)Forsyth                0.825477   0.851012   0.970 0.332146
## factor(CountyName)Franklin               0.052925   0.690269   0.077 0.938891
## factor(CountyName)Frederick              0.332652   0.851012   0.391 0.695913
## factor(CountyName)Fremont               -3.573558   0.851012  -4.199 2.78e-05
## factor(CountyName)Fresno                 5.460137   0.851012   6.416 1.68e-10
## factor(CountyName)Fulton                 1.899798   0.851012   2.232 0.025680
## factor(CountyName)Garland                1.234822   0.851012   1.451 0.146909
## factor(CountyName)Garrett               -1.900747   0.851012  -2.234 0.025606
## factor(CountyName)Genesee               -0.023468   0.851012  -0.028 0.978002
## factor(CountyName)Gloucester            -0.272670   0.851012  -0.320 0.748688
## factor(CountyName)Glynn                  0.570131   0.851012   0.670 0.502957
## factor(CountyName)Grafton               -1.926936   0.851012  -2.264 0.023645
## factor(CountyName)Grant                  0.992312   0.851012   1.166 0.243714
## factor(CountyName)Greene                -0.031792   0.686119  -0.046 0.963046
## factor(CountyName)Guilford               0.169227   0.851012   0.199 0.842394
## factor(CountyName)Gwinnett               1.990203   0.851012   2.339 0.019436
## factor(CountyName)Hall                  -0.019767   0.736998  -0.027 0.978605
## factor(CountyName)Hamilton               1.349904   0.672784   2.006 0.044920
## factor(CountyName)Hampden               -0.531549   0.851012  -0.625 0.532287
## factor(CountyName)Hampshire             -1.435912   0.851012  -1.687 0.091675
## factor(CountyName)Hancock               -0.825289   0.694848  -1.188 0.235058
## factor(CountyName)Hardin                 0.584326   0.851012   0.687 0.492385
## factor(CountyName)Harford               -0.326190   0.851012  -0.383 0.701533
## factor(CountyName)Harris                 2.302308   0.851012   2.705 0.006871
## factor(CountyName)Harrison               0.743875   0.675708   1.101 0.271057
## factor(CountyName)Hartford               0.060401   0.851012   0.071 0.943423
## factor(CountyName)Hawaii                -2.907969   0.878601  -3.310 0.000947
## factor(CountyName)Hennepin               0.511313   0.851012   0.601 0.548010
## factor(CountyName)Henry                  0.254847   0.851012   0.299 0.764612
## factor(CountyName)Hidalgo                2.800534   0.853647   3.281 0.001050
## factor(CountyName)Hillsborough          -1.541657   0.736998  -2.092 0.036560
## factor(CountyName)Hinds                  2.194784   0.851012   2.579 0.009967
## factor(CountyName)Honolulu              -3.981747   0.851012  -4.679 3.04e-06
## factor(CountyName)Houston                1.399836   0.776920   1.802 0.071705
## factor(CountyName)Howard                 0.504351   0.736998   0.684 0.493831
## factor(CountyName)Hudson                 0.818927   0.851012   0.962 0.335996
## factor(CountyName)Humboldt              -1.315370   0.931571  -1.412 0.158082
## factor(CountyName)Hunterdon              0.462829   0.851012   0.544 0.586589
## factor(CountyName)Iberville              0.783644   0.851012   0.921 0.357227
## factor(CountyName)Imperial              -9.764425   6.176878  -1.581 0.114054
## factor(CountyName)Ingham                 0.543211   0.851012   0.638 0.523331
## factor(CountyName)Inyo                  -3.103480   2.147501  -1.445 0.148543
```

```
## factor(CountyName)Jackson               0.436661   0.647526   0.674 0.500152
## factor(CountyName)Jefferson             1.548991   0.651298   2.378 0.017469
## factor(CountyName)Johnson               0.742285   0.736998   1.007 0.313952
## factor(CountyName)Johnston              0.429368   0.851012   0.505 0.613929
## factor(CountyName)Kalamazoo             1.337083   0.851012   1.571 0.116274
## factor(CountyName)Kane                  1.424053   0.851012   1.673 0.094385
## factor(CountyName)Kauai                -4.337156   0.851012  -5.096 3.73e-07
## factor(CountyName)Kay                   1.542490   0.851012   1.813 0.070028
## factor(CountyName)Kennebec             -1.851630   0.851012  -2.176 0.029667
## factor(CountyName)Kent                 -0.768153   0.672784  -1.142 0.253670
## factor(CountyName)Kern                  3.083106   0.851012   3.623 0.000297
## factor(CountyName)Kings                 4.337220   0.736998   5.885 4.53e-09
## factor(CountyName)Klamath               6.268481   0.851012   7.366 2.40e-13
## factor(CountyName)Knox                  1.753169   0.851012   2.060 0.039496
## factor(CountyName)La Paz               -3.494380   0.851012  -4.106 4.16e-05
## factor(CountyName)Lackawanna            0.262456   0.851012   0.308 0.757801
## factor(CountyName)Lafayette             0.539812   0.851012   0.634 0.525933
## factor(CountyName)Lake                 -3.227282   1.567209  -2.059 0.039577
## factor(CountyName)Lancaster             0.962302   0.736998   1.306 0.191777
## factor(CountyName)Lane                  2.016418   0.851012   2.369 0.017893
## factor(CountyName)LaPorte               0.602488   0.851012   0.708 0.479034
## factor(CountyName)Larimer              -0.055318   0.851012  -0.065 0.948178
## factor(CountyName)Lawrence             -0.342440   0.736998  -0.465 0.642230
## factor(CountyName)Lea                  -0.541696   0.851012  -0.637 0.524490
## factor(CountyName)Lebanon               1.936036   0.851012   2.275 0.022994
## factor(CountyName)Lee                   0.384916   0.736998   0.522 0.601526
## factor(CountyName)Lehigh                1.715154   0.851012   2.015 0.043970
## factor(CountyName)Lemhi                 3.238584   0.851012   3.806 0.000145
## factor(CountyName)Lenawee               1.108535   0.851012   1.303 0.192833
## factor(CountyName)Leon                 -0.103622   0.851012  -0.122 0.903097
## factor(CountyName)Lewis and Clark      -1.056927   0.851012  -1.242 0.214370
## factor(CountyName)Lincoln               3.541991   0.796110   4.449 9.01e-06
## factor(CountyName)Linn                  0.927881   0.851012   1.090 0.275678
## factor(CountyName)Litchfield           -2.248920   0.851012  -2.643 0.008279
## factor(CountyName)Los Angeles           4.236776   0.851012   4.979 6.86e-07
## factor(CountyName)Lowndes               0.763542   0.851012   0.897 0.369693
## factor(CountyName)Lucas                 0.916043   0.851012   1.076 0.281849
## factor(CountyName)Lyon                 -1.740389   0.869233  -2.002 0.045374
## factor(CountyName)Macomb                0.564963   0.851012   0.664 0.506835
## factor(CountyName)Macon                 1.894835   0.851012   2.227 0.026068
## factor(CountyName)Madera                5.297700   0.851012   6.225 5.65e-10
## factor(CountyName)Madison               0.934080   0.670092   1.394 0.163458
## factor(CountyName)Mahoning              0.829650   0.851012   0.975 0.329708
## factor(CountyName)Manistee             -2.089315   0.851012  -2.455 0.014155
## factor(CountyName)Maricopa              0.897476   0.851012   1.055 0.291714
## factor(CountyName)Marin                 0.458650   0.851012   0.539 0.589973
## factor(CountyName)Marion                1.822499   0.736998   2.473 0.013472
## factor(CountyName)Marshall              2.242450   0.851012   2.635 0.008467
## factor(CountyName)Maui                 -3.688461   0.851012  -4.334 1.52e-05
## factor(CountyName)McCracken             1.848704   0.851012   2.172 0.029926
## factor(CountyName)McHenry               1.118221   0.851012   1.314 0.188974
## factor(CountyName)McKenzie             -2.818482   0.851012  -3.312 0.000940
## factor(CountyName)McLean                1.584674   0.851012   1.862 0.062710
## factor(CountyName)Mecklenburg           1.097146   0.851012   1.289 0.197443
```

```
## factor(CountyName)Medina              -0.159513   0.851012  -0.187 0.851332
## factor(CountyName)Mendocino            1.646426   0.851012   1.935 0.053148
## factor(CountyName)Merced               4.758661   0.851012   5.592 2.50e-08
## factor(CountyName)Mercer              -0.345202   0.694848  -0.497 0.619374
## factor(CountyName)Mesa                -1.516382   0.851012  -1.782 0.074898
## factor(CountyName)Middlesex            0.022962   0.748103   0.031 0.975516
## factor(CountyName)Missaukee           -0.324248   0.851012  -0.381 0.703226
## factor(CountyName)Mitchell            -1.157025   0.851012  -1.360 0.174087
## factor(CountyName)Mobile               0.703633   0.851012   0.827 0.408421
## factor(CountyName)Monroe              -0.296145   0.699972  -0.423 0.672274
## factor(CountyName)Monterey            -1.547420   0.851012  -1.818 0.069138
## factor(CountyName)Montgomery           0.437962   0.642374   0.682 0.495439
## factor(CountyName)Morgan               0.821202   0.851012   0.965 0.334655
## factor(CountyName)Morris              -1.590320   0.851012  -1.869 0.061780
## factor(CountyName)Multnomah            0.057239   0.851012   0.067 0.946380
## factor(CountyName)Muscatine            0.748402   0.851012   0.879 0.379258
## factor(CountyName)Muscogee             1.343066   0.851012   1.578 0.114651
## factor(CountyName)Neosho               1.660161   0.851012   1.951 0.051195
## factor(CountyName)Nevada               0.212710   0.851012   0.250 0.802648
## factor(CountyName)New Castle           0.672569   0.851012   0.790 0.429420
## factor(CountyName)New Hanover         -2.489327   0.851012  -2.925 0.003475
## factor(CountyName)New Haven            0.431609   0.851012   0.507 0.612081
## factor(CountyName)New London          -0.864952   0.851012  -1.016 0.309550
## factor(CountyName)New York             0.507670   0.851012   0.597 0.550865
## factor(CountyName)Northampton          0.768099   0.761209   1.009 0.313051
## factor(CountyName)Oakland              0.405363   0.851012   0.476 0.633882
## factor(CountyName)Ocean               -0.759179   0.851012  -0.892 0.372433
## factor(CountyName)Ohio                 0.426778   0.851012   0.501 0.616069
## factor(CountyName)Oklahoma             1.985372   0.851012   2.333 0.019732
## factor(CountyName)Oliver              -1.297408   0.851012  -1.525 0.127503
## factor(CountyName)Olmsted             -0.604487   0.851012  -0.710 0.477577
## factor(CountyName)Onondaga            -1.460785   0.851012  -1.717 0.086194
## factor(CountyName)Orange               0.820277   0.682339   1.202 0.229422
## factor(CountyName)Orleans              0.507886   0.851012   0.597 0.550695
## factor(CountyName)Ouachita             0.373862   0.851012   0.439 0.660473
## factor(CountyName)Oxford              -1.862102   0.851012  -2.188 0.028758
## factor(CountyName)Palm Beach          -0.728934   0.851012  -0.857 0.391778
## factor(CountyName)Palo Alto           -0.421689   0.851012  -0.496 0.620282
## factor(CountyName)Park                -3.768490   0.796110  -4.734 2.33e-06
## factor(CountyName)Pennington          -0.547483   0.851012  -0.643 0.520069
## factor(CountyName)Penobscot           -2.176525   0.851012  -2.558 0.010601
## factor(CountyName)Peoria               1.468710   0.851012   1.726 0.084504
## factor(CountyName)Perry                0.760700   0.851012   0.894 0.371477
## factor(CountyName)Philadelphia         1.506149   0.851012   1.770 0.076881
## factor(CountyName)Phillips            -1.992059   0.851012  -2.341 0.019323
## factor(CountyName)Pierce               0.333607   0.851012   0.392 0.695083
## factor(CountyName)Pike                -0.058213   0.851012  -0.068 0.945470
## factor(CountyName)Pima                -2.246202   0.851012  -2.639 0.008358
## factor(CountyName)Pinal                2.192694   0.851012   2.577 0.010037
## factor(CountyName)Pinellas             0.001359   0.851012   0.002 0.998726
## factor(CountyName)Pitt                -0.948178   0.851012  -1.114 0.265314
## factor(CountyName)Pittsburg            1.342776   0.851012   1.578 0.114729
## factor(CountyName)Placer               1.548709   0.851012   1.820 0.068907
## factor(CountyName)Plumas               5.878065   0.851012   6.907 6.30e-12
```

```
## factor(CountyName)Plymouth             -0.230345   0.851012  -0.271 0.786666
## factor(CountyName)Polk                  0.308350   0.694848   0.444 0.657252
## factor(CountyName)Portage              -0.175069   0.851012  -0.206 0.837028
## factor(CountyName)Porter                0.794748   0.851012   0.934 0.350456
## factor(CountyName)Pottawattamie         0.707935   0.851012   0.832 0.405562
## factor(CountyName)Pueblo               -1.516508   0.851012  -1.782 0.074874
## factor(CountyName)Pulaski               1.297974   0.736998   1.761 0.078337
## factor(CountyName)Putnam               -0.512914   0.851012  -0.603 0.546757
## factor(CountyName)Queens               -0.272849   0.851012  -0.321 0.748528
## factor(CountyName)Ramsey                0.033343   0.851012   0.039 0.968750
## factor(CountyName)Randolph              0.767156   0.851012   0.901 0.367432
## factor(CountyName)Rapides               0.336531   0.851012   0.395 0.692547
## factor(CountyName)Richland             -1.029026   0.736998  -1.396 0.162771
## factor(CountyName)Richmond              1.557107   0.736998   2.113 0.034723
## factor(CountyName)Rio Blanco            0.872738   0.851012   1.026 0.305216
## factor(CountyName)Riverside             2.883296   0.851012   3.388 0.000715
## factor(CountyName)Rock Island           1.264823   0.851012   1.486 0.137342
## factor(CountyName)Rockingham           -1.016627   0.736998  -1.379 0.167894
## factor(CountyName)Russell               1.872899   0.851012   2.201 0.027845
## factor(CountyName)Sacramento            1.857484   0.851012   2.183 0.029156
## factor(CountyName)San Benito           -1.323478   0.851012  -1.555 0.120034
## factor(CountyName)San Bernardino        4.073637   0.851012   4.787 1.80e-06
## factor(CountyName)San Diego             2.902281   0.851012   3.410 0.000659
## factor(CountyName)San Francisco         1.286307   0.851012   1.512 0.130791
## factor(CountyName)San Joaquin           4.811596   0.851012   5.654 1.75e-08
## factor(CountyName)San Luis Obispo      -0.200578   0.851012  -0.236 0.813690
## factor(CountyName)San Mateo             0.800543   0.851012   0.941 0.346955
## factor(CountyName)Sangamon              1.119486   0.851012   1.315 0.188475
## factor(CountyName)Santa Barbara        -0.631755   0.851012  -0.742 0.457943
## factor(CountyName)Santa Clara           1.791913   0.851012   2.106 0.035340
## factor(CountyName)Santa Cruz            0.679576   0.736998   0.922 0.356575
## factor(CountyName)Sarasota             -0.030448   0.851012  -0.036 0.971461
## factor(CountyName)Sarpy                 0.711078   0.851012   0.836 0.403481
## factor(CountyName)Scioto               -0.181938   0.851012  -0.214 0.830729
## factor(CountyName)Scott                 0.260344   0.736998   0.353 0.723932
## factor(CountyName)Scotts Bluff         -1.822737   0.851012  -2.142 0.032306
## factor(CountyName)Sedgwick              0.499164   0.851012   0.587 0.557558
## factor(CountyName)Seminole             -0.385087   0.851012  -0.453 0.650946
## factor(CountyName)Sequoyah              0.614603   0.851012   0.722 0.470240
## factor(CountyName)Shasta                1.631063   0.851012   1.917 0.055405
## factor(CountyName)Shawnee               1.968376   0.851012   2.313 0.020807
## factor(CountyName)Shelby                1.188746   0.851012   1.397 0.162583
## factor(CountyName)Silver Bow           -0.226385   0.851012  -0.266 0.790247
## factor(CountyName)Siskiyou              3.916765   0.851012   4.602 4.39e-06
## factor(CountyName)Solano                2.325181   0.851012   2.732 0.006336
## factor(CountyName)Sonoma              -20.169374   9.299318  -2.169 0.030187
## factor(CountyName)Spencer               0.934914   0.851012   1.099 0.272056
## factor(CountyName)Stanislaus            5.776524   0.851012   6.788 1.43e-11
## factor(CountyName)Stark                 2.084536   0.851012   2.449 0.014377
## factor(CountyName)Stearns              -0.756900   0.851012  -0.889 0.373871
## factor(CountyName)Steuben              -1.815229   0.851012  -2.133 0.033023
## factor(CountyName)Suffolk              -0.406775   0.736998  -0.552 0.581043
## factor(CountyName)Sullivan             -0.048977   0.776920  -0.063 0.949740
## factor(CountyName)Summit                1.441830   0.851012   1.694 0.090346
```

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## factor(CountyName)Sumner                0.583797   0.736998   0.792 0.428363
## factor(CountyName)Sussex                0.259456   0.851012   0.305 0.760484
## factor(CountyName)Sutter                4.158613   0.851012   4.887 1.09e-06
## factor(CountyName)Swain                -0.210945   0.851012  -0.248 0.804252
## factor(CountyName)Taylor               -0.943732   0.851012  -1.109 0.267561
## factor(CountyName)Tehama                1.190557   0.851012   1.399 0.161944
## factor(CountyName)Terrebonne           -0.102577   0.851012  -0.121 0.904069
## factor(CountyName)Teton                -3.229246   0.851012  -3.795 0.000152
## factor(CountyName)Tioga                -1.076344   0.851012  -1.265 0.206072
## factor(CountyName)Tippecanoe            1.007473   0.851012   1.184 0.236588
## factor(CountyName)Trumbull             -0.073112   0.851012  -0.086 0.931543
## factor(CountyName)Tulare                7.680962   0.851012   9.026  < 2e-16
## factor(CountyName)Tulsa                 2.084976   0.851012   2.450 0.014356
## factor(CountyName)Tuscaloosa            0.365048   0.851012   0.429 0.667993
## factor(CountyName)Union                 0.846129   0.699948   1.209 0.226841
## factor(CountyName)Van Buren            -0.199310   0.851012  -0.234 0.814847
## factor(CountyName)Vanderburgh           1.528996   0.851012   1.797 0.072511
## factor(CountyName)Ventura               0.369110   0.851012   0.434 0.664523
## factor(CountyName)Vigo                  1.519780   0.851012   1.786 0.074249
## factor(CountyName)Volusia               0.252683   0.851012   0.297 0.766553
## factor(CountyName)Wake                  1.126472   0.851012   1.324 0.185733
## factor(CountyName)Walker                2.238657   0.851012   2.631 0.008578
## factor(CountyName)Warren                0.785203   0.736998   1.065 0.286798
## factor(CountyName)Washington           -0.118485   0.633174  -0.187 0.851576
## factor(CountyName)Washoe               -1.390314   1.345408  -1.033 0.301531
## factor(CountyName)Washtenaw             1.200965   0.851012   1.411 0.158308
## factor(CountyName)Wayne                 2.867612   0.851012   3.370 0.000764
## factor(CountyName)Weld                  1.511766   0.851012   1.776 0.075787
## factor(CountyName)West Baton Rouge      1.648342   0.851012   1.937 0.052872
## factor(CountyName)Westmoreland          0.422305   0.851012   0.496 0.619771
## factor(CountyName)Whitley               0.933658   0.851012   1.097 0.272700
## factor(CountyName)Will                  1.727519   0.851012   2.030 0.042470
## factor(CountyName)Winnebago             1.327997   0.851012   1.560 0.118775
## factor(CountyName)Wood                  0.325503   0.851012   0.382 0.702132
## factor(CountyName)Woodbury              0.468236   0.851012   0.550 0.582225
## factor(CountyName)Worcester             0.355214   0.851012   0.417 0.676422
## factor(CountyName)Wright               -0.690058   0.851012  -0.811 0.417521
## factor(CountyName)Wyandotte             2.522816   0.851012   2.964 0.003062
## factor(CountyName)Yellowstone           0.140739   0.851012   0.165 0.868660
## factor(CountyName)Yolo                  2.153390   0.851012   2.530 0.011457
## factor(CountyName)York                  1.092283   0.748103   1.460 0.144401
## factor(CountyName)Yuma                  1.303935   0.851012   1.532 0.125600
##
## (Intercept)                           ***
## Geothermal                            *
## factor(Year)2018                      ***
## factor(Year)2019
## factor(Year)2020                      ***
## factor(Year)2021                      ***
## factor(Year)2022
## factor(CountyName)Adams               *
## factor(CountyName)Alachua
## factor(CountyName)Alameda             *
## factor(CountyName)Albany              *
```

```
## factor(CountyName)Allegan
## factor(CountyName)Allegheny           ***
## factor(CountyName)Allen
## factor(CountyName)Androscoggin        *
## factor(CountyName)Apache              ***
## factor(CountyName)Arapahoe
## factor(CountyName)Arkansas
## factor(CountyName)Armstrong           .
## factor(CountyName)Aroostook           *
## factor(CountyName)Ashley
## factor(CountyName)Atlantic
## factor(CountyName)Baldwin
## factor(CountyName)Baltimore
## factor(CountyName)Bay
## factor(CountyName)Beaver
## factor(CountyName)Becker
## factor(CountyName)Belknap             ***
## factor(CountyName)Bell
## factor(CountyName)Beltrami
## factor(CountyName)Benewah             **
## factor(CountyName)Bergen              *
## factor(CountyName)Berks               .
## factor(CountyName)Berkshire
## factor(CountyName)Bernalillo
## factor(CountyName)Bibb
## factor(CountyName)Black Hawk
## factor(CountyName)Blair
## factor(CountyName)Boulder
## factor(CountyName)Bradford
## factor(CountyName)Brevard
## factor(CountyName)Bristol
## factor(CountyName)Bronx
## factor(CountyName)Broward
## factor(CountyName)Brown
## factor(CountyName)Buchanan
## factor(CountyName)Buncombe
## factor(CountyName)Burke               **
## factor(CountyName)Burleigh
## factor(CountyName)Butler              **
## factor(CountyName)Butte               ***
## factor(CountyName)Caddo               **
## factor(CountyName)Calaveras           *
## factor(CountyName)Calcasieu
## factor(CountyName)Cambria             *
## factor(CountyName)Camden              *
## factor(CountyName)Canyon              *
## factor(CountyName)Carlton             ***
## factor(CountyName)Carson City
## factor(CountyName)Cass
## factor(CountyName)Catawba
## factor(CountyName)Cecil
## factor(CountyName)Cedar
## factor(CountyName)Centre
## factor(CountyName)Champaign
```

```
## factor(CountyName)Charles
## factor(CountyName)Chatham              .
## factor(CountyName)Chautauqua
## factor(CountyName)Chester              .
## factor(CountyName)Christian            .
## factor(CountyName)Clark
## factor(CountyName)Clarke               .
## factor(CountyName)Clay
## factor(CountyName)Clayton
## factor(CountyName)Cleveland            **
## factor(CountyName)Clinton
## factor(CountyName)Cobb
## factor(CountyName)Colusa               ***
## factor(CountyName)Comanche
## factor(CountyName)Contra Costa         *
## factor(CountyName)Cook
## factor(CountyName)Crook                *
## factor(CountyName)Crow Wing            *
## factor(CountyName)Cumberland
## factor(CountyName)Custer               ***
## factor(CountyName)Cuyahoga             *
## factor(CountyName)Dakota
## factor(CountyName)Dallas               .
## factor(CountyName)Dauphin              *
## factor(CountyName)Davidson             *
## factor(CountyName)Daviess              .
## factor(CountyName)Davis
## factor(CountyName)DeKalb
## factor(CountyName)Delaware             *
## factor(CountyName)Denver
## factor(CountyName)DeSoto
## factor(CountyName)Dewey
## factor(CountyName)District of Columbia
## factor(CountyName)Dodge
## factor(CountyName)Dona Ana
## factor(CountyName)Dorchester
## factor(CountyName)Dougherty            *
## factor(CountyName)Douglas
## factor(CountyName)Dubois               .
## factor(CountyName)DuPage               **
## factor(CountyName)Durham
## factor(CountyName)Duval
## factor(CountyName)East Baton Rouge     .
## factor(CountyName)El Paso
## factor(CountyName)Elkhart
## factor(CountyName)Ellis
## factor(CountyName)Erie
## factor(CountyName)Escambia             .
## factor(CountyName)Essex                *
## factor(CountyName)Etowah
## factor(CountyName)Fairfield
## factor(CountyName)Fayette
## factor(CountyName)Flathead
## factor(CountyName)Forrest              *
```

```
## factor(CountyName)Forsyth
## factor(CountyName)Franklin
## factor(CountyName)Frederick
## factor(CountyName)Fremont             ***
## factor(CountyName)Fresno              ***
## factor(CountyName)Fulton              *
## factor(CountyName)Garland
## factor(CountyName)Garrett             *
## factor(CountyName)Genesee
## factor(CountyName)Gloucester
## factor(CountyName)Glynn
## factor(CountyName)Grafton             *
## factor(CountyName)Grant
## factor(CountyName)Greene
## factor(CountyName)Guilford
## factor(CountyName)Gwinnett            *
## factor(CountyName)Hall
## factor(CountyName)Hamilton            *
## factor(CountyName)Hampden
## factor(CountyName)Hampshire           .
## factor(CountyName)Hancock
## factor(CountyName)Hardin
## factor(CountyName)Harford
## factor(CountyName)Harris              **
## factor(CountyName)Harrison
## factor(CountyName)Hartford
## factor(CountyName)Hawaii              ***
## factor(CountyName)Hennepin
## factor(CountyName)Henry
## factor(CountyName)Hidalgo             **
## factor(CountyName)Hillsborough        *
## factor(CountyName)Hinds               **
## factor(CountyName)Honolulu            ***
## factor(CountyName)Houston             .
## factor(CountyName)Howard
## factor(CountyName)Hudson
## factor(CountyName)Humboldt
## factor(CountyName)Hunterdon
## factor(CountyName)Iberville
## factor(CountyName)Imperial
## factor(CountyName)Ingham
## factor(CountyName)Inyo
## factor(CountyName)Jackson
## factor(CountyName)Jefferson           *
## factor(CountyName)Johnson
## factor(CountyName)Johnston
## factor(CountyName)Kalamazoo
## factor(CountyName)Kane                .
## factor(CountyName)Kauai               ***
## factor(CountyName)Kay                 .
## factor(CountyName)Kennebec            *
## factor(CountyName)Kent
## factor(CountyName)Kern                ***
## factor(CountyName)Kings               ***
```

```
## factor(CountyName)Klamath             ***
## factor(CountyName)Knox                *
## factor(CountyName)La Paz              ***
## factor(CountyName)Lackawanna
## factor(CountyName)Lafayette
## factor(CountyName)Lake                *
## factor(CountyName)Lancaster
## factor(CountyName)Lane                *
## factor(CountyName)LaPorte
## factor(CountyName)Larimer
## factor(CountyName)Lawrence
## factor(CountyName)Lea
## factor(CountyName)Lebanon             *
## factor(CountyName)Lee
## factor(CountyName)Lehigh              *
## factor(CountyName)Lemhi               ***
## factor(CountyName)Lenawee
## factor(CountyName)Leon
## factor(CountyName)Lewis and Clark
## factor(CountyName)Lincoln             ***
## factor(CountyName)Linn
## factor(CountyName)Litchfield          **
## factor(CountyName)Los Angeles         ***
## factor(CountyName)Lowndes
## factor(CountyName)Lucas
## factor(CountyName)Lyon                *
## factor(CountyName)Macomb
## factor(CountyName)Macon               *
## factor(CountyName)Madera              ***
## factor(CountyName)Madison
## factor(CountyName)Mahoning
## factor(CountyName)Manistee            *
## factor(CountyName)Maricopa
## factor(CountyName)Marin
## factor(CountyName)Marion              *
## factor(CountyName)Marshall            **
## factor(CountyName)Maui                ***
## factor(CountyName)McCracken           *
## factor(CountyName)McHenry
## factor(CountyName)McKenzie            ***
## factor(CountyName)McLean              .
## factor(CountyName)Mecklenburg
## factor(CountyName)Medina
## factor(CountyName)Mendocino           .
## factor(CountyName)Merced              ***
## factor(CountyName)Mercer
## factor(CountyName)Mesa                .
## factor(CountyName)Middlesex
## factor(CountyName)Missaukee
## factor(CountyName)Mitchell
## factor(CountyName)Mobile
## factor(CountyName)Monroe
## factor(CountyName)Monterey            .
## factor(CountyName)Montgomery
```

```
## factor(CountyName)Morgan
## factor(CountyName)Morris               .
## factor(CountyName)Multnomah
## factor(CountyName)Muscatine
## factor(CountyName)Muscogee
## factor(CountyName)Neosho               .
## factor(CountyName)Nevada
## factor(CountyName)New Castle
## factor(CountyName)New Hanover          **
## factor(CountyName)New Haven
## factor(CountyName)New London
## factor(CountyName)New York
## factor(CountyName)Northampton
## factor(CountyName)Oakland
## factor(CountyName)Ocean
## factor(CountyName)Ohio
## factor(CountyName)Oklahoma             *
## factor(CountyName)Oliver
## factor(CountyName)Olmsted
## factor(CountyName)Onondaga             .
## factor(CountyName)Orange
## factor(CountyName)Orleans
## factor(CountyName)Ouachita
## factor(CountyName)Oxford               *
## factor(CountyName)Palm Beach
## factor(CountyName)Palo Alto
## factor(CountyName)Park                 ***
## factor(CountyName)Pennington
## factor(CountyName)Penobscot            *
## factor(CountyName)Peoria               .
## factor(CountyName)Perry
## factor(CountyName)Philadelphia         .
## factor(CountyName)Phillips             *
## factor(CountyName)Pierce
## factor(CountyName)Pike
## factor(CountyName)Pima                 **
## factor(CountyName)Pinal                *
## factor(CountyName)Pinellas
## factor(CountyName)Pitt
## factor(CountyName)Pittsburg
## factor(CountyName)Placer               .
## factor(CountyName)Plumas               ***
## factor(CountyName)Plymouth
## factor(CountyName)Polk
## factor(CountyName)Portage
## factor(CountyName)Porter
## factor(CountyName)Pottawattamie
## factor(CountyName)Pueblo               .
## factor(CountyName)Pulaski              .
## factor(CountyName)Putnam
## factor(CountyName)Queens
## factor(CountyName)Ramsey
## factor(CountyName)Randolph
## factor(CountyName)Rapides
```

```
## factor(CountyName)Richland
## factor(CountyName)Richmond            *
## factor(CountyName)Rio Blanco
## factor(CountyName)Riverside           ***
## factor(CountyName)Rock Island
## factor(CountyName)Rockingham
## factor(CountyName)Russell             *
## factor(CountyName)Sacramento          *
## factor(CountyName)San Benito
## factor(CountyName)San Bernardino      ***
## factor(CountyName)San Diego           ***
## factor(CountyName)San Francisco
## factor(CountyName)San Joaquin         ***
## factor(CountyName)San Luis Obispo
## factor(CountyName)San Mateo
## factor(CountyName)Sangamon
## factor(CountyName)Santa Barbara
## factor(CountyName)Santa Clara         *
## factor(CountyName)Santa Cruz
## factor(CountyName)Sarasota
## factor(CountyName)Sarpy
## factor(CountyName)Scioto
## factor(CountyName)Scott
## factor(CountyName)Scotts Bluff        *
## factor(CountyName)Sedgwick
## factor(CountyName)Seminole
## factor(CountyName)Sequoyah
## factor(CountyName)Shasta              .
## factor(CountyName)Shawnee             *
## factor(CountyName)Shelby
## factor(CountyName)Silver Bow
## factor(CountyName)Siskiyou            ***
## factor(CountyName)Solano              **
## factor(CountyName)Sonoma              *
## factor(CountyName)Spencer
## factor(CountyName)Stanislaus          ***
## factor(CountyName)Stark               *
## factor(CountyName)Stearns
## factor(CountyName)Steuben             *
## factor(CountyName)Suffolk
## factor(CountyName)Sullivan
## factor(CountyName)Summit              .
## factor(CountyName)Sumner
## factor(CountyName)Sussex
## factor(CountyName)Sutter              ***
## factor(CountyName)Swain
## factor(CountyName)Taylor
## factor(CountyName)Tehama
## factor(CountyName)Terrebonne
## factor(CountyName)Teton               ***
## factor(CountyName)Tioga
## factor(CountyName)Tippecanoe
## factor(CountyName)Trumbull
## factor(CountyName)Tulare              ***
```

```
## factor(CountyName)Tulsa                *
## factor(CountyName)Tuscaloosa
## factor(CountyName)Union
## factor(CountyName)Van Buren
## factor(CountyName)Vanderburgh          .
## factor(CountyName)Ventura
## factor(CountyName)Vigo                 .
## factor(CountyName)Volusia
## factor(CountyName)Wake
## factor(CountyName)Walker                **
## factor(CountyName)Warren
## factor(CountyName)Washington
## factor(CountyName)Washoe
## factor(CountyName)Washtenaw
## factor(CountyName)Wayne                ***
## factor(CountyName)Weld                 .
## factor(CountyName)West Baton Rouge     .
## factor(CountyName)Westmoreland
## factor(CountyName)Whitley
## factor(CountyName)Will                 *
## factor(CountyName)Winnebago
## factor(CountyName)Wood
## factor(CountyName)Woodbury
## factor(CountyName)Worcester
## factor(CountyName)Wright
## factor(CountyName)Wyandotte            **
## factor(CountyName)Yellowstone
## factor(CountyName)Yolo                 *
## factor(CountyName)York
## factor(CountyName)Yuma
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.474 on 2413 degrees of freedom
## Multiple R-squared:  0.5703, Adjusted R-squared:  0.5055
## F-statistic:   8.8 on 364 and 2413 DF,  p-value: < 2.2e-16
```

```
County_PM2.5_Energy_Data %>% filter(`Plant annual geothermal net generation (MWh)` > 0)
↪  %>% summary(`Plant annual geothermal net generation (MWh)`)
```

```
##  County.Name             Year       State.Name          PM2.5_Avg
##  Length:80          Min.   :2016   Length:80          Min.   : 2.506
##  Class :character   1st Qu.:2018   Class :character   1st Qu.: 5.866
##  Mode  :character   Median :2020   Mode  :character   Median : 7.088
##                     Mean   :2019                      Mean   : 7.599
##                     3rd Qu.:2021                      3rd Qu.: 9.615
##                     Max.   :2022                      Max.   :16.026
##  Plant annual coal net generation (MWh) Plant annual oil net generation (MWh)
##  Min.   :       0                       Min.   :     0.0
##  1st Qu.:       0                       1st Qu.:    83.3
##  Median :       0                       Median :  3265.3
##  Mean   :  821655                       Mean   : 53345.0
##  3rd Qu.: 1367861                       3rd Qu.:  9544.7
```

```
##  Max.   :11551542                        Max.   :830702.2
##  Plant annual gas net generation (MWh)
##  Min.   :      0
##  1st Qu.:   9046
##  Median : 953834
##  Mean   :1928046
##  3rd Qu.:3691158
##  Max.   :8086731
##  Plant annual nuclear net generation (MWh)
##  Min.   :       0
##  1st Qu.:       0
##  Median :       0
##  Mean   : 4401911
##  3rd Qu.:10334454
##  Max.   :15219574
##  Plant annual hydro net generation (MWh)
##  Min.   :      0
##  1st Qu.:  29416
##  Median : 229308
##  Mean   : 432845
##  3rd Qu.: 917853
##  Max.   :1020969
##  Plant annual biomass net generation (MWh)
##  Min.   :     0
##  1st Qu.:     0
##  Median : 38005
##  Mean   : 55421
##  3rd Qu.:127270
##  Max.   :183649
##  Plant annual wind net generation (MWh) Plant annual solar net generation (MWh)
##  Min.   :      0                        Min.   :      0
##  1st Qu.:      0                        1st Qu.:   9393
##  Median :      0                        Median :  66629
##  Mean   : 198798                        Mean   : 406323
##  3rd Qu.:  59572                        3rd Qu.: 276536
##  Max.   :3375415                        Max.   :4551923
##  Plant annual geothermal net generation (MWh)
##  Min.   :   9640
##  1st Qu.: 227769
##  Median : 790776
##  Mean   :1180154
##  3rd Qu.: 939923
##  Max.   :5574703
##  Plant annual other fossil net generation (MWh)
##  Min.   :      0
##  1st Qu.:      0
##  Median :      0
##  Mean   : 636610
##  3rd Qu.:1605219
##  Max.   :1978101
##  Plant annual other unknown/ purchased fuel net generation (MWh)
##  Min.   :-10077
##  1st Qu.:     0
##  Median :     0
```

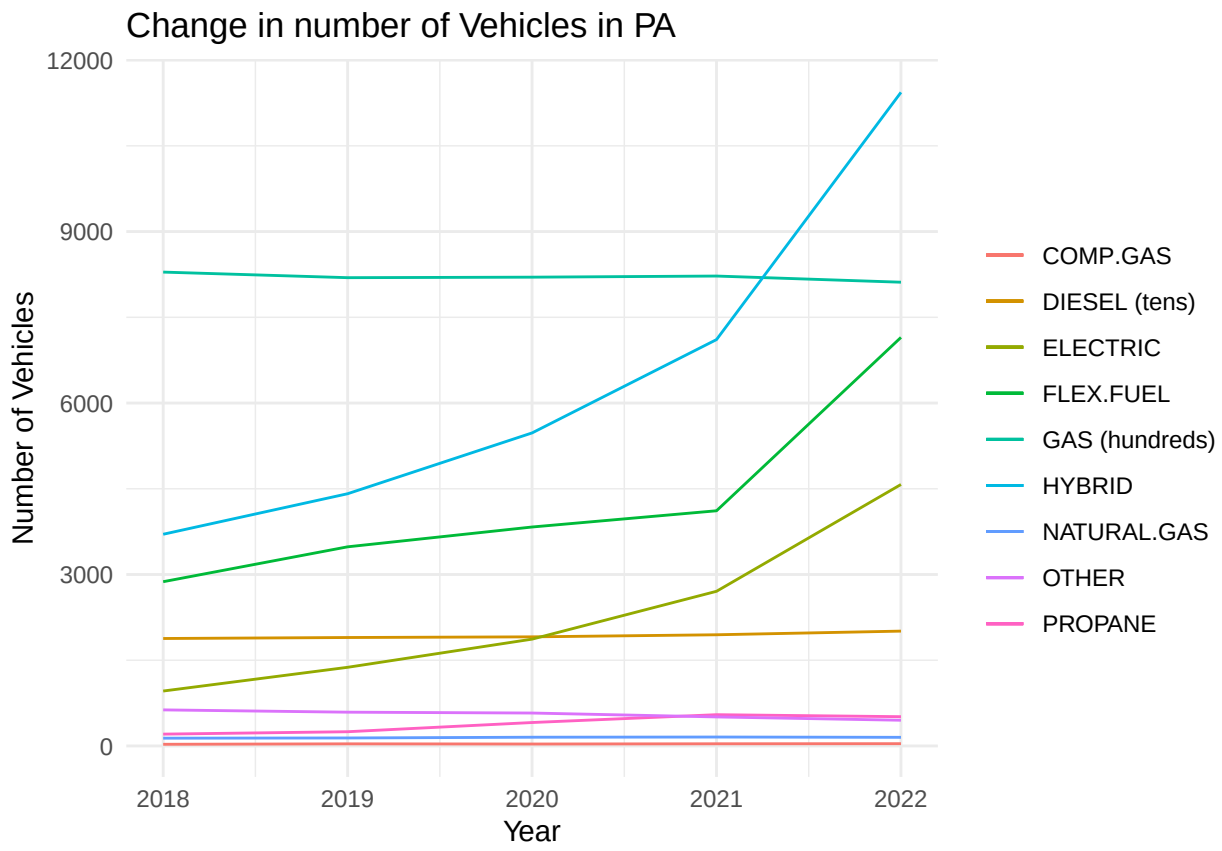
```
##  Mean   :146164
##  3rd Qu.:318126
##  Max.   :473454
##  Plant annual total nonrenewables net generation (MWh)
##  Min.   :   -9130
##  1st Qu.:  254667
##  Median : 1627137
##  Mean   : 7987730
##  3rd Qu.:17992044
##  Max.   :26833928
##  Plant annual total renewables net generation (MWh)
##  Min.   :  13138
##  1st Qu.: 796590
##  Median :1885009
##  Mean   :2273541
##  3rd Qu.:2154585
##  Max.   :8676238
```

By running the linear regression of PM2.5 on type (renewable/non renewable) of generation, we get inconclusive results. The standard deviation of both the input variables, Non Renewable Energy and Renewable Energy, is too high for us to make anything of these results. This may very well be due to the restricted and limited number of years this regression is being carried out for.

#Transportation Link

```
#Are we missing something? Literature tells us transportation is a very important
↪  contributor to PM2.5 emission. Let's narrow down to Pennsylvania's counties for now
↪  and check.

Transportation_2018<- read.csv("C:/Users/Harsh Vaibhav/Desktop/Data Science Data
↪  Sets/Final/Transporation Data/tabula-ReportofRegistration2018.csv")
Transportation_2019<- read.csv("C:/Users/Harsh Vaibhav/Desktop/Data Science Data
↪  Sets/Final/Transporation Data/tabula-ReportofRegistration2019.csv")
Transportation_2020<- read.csv("C:/Users/Harsh Vaibhav/Desktop/Data Science Data
↪  Sets/Final/Transporation Data/tabula-ReportofRegistration2020.csv")
Transportation_2021<- read.csv("C:/Users/Harsh Vaibhav/Desktop/Data Science Data
↪  Sets/Final/Transporation Data/tabula-ReportofRegistration2021.csv")
Transportation_2022<- read.csv("C:/Users/Harsh Vaibhav/Desktop/Data Science Data
↪  Sets/Final/Transporation Data/tabula-ReportofRegistration2022.csv")

combined_transportation_df <- bind_rows(Transportation_2018, Transportation_2019,
↪  Transportation_2020, Transportation_2021, Transportation_2022) %>%
  arrange(COUNTY, YEAR)

combined_transportation_df$COUNTY <- str_to_title(combined_transportation_df$COUNTY)

common_transportation_county_names <- Reduce(intersect,
↪  list(combined_transportation_df$COUNTY, combined_df$County.Name))

Filtered_transportation_df <- combined_transportation_df %>% filter(COUNTY %in%
↪  common_transportation_county_names)

Filtered_transportation_PM2.5_df <- combined_df %>%
  filter(County.Name %in% common_transportation_county_names) %>%
```

```r
  filter(State.Name %in% c("Pennsylvania", "Ohio", "Texas", "Iowa", "Georgia", "New
  ↪  York")) %>%
  filter(Year != 2016)

County_PM2.5_Transportation_Data <- merge(Filtered_transportation_df,
↪  Filtered_transportation_PM2.5_df,
                                  c("County.Name", "Year"), c("COUNTY", "YEAR"))

# Trend of Cars in Allegheny County

ggplot(County_PM2.5_Transportation_Data %>%
         filter(COUNTY == "Allegheny"),
       aes(x = YEAR)) +
  geom_line(aes(y = GAS/10^2, color = "GAS (hundreds)")) +
  geom_line(aes(y = DIESEL/10, color = "DIESEL (tens)")) +
  geom_line(aes(y = ELECTRIC, color = "ELECTRIC")) +
  geom_line(aes(y = PROPANE, color = "PROPANE")) +
  geom_line(aes(y = HYBRID, color = "HYBRID")) +
  geom_line(aes(y = OTHER, color = "OTHER")) +
  geom_line(aes(y = NATURAL.GAS, color = "NATURAL.GAS")) +
  geom_line(aes(y = COMP.GAS, color = "COMP.GAS")) +
  geom_line(aes(y = FLEX.FUEL, color = "FLEX.FUEL")) +
  labs(title = "Change in number of Vehicles in PA",
       x = "Year",
       y = "Number of Vehicles",
       color = "") +
  theme_minimal()
```



#Model 1: Linear Regression

```
County_PM2.5_Transportation_Data <- na.omit(County_PM2.5_Transportation_Data)
PM2.5_Avg <- County_PM2.5_Transportation_Data$PM2.5_Avg
Gas <- County_PM2.5_Transportation_Data$GAS
Diesel <- County_PM2.5_Transportation_Data$DIESEL
Electric <- County_PM2.5_Transportation_Data$ELECTRIC
Propane <- County_PM2.5_Transportation_Data$PROPANE
Hybrid <- County_PM2.5_Transportation_Data$HYBRID
NaturalGas <- County_PM2.5_Transportation_Data$NATURAL.GAS
CompGas <- County_PM2.5_Transportation_Data$COMP.GAS
FlexFuel <- County_PM2.5_Transportation_Data$FLEX.FUEL
Vehicles <- County_PM2.5_Transportation_Data$VEHICLES
PACounty <- County_PM2.5_Transportation_Data$COUNTY
Year <- County_PM2.5_Transportation_Data$YEAR

# Fit the linear regression model
emission_significance_transport <- lm(PM2.5_Avg ~ Diesel + factor(PACounty) + factor
↪  (Year), data = County_PM2.5_Transportation_Data)
summary(emission_significance_transport)
```

```
##
## Call:
## lm(formula = PM2.5_Avg ~ Diesel + factor(PACounty) + factor(Year),
##     data = County_PM2.5_Transportation_Data)
##
```

```
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.58669 -0.33014 -0.02606  0.37346  2.59196
##
## Coefficients:
##                                Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   7.2386469  0.8606233   8.411 5.13e-14 ***
## Diesel                        0.0003297  0.0002415   1.365 0.174421
## factor(PACounty)Allegheny    -3.5253077  3.8371102  -0.919 0.359870
## factor(PACounty)Armstrong     0.5923358  0.6238649   0.949 0.344082
## factor(PACounty)Beaver        0.7661569  0.5122517   1.496 0.137075
## factor(PACounty)Berks        -3.1070933  2.2317823  -1.392 0.166150
## factor(PACounty)Blair        -0.0815036  0.5397193  -0.151 0.880192
## factor(PACounty)Bradford     -1.3263561  0.5206159  -2.548 0.011965 *
## factor(PACounty)Butler        0.2026527  1.0362720   0.196 0.845249
## factor(PACounty)Cambria       0.6587299  0.5076066   1.298 0.196597
## factor(PACounty)Cameron       1.9581417  1.1345963   1.726 0.086663 .
## factor(PACounty)Centre       -0.3618091  0.5343255  -0.677 0.499481
## factor(PACounty)Chester      -3.0286256  2.3183966  -1.306 0.193657
## factor(PACounty)Clinton       0.4741009  0.8078060   0.587 0.558251
## factor(PACounty)Cumberland   -0.5694047  0.8949748  -0.636 0.525707
## factor(PACounty)Dauphin      -3.0271322  2.7527080  -1.100 0.273423
## factor(PACounty)Delaware      0.0277142  0.8694212   0.032 0.974618
## factor(PACounty)Erie         -2.2708305  0.6045143  -3.756 0.000255 ***
## factor(PACounty)Fayette      -0.9482909  0.6157276  -1.540 0.125873
## factor(PACounty)Franklin     -0.2028384  0.6493532  -0.312 0.755241
## factor(PACounty)Fulton        1.0732011  1.0071794   1.066 0.288529
## factor(PACounty)Greene       -0.8077882  0.8541086  -0.946 0.345957
## factor(PACounty)Jefferson     1.2385996  0.6236603   1.986 0.049057 *
## factor(PACounty)Lackawanna   -1.3800413  0.6205192  -2.224 0.027809 *
## factor(PACounty)Lancaster    -2.9777093  3.2072927  -0.928 0.354848
## factor(PACounty)Lawrence     -0.2013934  0.5807759  -0.347 0.729307
## factor(PACounty)Lebanon      -0.2041632  0.6145763  -0.332 0.740252
## factor(PACounty)Lehigh       -0.9973751  1.0550870  -0.945 0.346194
## factor(PACounty)Mercer       -0.5449211  0.5272480  -1.034 0.303209
## factor(PACounty)Monroe       -2.2433132  0.5048384  -4.444 1.83e-05 ***
## factor(PACounty)Montgomery   -4.3903952  3.0101937  -1.459 0.147023
## factor(PACounty)Northampton  -1.3901356  1.0509479  -1.323 0.188157
## factor(PACounty)Philadelphia -3.0752326  2.4312368  -1.265 0.208092
## factor(PACounty)Tioga        -2.1127840  0.7303584  -2.893 0.004453 **
## factor(PACounty)Washington   -0.9100479  0.9635973  -0.944 0.346638
## factor(PACounty)Westmoreland -2.9014249  1.5156865  -1.914 0.057702 .
## factor(PACounty)York         -1.7512968  2.0467268  -0.856 0.393703
## factor(Year)2019              0.2904668  0.2192590   1.325 0.187487
## factor(Year)2020             -0.3525152  0.2123549  -1.660 0.099230 .
## factor(Year)2021              0.8494907  0.2369703   3.585 0.000470 ***
## factor(Year)2022             -0.0999609  0.2860597  -0.349 0.727303
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.8025 on 135 degrees of freedom
## Multiple R-squared:  0.6827, Adjusted R-squared:  0.5887
## F-statistic: 7.263 on 40 and 135 DF,  p-value: < 2.2e-16
```

```r
emission_significance_transport <- lm(PM2.5_Avg ~ Gas + Diesel + Electric + Propane +
↪  Hybrid + NaturalGas + CompGas + FlexFuel + factor(PACounty), data =
↪  County_PM2.5_Transportation_Data)
summary(emission_significance_transport)
```

```
##
## Call:
## lm(formula = PM2.5_Avg ~ Gas + Diesel + Electric + Propane +
##     Hybrid + NaturalGas + CompGas + FlexFuel + factor(PACounty),
##     data = County_PM2.5_Transportation_Data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.04913 -0.45079 -0.01937  0.49620  2.60769
##
## Coefficients:
##                                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)                    4.869e+00  2.612e+00   1.864  0.06454 .
## Gas                           -4.404e-06  3.065e-05  -0.144  0.88596
## Diesel                         1.216e-03  3.840e-04   3.166  0.00192 **
## Electric                      -2.950e-04  4.891e-04  -0.603  0.54747
## Propane                        1.089e-03  2.940e-03   0.371  0.71159
## Hybrid                         2.362e-04  4.273e-04   0.553  0.58140
## NaturalGas                     8.818e-03  6.129e-03   1.439  0.15263
## CompGas                       -7.582e-04  1.005e-02  -0.075  0.93998
## FlexFuel                      -9.634e-04  4.590e-04  -2.099  0.03775 *
## factor(PACounty)Allegheny     -1.289e+01  2.016e+01  -0.639  0.52386
## factor(PACounty)Armstrong      1.053e+00  1.182e+00   0.891  0.37471
## factor(PACounty)Beaver         8.914e-01  1.444e+00   0.617  0.53814
## factor(PACounty)Berks         -9.429e+00  6.366e+00  -1.481  0.14092
## factor(PACounty)Blair         -4.096e-01  6.597e-01  -0.621  0.53578
## factor(PACounty)Bradford      -1.061e+00  1.398e+00  -0.759  0.44939
## factor(PACounty)Butler        -2.479e+00  2.030e+00  -1.221  0.22420
## factor(PACounty)Cambria        7.005e-01  7.953e-01   0.881  0.38000
## factor(PACounty)Cameron        4.669e+00  2.564e+00   1.821  0.07086 .
## factor(PACounty)Centre        -1.382e+00  6.839e-01  -2.021  0.04527 *
## factor(PACounty)Chester       -9.482e+00  8.021e+00  -1.182  0.23925
## factor(PACounty)Clinton        1.882e+00  1.891e+00   0.995  0.32151
## factor(PACounty)Cumberland    -2.556e+00  2.951e+00  -0.866  0.38798
## factor(PACounty)Dauphin       -1.161e+01  4.298e+00  -2.702  0.00781 **
## factor(PACounty)Delaware      -1.098e+00  7.938e+00  -0.138  0.89016
## factor(PACounty)Erie          -2.764e+00  2.765e+00  -1.000  0.31935
## factor(PACounty)Fayette       -1.845e+00  7.944e-01  -2.322  0.02176 *
## factor(PACounty)Franklin      -1.489e+00  1.238e+00  -1.202  0.23141
## factor(PACounty)Fulton         3.260e+00  2.304e+00   1.415  0.15952
## factor(PACounty)Greene         6.593e-01  2.005e+00   0.329  0.74280
## factor(PACounty)Jefferson      2.316e+00  1.688e+00   1.372  0.17232
## factor(PACounty)Lackawanna    -2.060e+00  1.842e+00  -1.118  0.26550
## factor(PACounty)Lancaster     -1.282e+01  8.441e+00  -1.519  0.13126
## factor(PACounty)Lawrence       6.993e-01  9.261e-01   0.755  0.45154
## factor(PACounty)Lebanon       -1.445e+00  8.323e-01  -1.737  0.08480 .
## factor(PACounty)Lehigh        -3.611e+00  5.163e+00  -0.699  0.48551
## factor(PACounty)Mercer         3.079e-01  6.762e-01   0.455  0.64960
```

```
## factor(PACounty)Monroe       -2.654e+00  1.450e+00  -1.830  0.06952 .
## factor(PACounty)Montgomery   -1.296e+01  1.441e+01  -0.900  0.36992
## factor(PACounty)Northampton  -3.955e+00  4.230e+00  -0.935  0.35154
## factor(PACounty)Philadelphia -8.671e+00  1.751e+01  -0.495  0.62123
## factor(PACounty)Tioga        -1.639e+00  1.878e+00  -0.873  0.38447
## factor(PACounty)Washington   -3.759e+00  2.293e+00  -1.640  0.10343
## factor(PACounty)Westmoreland -6.798e+00  5.331e+00  -1.275  0.20454
## factor(PACounty)York         -7.903e+00  8.032e+00  -0.984  0.32689
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.8852 on 132 degrees of freedom
## Multiple R-squared:  0.6226, Adjusted R-squared:  0.4996
## F-statistic: 5.063 on 43 and 132 DF,  p-value: 3.258e-13
```

```r
# Set seed for reproducibility
set.seed(123)

# Generate random indices for splitting data into train and test sets
train_indices <- sample(1:nrow(County_PM2.5_Transportation_Data), 0.8 *
↪  nrow(County_PM2.5_Transportation_Data))

# Create train and test data sets
train_data <- County_PM2.5_Transportation_Data[train_indices, ]
test_data <- County_PM2.5_Transportation_Data[-train_indices, ]

# Case 1: Looking at all the vehicles
# Train the model on the entire data-set
AllVehicles <- lm(PM2.5_Avg ~ VEHICLES + factor(COUNTY) + factor(YEAR), data =
↪  train_data)
summary(AllVehicles)
```

```
##
## Call:
## lm(formula = PM2.5_Avg ~ VEHICLES + factor(COUNTY) + factor(YEAR),
##     data = train_data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.2275 -0.3974 -0.1027  0.3864  2.6140
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 8.075e+00  2.123e+00   3.804 0.000247 ***
## VEHICLES                    3.733e-07  2.042e-05   0.018 0.985446
## factor(COUNTY)Allegheny     1.670e+00  1.535e+01   0.109 0.913541
## factor(COUNTY)Armstrong     4.141e-01  1.053e+00   0.393 0.694933
## factor(COUNTY)Beaver        1.081e+00  1.026e+00   1.053 0.295020
## factor(COUNTY)Berks        -1.130e-01  5.240e+00  -0.022 0.982837
## factor(COUNTY)Blair         5.302e-02  6.133e-01   0.086 0.931281
## factor(COUNTY)Bradford     -1.414e+00  1.176e+00  -1.202 0.232207
## factor(COUNTY)Butler        1.484e+00  1.658e+00   0.895 0.372860
## factor(COUNTY)Cambria       7.880e-01  6.413e-01   1.229 0.222064
```

```
## factor(COUNTY)Cameron       7.918e-01  2.203e+00   0.360 0.719978
## factor(COUNTY)Centre       -3.619e-01  6.091e-01  -0.594 0.553727
## factor(COUNTY)Chester      -2.547e-02  6.618e+00  -0.004 0.996937
## factor(COUNTY)Clinton      -5.213e-02  1.623e+00  -0.032 0.974439
## factor(COUNTY)Cumberland    6.752e-01  2.401e+00   0.281 0.779123
## factor(COUNTY)Dauphin       3.839e-01  3.359e+00   0.114 0.909224
## factor(COUNTY)Delaware      1.267e+00  5.737e+00   0.221 0.825708
## factor(COUNTY)Erie         -1.701e+00  1.939e+00  -0.877 0.382582
## factor(COUNTY)Fayette      -3.285e-01  7.453e-01  -0.441 0.660290
## factor(COUNTY)Franklin      5.288e-01  1.139e+00   0.464 0.643531
## factor(COUNTY)Fulton        1.271e-01  1.974e+00   0.064 0.948783
## factor(COUNTY)Greene       -1.453e+00  1.700e+00  -0.855 0.394813
## factor(COUNTY)Jefferson     1.228e+00  1.430e+00   0.859 0.392369
## factor(COUNTY)Lackawanna   -8.896e-01  1.459e+00  -0.610 0.543579
## factor(COUNTY)Lancaster     1.338e+00  7.118e+00   0.188 0.851239
## factor(COUNTY)Lawrence     -9.735e-01  9.568e-01  -1.017 0.311448
## factor(COUNTY)Lebanon       3.823e-01  7.565e-01   0.505 0.614448
## factor(COUNTY)Lehigh        3.543e-01  3.974e+00   0.089 0.929135
## factor(COUNTY)Mercer       -6.664e-01  6.967e-01  -0.957 0.341099
## factor(COUNTY)Monroe       -1.964e+00  1.075e+00  -1.826 0.070897 .
## factor(COUNTY)Montgomery   -2.803e-01  1.133e+01  -0.025 0.980308
## factor(COUNTY)Northampton  -2.552e-01  3.383e+00  -0.075 0.940018
## factor(COUNTY)Philadelphia  5.339e-02  1.312e+01   0.004 0.996762
## factor(COUNTY)Tioga        -2.072e+00  1.671e+00  -1.240 0.217837
## factor(COUNTY)Washington    3.270e-01  1.808e+00   0.181 0.856879
## factor(COUNTY)Westmoreland -9.203e-01  4.194e+00  -0.219 0.826754
## factor(COUNTY)York          9.609e-01  6.427e+00   0.150 0.881453
## factor(YEAR)2019            3.356e-01  2.530e-01   1.326 0.187756
## factor(YEAR)2020           -2.922e-01  2.313e-01  -1.263 0.209416
## factor(YEAR)2021            1.231e+00  2.417e-01   5.092 1.69e-06 ***
## factor(YEAR)2022            2.483e-01  2.601e-01   0.955 0.342106
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7947 on 99 degrees of freedom
## Multiple R-squared:  0.7109, Adjusted R-squared:  0.5941
## F-statistic: 6.086 on 40 and 99 DF,  p-value: 1.49e-13
```

```
# Calculate MSE
predicted_PM2.5_allvehicles <- predict(AllVehicles, newdata = test_data)
mse_allegheny_all <- mean((predicted_PM2.5_allvehicles - test_data$PM2.5_Avg)^2)
print(mse_allegheny_all)
```

```
## [1] 0.8875131
```

```
# Predict PM2.5 levels for different number of cars in Allegheny County
predicted_PM2.5 <- predict(AllVehicles, newdata = data.frame(VEHICLES = c(855788,
↪  855789), COUNTY = "Allegheny", YEAR = "2022"))

# Calculate PM2.5 values for an addition of 1 car
difference <- predicted_PM2.5[2] - predicted_PM2.5[1]
print(difference)
```

```
##            2
## 3.733357e-07
```

```r
# Case 2: Looking specifically at Gas, Diesel and Electric Vehicles
# Train the model on the entire data-set
GDE <- lm(PM2.5_Avg ~ GAS + DIESEL + ELECTRIC + factor(COUNTY)+ factor(YEAR), data =
↪  train_data)
summary(GDE)
```

```
##
## Call:
## lm(formula = PM2.5_Avg ~ GAS + DIESEL + ELECTRIC + factor(COUNTY) +
##     factor(YEAR), data = train_data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.97729 -0.38296 -0.08271  0.37160  2.50687
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  6.111e+00  2.364e+00   2.585  0.01123 *
## GAS                         -3.764e-06  2.185e-05  -0.172  0.86356
## DIESEL                       7.369e-04  3.346e-04   2.202  0.03001 *
## ELECTRIC                    -2.641e-04  1.621e-04  -1.629  0.10648
## factor(COUNTY)Allegheny     -6.434e+00  1.617e+01  -0.398  0.69163
## factor(COUNTY)Armstrong      8.077e-01  1.082e+00   0.746  0.45717
## factor(COUNTY)Beaver         1.023e+00  1.028e+00   0.994  0.32248
## factor(COUNTY)Berks         -5.678e+00  5.887e+00  -0.964  0.33720
## factor(COUNTY)Blair         -3.986e-02  6.052e-01  -0.066  0.94762
## factor(COUNTY)Bradford      -1.227e+00  1.206e+00  -1.017  0.31166
## factor(COUNTY)Butler        -8.560e-01  1.950e+00  -0.439  0.66168
## factor(COUNTY)Cambria        7.835e-01  6.348e-01   1.234  0.22013
## factor(COUNTY)Cameron        3.047e+00  2.435e+00   1.251  0.21392
## factor(COUNTY)Centre        -8.292e-01  6.392e-01  -1.297  0.19763
## factor(COUNTY)Chester       -5.188e+00  7.134e+00  -0.727  0.46880
## factor(COUNTY)Clinton        1.227e+00  1.753e+00   0.700  0.48557
## factor(COUNTY)Cumberland    -1.120e+00  2.576e+00  -0.435  0.66479
## factor(COUNTY)Dauphin       -7.139e+00  4.727e+00  -1.510  0.13422
## factor(COUNTY)Delaware       5.077e-01  5.971e+00   0.085  0.93242
## factor(COUNTY)Erie          -2.542e+00  2.023e+00  -1.257  0.21194
## factor(COUNTY)Fayette       -1.212e+00  8.324e-01  -1.456  0.14861
## factor(COUNTY)Franklin      -5.017e-01  1.228e+00  -0.409  0.68365
## factor(COUNTY)Fulton         1.928e+00  2.144e+00   0.899  0.37092
## factor(COUNTY)Greene        -2.791e-01  1.794e+00  -0.156  0.87668
## factor(COUNTY)Jefferson      2.077e+00  1.516e+00   1.370  0.17389
## factor(COUNTY)Lackawanna    -1.317e+00  1.486e+00  -0.887  0.37753
## factor(COUNTY)Lancaster     -6.847e+00  8.088e+00  -0.847  0.39931
## factor(COUNTY)Lawrence      -5.087e-01  9.957e-01  -0.511  0.61060
## factor(COUNTY)Lebanon       -6.055e-01  8.692e-01  -0.697  0.48772
## factor(COUNTY)Lehigh        -1.503e+00  4.181e+00  -0.359  0.72008
## factor(COUNTY)Mercer        -3.225e-01  7.146e-01  -0.451  0.65277
## factor(COUNTY)Monroe        -2.191e+00  1.094e+00  -2.003  0.04793 *
## factor(COUNTY)Montgomery    -6.374e+00  1.195e+01  -0.534  0.59481
```

```
## factor(COUNTY)Northampton  -2.285e+00  3.597e+00  -0.635  0.52668
## factor(COUNTY)Philadelphia -4.274e+00  1.372e+01  -0.312  0.75599
## factor(COUNTY)Tioga        -9.394e-01  1.736e+00  -0.541  0.58968
## factor(COUNTY)Washington   -1.911e+00  2.075e+00  -0.921  0.35924
## factor(COUNTY)Westmoreland -4.442e+00  4.560e+00  -0.974  0.33243
## factor(COUNTY)York         -3.751e+00  6.923e+00  -0.542  0.58921
## factor(YEAR)2019            2.715e-01  2.515e-01   1.079  0.28304
## factor(YEAR)2020           -4.264e-01  2.373e-01  -1.797  0.07540 .
## factor(YEAR)2021            9.422e-01  2.758e-01   3.416  0.00093 ***
## factor(YEAR)2022           -1.713e-01  3.558e-01  -0.481  0.63130
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7823 on 97 degrees of freedom
## Multiple R-squared:  0.7255, Adjusted R-squared:  0.6067
## F-statistic: 6.104 on 42 and 97 DF,  p-value: 1.1e-13
```

```
# Calculate MSE
predicted_PM2.5_allegheny_GDE <- predict(GDE, newdata = test_data)
mse_allegheny_GDE <- mean((predicted_PM2.5_allegheny_GDE - test_data$PM2.5_Avg)^2,
↪  na.rm=TRUE)
print(mse_allegheny_GDE)
```

```
## [1] 0.9388585
```

```
# Predict PM2.5 levels for different number of cars in Allegheny County
predicted_PM2.5 <- predict(GDE, newdata = data.frame(GAS = c(811383, 811384), DIESEL =
↪  c(20091, 20092), ELECTRIC = c(4574,4575), COUNTY = "Allegheny", YEAR = "2022"))

# Calculate PM2.5 values for an addition of 1 gas, 1 diesel and 1 electric car
difference <- predicted_PM2.5[2] - predicted_PM2.5[1]
print(difference)
```

```
##            2
## 0.0004691006
```

```
# Case 3: Looking specifically at Diesel Vehicles
# Train the model on the entire data-set
Diesel_Cars <- lm(PM2.5_Avg ~ DIESEL + factor(COUNTY) + factor(YEAR), data = train_data)
summary(Diesel_Cars)
```

```
##
## Call:
## lm(formula = PM2.5_Avg ~ DIESEL + factor(COUNTY) + factor(YEAR),
##     data = train_data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.3315 -0.3569 -0.1084  0.3670  2.6110
##
## Coefficients:
```

```
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 6.7211093  1.0000589   6.721 1.16e-09 ***
## DIESEL                      0.0004507  0.0002854   1.579 0.117513
## factor(COUNTY)Allegheny    -5.1599337  4.5435545  -1.136 0.258841
## factor(COUNTY)Armstrong     0.7596139  0.6845709   1.110 0.269851
## factor(COUNTY)Beaver        0.9144765  0.6549899   1.396 0.165787
## factor(COUNTY)Berks        -4.1100440  2.6548839  -1.548 0.124787
## factor(COUNTY)Blair        -0.0157634  0.6068285  -0.026 0.979328
## factor(COUNTY)Bradford     -1.1770709  0.6651820  -1.770 0.079882 .
## factor(COUNTY)Butler       -0.1394174  1.2288220  -0.113 0.909899
## factor(COUNTY)Cambria       0.7410301  0.5772042   1.284 0.202199
## factor(COUNTY)Cameron       2.4369225  1.2860709   1.895 0.061029 .
## factor(COUNTY)Centre       -0.6837615  0.6348089  -1.077 0.284047
## factor(COUNTY)Chester      -4.2115361  2.7936595  -1.508 0.134858
## factor(COUNTY)Clinton       0.8596817  0.9372722   0.917 0.361258
## factor(COUNTY)Cumberland   -0.7351634  1.1011006  -0.668 0.505903
## factor(COUNTY)Dauphin      -4.6148992  3.2690398  -1.412 0.161174
## factor(COUNTY)Delaware      0.0155484  1.0498617   0.015 0.988214
## factor(COUNTY)Erie         -2.4252703  0.7282711  -3.330 0.001220 **
## factor(COUNTY)Fayette      -0.9130806  0.7453611  -1.225 0.223475
## factor(COUNTY)Franklin     -0.2443743  0.7852714  -0.311 0.756305
## factor(COUNTY)Fulton        1.4694778  1.1301044   1.300 0.196516
## factor(COUNTY)Greene       -0.5240388  0.9408305  -0.557 0.578787
## factor(COUNTY)Jefferson     1.8775112  0.7362171   2.550 0.012298 *
## factor(COUNTY)Lackawanna   -1.3206991  0.9668040  -1.366 0.175020
## factor(COUNTY)Lancaster    -4.4788314  3.8099982  -1.176 0.242595
## factor(COUNTY)Lawrence     -0.6554341  0.7558840  -0.867 0.387979
## factor(COUNTY)Lebanon      -0.2912050  0.7202618  -0.404 0.686861
## factor(COUNTY)Lehigh       -1.2793802  1.2579044  -1.017 0.311598
## factor(COUNTY)Mercer       -0.4314269  0.6206964  -0.695 0.488640
## factor(COUNTY)Monroe       -2.2480843  0.6341493  -3.545 0.000601 ***
## factor(COUNTY)Montgomery   -5.6873267  3.5916709  -1.583 0.116502
## factor(COUNTY)Northampton  -1.9115241  1.2648695  -1.511 0.133912
## factor(COUNTY)Philadelphia -4.1806505  2.8911944  -1.446 0.151337
## factor(COUNTY)Tioga        -1.1364728  1.0986414  -1.034 0.303453
## factor(COUNTY)Washington   -1.2545844  1.1523716  -1.089 0.278930
## factor(COUNTY)Westmoreland -3.5479577  1.8147245  -1.955 0.053392 .
## factor(COUNTY)York         -2.6587293  2.4355332  -1.092 0.277640
## factor(YEAR)2019            0.2982283  0.2496762   1.194 0.235152
## factor(YEAR)2020           -0.3939943  0.2370683  -1.662 0.099687 .
## factor(YEAR)2021            0.9807778  0.2716860   3.610 0.000483 ***
## factor(YEAR)2022           -0.1806101  0.3569154  -0.506 0.613960
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7849 on 99 degrees of freedom
## Multiple R-squared:  0.718,  Adjusted R-squared:  0.6041
## F-statistic: 6.302 on 40 and 99 DF,  p-value: 5.222e-14
```

```r
# Calculate MSE
predicted_PM2.5_allegheny_diesel <- predict(Diesel_Cars, newdata = test_data)
mse_allegheny_diesel <- mean((predicted_PM2.5_allegheny_diesel - test_data$PM2.5_Avg)^2)
print(mse_allegheny_diesel)
```

```
## [1] 0.9179705
```

```
# Predict PM2.5 levels for different number of cars in Allegheny County
predicted_PM2.5 <- predict(Diesel_Cars, newdata = data.frame(DIESEL = c(20091, 20092),
↪  COUNTY = "Allegheny", YEAR = "2022"))

# Calculate the difference between predicted PM2.5 values to get the PM2.5 for an
↪  addition of 1 diesel car
difference <- predicted_PM2.5[2] - predicted_PM2.5[1]
print(difference)
```

```
##           2
## 0.0004507233
```

```
#k-fold Cross validation
# Load the caret package
library(caret)

# Define the number of folds for cross-validation
num_folds <- 10

# Define the control parameters for cross-validation
train_control <- trainControl(method = "cv",   # Use k-fold cross-validation
                              number = num_folds)  # Number of folds

# Case 1: Looking at all the vehicles
# Train the model on the entire data-set using k-fold cross-validation
AllVehicles_cv <- train(PM2.5_Avg ~ VEHICLES + factor(COUNTY) + factor(YEAR),
                        data = County_PM2.5_Transportation_Data,
                        method = "lm",
                        trControl = train_control)

# Print the results
print(AllVehicles_cv)
```

```
## Linear Regression
##
## 176 samples
##   3 predictor
##
## No pre-processing
## Resampling: Cross-Validated (10 fold)
## Summary of sample sizes: 156, 160, 159, 158, 159, 159, ...
## Resampling results:
##
##   RMSE       Rsquared   MAE
##   0.8752253  0.5347608  0.670511
##
## Tuning parameter 'intercept' was held constant at a value of TRUE
```

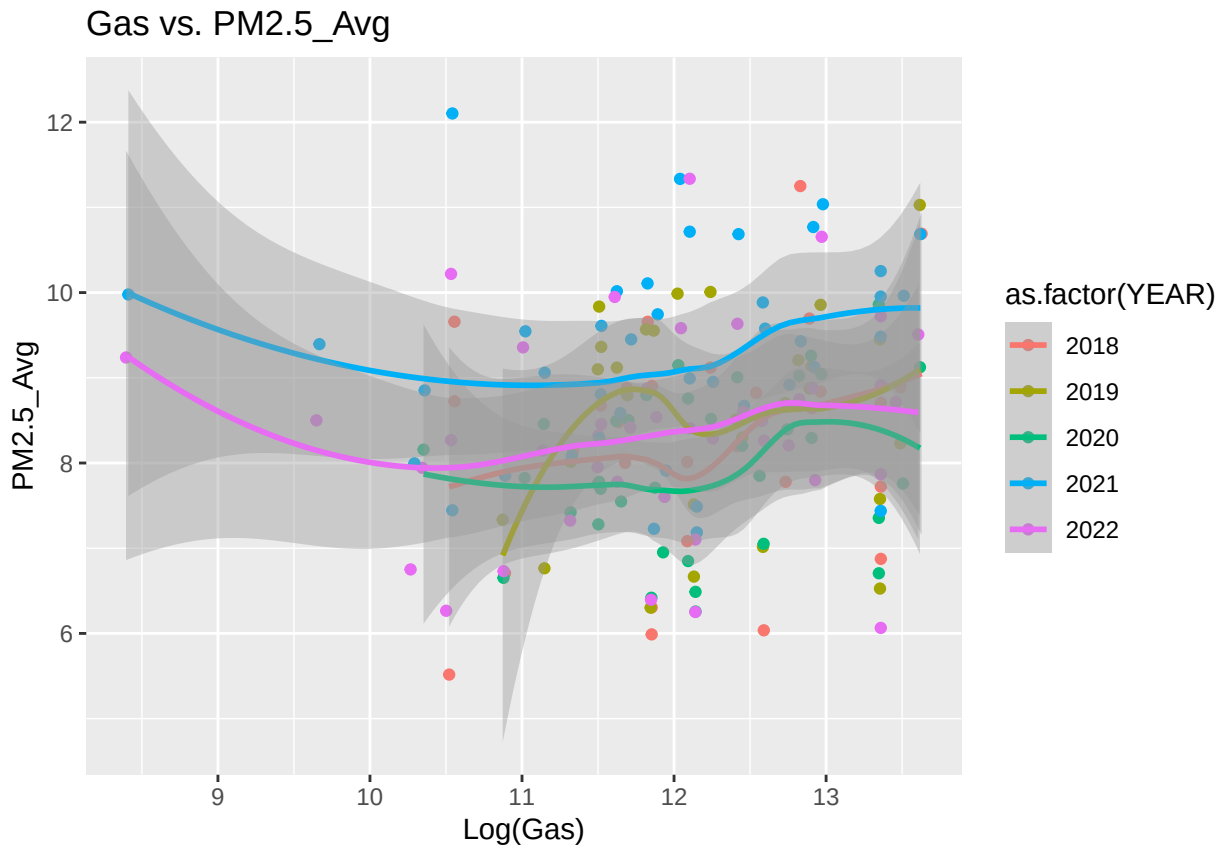
```r
# Case 2: Looking specifically at Gas, Diesel, and Electric Vehicles
# Train the model on the entire data-set using k-fold cross-validation
GDE_cv <- train(PM2.5_Avg ~ GAS + DIESEL + ELECTRIC + factor(COUNTY) + factor(YEAR),
                data = County_PM2.5_Transportation_Data,
                method = "lm",
                trControl = train_control)

# Print the results
print(GDE_cv)
```

```
## Linear Regression
##
## 176 samples
##   5 predictor
##
## No pre-processing
## Resampling: Cross-Validated (10 fold)
## Summary of sample sizes: 158, 157, 158, 159, 158, 159, ...
## Resampling results:
##
##   RMSE     Rsquared   MAE
##   0.87055  0.5519457  0.6642736
##
## Tuning parameter 'intercept' was held constant at a value of TRUE
```

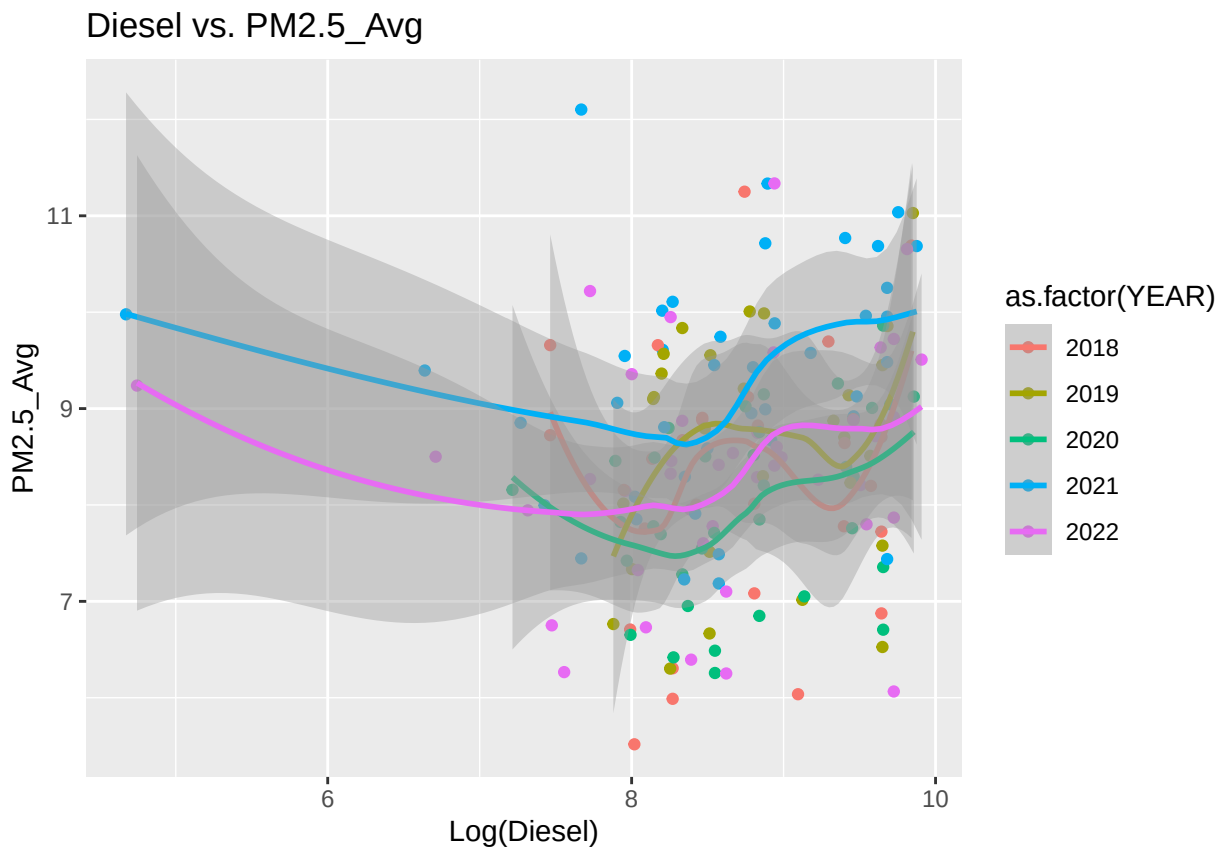
```r
# Case 3: Looking specifically at Diesel Vehicles
# Train the model on the entire data-set using k-fold cross-validation
Diesel_Cars_cv <- train(PM2.5_Avg ~ DIESEL + factor(COUNTY) + factor(YEAR),
                        data = County_PM2.5_Transportation_Data,
                        method = "lm",
                        trControl = train_control)

# Print the results
print(Diesel_Cars_cv)
```

```
## Linear Regression
##
## 176 samples
##   3 predictor
##
## No pre-processing
## Resampling: Cross-Validated (10 fold)
## Summary of sample sizes: 159, 158, 158, 159, 158, 159, ...
## Resampling results:
##
##   RMSE       Rsquared   MAE
##   0.8907525  0.5214265  0.6741556
##
## Tuning parameter 'intercept' was held constant at a value of TRUE
```

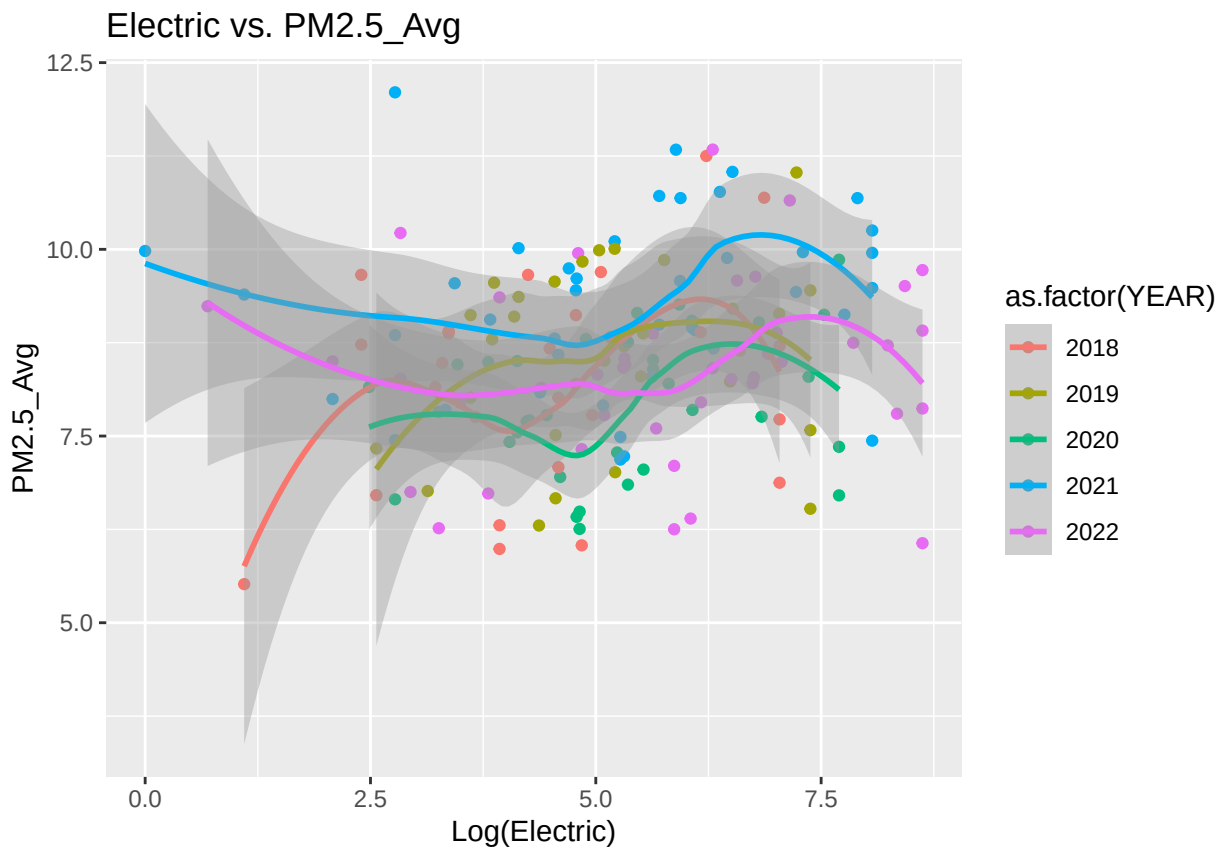
```r
# Visualizing Gas vs. PM2.5_Avg with color based on year
ggplot(County_PM2.5_Transportation_Data) +
  geom_point(aes(x = log(Gas), y = PM2.5_Avg, color = as.factor(YEAR))) +
  geom_smooth(aes(x = log(Gas), y = PM2.5_Avg, color = as.factor(YEAR))) +
  labs(title = "Gas vs. PM2.5_Avg", x = "Log(Gas)", y = "PM2.5_Avg")
```



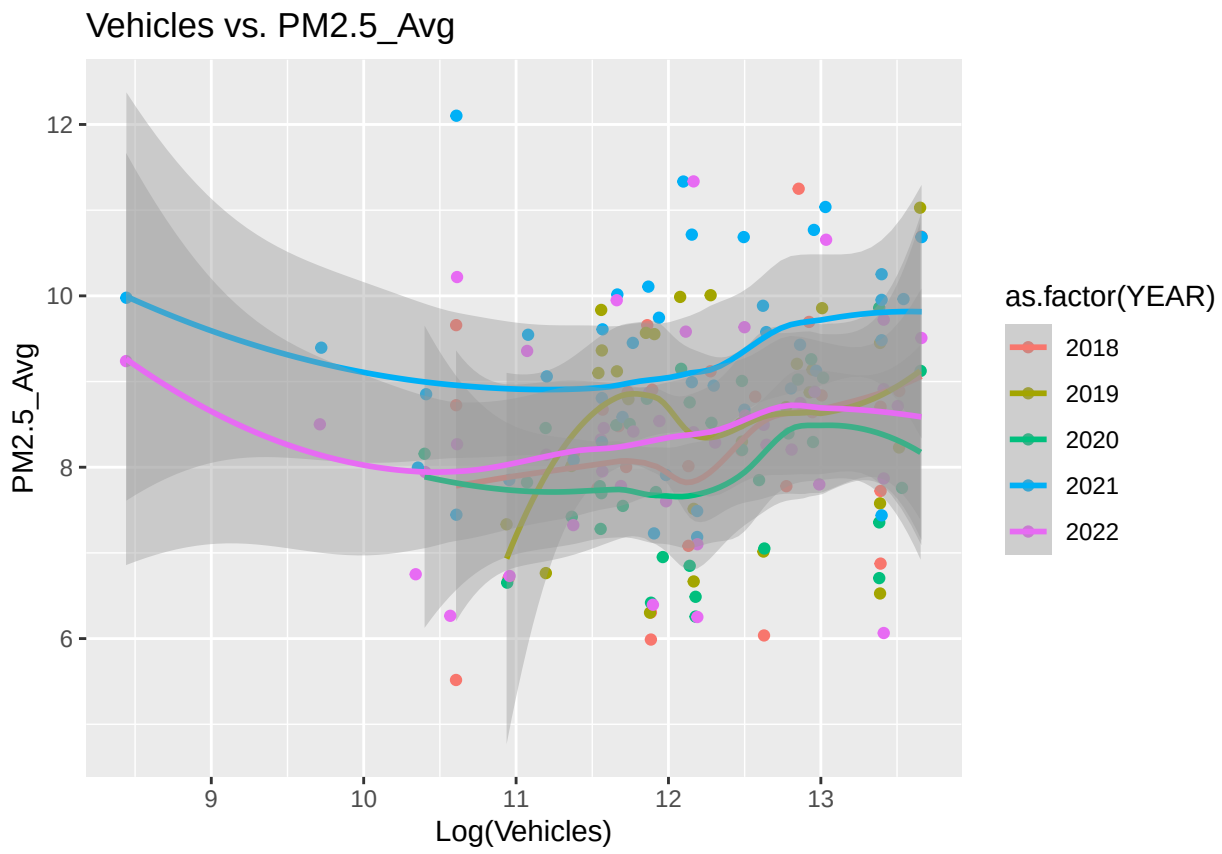

```r
# Visualizing Diesel vs. PM2.5_Avg with color based on year
ggplot(County_PM2.5_Transportation_Data) +
  geom_point(aes(x = log(Diesel), y = PM2.5_Avg, color = as.factor(YEAR))) +
  geom_smooth(aes(x = log(Diesel), y = PM2.5_Avg, color = as.factor(YEAR))) +
  labs(title = "Diesel vs. PM2.5_Avg", x = "Log(Diesel)", y = "PM2.5_Avg")
```




```
# Visualizing Electric vs. PM2.5_Avg with color based on year
ggplot(County_PM2.5_Transportation_Data) +
  geom_point(aes(x = log(Electric), y = PM2.5_Avg, color = as.factor(YEAR))) +
  geom_smooth(aes(x = log(Electric), y = PM2.5_Avg, color = as.factor(YEAR))) +
  labs(title = "Electric vs. PM2.5_Avg", x = "Log(Electric)", y = "PM2.5_Avg")
```




```
# Visualizing Vehicles vs. PM2.5_Avg with color based on year
ggplot(County_PM2.5_Transportation_Data) +
  geom_point(aes(x = log(Vehicles), y = PM2.5_Avg, color = as.factor(YEAR))) +
  geom_smooth(aes(x = log(Vehicles), y = PM2.5_Avg, color = as.factor(YEAR))) +
  labs(title = "Vehicles vs. PM2.5_Avg", x = "Log(Vehicles)", y = "PM2.5_Avg")
```



#Model 2: Ridge

```
# Install and load the glmnet package
library(glmnet)

County_PM2.5_Transportation_Data1 <- na.omit(County_PM2.5_Transportation_Data)

# Prepare the predictor matrix
x_all <- model.matrix(~ VEHICLES + factor(COUNTY) + factor(YEAR), data =
↪  County_PM2.5_Transportation_Data1)
y_all <- County_PM2.5_Transportation_Data1$PM2.5_Avg

# Perform cross-validated ridge regression
ridge_model_all <- cv.glmnet(x_all, y_all, alpha = 0)
best_lambda_all <- ridge_model_all$lambda.min
final_model_all <- glmnet(x_all, y_all, alpha = 0, lambda = best_lambda_all)

# Extract coefficients
coefficients_all <- coef(final_model_all)

# Predict PM2.5 levels
predicted_PM2.5_all <- predict(final_model_all, newx = x_all)

# Calculate mean squared error
mse_all <- mean((predicted_PM2.5_all - y_all)^2)
```

```r
# Print results
print(coefficients_all)
```

```
## 42 x 1 sparse Matrix of class "dgCMatrix"
##                                       s0
## (Intercept)                 8.264440e+00
## (Intercept)                 .
## VEHICLES                    4.970047e-07
## factor(COUNTY)Allegheny     1.173067e+00
## factor(COUNTY)Armstrong     3.893670e-01
## factor(COUNTY)Beaver        7.931466e-01
## factor(COUNTY)Berks        -1.366907e-01
## factor(COUNTY)Blair         6.741143e-02
## factor(COUNTY)Bradford     -1.139366e+00
## factor(COUNTY)Butler        1.264929e+00
## factor(COUNTY)Cambria       6.443233e-01
## factor(COUNTY)Cameron       7.865852e-01
## factor(COUNTY)Centre       -2.595850e-02
## factor(COUNTY)Chester       3.157000e-03
## factor(COUNTY)Clinton      -9.241868e-02
## factor(COUNTY)Cumberland    4.061937e-01
## factor(COUNTY)Dauphin       5.791803e-01
## factor(COUNTY)Delaware      8.022684e-01
## factor(COUNTY)Erie         -1.382391e+00
## factor(COUNTY)Fayette      -3.819780e-01
## factor(COUNTY)Franklin      3.612116e-01
## factor(COUNTY)Fulton        2.292016e-01
## factor(COUNTY)Greene       -1.094200e+00
## factor(COUNTY)Jefferson     7.145959e-01
## factor(COUNTY)Lackawanna   -8.397608e-01
## factor(COUNTY)Lancaster     1.071436e+00
## factor(COUNTY)Lawrence     -2.888633e-01
## factor(COUNTY)Lebanon       3.028333e-01
## factor(COUNTY)Lehigh        2.013043e-01
## factor(COUNTY)Mercer       -5.270316e-01
## factor(COUNTY)Monroe       -1.677733e+00
## factor(COUNTY)Montgomery   -4.086936e-01
## factor(COUNTY)Northampton  -8.698864e-02
## factor(COUNTY)Philadelphia -3.722913e-02
## factor(COUNTY)Tioga        -2.015329e+00
## factor(COUNTY)Washington    2.527876e-01
## factor(COUNTY)Westmoreland -7.960697e-01
## factor(COUNTY)York          7.582302e-01
## factor(YEAR)2019            1.611405e-01
## factor(YEAR)2020           -3.604328e-01
## factor(YEAR)2021            7.702949e-01
## factor(YEAR)2022            3.208717e-02
```

```r
print(mse_all)
```

```
## [1] 0.5283775
```

```r
#Carry out the same 3 cases as in the Linear Regression Model by changing features in the
↪  first line 511
```

#Model 3: Lasso

```r
library(glmnet)

# Prepare the predictor matrix
x_all <- model.matrix(~ DIESEL + factor(COUNTY) + factor(YEAR), data =
↪  County_PM2.5_Transportation_Data)
y_all <- County_PM2.5_Transportation_Data$PM2.5_Avg

# Perform cross-validated lasso regression
lasso_model_all <- cv.glmnet(x_all, y_all, alpha = 1)
best_lambda_all <- lasso_model_all$lambda.min
final_model_all <- glmnet(x_all, y_all, alpha = 1, lambda = best_lambda_all)

# Extract coefficients
coefficients_all <- coef(final_model_all)

# Predict PM2.5 levels
predicted_PM2.5_all <- predict(final_model_all, newx = x_all)

# Calculate mean squared error
mse_all <- mean((predicted_PM2.5_all - y_all)^2)

# Print results
print(coefficients_all)
```

```
## 42 x 1 sparse Matrix of class "dgCMatrix"
##                                       s0
## (Intercept)                 8.336492e+00
## (Intercept)                 .
## DIESEL                      1.262304e-05
## factor(COUNTY)Allegheny     1.378618e+00
## factor(COUNTY)Armstrong     2.192218e-01
## factor(COUNTY)Beaver        7.671473e-01
## factor(COUNTY)Berks        -2.000748e-01
## factor(COUNTY)Blair         .
## factor(COUNTY)Bradford     -1.425306e+00
## factor(COUNTY)Butler        1.282601e+00
## factor(COUNTY)Cambria       5.802142e-01
## factor(COUNTY)Cameron       6.535588e-01
## factor(COUNTY)Centre       -8.907222e-02
## factor(COUNTY)Chester      -4.936653e-03
## factor(COUNTY)Clinton      -1.673372e-01
## factor(COUNTY)Cumberland    3.083967e-01
## factor(COUNTY)Dauphin       4.352432e-01
## factor(COUNTY)Delaware      8.645100e-01
## factor(COUNTY)Erie         -1.699068e+00
## factor(COUNTY)Fayette      -5.054070e-01
## factor(COUNTY)Franklin      2.389247e-01
```

```
## factor(COUNTY)Fulton         .
## factor(COUNTY)Greene       -1.372770e+00
## factor(COUNTY)Jefferson     6.404540e-01
## factor(COUNTY)Lackawanna   -1.036332e+00
## factor(COUNTY)Lancaster     1.090469e+00
## factor(COUNTY)Lawrence     -4.052139e-01
## factor(COUNTY)Lebanon       1.608137e-01
## factor(COUNTY)Lehigh        8.539344e-02
## factor(COUNTY)Mercer       -6.791098e-01
## factor(COUNTY)Monroe       -2.030325e+00
## factor(COUNTY)Montgomery   -4.522416e-01
## factor(COUNTY)Northampton  -1.267237e-01
## factor(COUNTY)Philadelphia  .
## factor(COUNTY)Tioga        -2.401181e+00
## factor(COUNTY)Washington    1.190148e-01
## factor(COUNTY)Westmoreland -9.727019e-01
## factor(COUNTY)York          7.622008e-01
## factor(YEAR)2019            2.154517e-01
## factor(YEAR)2020           -3.335034e-01
## factor(YEAR)2021            9.260553e-01
## factor(YEAR)2022            7.831847e-02
```

```
print(mse_all)
```

```
## [1] 0.5064293
```

```
#Carry out the same 3 cases as in the Linear Regression Model by changing features in the
↪  first line 538
```