Econ 216 Final Project

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Load and Inspect Data

```
# Load necessary libraries
library(tidyverse)
```

```
## Warning: package 'tidyverse' was built under R version 4.3.3
```

```
## Warning: package 'readr' was built under R version 4.3.3
```

```
## Warning: package 'forcats' was built under R version 4.3.3
```

```
## Warning: package 'lubridate' was built under R version 4.3.3
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.0     v stringr   1.5.1
## v ggplot2   3.4.4     v tibble    3.2.1
## v lubridate 1.9.3     v tidyr     1.3.1
## v purrr     1.0.2
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```
library(lubridate)
library(ggmap)
```

```
## Warning: package 'ggmap' was built under R version 4.3.3
```

```
## i Google's Terms of Service: <https://mapsplatform.google.com>
##   Stadia Maps' Terms of Service: <https://stadiamaps.com/terms-of-service/>
##   OpenStreetMap's Tile Usage Policy: <https://operations.osmfoundation.org/policies/tiles/>
## i Please cite ggmap if you use it! Use `citation("ggmap")` for details.
```

```
us_map <- map_data("state")


# Load the data
data <- read.csv("uswtdb_v4_3_20220114.csv")

# Inspect the first few rows of the data
head(data)
```

```
##   case_id   faa_ors          faa_asn usgs_pr_id eia_id t_state     t_county
## 1 3072661                               5149  52161      CA  Kern County
## 2 3072695                               5143  52161      CA  Kern County
## 3 3072704                               5146  52161      CA  Kern County
```

```
## 4 3063272 19-028134 2014-WTE-4084-OE         NA     NA      IA Story County
## 5 3053390 19-028015 2015-WTE-6386-OE         NA     NA      IA Boone County
## 6 3063269 19-028130 2016-WTE-5934-OE         NA     NA      IA Story County
##   t_fips                  p_name p_year p_tnum p_cap t_manu    t_model t_cap
## 1   6029                251 Wind   1987    194 18.43 Vestas               95
## 2   6029                251 Wind   1987    194 18.43 Vestas               95
## 3   6029                251 Wind   1987    194 18.43 Vestas               95
## 4  19169 30 MW Iowa DG Portfolio   2017     10 30.00 Nordex AW125/3000  3000
## 5  19015 30 MW Iowa DG Portfolio   2017     10 30.00 Nordex AW125/3000  3000
## 6  19169 30 MW Iowa DG Portfolio   2017     10 30.00 Nordex AW125/3000  3000
##   t_hh t_rd    t_rsa t_ttlh retrofit retrofit_year t_conf_atr t_conf_loc
## 1   NA   NA       NA     NA        0            NA          2          3
## 2   NA   NA       NA     NA        0            NA          2          3
## 3   NA   NA       NA     NA        0            NA          2          3
## 4 87.5  125 12271.85    150        0            NA          3          3
## 5 87.5  125 12271.85    150        0            NA          3          3
## 6 87.5  125 12271.85    150        0            NA          3          3
##   t_img_date    t_img_srce      xlong     ylat
## 1   5/8/2018 Digital Globe -118.36376 35.07791
## 2   5/8/2018 Digital Globe -118.36441 35.07744
## 3   5/8/2018 Digital Globe -118.36420 35.07764
## 4  4/24/2017 Digital Globe  -93.43037 42.02823
## 5   6/1/2017 Digital Globe  -93.70042 41.97761
## 6  7/23/2017 Digital Globe  -93.63284 41.88248
```

```
# Summarize the data to understand its structure
summary(data)
```

```
##     case_id          faa_ors            faa_asn            usgs_pr_id
##  Min.   :3000001   Length:70808       Length:70808       Min.   :    1
##  1st Qu.:3032230   Class :character   Class :character   1st Qu.:18626
##  Median :3050979   Mode  :character   Mode  :character   Median :28598
##  Mean   :3058490                                         Mean   :27524
##  3rd Qu.:3090448                                         3rd Qu.:38720
##  Max.   :3118671                                         Max.   :49135
##                                                          NA's   :32545
##      eia_id        t_state            t_county            t_fips
##  Min.   :   90   Length:70808       Length:70808       Min.   : 2013
##  1st Qu.:56763   Class :character   Class :character   1st Qu.:19081
##  Median :57752   Mode  :character   Mode  :character   Median :35057
##  Mean   :57878                                         Mean   :32244
##  3rd Qu.:60338                                         3rd Qu.:48141
##  Max.   :65270                                         Max.   :72133
##  NA's   :5793
##     p_name              p_year         p_tnum          p_cap
##  Length:70808       Min.   :1981   Min.   :  1.0   Min.   :  0.05
##  Class :character   1st Qu.:2008   1st Qu.: 56.0   1st Qu.: 99.00
##  Mode  :character   Median :2012   Median : 85.0   Median :158.00
##                     Mean   :2012   Mean   :104.4   Mean   :170.18
##                     3rd Qu.:2018   3rd Qu.:121.0   3rd Qu.:211.22
##                     Max.   :2021   Max.   :731.0   Max.   :525.02
##                     NA's   :613                    NA's   :4482
##     t_manu            t_model              t_cap           t_hh
##  Length:70808       Length:70808       Min.   :  50   Min.   : 19.00
##  Class :character   Class :character   1st Qu.:1500   1st Qu.: 80.00
```

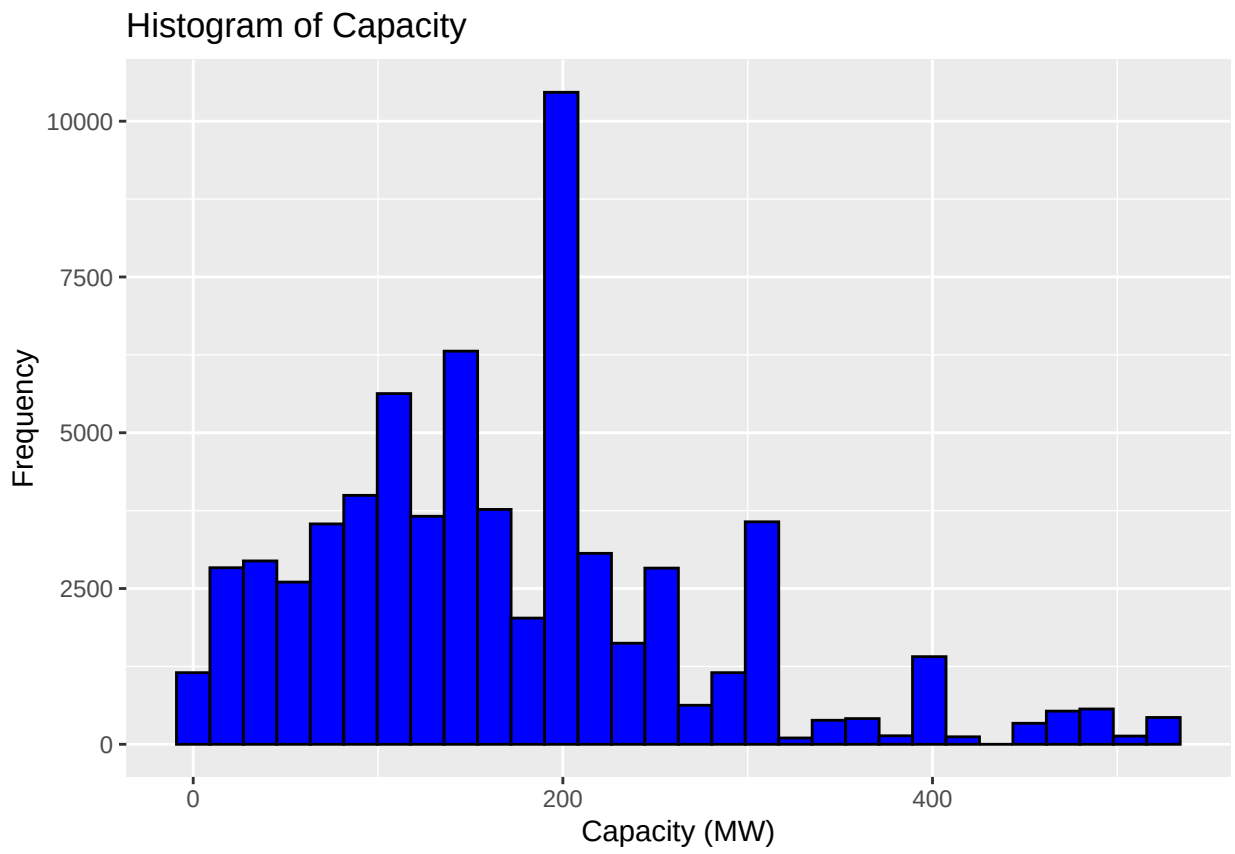
```
##  Mode  :character   Mode  :character   Median :2000   Median : 80.00
##                                        Mean   :1964   Mean   : 81.06
##                                        3rd Qu.:2300   3rd Qu.: 87.00
##                                        Max.   :6000   Max.   :131.00
##                                        NA's   :5480   NA's   :6180
##       t_rd            t_rsa           t_ttlh         retrofit
##  Min.   : 13.40   Min.   :  141   Min.   : 30.4   Min.   :0.00000
##  1st Qu.: 82.00   1st Qu.: 5281   1st Qu.:121.0   1st Qu.:0.00000
##  Median :100.00   Median : 7854   Median :130.1   Median :0.00000
##  Mean   : 95.66   Mean   : 7619   Mean   :129.1   Mean   :0.08454
##  3rd Qu.:110.00   3rd Qu.: 9503   3rd Qu.:145.1   3rd Qu.:0.00000
##  Max.   :155.00   Max.   :18869   Max.   :199.6   Max.   :1.00000
##  NA's   :5934     NA's   :5934    NA's   :6180
##  retrofit_year     t_conf_atr      t_conf_loc     t_img_date
##  Min.   :2015    Min.   :1.000   Min.   :1.000   Length:70808
##  1st Qu.:2018    1st Qu.:3.000   1st Qu.:3.000   Class :character
##  Median :2019    Median :3.000   Median :3.000   Mode  :character
##  Mean   :2019    Mean   :2.767   Mean   :2.884
##  3rd Qu.:2020    3rd Qu.:3.000   3rd Qu.:3.000
##  Max.   :2020    Max.   :3.000   Max.   :3.000
##  NA's   :64822
##   t_img_srce            xlong             ylat
##  Length:70808       Min.   :-171.71   Min.   :13.39
##  Class :character   1st Qu.:-103.04   1st Qu.:34.43
##  Mode  :character   Median : -99.39   Median :39.05
##                     Mean   :-100.09   Mean   :38.48
##                     3rd Qu.: -95.20   3rd Qu.:42.81
##                     Max.   : 144.72   Max.   :66.84
##
```

Histograms and Bar Plots

Discuss the distribution of each variable using histograms for continuous variables and bar plots for categorical variables.

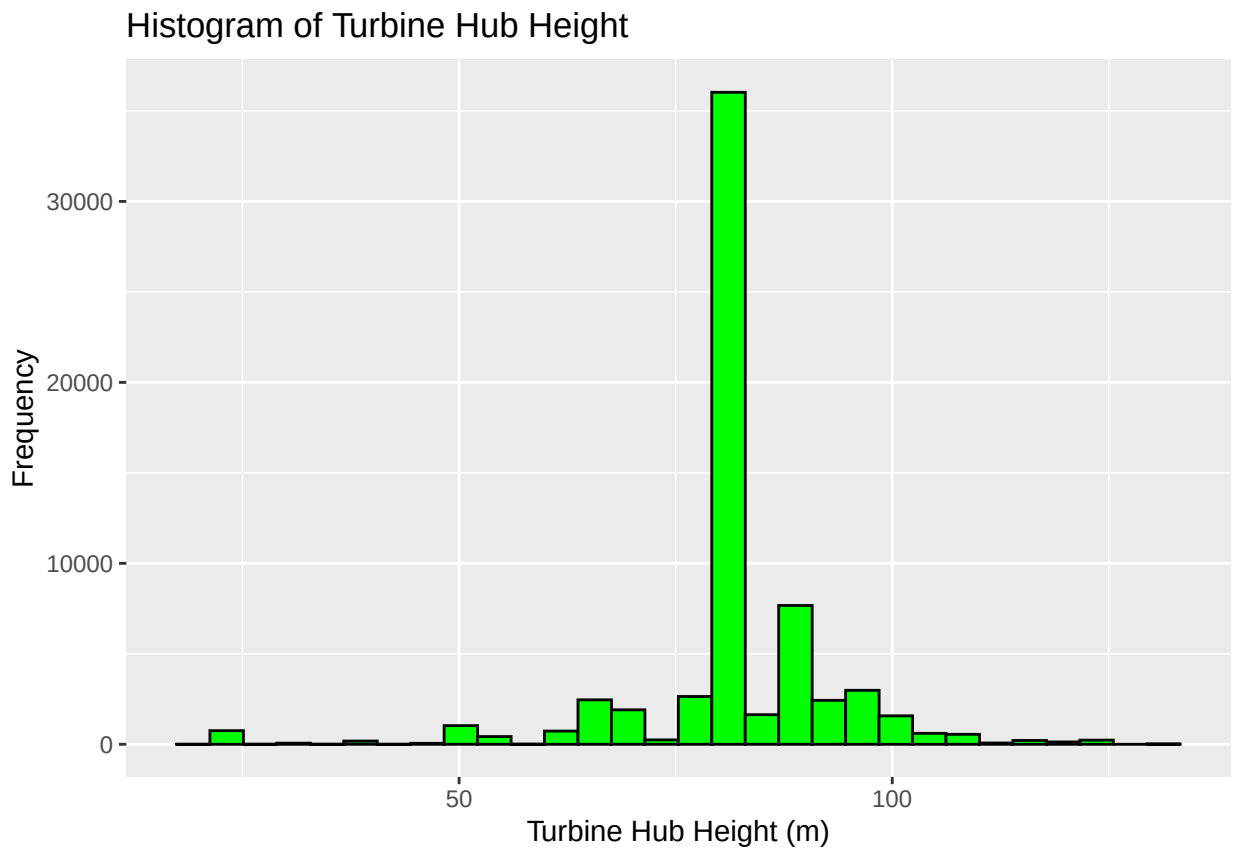
```
# Histogram for 'p_cap'
ggplot(data, aes(x = p_cap)) +
  geom_histogram(bins = 30, fill = "blue", color = "black") +
  labs(x = "Capacity (MW)", y = "Frequency", title = "Histogram of Capacity")
```

```
## Warning: Removed 4482 rows containing non-finite values (`stat_bin()`).
```

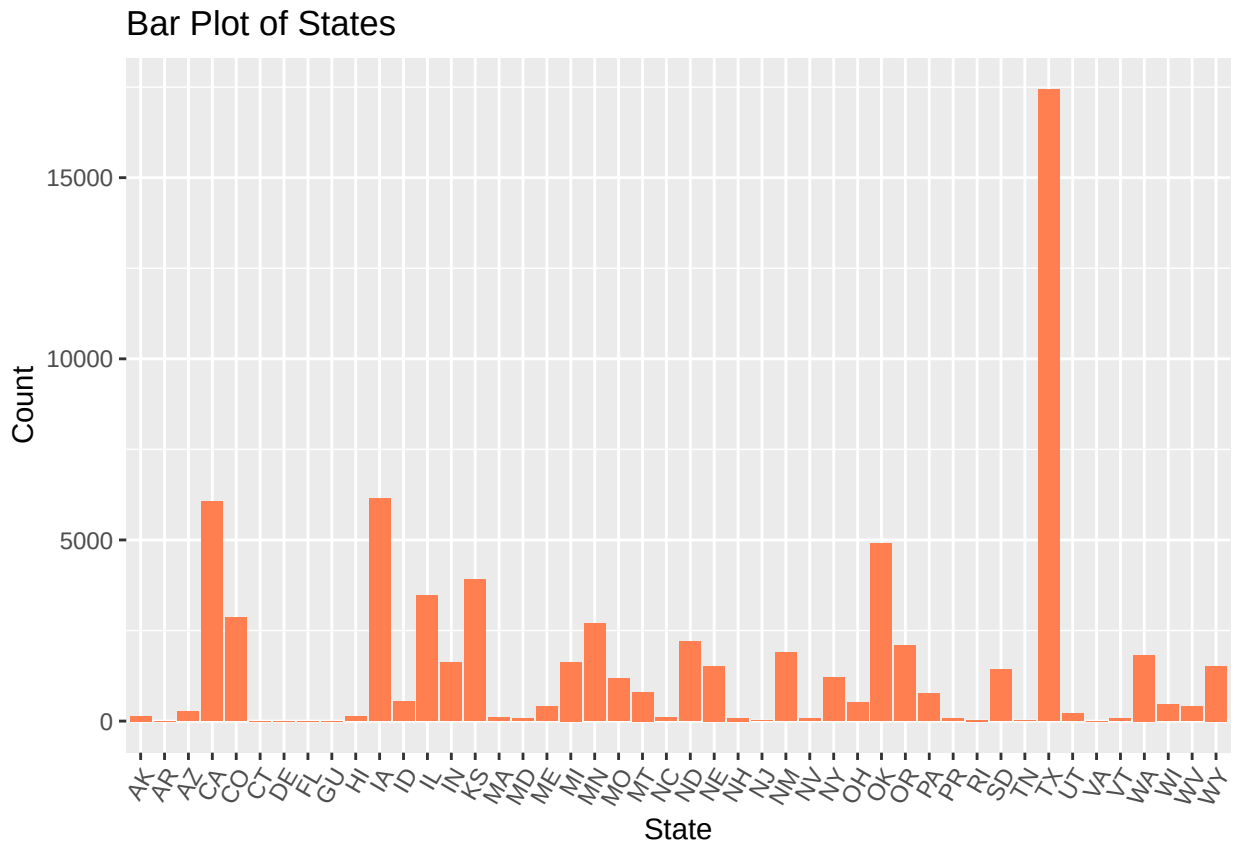



```
# Histogram for 't_hh'
ggplot(data, aes(x = t_hh)) +
  geom_histogram(bins = 30, fill = "green", color = "black") +
  labs(x = "Turbine Hub Height (m)", y = "Frequency", title = "Histogram of Turbine Hub Height")
```

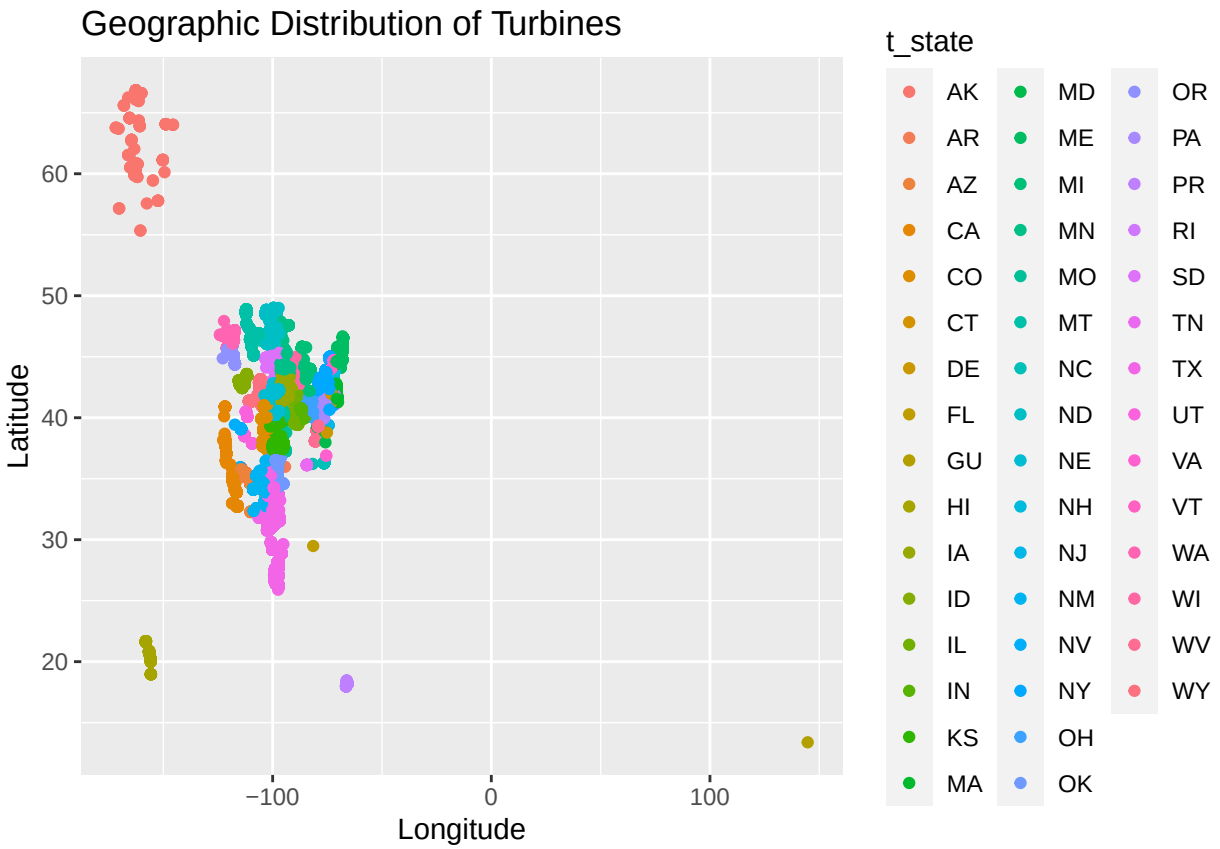
```
## Warning: Removed 6180 rows containing non-finite values (`stat_bin()`).
```




```
# Bar plot for 't_state'
ggplot(data, aes(x = t_state)) +
  geom_bar(stat = "count", fill = "coral") +
  labs(x = "State", y = "Count", title = "Bar Plot of States") +
theme(axis.text.x = element_text(angle = 60, hjust = 1))
```




```r
# Scatter plot for geographic coordinates 'xlong' and 'ylat'
ggplot(data, aes(x = xlong, y = ylat)) +
  geom_point(aes(color = t_state)) +
  labs(x = "Longitude", y = "Latitude", title = "Geographic Distribution of Turbines")
```



Exploring Relationships

Analyze relationships between variables using scatter plots, box plots, etc.

Scatter plot for two continuous variables

ggplot(data, aes(x = continuous_variable_1, y = continuous_variable_2)) + geom_point() + labs(title = “Scatter Plot of Variable 1 vs Variable 2”, x = “Variable 1”, y = “Variable 2”)

Box plot for a continuous and a categorical variable

ggplot(data, aes(x = factor_variable_1, y = continuous_variable_1)) + geom_boxplot() + labs(title = “Box Plot of Continuous Variable 1 by Factor Variable 1”, x = “Factor Variable 1”, y = “Continuous Variable 1”)

Documentation of Findings

Include comments and observations about each visualization to discuss the features of the data that are important for understanding your analysis. Highlight any issues or anomalies found during the exploratory phase and describe how they might impact your further analysis or decision-making process.

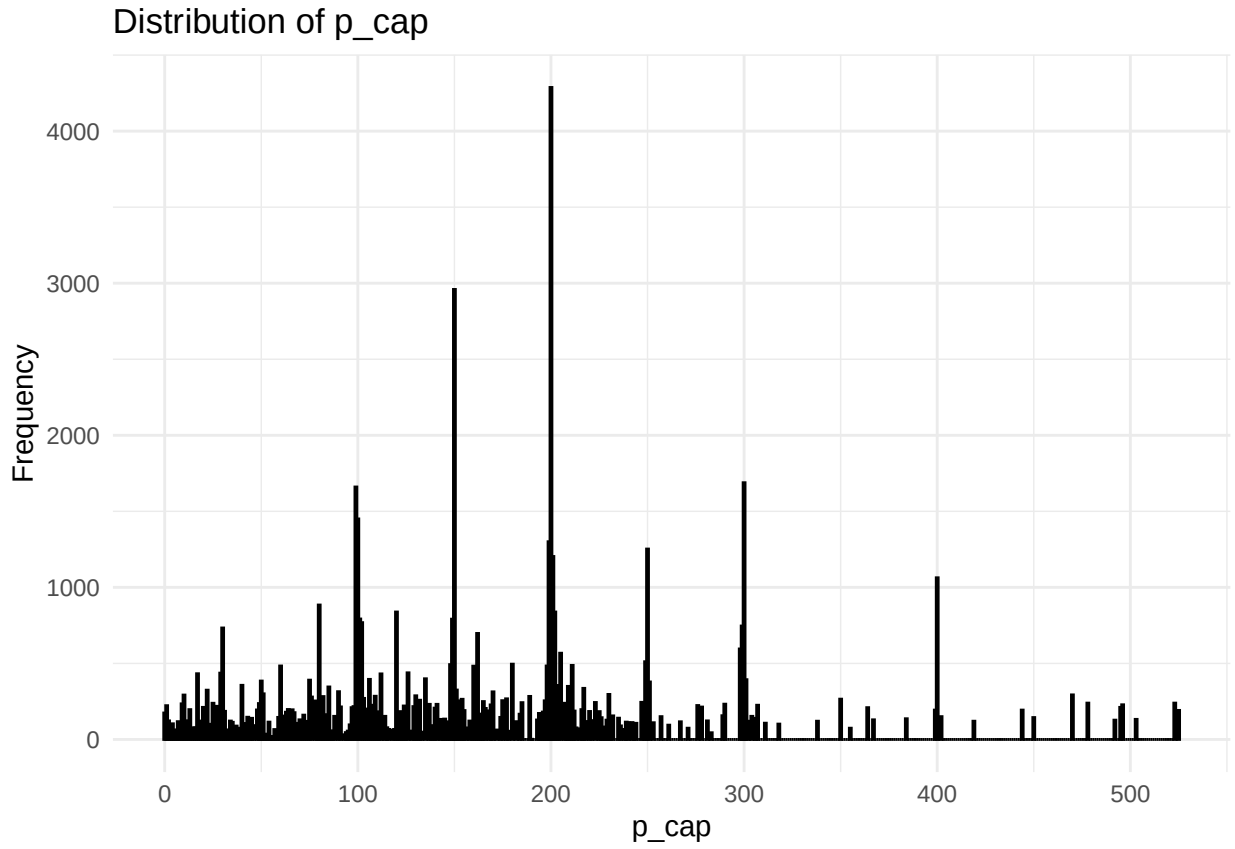
Throughout this process, make sure to label all visualizations clearly with plain English descriptions of the variables on the axes or facet labels to ensure they are understandable and accessible.

```r
```

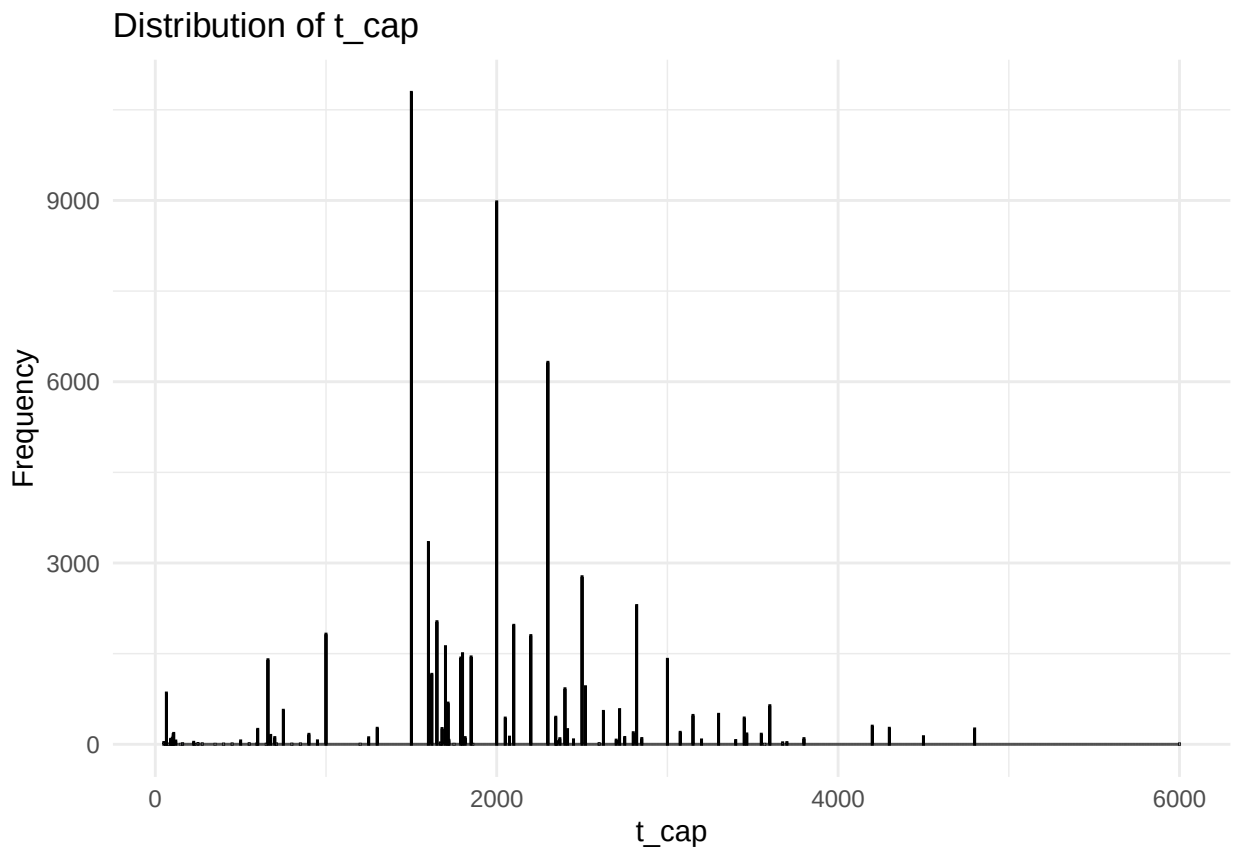
```
# Histograms for continuous variables (e.g., p_cap, t_cap, t_hh, t_rd, t_rsa, t_ttlh)
continuous_vars <- c("p_cap", "t_cap", "t_hh", "t_rd", "t_rsa", "t_ttlh")

for (var in continuous_vars) {
  print(ggplot(data, aes_string(x = var)) +
          geom_histogram(binwidth = 1, fill = "blue", color = "black") +
          labs(x = var, y = "Frequency", title = paste("Distribution of", var)) +
          theme_minimal())
}
```

```
## Warning: `aes_string()` was deprecated in ggplot2 3.0.0.
## i Please use tidy evaluation idioms with `aes()`.
## i See also `vignette("ggplot2-in-packages")` for more information.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.
```

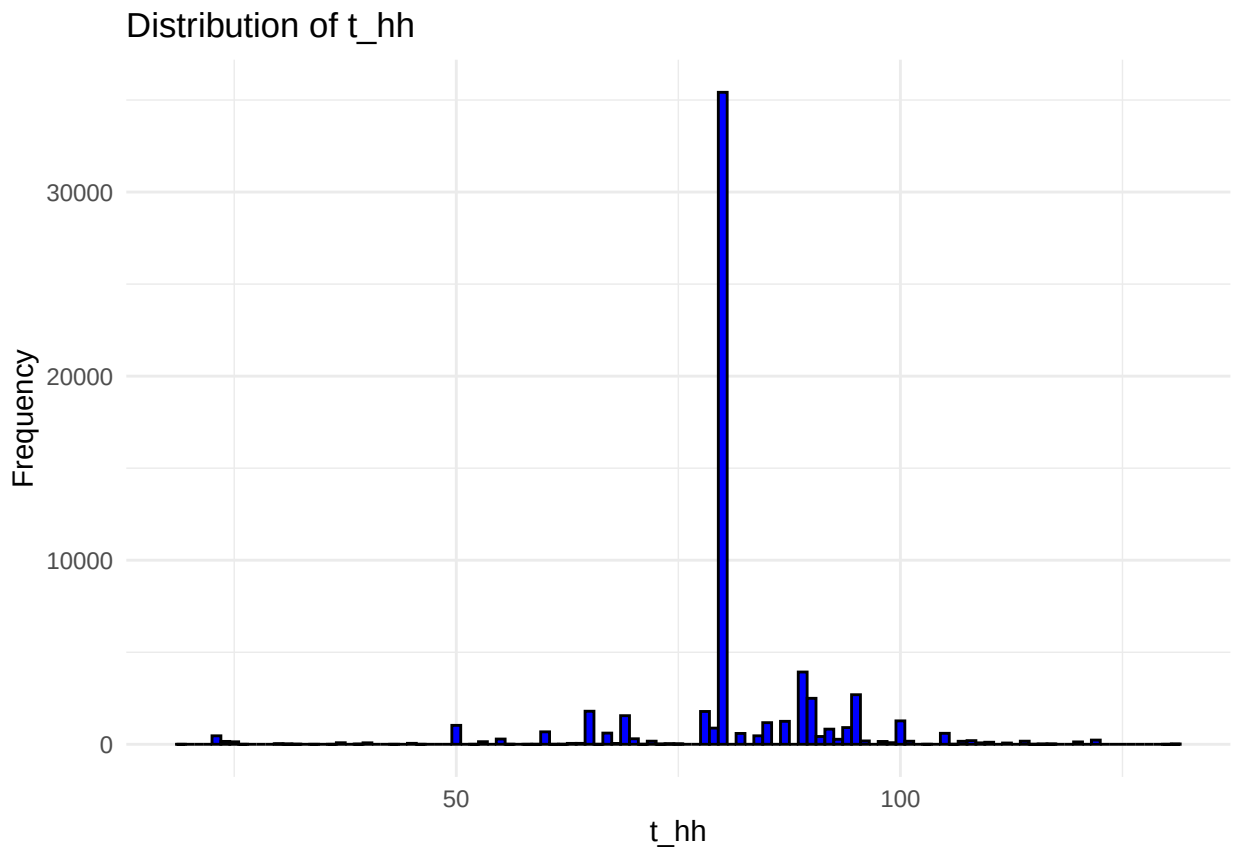
```
## Warning: Removed 4482 rows containing non-finite values (`stat_bin()`).
```



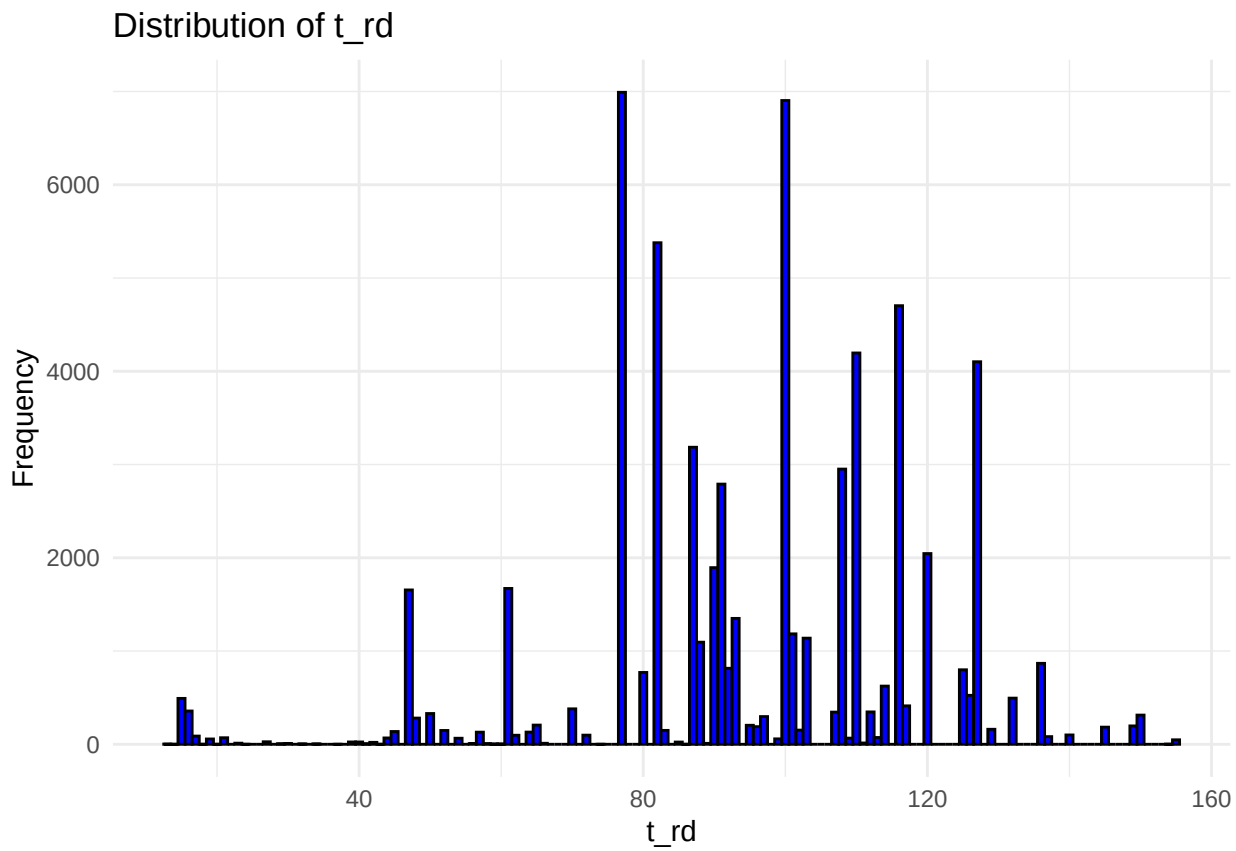

```
## Warning: Removed 5480 rows containing non-finite values (`stat_bin()`).
```



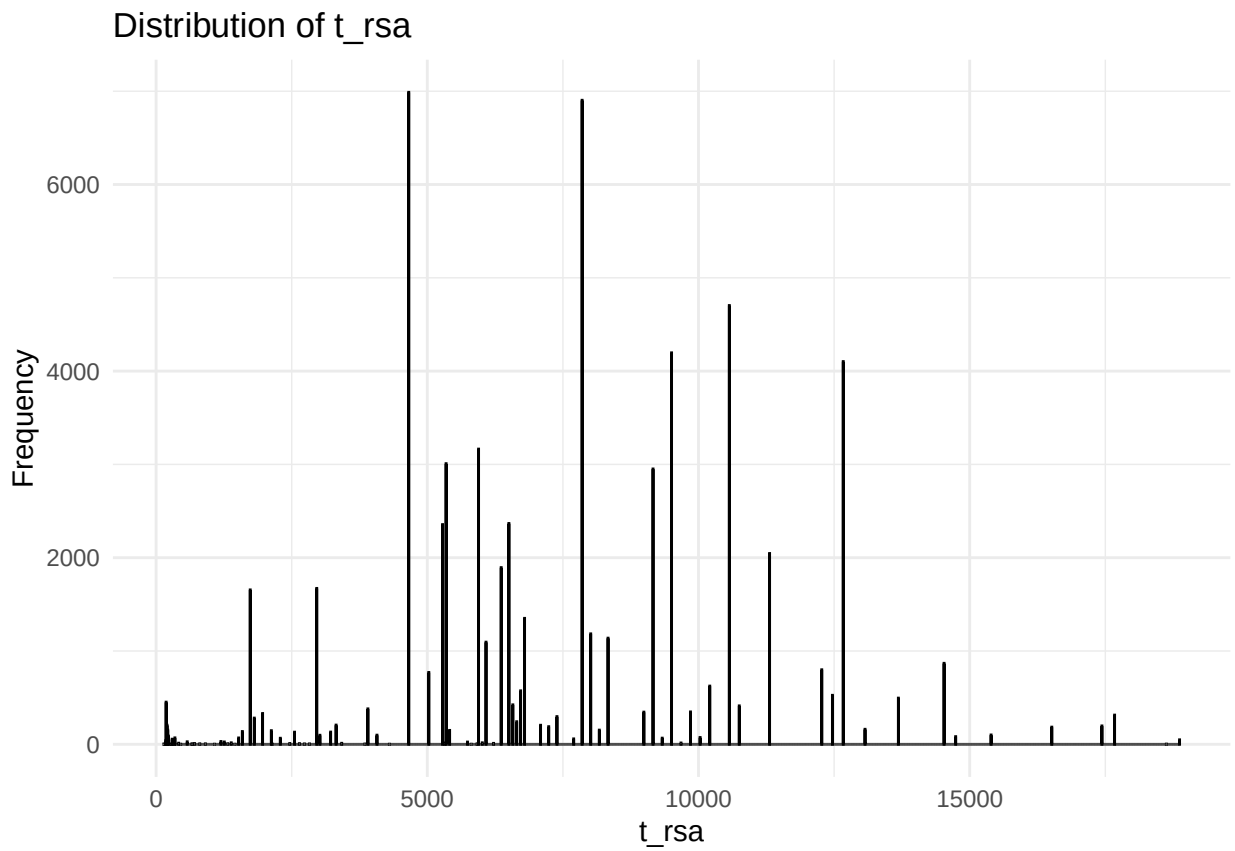

```
## Warning: Removed 6180 rows containing non-finite values (`stat_bin()`).
```



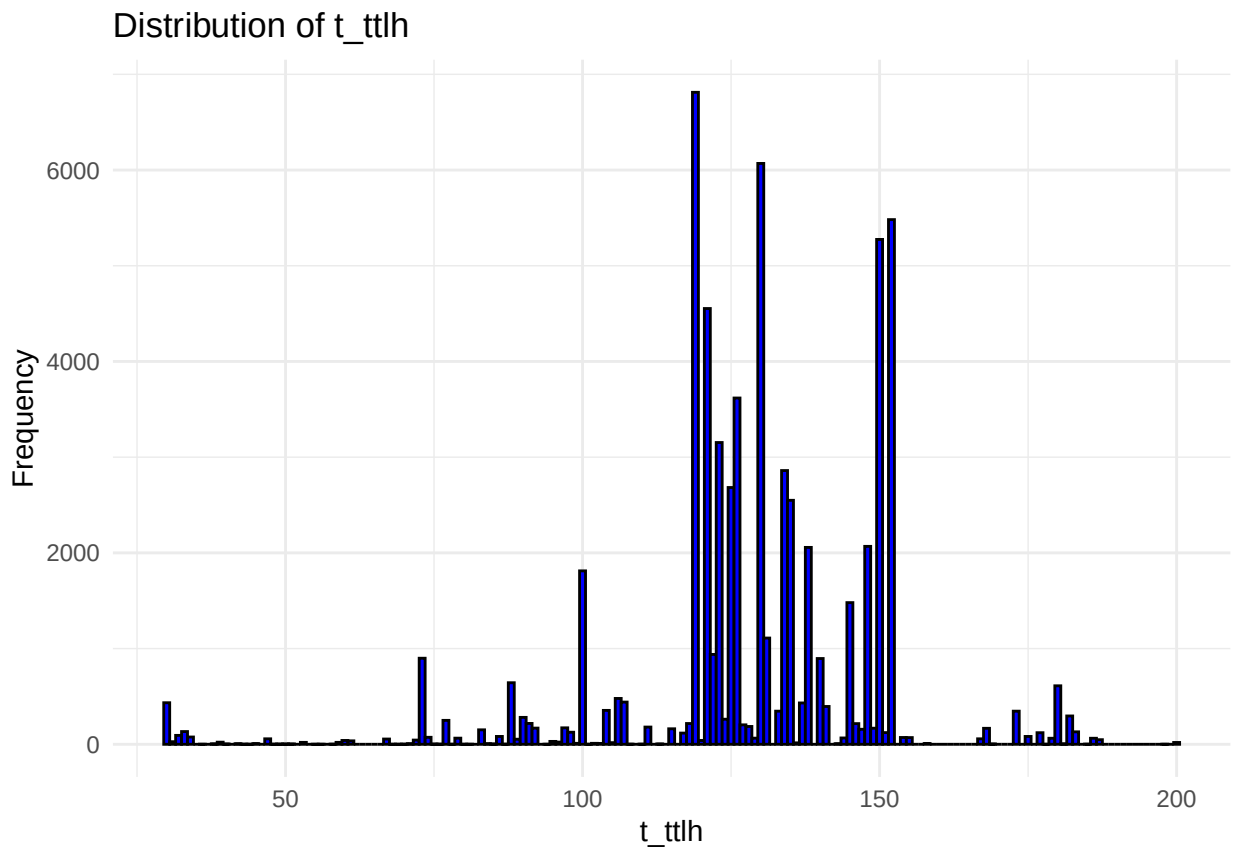

```
## Warning: Removed 5934 rows containing non-finite values (`stat_bin()`).
```



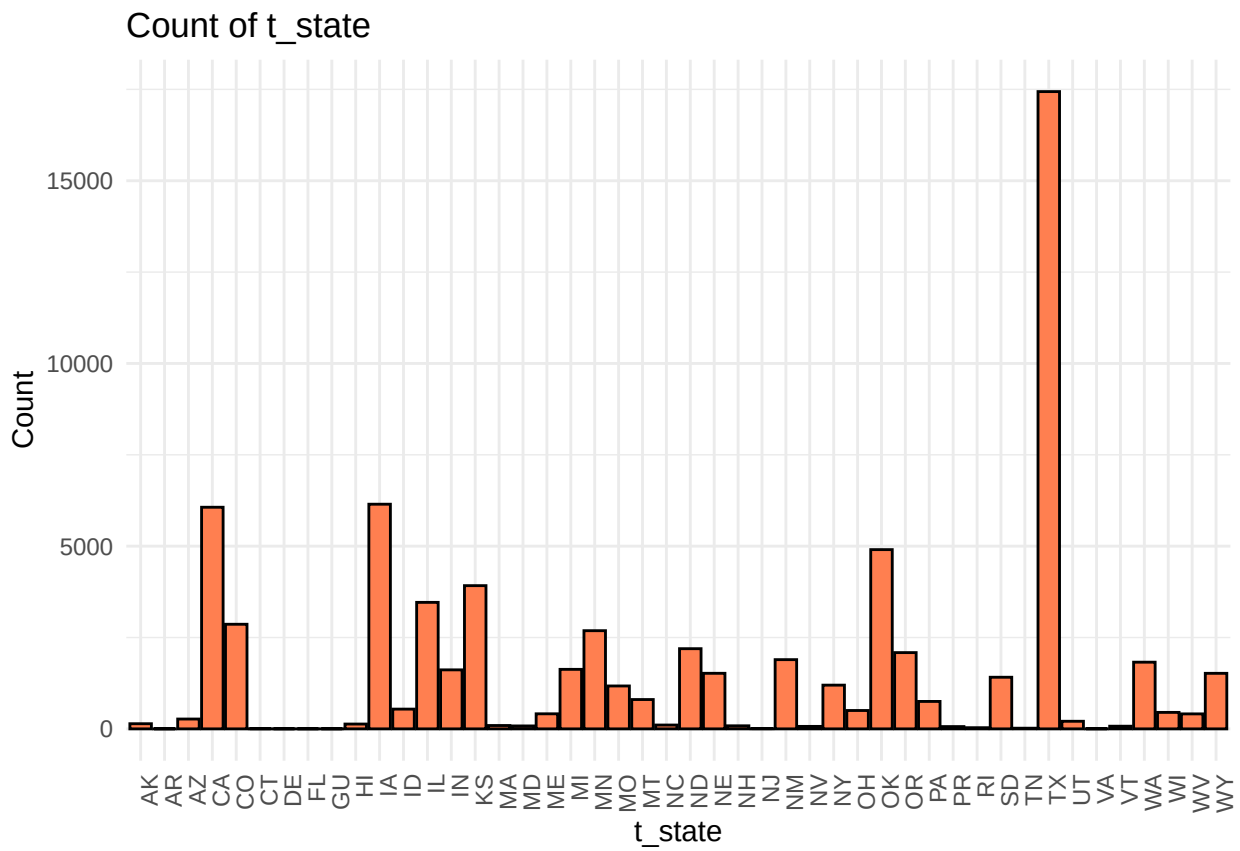

```
## Warning: Removed 5934 rows containing non-finite values (`stat_bin()`).
```



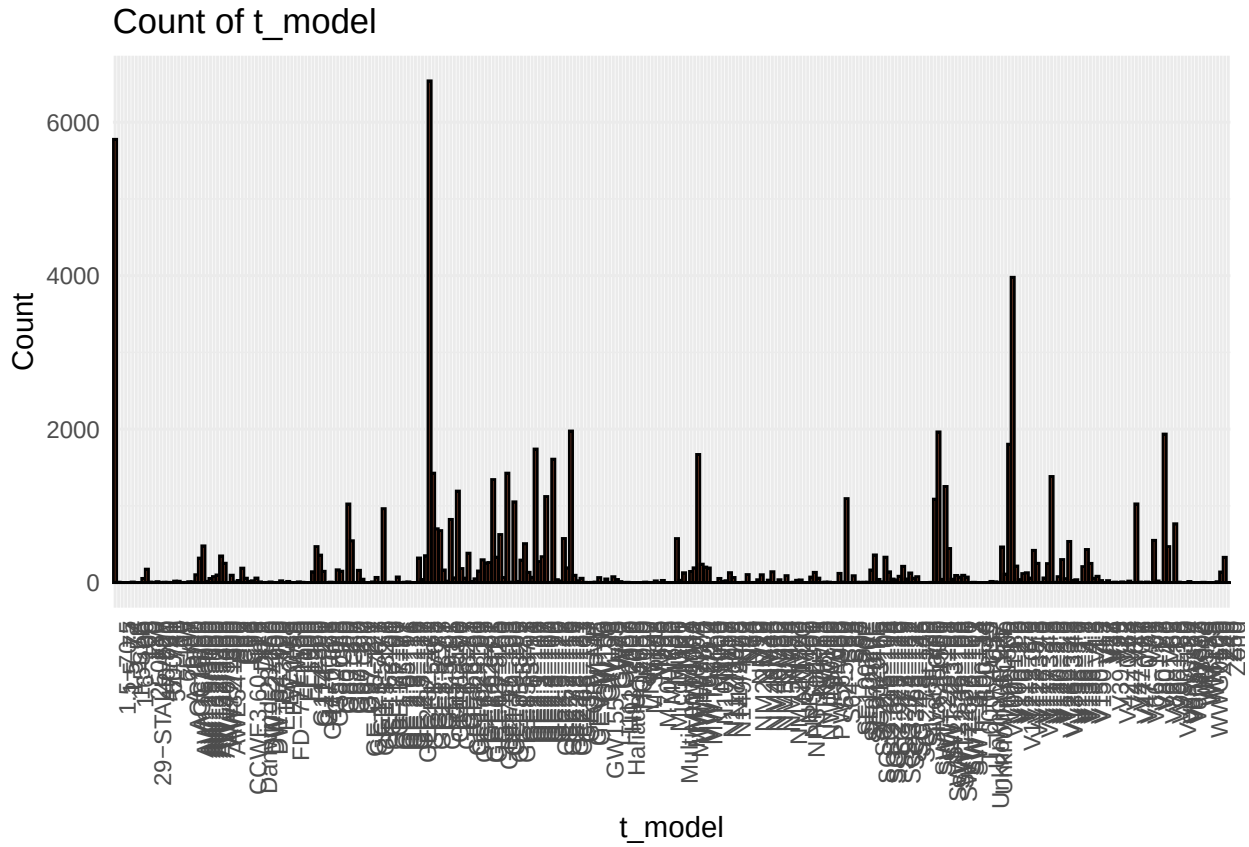

```
## Warning: Removed 6180 rows containing non-finite values (`stat_bin()`).
```

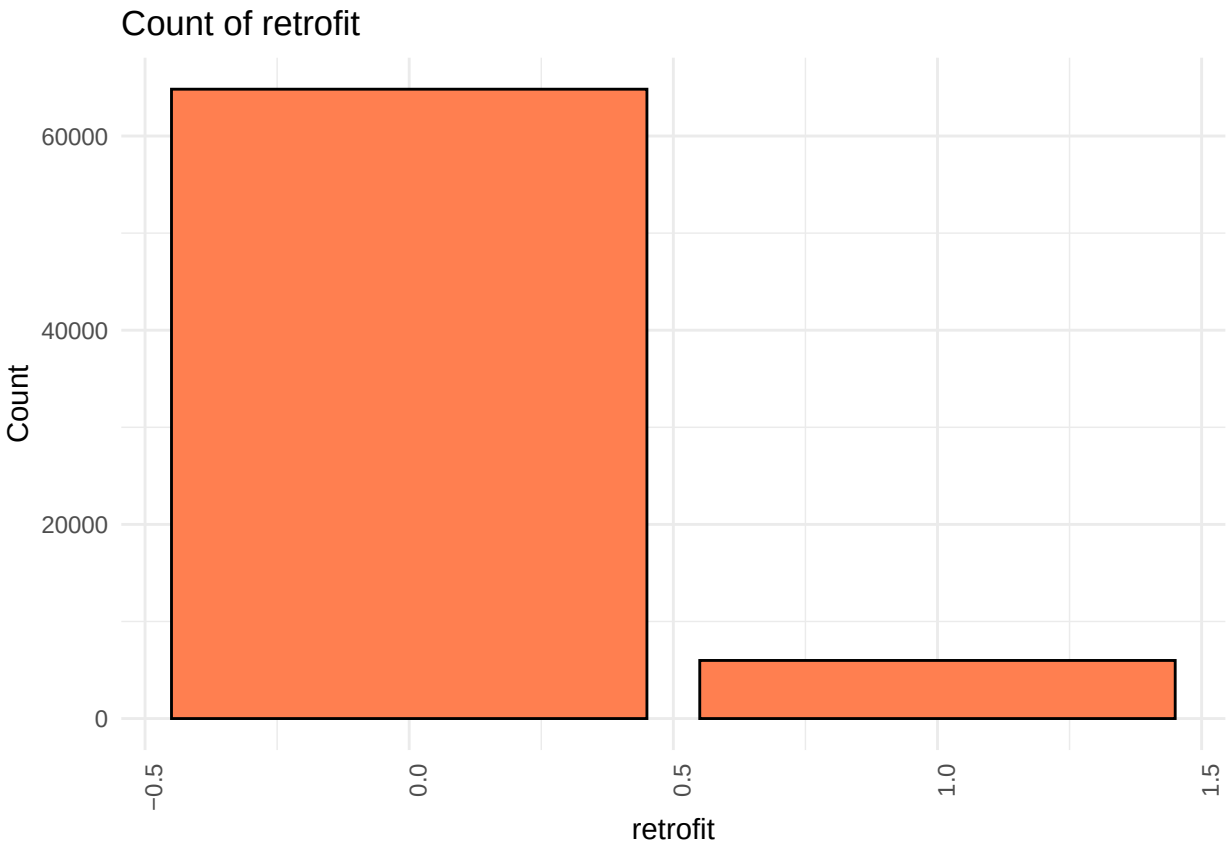


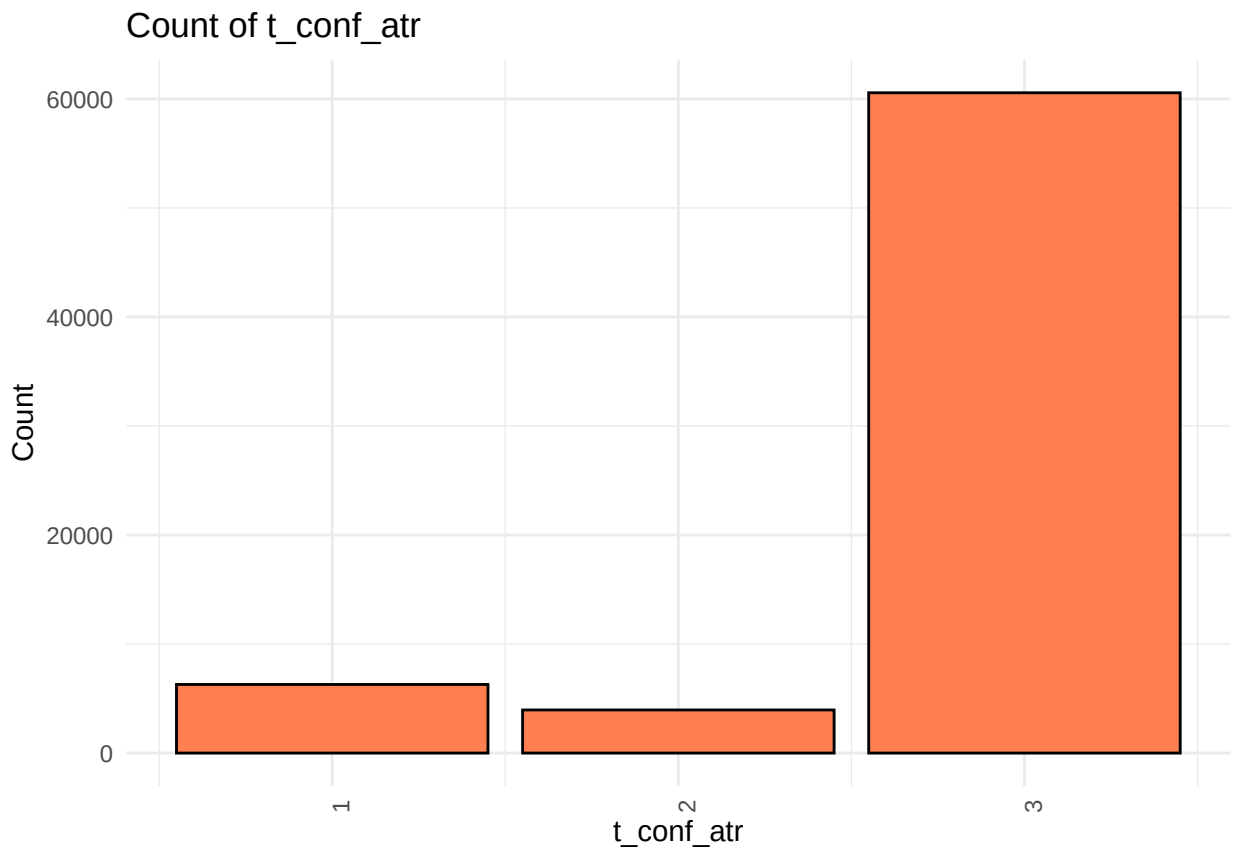

```
# Bar plots for categorical variables (e.g., t_state, t_county, t_manu, t_model, retrofit, t_conf_atr,
categorical_vars <- c("t_state", "t_manu", "t_model", "retrofit", "t_conf_atr", "t_conf_loc")

for (var in categorical_vars) {
  print(ggplot(data, aes_string(x = var)) +
          geom_bar(fill = "coral", color = "black") +
          labs(x = var, y = "Count", title = paste("Count of", var)) +
          theme_minimal() +
          theme(axis.text.x = element_text(angle = 90, hjust = 1)))
}
```

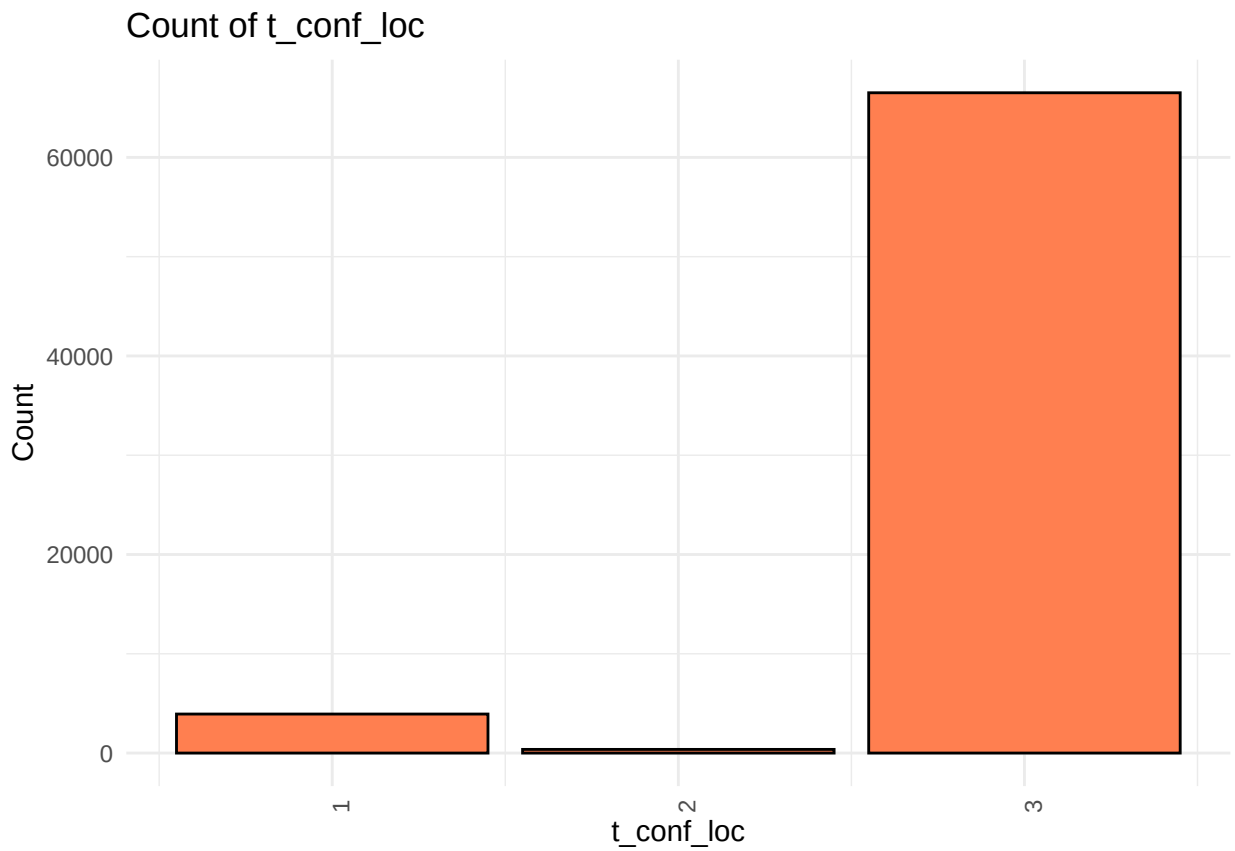

Count of t_state
Count
15000
10000
5000
0
AK
AR
AZ
CA
CO
CT
DE
FL
GU
HI
IA
ID
IL
IN
KS
MA
MD
ME
MI
MN
MO
MT
NC
ND
NE
NH
NJ
NM
NV
NY
OH
OK
OR
PA
PR
RI
SD
TN
TX
UT
VA
VT
WA
WI
WV
WY
t_state

Cou
20000
AAER
Acciona
Aeronautica
Alstom
AOC
AWE
Bergey Energy
Bonus
Bora
Changzhou Railcar Propulsion Engineering Research and Development Center
China Creative Wind Energy
Clipper
DeWind
DWT
Elecon
Endurance
Enron
Entegrity
EWT
Fuhrlander
Gamesa
GE Wind
Goldwind
Goldwind Americas
Guodian
Hyundai
HZ Windpower
Kenersys
Leitner Poma
Loiland
Micon
Mitsubishi
NedWind
NEG Micon
Nordex
Nordtank
Northern Power Systems
Norwin
PowerWind
Renewtech LLC
REpower
RRB
Samsung
Sany
Seaforth
Siemens
Siemens Gamesa Renewable Energy
Silver Eagle
Singovel
Siva
Suzlon
Turbowinds
Unison
Vensys
Vergnet
Vestas
Westinghouse
Wincon
Wind Energy Solutions
Wind World
Windmatic
Zond

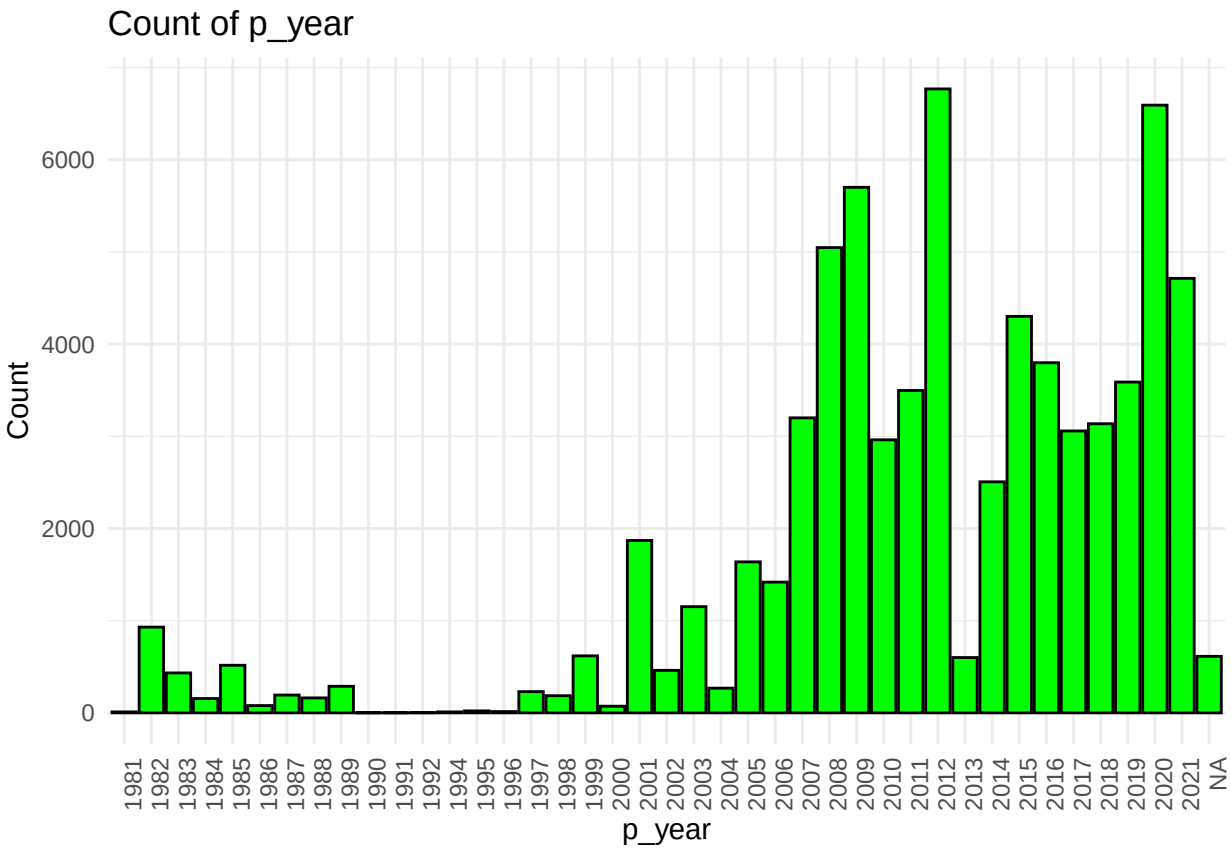

Count of t_model
Count
6000
4000
2000
0
t_model

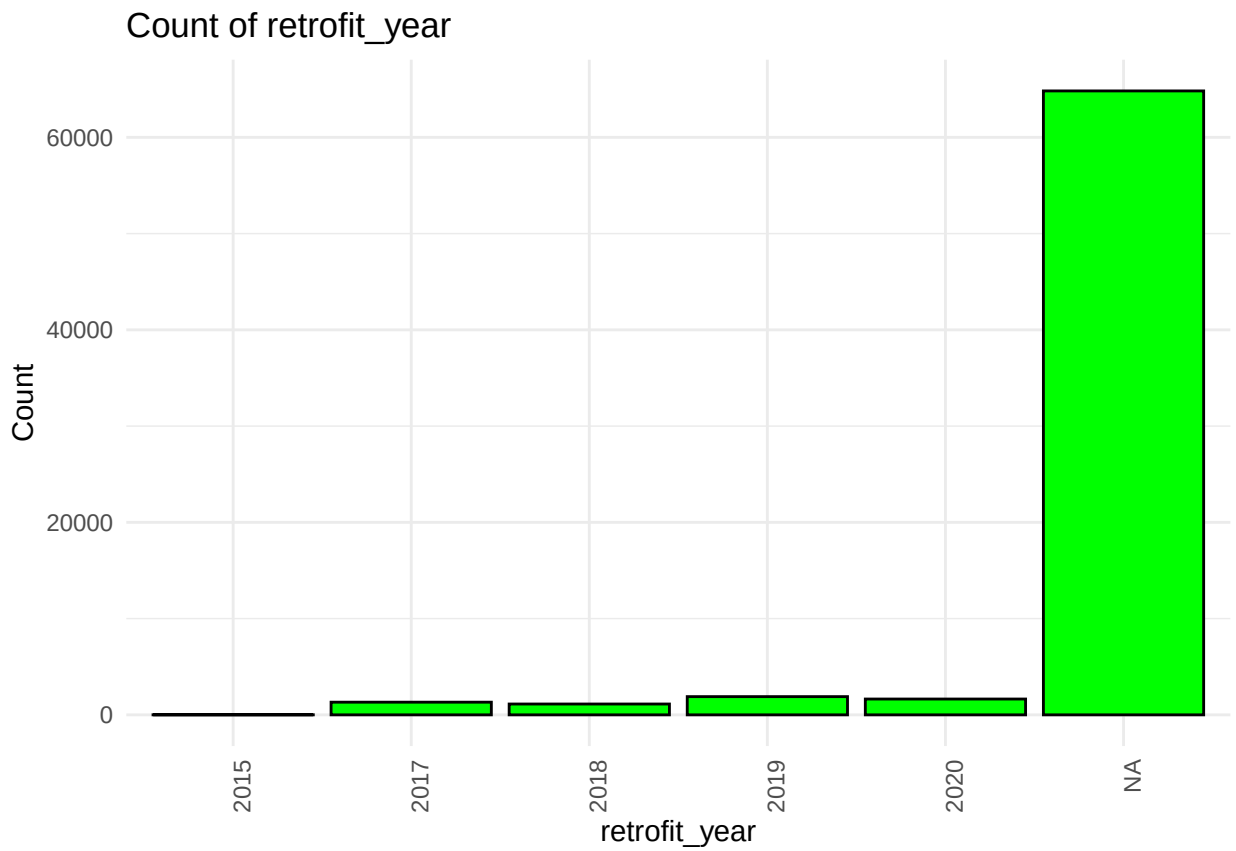

Count of retrofit
60000
40000
20000
0
Count
−0.5
0.0
0.5
1.0
1.5
retrofit


Count of t_conf_atr
60000
40000
20000
0
Count
1
2
3
t_conf_atr



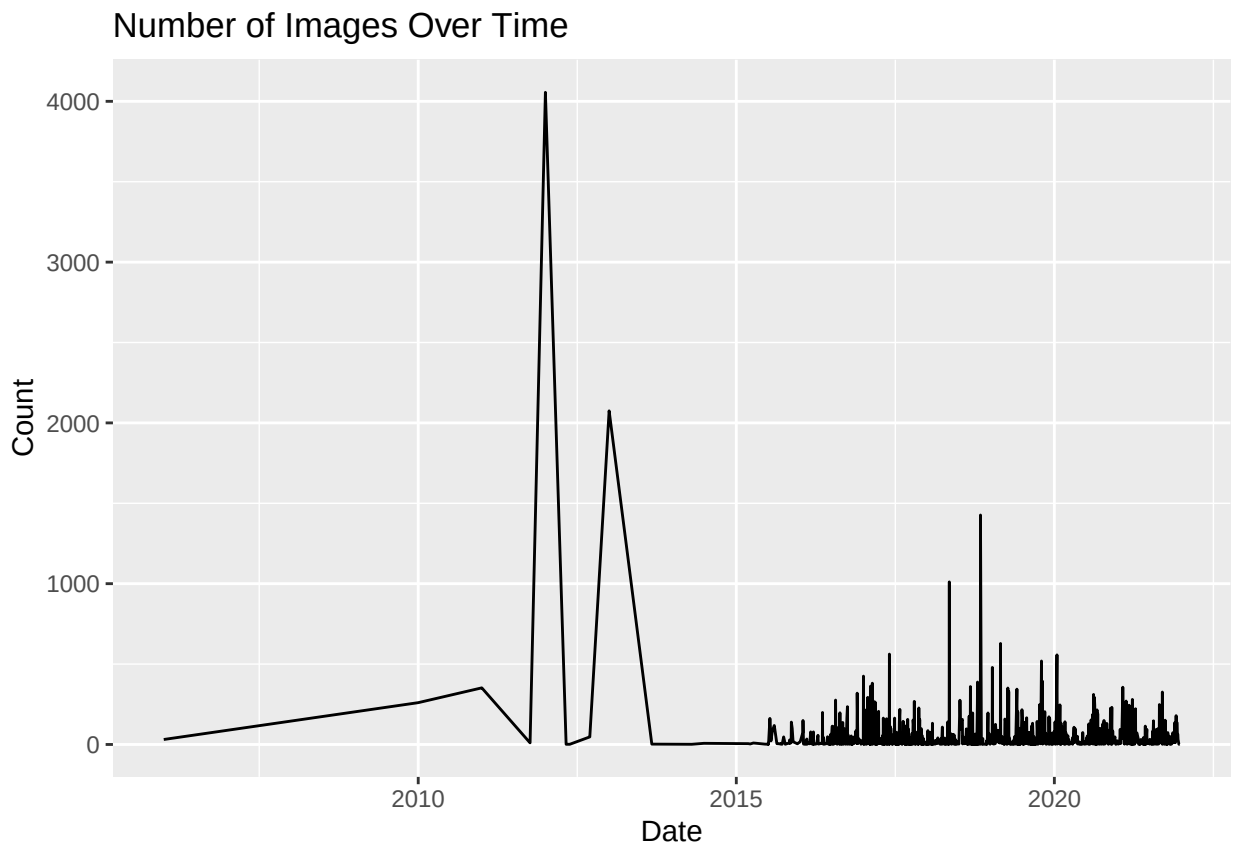

```r
# Bar plot for year variables (e.g., p_year, retrofit_year)
year_vars <- c("p_year", "retrofit_year")

for (var in year_vars) {
  data[[var]] <- as.factor(data[[var]])

  print(ggplot(data, aes_string(x = var)) +
          geom_bar(fill = "green", color = "black") +
          labs(x = var, y = "Count", title = paste("Count of", var)) +
          theme_minimal() +
          theme(axis.text.x = element_text(angle = 90, hjust = 1)))
}
```


Count of p_year
Count
6000
4000
2000
0
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
NA
p_year




```
# Convert date to Date format
data$t_img_date <- as.Date(data$t_img_date, format = "%m/%d/%Y")

# Line chart for date variable 't_img_date'
ggplot(data, aes(x = t_img_date)) +
  geom_line(stat = "count", aes(group = 1)) +
  labs(x = "Date", y = "Count", title = "Number of Images Over Time")
```

```
## Warning: Removed 8316 rows containing non-finite values (`stat_count()`).
```




```
register_stadiamaps("f94c64ea-35d9-425f-af7a-e139e3bd6242", write = TRUE)
```

```
## i Creating file C:\Users\Gordon Bradley\Documents/.Renviron
```

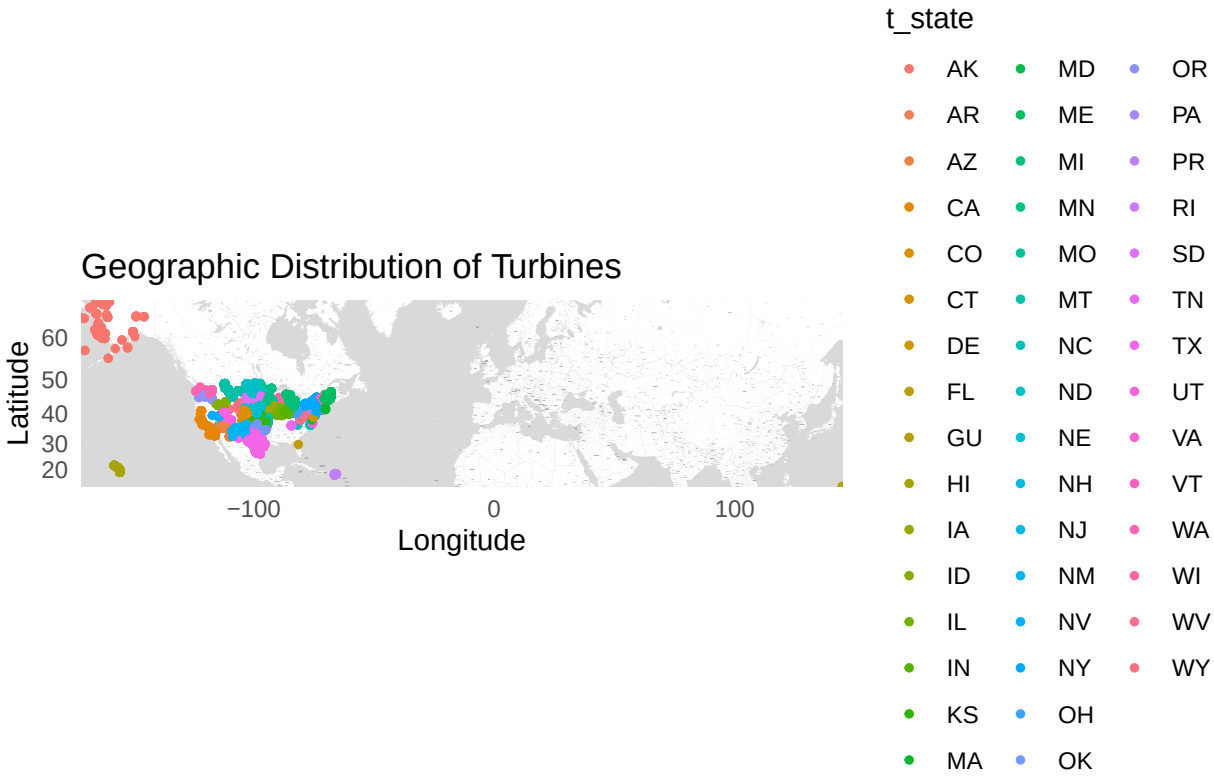
```
## i Adding key to C:\Users\Gordon Bradley\Documents/.Renviron
```

```
base_map <- get_stadiamap(bbox = c(left = min(data$xlong), bottom = min(data$ylat),
                                   right = max(data$xlong), top = max(data$ylat)),
                          zoom = 6, maptype = "stamen_toner_lite")
```

```
## i © Stadia Maps © Stamen Design © OpenMapTiles © OpenStreetMap contributors.
```

```
## i 855 tiles needed, this may take a while (try a smaller zoom?)
```

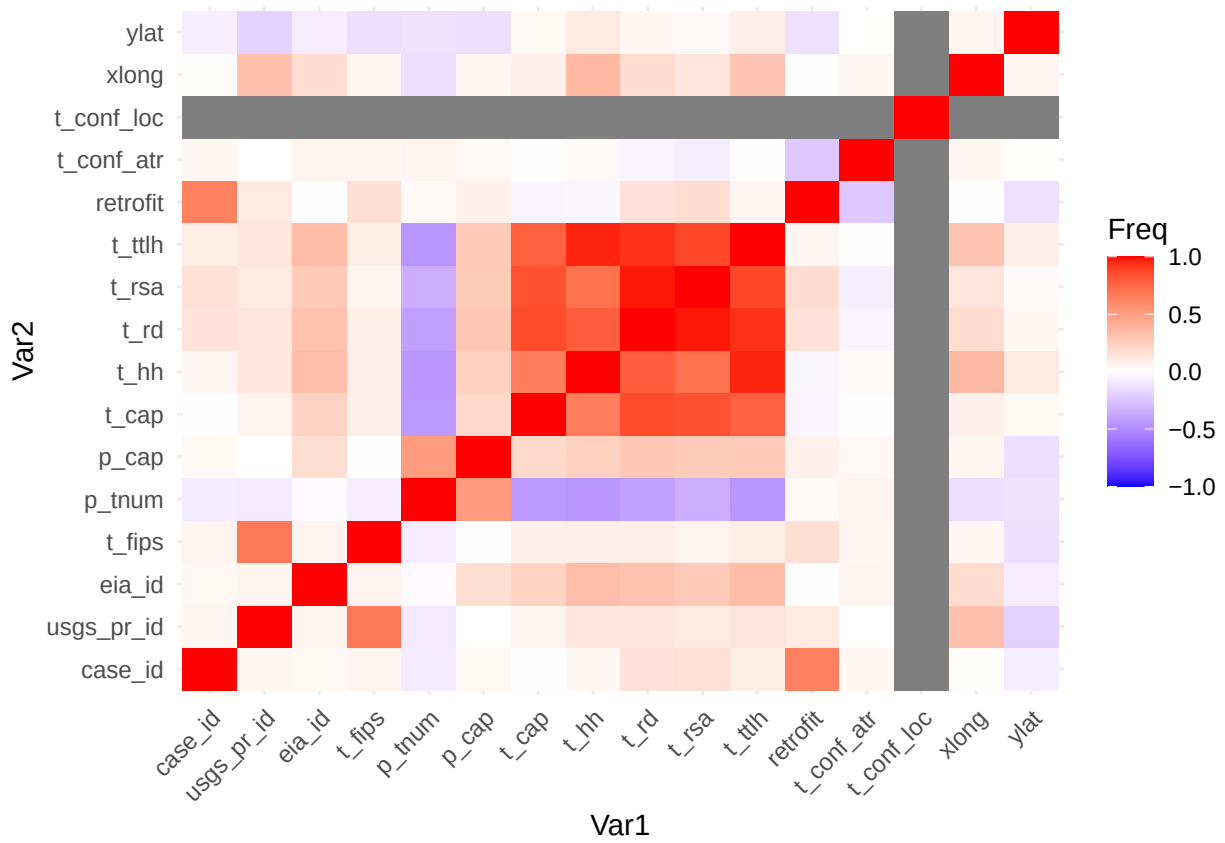
```
# Now plot the map with points
ggmap(base_map) +
  geom_point(data = data, aes(x = xlong, y = ylat, color = t_state), size = 1) +
  labs(x = "Longitude", y = "Latitude", title = "Geographic Distribution of Turbines") +
  theme_minimal()
```




```
# Correlation plot if there are multiple numeric variables
numeric_data <- data %>% select_if(is.numeric)
correlation_matrix <- cor(numeric_data, use = "complete.obs")
```

```
## Warning in cor(numeric_data, use = "complete.obs"): the standard deviation is
## zero
```

```
print(ggplot(data = as.data.frame(as.table(correlation_matrix)),
       aes(x = Var1, y = Var2, fill = Freq)) +
  geom_tile() +
  scale_fill_gradient2(low = "blue", high = "red", mid = "white", midpoint = 0, limit = c(-1,1)) +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1)))
```




```
# Add comments for each visualization in R Markdown

# End of EDA section with session information
sessionInfo()
```

```
## R version 4.3.2 (2023-10-31 ucrt)
## Platform: x86_64-w64-mingw32/x64 (64-bit)
## Running under: Windows 10 x64 (build 19045)
##
## Matrix products: default
##
##
## locale:
## [1] LC_COLLATE=English_United States.utf8
## [2] LC_CTYPE=English_United States.utf8
## [3] LC_MONETARY=English_United States.utf8
## [4] LC_NUMERIC=C
## [5] LC_TIME=English_United States.utf8
##
## time zone: America/New_York
## tzcode source: internal
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] ggmap_4.0.0     lubridate_1.9.3 forcats_1.0.0   stringr_1.5.1
```

```
##  [5] dplyr_1.1.4     purrr_1.0.2     readr_2.1.5     tidyr_1.3.1
##  [9] tibble_3.2.1    ggplot2_3.4.4   tidyverse_2.0.0
##
## loaded via a namespace (and not attached):
##  [1] utf8_1.2.4        generics_0.1.3    bitops_1.0-7      jpeg_0.1-10
##  [5] stringi_1.8.3     hms_1.1.3         digest_0.6.34     magrittr_2.0.3
##  [9] evaluate_0.23     grid_4.3.2        timechange_0.3.0  fastmap_1.1.1
## [13] maps_3.4.2        plyr_1.8.9        httr_1.4.7        fansi_1.0.6
## [17] scales_1.3.0      cli_3.6.2         rlang_1.1.3       munsell_0.5.0
## [21] withr_3.0.0       yaml_2.3.8        tools_4.3.2       tzdb_0.4.0
## [25] colorspace_2.1-0  curl_5.2.1        vctrs_0.6.5       R6_2.5.1
## [29] png_0.1-8         lifecycle_1.0.4   pkgconfig_2.0.3   pillar_1.9.0
## [33] gtable_0.3.4      glue_1.7.0        Rcpp_1.0.12       highr_0.10
## [37] xfun_0.41         tidyselect_1.2.0  rstudioapi_0.15.0 knitr_1.45
## [41] farver_2.1.1      htmltools_0.5.7   rmarkdown_2.25    labeling_0.4.3
## [45] compiler_4.3.2
```