IST 687_Group Project_R.Parker_Q

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```
##############################################################################
#' Research Question

#'"How do residential cooling systems impact energy usage during peak summer
#'conditions, and what strategies can be implemented to optimize cooling
#'efficiency and reduce overall electricity demand?"

##############################################################################
```

```
##############################################################################
# MetaData
##############################################################################

library(data.table)

metadata_url <- "https://intro-datascience.s3.us-east-2.amazonaws.com/SC-data/data_dictionary.csv"

metadata <- fread(metadata_url)

##############################################################################
# Energy and Weather Data Analysis Script
##############################################################################

# Load required packages
library(tidyverse)  # For data manipulation and visualization
```

```
## -- 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   3.5.1     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::between()     masks data.table::between()
## x dplyr::filter()      masks stats::filter()
## x dplyr::first()       masks data.table::first()
## x lubridate::hour()    masks data.table::hour()
## x lubridate::isoweek() masks data.table::isoweek()
## x dplyr::lag()         masks stats::lag()
## x dplyr::last()        masks data.table::last()
## x lubridate::mday()    masks data.table::mday()
```

```
## x lubridate::minute()  masks data.table::minute()
## x lubridate::month()   masks data.table::month()
## x lubridate::quarter() masks data.table::quarter()
## x lubridate::second()  masks data.table::second()
## x purrr::transpose()   masks data.table::transpose()
## x lubridate::wday()    masks data.table::wday()
## x lubridate::week()    masks data.table::week()
## x lubridate::yday()    masks data.table::yday()
## x lubridate::year()    masks data.table::year()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```r
library(lubridate)  # For date/time handling
library(data.table) # For handling large data

################################################################################
# MAIN EXECUTION FUNCTION
################################################################################

#' Main Function to Combine Housing, Weather, and Energy Data
#' Note: data transformations from original state were saved in a seperate .rmd file
#' @param housing_file Path to the housing data CSV file
#' @param weather_file Path to the July daily weather data CSV file
#' @param energy_file Path to the July daily energy usage data CSV file
#' @return Combined data frame with energy, weather, and housing information

main <- function(housing_file, weather_file, energy_file) {

  message("\n1. Reading housing data...")
  # Load housing data
  housing_data <- read_csv(housing_file, show_col_types = FALSE)

  message("\n2. Reading weather data...")
  # Load weather data
  weather_data <- read_csv(weather_file, show_col_types = FALSE) %>%
    rename(date = date)  # Ensure consistent column naming for joining

  message("\n3. Reading energy usage data...")
  # Load energy usage data
  energy_data <- read_csv(energy_file, show_col_types = FALSE) %>%
    rename(date = date)  # Ensure consistent column naming for joining

  message("\n4. Adding `in.county` to energy data...")
  # Add `in.county` to energy data by joining with housing data on `bldg_id`
  energy_data <- energy_data %>%
    inner_join(housing_data %>% select(bldg_id, in.county), by = "bldg_id")

  message("\n5. Combining energy and weather data...")
  # Combine energy data and weather data on `date` and `in.county`
  combined_data <- energy_data %>%
    left_join(weather_data, by = c("date", "in.county")) %>%  # Join on date and county
    left_join(housing_data, by = "bldg_id")                   # Join on building ID

  message("\nData combination complete!")
  return(combined_data)
```

```
}

################################################################################
# FINAL FILE COMBINATION -  Housing, Weather, and Energy Data (DAILY ONLY)
################################################################################

housing_file <- "~/Downloads/filtered_housing_data.csv"
weather_file <- "~/Downloads/july_daily_weather_data.csv"
energy_file <- "~/Downloads/july_daily_energy_usage_final.csv"
output_file <- "~/Downloads/final_combined_data.csv"

# Load data
message("Loading datasets...")
```

```
## Loading datasets...
```

```
housing_data <- fread(housing_file)
str(housing_data)
```

```
## Classes 'data.table' and 'data.frame':   5710 obs. of  22 variables:
##  $ bldg_id                                    : int  65 121 500 504 581 590 670 736 862 952 ...
##  $ in.sqft                                    : int  885 1220 1220 1690 1690 2176 885 2663 885 2663 .
##  $ in.bedrooms                                : int  3 2 3 3 3 2 2 4 2 3 ...
##  $ in.county                                  : chr  "G4500910" "G4500730" "G4500710" "G4500790" ...
##  $ in.geometry_wall_type                      : chr  "Wood Frame" "Wood Frame" "Wood Frame" "Wood Fra
##  $ in.has_pv                                  : chr  "No" "Yes" "No" "No" ...
##  $ in.income                                  : chr  "10000-14999" "15000-19999" "20000-24999" "80000
##  $ in.occupants                               : chr  "3" "1" "2" "2" ...
##  $ in.roof_material                           : chr  "Composition Shingles" "Composition Shingles" "C
##  $ in.tenure                                  : chr  "Renter" "Owner" "Owner" "Owner" ...
##  $ in.usage_level                             : chr  "Medium" "Medium" "Low" "Low" ...
##  $ in.vacancy_status                          : chr  "Occupied" "Occupied" "Occupied" "Occupied" ...
##  $ in.vintage                                 : chr  "1950s" "1950s" "2000s" "<1940" ...
##  $ in.weather_file_city                       : chr  "Rock Hill York Co" "Oconee Co Rgnl" "Columbia M
##  $ in.hvac_cooling_efficiency                 : chr  "AC, SEER 15" "AC, SEER 13" "AC, SEER 13" "None"
##  $ in.hvac_cooling_partial_space_conditioning: chr  "100% Conditioned" "100% Conditioned" "100% Condi
##  $ in.hvac_cooling_type                       : chr  "Central AC" "Central AC" "Central AC" "None" ..
##  $ upgrade.hvac_cooling_efficiency            : chr  "Heat Pump" "Heat Pump" "Heat Pump" "Heat Pump"
##  $ in.cooling_setpoint                        : chr  "72F" "76F" "70F" "70F" ...
##  $ in.cooling_setpoint_has_offset             : chr  "No" "No" "No" "Yes" ...
##  $ in.cooling_setpoint_offset_magnitude       : chr  "0F" "0F" "0F" "2F" ...
##  $ in.cooling_setpoint_offset_period          : chr  "None" "None" "None" "Night Setup +3h" ...
##  - attr(*, ".internal.selfref")=<externalptr>
```

```
weather_data <- fread(weather_file)
str(weather_data)
```

```
## Classes 'data.table' and 'data.frame':   1426 obs. of  9 variables:
##  $ in.county                          : chr  "G4500010" "G4500010" "G4500010" "G4500010" ...
##  $ date                               : IDate, format: "2018-07-01" "2018-07-02" ...
##  $ Dry Bulb Temperature [°C]          : num  25.7 25.8 26.5 26.6 26.8 ...
##  $ Relative Humidity [%]              : num  85.1 86.4 83.6 79.5 77.8 ...
```

```
##  $ Wind Speed [m/s]                    : num  1.117 0.836 1.418 1.883 1.274 ...
##  $ Wind Direction [Deg]                : num  87.6 94.7 108.7 60.7 59.6 ...
##  $ Global Horizontal Radiation [W/m2] : num  282 249 295 290 315 ...
##  $ Direct Normal Radiation [W/m2]     : num  257 165 276 273 301 ...
##  $ Diffuse Horizontal Radiation [W/m2]: num  90.6 102 91.6 103 109.3 ...
##  - attr(*, ".internal.selfref")=<externalptr>
```

```
energy_data <- fread(energy_file)
str(energy_data)
```

```
## Classes 'data.table' and 'data.frame':   177010 obs. of  47 variables:
##  $ bldg_id                                              : int  65 65 65 65 65 65 65 65 65 65 ...
##  $ date                                                 : IDate, format: "2018-07-01" "2018-07-02" .
##  $ out.electricity.ceiling_fan.energy_consumption       : num  0.14 0.143 0.146 0.148 0.152 0.139 0.1
##  $ out.electricity.clothes_dryer.energy_consumption     : num  0.178 2.457 2.422 1.425 0 ...
##  $ out.electricity.clothes_washer.energy_consumption    : num  0 0.184 0.18 0.305 0 0 0.184 0.121 0 0
##  $ out.electricity.cooling_fans_pumps.energy_consumption: num  0.607 0.728 0.927 0.778 0.739 0.609 0
##  $ out.electricity.cooling.energy_consumption           : num  9.79 11.24 13.58 12.06 11.51 ...
##  $ out.electricity.dishwasher.energy_consumption        : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.freezer.energy_consumption           : num  0.932 0.932 0.932 0.932 0.932 0.932 0
##  $ out.electricity.heating_fans_pumps.energy_consumption: num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.heating_hp_bkup.energy_consumption   : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.heating.energy_consumption           : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.hot_tub_heater.energy_consumption    : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.hot_tub_pump.energy_consumption      : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.hot_water.energy_consumption         : num  1.71 1.15 2.22 1.29 1.25 ...
##  $ out.electricity.lighting_exterior.energy_consumption : num  0.304 0.304 0.304 0.304 0.304 0.304 0
##  $ out.electricity.lighting_garage.energy_consumption   : num  0.208 0.208 0.208 0.208 0.208 0.208 0
##  $ out.electricity.lighting_interior.energy_consumption : num  2.09 2.77 2.76 2.91 2.47 ...
##  $ out.electricity.mech_vent.energy_consumption         : num  0.064 0.064 0.064 0.064 0.064 0.064 0
##  $ out.electricity.plug_loads.energy_consumption        : num  5.57 5.85 5.84 5.82 5.68 ...
##  $ out.electricity.pool_heater.energy_consumption       : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.pool_pump.energy_consumption         : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.pv.energy_consumption                : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.range_oven.energy_consumption        : num  1.334 0.799 1.866 0.266 2.934 ...
##  $ out.electricity.refrigerator.energy_consumption      : num  5.12 5.12 5.12 5.12 5.12 ...
##  $ out.electricity.well_pump.energy_consumption         : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.fuel_oil.heating_hp_bkup.energy_consumption      : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.fuel_oil.heating.energy_consumption              : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.fuel_oil.hot_water.energy_consumption            : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.clothes_dryer.energy_consumption     : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.fireplace.energy_consumption         : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.grill.energy_consumption             : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.heating_hp_bkup.energy_consumption   : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.heating.energy_consumption           : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.hot_tub_heater.energy_consumption    : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.hot_water.energy_consumption         : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.lighting.energy_consumption          : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.pool_heater.energy_consumption       : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.range_oven.energy_consumption        : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.clothes_dryer.energy_consumption         : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.heating_hp_bkup.energy_consumption       : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.heating.energy_consumption               : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.hot_water.energy_consumption             : int  0 0 0 0 0 0 0 0 0 0 ...
```

```
##  $ out.propane.range_oven.energy_consumption            : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ time                                                 : POSIXct, format: "3085-06-14 12:00:00" "308
##  $ Total_Energy_Consumption                             : num  28 31.9 36.6 31.6 31.4 ...
##  $ in.county                                            : chr  "G4500910" "G4500910" "G4500910" "G450
##  - attr(*, ".internal.selfref")=<externalptr>
```

```
# Standardize date columns
message("Standardizing `date` column formats...")
```

```
## Standardizing ‘date‘ column formats...
```

```
if ("date" %in% colnames(weather_data)) {
  weather_data[, date := as.Date(as.character(date), format = "%Y-%m-%d")]
}

# Standardize `date` in `energy_data`
if ("date" %in% colnames(energy_data)) {
  energy_data[, date := as.Date(as.character(date), format = "%Y-%m-%d")]
}

# Combine energy_data and weather_data on `date` and `in.county`
message("\nCombining energy and weather data...")
```

```
##
## Combining energy and weather data...
```

```
combined_data <- merge(
  energy_data,
  weather_data,
  by = c("date", "in.county"),
  all.x = TRUE  # Keep all rows from `energy_data`
)

# Add housing data to the combined dataset
message("\nAdding housing data to the combined dataset...")
```

```
##
## Adding housing data to the combined dataset...
```

```
combined_data <- merge(
  combined_data,
  housing_data,
  by = "bldg_id",  # Merge on `bldg_id`
  all.x = TRUE  # Keep all rows from the combined energy and weather data
)

# Output Combined File
fwrite(combined_data, output_file)

print(head(combined_data))
```

```
## Key: <bldg_id>
##    bldg_id       date in.county.x
##      <int>     <Date>      <char>
## 1:      65 2018-07-01    G4500910
## 2:      65 2018-07-02    G4500910
## 3:      65 2018-07-03    G4500910
## 4:      65 2018-07-04    G4500910
## 5:      65 2018-07-05    G4500910
## 6:      65 2018-07-06    G4500910
##    out.electricity.ceiling_fan.energy_consumption
##                                             <num>
## 1:                                          0.140
## 2:                                          0.143
## 3:                                          0.146
## 4:                                          0.148
## 5:                                          0.152
## 6:                                          0.139
##    out.electricity.clothes_dryer.energy_consumption
##                                               <num>
## 1:                                            0.178
## 2:                                            2.457
## 3:                                            2.422
## 4:                                            1.425
## 5:                                            0.000
## 6:                                            0.000
##    out.electricity.clothes_washer.energy_consumption
##                                                <num>
## 1:                                             0.000
## 2:                                             0.184
## 3:                                             0.180
## 4:                                             0.305
## 5:                                             0.000
## 6:                                             0.000
##    out.electricity.cooling_fans_pumps.energy_consumption
##                                                    <num>
## 1:                                                 0.607
## 2:                                                 0.728
## 3:                                                 0.927
## 4:                                                 0.778
## 5:                                                 0.739
## 6:                                                 0.609
##    out.electricity.cooling.energy_consumption
##                                         <num>
## 1:                                      9.789
## 2:                                     11.244
## 3:                                     13.580
## 4:                                     12.059
## 5:                                     11.511
## 6:                                      9.769
##    out.electricity.dishwasher.energy_consumption
##                                             <num>
## 1:                                              0
## 2:                                              0
## 3:                                              0
```

```
## 4:                                          0
## 5:                                          0
## 6:                                          0
##    out.electricity.freezer.energy_consumption
##                                         <num>
## 1:                                      0.932
## 2:                                      0.932
## 3:                                      0.932
## 4:                                      0.932
## 5:                                      0.932
## 6:                                      0.932
##    out.electricity.heating_fans_pumps.energy_consumption
##                                                    <num>
## 1:                                                     0
## 2:                                                     0
## 3:                                                     0
## 4:                                                     0
## 5:                                                     0
## 6:                                                     0
##    out.electricity.heating_hp_bkup.energy_consumption
##                                                 <int>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.electricity.heating.energy_consumption
##                                         <num>
## 1:                                          0
## 2:                                          0
## 3:                                          0
## 4:                                          0
## 5:                                          0
## 6:                                          0
##    out.electricity.hot_tub_heater.energy_consumption
##                                                 <num>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.electricity.hot_tub_pump.energy_consumption
##                                               <num>
## 1:                                                0
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.electricity.hot_water.energy_consumption
##                                           <num>
## 1:                                        1.709
```

```
## 2:                                        1.154
## 3:                                        2.223
## 4:                                        1.289
## 5:                                        1.247
## 6:                                        1.315
##    out.electricity.lighting_exterior.energy_consumption
##                                                   <num>
## 1:                                                0.304
## 2:                                                0.304
## 3:                                                0.304
## 4:                                                0.304
## 5:                                                0.304
## 6:                                                0.304
##    out.electricity.lighting_garage.energy_consumption
##                                                 <num>
## 1:                                              0.208
## 2:                                              0.208
## 3:                                              0.208
## 4:                                              0.208
## 5:                                              0.208
## 6:                                              0.208
##    out.electricity.lighting_interior.energy_consumption
##                                                   <num>
## 1:                                                2.087
## 2:                                                2.765
## 3:                                                2.759
## 4:                                                2.906
## 5:                                                2.469
## 6:                                                2.612
##    out.electricity.mech_vent.energy_consumption
##                                           <num>
## 1:                                        0.064
## 2:                                        0.064
## 3:                                        0.064
## 4:                                        0.064
## 5:                                        0.064
## 6:                                        0.064
##    out.electricity.plug_loads.energy_consumption
##                                            <num>
## 1:                                         5.567
## 2:                                         5.847
## 3:                                         5.837
## 4:                                         5.821
## 5:                                         5.683
## 6:                                         5.830
##    out.electricity.pool_heater.energy_consumption
##                                             <num>
## 1:                                              0
## 2:                                              0
## 3:                                              0
## 4:                                              0
## 5:                                              0
## 6:                                              0
##    out.electricity.pool_pump.energy_consumption
```

```
##                                          <num>
## 1:                                           0
## 2:                                           0
## 3:                                           0
## 4:                                           0
## 5:                                           0
## 6:                                           0
##    out.electricity.pv.energy_consumption
##                                    <num>
## 1:                                     0
## 2:                                     0
## 3:                                     0
## 4:                                     0
## 5:                                     0
## 6:                                     0
##    out.electricity.range_oven.energy_consumption
##                                            <num>
## 1:                                         1.334
## 2:                                         0.799
## 3:                                         1.866
## 4:                                         0.266
## 5:                                         2.934
## 6:                                         1.601
##    out.electricity.refrigerator.energy_consumption
##                                                <num>
## 1:                                             5.119
## 2:                                             5.119
## 3:                                             5.119
## 4:                                             5.119
## 5:                                             5.119
## 6:                                             5.119
##    out.electricity.well_pump.energy_consumption
##                                           <num>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.fuel_oil.heating_hp_bkup.energy_consumption
##                                               <int>
## 1:                                                0
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.fuel_oil.heating.energy_consumption
##                                      <int>
## 1:                                       0
## 2:                                       0
## 3:                                       0
## 4:                                       0
## 5:                                       0
```

```
## 6:                                       0
##    out.fuel_oil.hot_water.energy_consumption
##                                       <int>
## 1:                                        0
## 2:                                        0
## 3:                                        0
## 4:                                        0
## 5:                                        0
## 6:                                        0
##    out.natural_gas.clothes_dryer.energy_consumption
##                                               <int>
## 1:                                                0
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.natural_gas.fireplace.energy_consumption
##                                           <num>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.natural_gas.grill.energy_consumption
##                                       <num>
## 1:                                        0
## 2:                                        0
## 3:                                        0
## 4:                                        0
## 5:                                        0
## 6:                                        0
##    out.natural_gas.heating_hp_bkup.energy_consumption
##                                                 <int>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.natural_gas.heating.energy_consumption
##                                         <int>
## 1:                                          0
## 2:                                          0
## 3:                                          0
## 4:                                          0
## 5:                                          0
## 6:                                          0
##    out.natural_gas.hot_tub_heater.energy_consumption
##                                                 <num>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
```

```
## 4:                                                    0
## 5:                                                    0
## 6:                                                    0
##    out.natural_gas.hot_water.energy_consumption
##                                           <int>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.natural_gas.lighting.energy_consumption
##                                          <num>
## 1:                                           0
## 2:                                           0
## 3:                                           0
## 4:                                           0
## 5:                                           0
## 6:                                           0
##    out.natural_gas.pool_heater.energy_consumption
##                                             <num>
## 1:                                              0
## 2:                                              0
## 3:                                              0
## 4:                                              0
## 5:                                              0
## 6:                                              0
##    out.natural_gas.range_oven.energy_consumption
##                                            <int>
## 1:                                             0
## 2:                                             0
## 3:                                             0
## 4:                                             0
## 5:                                             0
## 6:                                             0
##    out.propane.clothes_dryer.energy_consumption
##                                           <int>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.propane.heating_hp_bkup.energy_consumption
##                                             <int>
## 1:                                              0
## 2:                                              0
## 3:                                              0
## 4:                                              0
## 5:                                              0
## 6:                                              0
##    out.propane.heating.energy_consumption
##                                     <int>
## 1:                                      0
```

```
## 2:                                     0
## 3:                                     0
## 4:                                     0
## 5:                                     0
## 6:                                     0
##    out.propane.hot_water.energy_consumption
##                                       <int>
## 1:                                        0
## 2:                                        0
## 3:                                        0
## 4:                                        0
## 5:                                        0
## 6:                                        0
##    out.propane.range_oven.energy_consumption               time
##                                       <int>             <POSc>
## 1:                                        0 3085-06-14 12:00:00
## 2:                                        0 3085-07-07 12:00:00
## 3:                                        0 3085-07-30 12:00:00
## 4:                                        0 3085-08-22 12:00:00
## 5:                                        0 3085-09-14 12:00:00
## 6:                                        0 3085-10-07 12:00:00
##    Total_Energy_Consumption Dry Bulb Temperature [°C] Relative Humidity [%]
##                       <num>                    <num>                 <num>
## 1:                   28.038                 26.76000              82.89957
## 2:                   31.948                 27.04826              82.45609
## 3:                   36.567                 29.61609              69.47478
## 4:                   31.624                 28.40000              71.30652
## 5:                   31.362                 28.01522              71.62957
## 6:                   28.502                 25.75261              83.79261
##    Wind Speed [m/s] Wind Direction [Deg] Global Horizontal Radiation [W/m2]
##               <num>                <num>                              <num>
## 1:        0.9147826             98.90217                             296.5652
## 2:        0.7086957             85.43478                             255.1522
## 3:        1.5030435            117.12348                             316.5435
## 4:        1.2956522             50.96391                             272.4783
## 5:        1.1869565             90.75000                             305.9130
## 6:        1.9669565            138.33696                             238.2174
##    Direct Normal Radiation [W/m2] Diffuse Horizontal Radiation [W/m2] in.sqft
##                             <num>                              <num>   <int>
## 1:                       284.0435                           94.54348     885
## 2:                       150.8696                          162.00000     885
## 3:                       313.2391                          106.45652     885
## 4:                       226.6522                          127.19565     885
## 5:                       286.4348                          106.91304     885
## 6:                       204.2609                           91.69565     885
##    in.bedrooms in.county.y in.geometry_wall_type in.has_pv   in.income
##          <int>      <char>                <char>    <char>      <char>
## 1:           3    G4500910            Wood Frame        No 10000-14999
## 2:           3    G4500910            Wood Frame        No 10000-14999
## 3:           3    G4500910            Wood Frame        No 10000-14999
## 4:           3    G4500910            Wood Frame        No 10000-14999
## 5:           3    G4500910            Wood Frame        No 10000-14999
## 6:           3    G4500910            Wood Frame        No 10000-14999
##    in.occupants     in.roof_material in.tenure in.usage_level in.vacancy_status
```

```
##          <char>               <char>    <char>         <char>           <char>
## 1:            3 Composition Shingles    Renter         Medium         Occupied
## 2:            3 Composition Shingles    Renter         Medium         Occupied
## 3:            3 Composition Shingles    Renter         Medium         Occupied
## 4:            3 Composition Shingles    Renter         Medium         Occupied
## 5:            3 Composition Shingles    Renter         Medium         Occupied
## 6:            3 Composition Shingles    Renter         Medium         Occupied
##    in.vintage in.weather_file_city in.hvac_cooling_efficiency
##        <char>               <char>                     <char>
## 1:      1950s    Rock Hill York Co               AC, SEER 15
## 2:      1950s    Rock Hill York Co               AC, SEER 15
## 3:      1950s    Rock Hill York Co               AC, SEER 15
## 4:      1950s    Rock Hill York Co               AC, SEER 15
## 5:      1950s    Rock Hill York Co               AC, SEER 15
## 6:      1950s    Rock Hill York Co               AC, SEER 15
##    in.hvac_cooling_partial_space_conditioning in.hvac_cooling_type
##                                        <char>              <char>
## 1:                          100% Conditioned           Central AC
## 2:                          100% Conditioned           Central AC
## 3:                          100% Conditioned           Central AC
## 4:                          100% Conditioned           Central AC
## 5:                          100% Conditioned           Central AC
## 6:                          100% Conditioned           Central AC
##    upgrade.hvac_cooling_efficiency in.cooling_setpoint
##                             <char>              <char>
## 1:                      Heat Pump                72F
## 2:                      Heat Pump                72F
## 3:                      Heat Pump                72F
## 4:                      Heat Pump                72F
## 5:                      Heat Pump                72F
## 6:                      Heat Pump                72F
##    in.cooling_setpoint_has_offset in.cooling_setpoint_offset_magnitude
##                            <char>                                <char>
## 1:                             No                                    0F
## 2:                             No                                    0F
## 3:                             No                                    0F
## 4:                             No                                    0F
## 5:                             No                                    0F
## 6:                             No                                    0F
##    in.cooling_setpoint_offset_period
##                               <char>
## 1:                             None
## 2:                             None
## 3:                             None
## 4:                             None
## 5:                             None
## 6:                             None
```

```
print(tail(combined_data))
```

```
## Key: <bldg_id>
##    bldg_id       date in.county.x
##      <int>     <Date>      <char>
## 1:  549916 2018-07-26    G4500190
```

```
## 2:  549916 2018-07-27    G4500190
## 3:  549916 2018-07-28    G4500190
## 4:  549916 2018-07-29    G4500190
## 5:  549916 2018-07-30    G4500190
## 6:  549916 2018-07-31    G4500190
##    out.electricity.ceiling_fan.energy_consumption
##                                             <num>
## 1:                                          0.231
## 2:                                          0.235
## 3:                                          0.238
## 4:                                          0.221
## 5:                                          0.233
## 6:                                          0.229
##    out.electricity.clothes_dryer.energy_consumption
##                                               <num>
## 1:                                                0
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.electricity.clothes_washer.energy_consumption
##                                                <num>
## 1:                                                 0
## 2:                                                 0
## 3:                                                 0
## 4:                                                 0
## 5:                                                 0
## 6:                                                 0
##    out.electricity.cooling_fans_pumps.energy_consumption
##                                                    <num>
## 1:                                                 2.511
## 2:                                                 2.094
## 3:                                                 2.793
## 4:                                                 2.671
## 5:                                                 2.934
## 6:                                                 2.230
##    out.electricity.cooling.energy_consumption
##                                         <num>
## 1:                                     40.899
## 2:                                     35.678
## 3:                                     46.001
## 4:                                     44.392
## 5:                                     46.545
## 6:                                     37.353
##    out.electricity.dishwasher.energy_consumption
##                                             <num>
## 1:                                              0
## 2:                                              0
## 3:                                              0
## 4:                                              0
## 5:                                              0
## 6:                                              0
##    out.electricity.freezer.energy_consumption
```

```
##                                         <num>
## 1:                                      0.932
## 2:                                      0.932
## 3:                                      0.932
## 4:                                      0.932
## 5:                                      0.932
## 6:                                      0.932
##    out.electricity.heating_fans_pumps.energy_consumption
##                                                    <num>
## 1:                                                     0
## 2:                                                     0
## 3:                                                     0
## 4:                                                     0
## 5:                                                     0
## 6:                                                     0
##    out.electricity.heating_hp_bkup.energy_consumption
##                                                 <int>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.electricity.heating.energy_consumption
##                                         <num>
## 1:                                          0
## 2:                                          0
## 3:                                          0
## 4:                                          0
## 5:                                          0
## 6:                                          0
##    out.electricity.hot_tub_heater.energy_consumption
##                                                 <num>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.electricity.hot_tub_pump.energy_consumption
##                                               <num>
## 1:                                                0
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.electricity.hot_water.energy_consumption
##                                           <num>
## 1:                                        0.885
## 2:                                        1.003
## 3:                                        1.154
## 4:                                        0.944
## 5:                                        1.080
```

```
## 6:                                        0.596
##    out.electricity.lighting_exterior.energy_consumption
##                                                   <num>
## 1:                                                0.276
## 2:                                                0.276
## 3:                                                0.276
## 4:                                                0.276
## 5:                                                0.276
## 6:                                                0.276
##    out.electricity.lighting_garage.energy_consumption
##                                                  <num>
## 1:                                               0.056
## 2:                                               0.056
## 3:                                               0.056
## 4:                                               0.056
## 5:                                               0.056
## 6:                                               0.056
##    out.electricity.lighting_interior.energy_consumption
##                                                   <num>
## 1:                                                4.827
## 2:                                                4.643
## 3:                                                6.068
## 4:                                                3.817
## 5:                                                5.361
## 6:                                                4.397
##    out.electricity.mech_vent.energy_consumption
##                                           <num>
## 1:                                        0.064
## 2:                                        0.064
## 3:                                        0.064
## 4:                                        0.064
## 5:                                        0.064
## 6:                                        0.064
##    out.electricity.plug_loads.energy_consumption
##                                            <num>
## 1:                                        10.604
## 2:                                        10.356
## 3:                                        10.689
## 4:                                        10.431
## 5:                                        10.626
## 6:                                        10.546
##    out.electricity.pool_heater.energy_consumption
##                                             <num>
## 1:                                              0
## 2:                                              0
## 3:                                              0
## 4:                                              0
## 5:                                              0
## 6:                                              0
##    out.electricity.pool_pump.energy_consumption
##                                           <num>
## 1:                                        9.438
## 2:                                        9.438
## 3:                                        9.438
```

```
## 4:                                        9.438
## 5:                                        9.438
## 6:                                        9.438
##    out.electricity.pv.energy_consumption
##                                    <num>
## 1:                                     0
## 2:                                     0
## 3:                                     0
## 4:                                     0
## 5:                                     0
## 6:                                     0
##    out.electricity.range_oven.energy_consumption
##                                             <num>
## 1:                                          0.402
## 2:                                          0.000
## 3:                                          0.603
## 4:                                          3.629
## 5:                                          1.808
## 6:                                          1.407
##    out.electricity.refrigerator.energy_consumption
##                                                <num>
## 1:                                              1.24
## 2:                                              1.24
## 3:                                              1.24
## 4:                                              1.24
## 5:                                              1.24
## 6:                                              1.24
##    out.electricity.well_pump.energy_consumption
##                                           <num>
## 1:                                        1.534
## 2:                                        1.534
## 3:                                        1.534
## 4:                                        1.534
## 5:                                        1.534
## 6:                                        1.534
##    out.fuel_oil.heating_hp_bkup.energy_consumption
##                                              <int>
## 1:                                               0
## 2:                                               0
## 3:                                               0
## 4:                                               0
## 5:                                               0
## 6:                                               0
##    out.fuel_oil.heating.energy_consumption
##                                     <int>
## 1:                                      0
## 2:                                      0
## 3:                                      0
## 4:                                      0
## 5:                                      0
## 6:                                      0
##    out.fuel_oil.hot_water.energy_consumption
##                                        <int>
## 1:                                         0
```

```
## 2:                                          0
## 3:                                          0
## 4:                                          0
## 5:                                          0
## 6:                                          0
##    out.natural_gas.clothes_dryer.energy_consumption
##                                               <int>
## 1:                                                0
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.natural_gas.fireplace.energy_consumption
##                                           <num>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.natural_gas.grill.energy_consumption
##                                       <num>
## 1:                                        0
## 2:                                        0
## 3:                                        0
## 4:                                        0
## 5:                                        0
## 6:                                        0
##    out.natural_gas.heating_hp_bkup.energy_consumption
##                                                 <int>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.natural_gas.heating.energy_consumption
##                                         <int>
## 1:                                          0
## 2:                                          0
## 3:                                          0
## 4:                                          0
## 5:                                          0
## 6:                                          0
##    out.natural_gas.hot_tub_heater.energy_consumption
##                                                 <num>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.natural_gas.hot_water.energy_consumption
```

```
##                                          <int>
## 1:                                           0
## 2:                                           0
## 3:                                           0
## 4:                                           0
## 5:                                           0
## 6:                                           0
##    out.natural_gas.lighting.energy_consumption
##                                          <num>
## 1:                                           0
## 2:                                           0
## 3:                                           0
## 4:                                           0
## 5:                                           0
## 6:                                           0
##    out.natural_gas.pool_heater.energy_consumption
##                                           <num>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.natural_gas.range_oven.energy_consumption
##                                           <int>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.propane.clothes_dryer.energy_consumption
##                                          <int>
## 1:                                           0
## 2:                                           0
## 3:                                           0
## 4:                                           0
## 5:                                           0
## 6:                                           0
##    out.propane.heating_hp_bkup.energy_consumption
##                                           <int>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.propane.heating.energy_consumption
##                                     <int>
## 1:                                      0
## 2:                                      0
## 3:                                      0
## 4:                                      0
## 5:                                      0
```

```
## 6:                                     0
##    out.propane.hot_water.energy_consumption
##                                       <int>
## 1:                                        0
## 2:                                        0
## 3:                                        0
## 4:                                        0
## 5:                                        0
## 6:                                        0
##    out.propane.range_oven.energy_consumption                time
##                                        <int>              <POSc>
## 1:                                         0 3087-01-10 12:00:00
## 2:                                         0 3087-02-02 12:00:00
## 3:                                         0 3087-02-25 12:00:00
## 4:                                         0 3087-03-20 12:00:00
## 5:                                         0 3087-04-12 12:00:00
## 6:                                         0 3087-05-05 12:00:00
##    Total_Energy_Consumption Dry Bulb Temperature [°C] Relative Humidity [%]
##                       <num>                    <num>                 <num>
## 1:                   73.899                 26.78870              87.52435
## 2:                   67.549                 27.06304              88.45913
## 3:                   81.086                 28.03391              81.92391
## 4:                   79.645                 27.35304              82.22783
## 5:                   82.127                 27.09609              83.46217
## 6:                   70.298                 26.68522              86.52652
##    Wind Speed [m/s] Wind Direction [Deg] Global Horizontal Radiation [W/m2]
##               <num>                <num>                             <num>
## 1:         1.790870             163.2430                            180.8478
## 2:         2.012174             180.1987                            137.9348
## 3:         2.553043             202.1013                            279.5217
## 4:         3.095652             179.0583                            229.3043
## 5:         2.775652             182.7391                            243.9783
## 6:         2.988696             218.1448                            203.2609
##    Direct Normal Radiation [W/m2] Diffuse Horizontal Radiation [W/m2] in.sqft
##                             <num>                              <num>   <int>
## 1:                      148.71739                           81.65217    8194
## 2:                       64.08696                          105.93478    8194
## 3:                      253.02174                           95.93478    8194
## 4:                      157.26087                          128.39130    8194
## 5:                      150.50000                          133.36957    8194
## 6:                      171.65217                           91.73913    8194
##    in.bedrooms in.county.y in.geometry_wall_type in.has_pv     in.income
##          <int>      <char>                <char>    <char>        <char>
## 1:           3    G4500190                 Brick        No 160000-179999
## 2:           3    G4500190                 Brick        No 160000-179999
## 3:           3    G4500190                 Brick        No 160000-179999
## 4:           3    G4500190                 Brick        No 160000-179999
## 5:           3    G4500190                 Brick        No 160000-179999
## 6:           3    G4500190                 Brick        No 160000-179999
##    in.occupants     in.roof_material in.tenure in.usage_level in.vacancy_status
##          <char>               <char>    <char>         <char>            <char>
## 1:            2 Composition Shingles     Owner         Medium          Occupied
## 2:            2 Composition Shingles     Owner         Medium          Occupied
## 3:            2 Composition Shingles     Owner         Medium          Occupied
```

```
## 4:            2 Composition Shingles     Owner         Medium          Occupied
## 5:            2 Composition Shingles     Owner         Medium          Occupied
## 6:            2 Composition Shingles     Owner         Medium          Occupied
##    in.vintage in.weather_file_city in.hvac_cooling_efficiency
##        <char>               <char>                    <char>
## 1:      1990s      Charleston Muni                 Heat Pump
## 2:      1990s      Charleston Muni                 Heat Pump
## 3:      1990s      Charleston Muni                 Heat Pump
## 4:      1990s      Charleston Muni                 Heat Pump
## 5:      1990s      Charleston Muni                 Heat Pump
## 6:      1990s      Charleston Muni                 Heat Pump
##    in.hvac_cooling_partial_space_conditioning in.hvac_cooling_type
##                                        <char>               <char>
## 1:                          100% Conditioned            Heat Pump
## 2:                          100% Conditioned            Heat Pump
## 3:                          100% Conditioned            Heat Pump
## 4:                          100% Conditioned            Heat Pump
## 5:                          100% Conditioned            Heat Pump
## 6:                          100% Conditioned            Heat Pump
##    upgrade.hvac_cooling_efficiency in.cooling_setpoint
##                             <char>              <char>
## 1:                      Heat Pump                 68F
## 2:                      Heat Pump                 68F
## 3:                      Heat Pump                 68F
## 4:                      Heat Pump                 68F
## 5:                      Heat Pump                 68F
## 6:                      Heat Pump                 68F
##    in.cooling_setpoint_has_offset in.cooling_setpoint_offset_magnitude
##                            <char>                                <char>
## 1:                            Yes                                    2F
## 2:                            Yes                                    2F
## 3:                            Yes                                    2F
## 4:                            Yes                                    2F
## 5:                            Yes                                    2F
## 6:                            Yes                                    2F
##    in.cooling_setpoint_offset_period
##                               <char>
## 1:   Day Setup and Night Setback -5h
## 2:   Day Setup and Night Setback -5h
## 3:   Day Setup and Night Setback -5h
## 4:   Day Setup and Night Setback -5h
## 5:   Day Setup and Night Setback -5h
## 6:   Day Setup and Night Setback -5h
```

```
print(str(combined_data))
```

```
## Classes 'data.table' and 'data.frame':   177010 obs. of  75 variables:
##  $ bldg_id                                          : int  65 65 65 65 65 65 65 65 65 65 ...
##  $ date                                             : Date, format: "2018-07-01" "2018-07-02" ..
##  $ in.county.x                                      : chr  "G4500910" "G4500910" "G4500910" "G450
##  $ out.electricity.ceiling_fan.energy_consumption   : num  0.14 0.143 0.146 0.148 0.152 0.139 0.1
##  $ out.electricity.clothes_dryer.energy_consumption : num  0.178 2.457 2.422 1.425 0 ...
##  $ out.electricity.clothes_washer.energy_consumption: num  0 0.184 0.18 0.305 0 0 0.184 0.121 0 0
##  $ out.electricity.cooling_fans_pumps.energy_consumption: num  0.607 0.728 0.927 0.778 0.739 0.609 0
```

```
##  $ out.electricity.cooling.energy_consumption           : num  9.79 11.24 13.58 12.06 11.51 ...
##  $ out.electricity.dishwasher.energy_consumption        : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.freezer.energy_consumption           : num  0.932 0.932 0.932 0.932 0.932 0.932 0
##  $ out.electricity.heating_fans_pumps.energy_consumption: num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.heating_hp_bkup.energy_consumption   : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.heating.energy_consumption           : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.hot_tub_heater.energy_consumption    : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.hot_tub_pump.energy_consumption      : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.hot_water.energy_consumption         : num  1.71 1.15 2.22 1.29 1.25 ...
##  $ out.electricity.lighting_exterior.energy_consumption : num  0.304 0.304 0.304 0.304 0.304 0.304 0
##  $ out.electricity.lighting_garage.energy_consumption   : num  0.208 0.208 0.208 0.208 0.208 0.208 0
##  $ out.electricity.lighting_interior.energy_consumption : num  2.09 2.77 2.76 2.91 2.47 ...
##  $ out.electricity.mech_vent.energy_consumption         : num  0.064 0.064 0.064 0.064 0.064 0.064 0
##  $ out.electricity.plug_loads.energy_consumption        : num  5.57 5.85 5.84 5.82 5.68 ...
##  $ out.electricity.pool_heater.energy_consumption       : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.pool_pump.energy_consumption         : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.pv.energy_consumption                : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.range_oven.energy_consumption        : num  1.334 0.799 1.866 0.266 2.934 ...
##  $ out.electricity.refrigerator.energy_consumption      : num  5.12 5.12 5.12 5.12 5.12 ...
##  $ out.electricity.well_pump.energy_consumption         : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.fuel_oil.heating_hp_bkup.energy_consumption      : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.fuel_oil.heating.energy_consumption              : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.fuel_oil.hot_water.energy_consumption            : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.clothes_dryer.energy_consumption     : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.fireplace.energy_consumption         : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.grill.energy_consumption             : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.heating_hp_bkup.energy_consumption   : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.heating.energy_consumption           : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.hot_tub_heater.energy_consumption    : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.hot_water.energy_consumption         : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.lighting.energy_consumption          : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.pool_heater.energy_consumption       : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.range_oven.energy_consumption        : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.clothes_dryer.energy_consumption         : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.heating_hp_bkup.energy_consumption       : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.heating.energy_consumption               : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.hot_water.energy_consumption             : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.range_oven.energy_consumption            : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ time                                                 : POSIXct, format: "3085-06-14 12:00:00" "308
##  $ Total_Energy_Consumption                             : num  28 31.9 36.6 31.6 31.4 ...
##  $ Dry Bulb Temperature [°C]                            : num  26.8 27 29.6 28.4 28 ...
##  $ Relative Humidity [%]                                : num  82.9 82.5 69.5 71.3 71.6 ...
##  $ Wind Speed [m/s]                                     : num  0.915 0.709 1.503 1.296 1.187 ...
##  $ Wind Direction [Deg]                                 : num  98.9 85.4 117.1 51 90.8 ...
##  $ Global Horizontal Radiation [W/m2]                   : num  297 255 317 272 306 ...
##  $ Direct Normal Radiation [W/m2]                       : num  284 151 313 227 286 ...
##  $ Diffuse Horizontal Radiation [W/m2]                  : num  94.5 162 106.5 127.2 106.9 ...
##  $ in.sqft                                              : int  885 885 885 885 885 885 885 885 885 88
##  $ in.bedrooms                                          : int  3 3 3 3 3 3 3 3 3 3 ...
##  $ in.county.y                                          : chr  "G4500910" "G4500910" "G4500910" "G450
##  $ in.geometry_wall_type                                : chr  "Wood Frame" "Wood Frame" "Wood Frame
##  $ in.has_pv                                            : chr  "No" "No" "No" "No" ...
##  $ in.income                                            : chr  "10000-14999" "10000-14999" "10000-149
##  $ in.occupants                                         : chr  "3" "3" "3" "3" ...
```

```
##  $ in.roof_material                                  : chr  "Composition Shingles" "Composition Sh
##  $ in.tenure                                         : chr  "Renter" "Renter" "Renter" "Renter" .
##  $ in.usage_level                                    : chr  "Medium" "Medium" "Medium" "Medium" .
##  $ in.vacancy_status                                 : chr  "Occupied" "Occupied" "Occupied" "Occu
##  $ in.vintage                                        : chr  "1950s" "1950s" "1950s" "1950s" ...
##  $ in.weather_file_city                              : chr  "Rock Hill York Co" "Rock Hill York Co
##  $ in.hvac_cooling_efficiency                        : chr  "AC, SEER 15" "AC, SEER 15" "AC, SEER
##  $ in.hvac_cooling_partial_space_conditioning        : chr  "100% Conditioned" "100% Conditioned"
##  $ in.hvac_cooling_type                              : chr  "Central AC" "Central AC" "Central AC
##  $ upgrade.hvac_cooling_efficiency                   : chr  "Heat Pump" "Heat Pump" "Heat Pump" "H
##  $ in.cooling_setpoint                               : chr  "72F" "72F" "72F" "72F" ...
##  $ in.cooling_setpoint_has_offset                    : chr  "No" "No" "No" "No" ...
##  $ in.cooling_setpoint_offset_magnitude              : chr  "0F" "0F" "0F" "0F" ...
##  $ in.cooling_setpoint_offset_period                 : chr  "None" "None" "None" "None" ...
##  - attr(*, ".internal.selfref")=<externalptr>
##  - attr(*, "sorted")= chr "bldg_id"
## NULL
```

```r
################################################################################
# DATA CLEANING (DAILY)
################################################################################

library(dplyr)

# Function for missing values
analyze_missing_values <- function(data) {

  missing_summary <- colSums(is.na(data))
  missing_table <- data.frame(
    Column = names(missing_summary),
    Missing_Values = missing_summary,
    Total_Values = nrow(data),
    Percentage_Missing = (missing_summary / nrow(data)) * 100
  )

  print(missing_table)

}

analyze_missing_values(combined_data) # missing values for dataset
```

```
##
## bldg_id                                                                                            b
## date
## in.county.x                                                                                    in.co
## out.electricity.ceiling_fan.energy_consumption               out.electricity.ceiling_fan.energy_consu
## out.electricity.clothes_dryer.energy_consumption           out.electricity.clothes_dryer.energy_consu
## out.electricity.clothes_washer.energy_consumption         out.electricity.clothes_washer.energy_consu
## out.electricity.cooling_fans_pumps.energy_consumption out.electricity.cooling_fans_pumps.energy_consu
## out.electricity.cooling.energy_consumption                       out.electricity.cooling.energy_consu
## out.electricity.dishwasher.energy_consumption                 out.electricity.dishwasher.energy_consu
## out.electricity.freezer.energy_consumption                       out.electricity.freezer.energy_consu
## out.electricity.heating_fans_pumps.energy_consumption out.electricity.heating_fans_pumps.energy_consu
## out.electricity.heating_hp_bkup.energy_consumption       out.electricity.heating_hp_bkup.energy_consu
```

```
## out.electricity.heating.energy_consumption                    out.electricity.heating.energy_consu
## out.electricity.hot_tub_heater.energy_consumption          out.electricity.hot_tub_heater.energy_consu
## out.electricity.hot_tub_pump.energy_consumption              out.electricity.hot_tub_pump.energy_consu
## out.electricity.hot_water.energy_consumption                 out.electricity.hot_water.energy_consu
## out.electricity.lighting_exterior.energy_consumption     out.electricity.lighting_exterior.energy_consu
## out.electricity.lighting_garage.energy_consumption        out.electricity.lighting_garage.energy_consu
## out.electricity.lighting_interior.energy_consumption     out.electricity.lighting_interior.energy_consu
## out.electricity.mech_vent.energy_consumption                 out.electricity.mech_vent.energy_consu
## out.electricity.plug_loads.energy_consumption                out.electricity.plug_loads.energy_consu
## out.electricity.pool_heater.energy_consumption              out.electricity.pool_heater.energy_consu
## out.electricity.pool_pump.energy_consumption                out.electricity.pool_pump.energy_consu
## out.electricity.pv.energy_consumption                              out.electricity.pv.energy_consu
## out.electricity.range_oven.energy_consumption               out.electricity.range_oven.energy_consu
## out.electricity.refrigerator.energy_consumption            out.electricity.refrigerator.energy_consu
## out.electricity.well_pump.energy_consumption                 out.electricity.well_pump.energy_consu
## out.fuel_oil.heating_hp_bkup.energy_consumption            out.fuel_oil.heating_hp_bkup.energy_consu
## out.fuel_oil.heating.energy_consumption                          out.fuel_oil.heating.energy_consu
## out.fuel_oil.hot_water.energy_consumption                      out.fuel_oil.hot_water.energy_consu
## out.natural_gas.clothes_dryer.energy_consumption         out.natural_gas.clothes_dryer.energy_consu
## out.natural_gas.fireplace.energy_consumption                 out.natural_gas.fireplace.energy_consu
## out.natural_gas.grill.energy_consumption                       out.natural_gas.grill.energy_consu
## out.natural_gas.heating_hp_bkup.energy_consumption       out.natural_gas.heating_hp_bkup.energy_consu
## out.natural_gas.heating.energy_consumption                     out.natural_gas.heating.energy_consu
## out.natural_gas.hot_tub_heater.energy_consumption        out.natural_gas.hot_tub_heater.energy_consu
## out.natural_gas.hot_water.energy_consumption                 out.natural_gas.hot_water.energy_consu
## out.natural_gas.lighting.energy_consumption                   out.natural_gas.lighting.energy_consu
## out.natural_gas.pool_heater.energy_consumption             out.natural_gas.pool_heater.energy_consu
## out.natural_gas.range_oven.energy_consumption              out.natural_gas.range_oven.energy_consu
## out.propane.clothes_dryer.energy_consumption               out.propane.clothes_dryer.energy_consu
## out.propane.heating_hp_bkup.energy_consumption             out.propane.heating_hp_bkup.energy_consu
## out.propane.heating.energy_consumption                           out.propane.heating.energy_consu
## out.propane.hot_water.energy_consumption                       out.propane.hot_water.energy_consu
## out.propane.range_oven.energy_consumption                      out.propane.range_oven.energy_consu
## time
## Total_Energy_Consumption                                                        Total_Energy_Consu
## Dry Bulb Temperature [°C]                                                      Dry Bulb Temperatu
## Relative Humidity [%]                                                             Relative Humidi
## Wind Speed [m/s]                                                                       Wind Speed
## Wind Direction [Deg]                                                            Wind Direction
## Global Horizontal Radiation [W/m2]                                   Global Horizontal Radiation
## Direct Normal Radiation [W/m2]                                           Direct Normal Radiation
## Diffuse Horizontal Radiation [W/m2]                                 Diffuse Horizontal Radiation
## in.sqft                                                                                        i
## in.bedrooms                                                                                 in.b
## in.county.y                                                                                 in.c
## in.geometry_wall_type                                                             in.geometry_wal
## in.has_pv                                                                                     in
## in.income                                                                                     in
## in.occupants                                                                               in.oc
## in.roof_material                                                                        in.roof_ma
## in.tenure                                                                                     in
## in.usage_level                                                                           in.usag
## in.vacancy_status                                                                     in.vacancy
## in.vintage                                                                                    in.
```

```
## in.weather_file_city                                                    in.weather_fil
## in.hvac_cooling_efficiency                                            in.hvac_cooling_effi
## in.hvac_cooling_partial_space_conditioning                  in.hvac_cooling_partial_space_condit
## in.hvac_cooling_type                                                    in.hvac_cooli
## upgrade.hvac_cooling_efficiency                                 upgrade.hvac_cooling_effi
## in.cooling_setpoint                                                      in.cooling_se
## in.cooling_setpoint_has_offset                                   in.cooling_setpoint_has_
## in.cooling_setpoint_offset_magnitude                          in.cooling_setpoint_offset_mag
## in.cooling_setpoint_offset_period                                in.cooling_setpoint_offset_
##                                                    Missing_Values
## bldg_id                                                         0
## date                                                            0
## in.county.x                                                     0
## out.electricity.ceiling_fan.energy_consumption                  0
## out.electricity.clothes_dryer.energy_consumption                0
## out.electricity.clothes_washer.energy_consumption               0
## out.electricity.cooling_fans_pumps.energy_consumption           0
## out.electricity.cooling.energy_consumption                      0
## out.electricity.dishwasher.energy_consumption                   0
## out.electricity.freezer.energy_consumption                      0
## out.electricity.heating_fans_pumps.energy_consumption           0
## out.electricity.heating_hp_bkup.energy_consumption              0
## out.electricity.heating.energy_consumption                      0
## out.electricity.hot_tub_heater.energy_consumption               0
## out.electricity.hot_tub_pump.energy_consumption                 0
## out.electricity.hot_water.energy_consumption                    0
## out.electricity.lighting_exterior.energy_consumption            0
## out.electricity.lighting_garage.energy_consumption              0
## out.electricity.lighting_interior.energy_consumption            0
## out.electricity.mech_vent.energy_consumption                    0
## out.electricity.plug_loads.energy_consumption                   0
## out.electricity.pool_heater.energy_consumption                  0
## out.electricity.pool_pump.energy_consumption                    0
## out.electricity.pv.energy_consumption                           0
## out.electricity.range_oven.energy_consumption                   0
## out.electricity.refrigerator.energy_consumption                 0
## out.electricity.well_pump.energy_consumption                    0
## out.fuel_oil.heating_hp_bkup.energy_consumption                 0
## out.fuel_oil.heating.energy_consumption                         0
## out.fuel_oil.hot_water.energy_consumption                       0
## out.natural_gas.clothes_dryer.energy_consumption                0
## out.natural_gas.fireplace.energy_consumption                    0
## out.natural_gas.grill.energy_consumption                        0
## out.natural_gas.heating_hp_bkup.energy_consumption              0
## out.natural_gas.heating.energy_consumption                      0
## out.natural_gas.hot_tub_heater.energy_consumption               0
## out.natural_gas.hot_water.energy_consumption                    0
## out.natural_gas.lighting.energy_consumption                     0
## out.natural_gas.pool_heater.energy_consumption                  0
## out.natural_gas.range_oven.energy_consumption                   0
## out.propane.clothes_dryer.energy_consumption                    0
## out.propane.heating_hp_bkup.energy_consumption                  0
## out.propane.heating.energy_consumption                          0
## out.propane.hot_water.energy_consumption                        0
```

```
## out.propane.range_oven.energy_consumption                          0
## time                                                               0
## Total_Energy_Consumption                                           0
## Dry Bulb Temperature [°C]                                          0
## Relative Humidity [%]                                              0
## Wind Speed [m/s]                                                   0
## Wind Direction [Deg]                                               0
## Global Horizontal Radiation [W/m2]                                 0
## Direct Normal Radiation [W/m2]                                     0
## Diffuse Horizontal Radiation [W/m2]                                0
## in.sqft                                                            0
## in.bedrooms                                                        0
## in.county.y                                                        0
## in.geometry_wall_type                                              0
## in.has_pv                                                          0
## in.income                                                          0
## in.occupants                                                       0
## in.roof_material                                                   0
## in.tenure                                                          0
## in.usage_level                                                     0
## in.vacancy_status                                                  0
## in.vintage                                                         0
## in.weather_file_city                                               0
## in.hvac_cooling_efficiency                                         0
## in.hvac_cooling_partial_space_conditioning                         0
## in.hvac_cooling_type                                               0
## upgrade.hvac_cooling_efficiency                                    0
## in.cooling_setpoint                                                0
## in.cooling_setpoint_has_offset                                     0
## in.cooling_setpoint_offset_magnitude                               0
## in.cooling_setpoint_offset_period                                  0
##                                                          Total_Values
## bldg_id                                                        177010
## date                                                           177010
## in.county.x                                                    177010
## out.electricity.ceiling_fan.energy_consumption                 177010
## out.electricity.clothes_dryer.energy_consumption               177010
## out.electricity.clothes_washer.energy_consumption              177010
## out.electricity.cooling_fans_pumps.energy_consumption          177010
## out.electricity.cooling.energy_consumption                     177010
## out.electricity.dishwasher.energy_consumption                  177010
## out.electricity.freezer.energy_consumption                     177010
## out.electricity.heating_fans_pumps.energy_consumption          177010
## out.electricity.heating_hp_bkup.energy_consumption             177010
## out.electricity.heating.energy_consumption                     177010
## out.electricity.hot_tub_heater.energy_consumption              177010
## out.electricity.hot_tub_pump.energy_consumption                177010
## out.electricity.hot_water.energy_consumption                   177010
## out.electricity.lighting_exterior.energy_consumption           177010
## out.electricity.lighting_garage.energy_consumption             177010
## out.electricity.lighting_interior.energy_consumption           177010
## out.electricity.mech_vent.energy_consumption                   177010
## out.electricity.plug_loads.energy_consumption                  177010
## out.electricity.pool_heater.energy_consumption                 177010
```

```
## out.electricity.pool_pump.energy_consumption                177010
## out.electricity.pv.energy_consumption                       177010
## out.electricity.range_oven.energy_consumption               177010
## out.electricity.refrigerator.energy_consumption             177010
## out.electricity.well_pump.energy_consumption                177010
## out.fuel_oil.heating_hp_bkup.energy_consumption             177010
## out.fuel_oil.heating.energy_consumption                     177010
## out.fuel_oil.hot_water.energy_consumption                   177010
## out.natural_gas.clothes_dryer.energy_consumption            177010
## out.natural_gas.fireplace.energy_consumption                177010
## out.natural_gas.grill.energy_consumption                    177010
## out.natural_gas.heating_hp_bkup.energy_consumption          177010
## out.natural_gas.heating.energy_consumption                  177010
## out.natural_gas.hot_tub_heater.energy_consumption           177010
## out.natural_gas.hot_water.energy_consumption                177010
## out.natural_gas.lighting.energy_consumption                 177010
## out.natural_gas.pool_heater.energy_consumption              177010
## out.natural_gas.range_oven.energy_consumption               177010
## out.propane.clothes_dryer.energy_consumption                177010
## out.propane.heating_hp_bkup.energy_consumption              177010
## out.propane.heating.energy_consumption                      177010
## out.propane.hot_water.energy_consumption                    177010
## out.propane.range_oven.energy_consumption                   177010
## time                                                        177010
## Total_Energy_Consumption                                    177010
## Dry Bulb Temperature [°C]                                   177010
## Relative Humidity [%]                                       177010
## Wind Speed [m/s]                                            177010
## Wind Direction [Deg]                                        177010
## Global Horizontal Radiation [W/m2]                          177010
## Direct Normal Radiation [W/m2]                              177010
## Diffuse Horizontal Radiation [W/m2]                         177010
## in.sqft                                                     177010
## in.bedrooms                                                 177010
## in.county.y                                                 177010
## in.geometry_wall_type                                       177010
## in.has_pv                                                   177010
## in.income                                                   177010
## in.occupants                                                177010
## in.roof_material                                            177010
## in.tenure                                                   177010
## in.usage_level                                              177010
## in.vacancy_status                                           177010
## in.vintage                                                  177010
## in.weather_file_city                                        177010
## in.hvac_cooling_efficiency                                  177010
## in.hvac_cooling_partial_space_conditioning                  177010
## in.hvac_cooling_type                                        177010
## upgrade.hvac_cooling_efficiency                             177010
## in.cooling_setpoint                                         177010
## in.cooling_setpoint_has_offset                              177010
## in.cooling_setpoint_offset_magnitude                        177010
## in.cooling_setpoint_offset_period                           177010
##                                                  Percentage_Missing
```

```
## bldg_id                                                    0
## date                                                       0
## in.county.x                                                0
## out.electricity.ceiling_fan.energy_consumption             0
## out.electricity.clothes_dryer.energy_consumption           0
## out.electricity.clothes_washer.energy_consumption          0
## out.electricity.cooling_fans_pumps.energy_consumption      0
## out.electricity.cooling.energy_consumption                 0
## out.electricity.dishwasher.energy_consumption              0
## out.electricity.freezer.energy_consumption                 0
## out.electricity.heating_fans_pumps.energy_consumption      0
## out.electricity.heating_hp_bkup.energy_consumption         0
## out.electricity.heating.energy_consumption                 0
## out.electricity.hot_tub_heater.energy_consumption          0
## out.electricity.hot_tub_pump.energy_consumption            0
## out.electricity.hot_water.energy_consumption               0
## out.electricity.lighting_exterior.energy_consumption       0
## out.electricity.lighting_garage.energy_consumption         0
## out.electricity.lighting_interior.energy_consumption       0
## out.electricity.mech_vent.energy_consumption               0
## out.electricity.plug_loads.energy_consumption              0
## out.electricity.pool_heater.energy_consumption             0
## out.electricity.pool_pump.energy_consumption               0
## out.electricity.pv.energy_consumption                      0
## out.electricity.range_oven.energy_consumption              0
## out.electricity.refrigerator.energy_consumption            0
## out.electricity.well_pump.energy_consumption               0
## out.fuel_oil.heating_hp_bkup.energy_consumption            0
## out.fuel_oil.heating.energy_consumption                    0
## out.fuel_oil.hot_water.energy_consumption                  0
## out.natural_gas.clothes_dryer.energy_consumption           0
## out.natural_gas.fireplace.energy_consumption               0
## out.natural_gas.grill.energy_consumption                   0
## out.natural_gas.heating_hp_bkup.energy_consumption         0
## out.natural_gas.heating.energy_consumption                 0
## out.natural_gas.hot_tub_heater.energy_consumption          0
## out.natural_gas.hot_water.energy_consumption               0
## out.natural_gas.lighting.energy_consumption                0
## out.natural_gas.pool_heater.energy_consumption             0
## out.natural_gas.range_oven.energy_consumption              0
## out.propane.clothes_dryer.energy_consumption               0
## out.propane.heating_hp_bkup.energy_consumption             0
## out.propane.heating.energy_consumption                     0
## out.propane.hot_water.energy_consumption                   0
## out.propane.range_oven.energy_consumption                  0
## time                                                       0
## Total_Energy_Consumption                                   0
## Dry Bulb Temperature [°C]                                  0
## Relative Humidity [%]                                      0
## Wind Speed [m/s]                                           0
## Wind Direction [Deg]                                       0
## Global Horizontal Radiation [W/m2]                         0
## Direct Normal Radiation [W/m2]                             0
## Diffuse Horizontal Radiation [W/m2]                        0
```

```
## in.sqft                                                                    0
## in.bedrooms                                                                0
## in.county.y                                                                0
## in.geometry_wall_type                                                      0
## in.has_pv                                                                  0
## in.income                                                                  0
## in.occupants                                                               0
## in.roof_material                                                           0
## in.tenure                                                                  0
## in.usage_level                                                             0
## in.vacancy_status                                                          0
## in.vintage                                                                 0
## in.weather_file_city                                                       0
## in.hvac_cooling_efficiency                                                 0
## in.hvac_cooling_partial_space_conditioning                                 0
## in.hvac_cooling_type                                                       0
## upgrade.hvac_cooling_efficiency                                            0
## in.cooling_setpoint                                                        0
## in.cooling_setpoint_has_offset                                             0
## in.cooling_setpoint_offset_magnitude                                       0
## in.cooling_setpoint_offset_period                                          0
```

```
##############################################################################
# DATA EXPLORATION VIEWS AND GENERAL QUESTIONS
##############################################################################
##############################################################################
# FILTER COMBINED DATA
##############################################################################

# Inspect Data
cat("Initial number of rows in combined_data:", nrow(combined_data), "\n")
```

```
## Initial number of rows in combined_data: 177010
```

```
# Filter out rows where in.has_pv is "yes"; renewable's have negative usage
combined_data <- combined_data[combined_data$in.has_pv != "yes", ]
cat("After removing rows with PV systems, rows left:", nrow(combined_data), "\n")
```

```
## After removing rows with PV systems, rows left: 177010
```

```
# Remove all renters; they cannot implement strategies
combined_data <- combined_data[combined_data$in.tenure != "renter", ]
cat("After removing renters, rows left:", nrow(combined_data), "\n")
```

```
## After removing renters, rows left: 177010
```

```
# Remove all vacancies
combined_data <- combined_data[combined_data$in.vacancy_status != "vacant", ]
cat("After removing vacant properties, rows left:", nrow(combined_data), "\n")
```

```
## After removing vacant properties, rows left: 177010
```

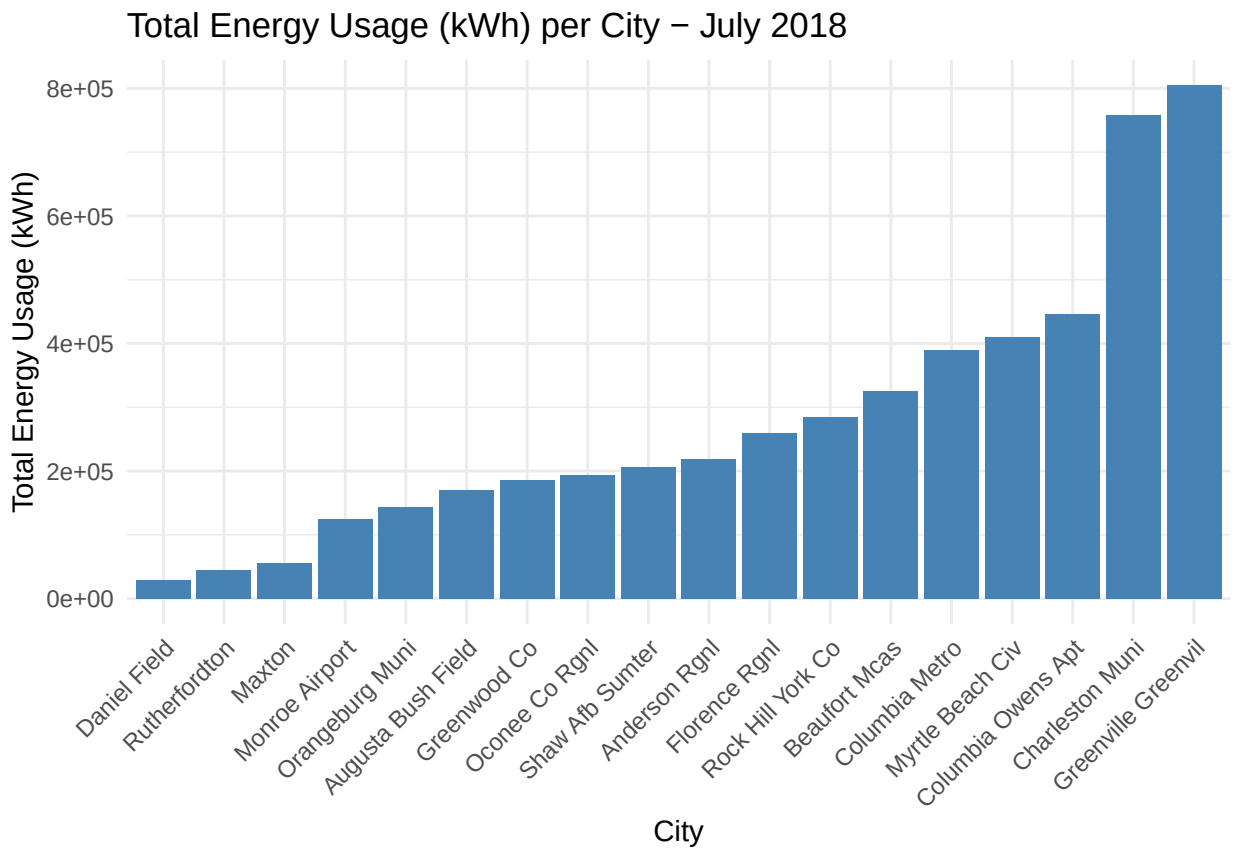
```r
# Check if combined_data is empty
if (nrow(combined_data) == 0) {
  cat("No data available after filtering. Please review the filtering criteria.\n")
  stop("Dataset is empty. Aborting further analysis.")
} else {
  cat("Rows with negative Total Energy Consumption, homes with PV systems, renters, and vacant properti
}
```

```
## Rows with negative Total Energy Consumption, homes with PV systems, renters, and vacant properties ha
```

```r
################################################################################
# 1. In July, What city has the highest energy usage?
################################################################################
county_usage_summary <- combined_data %>%
  group_by(in.weather_file_city) %>%
  summarise(total_usage_kWh = sum(Total_Energy_Consumption, na.rm = TRUE)) %>%
  arrange(desc(total_usage_kWh))

print(county_usage_summary)
```

```
## # A tibble: 18 x 2
##    in.weather_file_city total_usage_kWh
##    <chr>                          <dbl>
##  1 Greenville Greenvil          804704.
##  2 Charleston Muni              757873.
##  3 Columbia Owens Apt           446761.
##  4 Myrtle Beach Civ             410322.
##  5 Columbia Metro               388980.
##  6 Beaufort Mcas                326026.
##  7 Rock Hill York Co            284600.
##  8 Florence Rgnl                260202.
##  9 Anderson Rgnl                217990.
## 10 Shaw Afb Sumter              205539.
## 11 Oconee Co Rgnl               193894.
## 12 Greenwood Co                 186329.
## 13 Augusta Bush Field           170494.
## 14 Orangeburg Muni              143674.
## 15 Monroe Airport               124373.
## 16 Maxton                        55254.
## 17 Rutherfordton                 44902.
## 18 Daniel Field                  28797.
```

```r
barplot <- ggplot(county_usage_summary, aes(x = reorder(in.weather_file_city, total_usage_kWh), y = tota
  geom_bar(stat = "identity", fill = "steelblue") +
  labs(
    title = "Total Energy Usage (kWh) per City - July 2018",
    x = "City",
    y = "Total Energy Usage (kWh)"
  ) +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))

print(barplot)
```

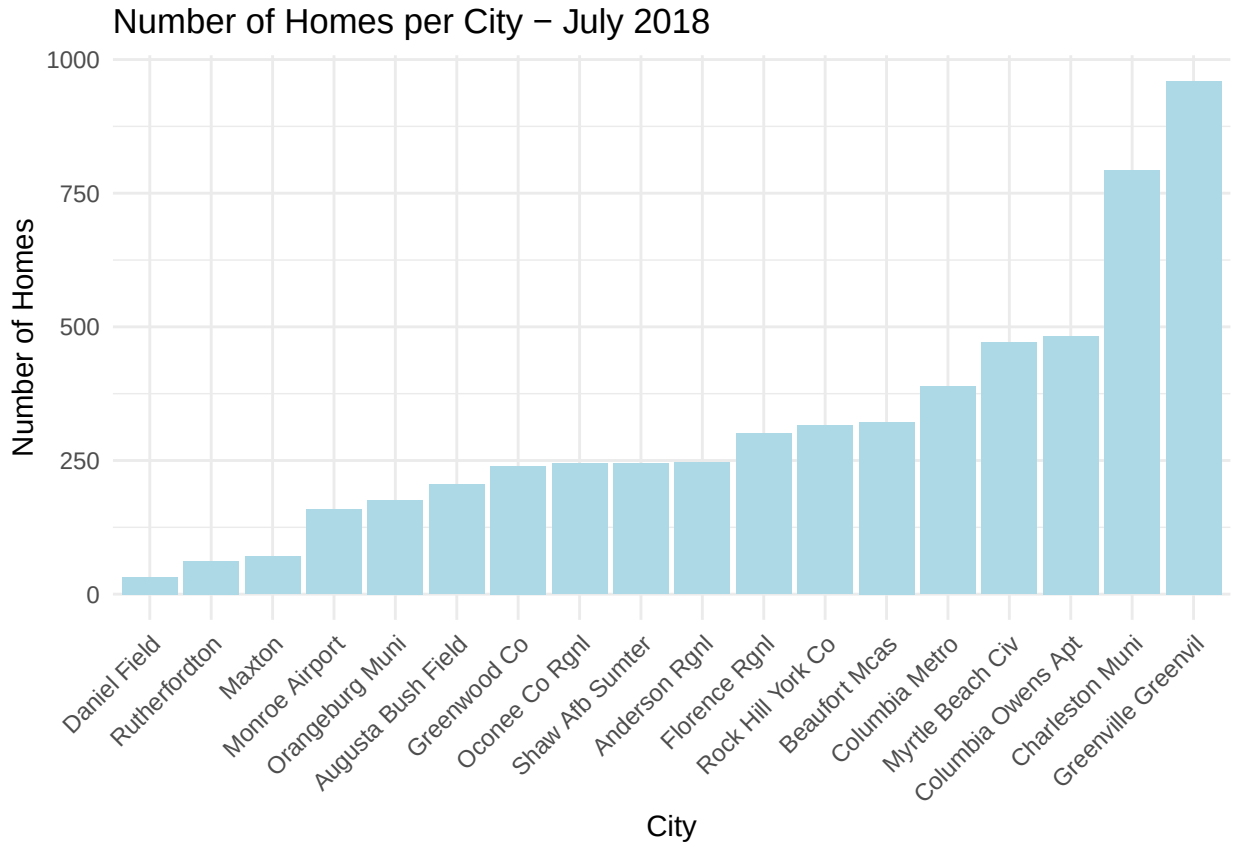



```
################################################################################
# 2. What is the number of homes per city?
################################################################################
homes_per_city <- housing_data %>%
  group_by(in.weather_file_city) %>%
  summarise(num_homes = n_distinct(bldg_id)) %>%
  arrange(desc(num_homes))

print(homes_per_city)
```

```
## # A tibble: 18 x 2
##    in.weather_file_city num_homes
##    <chr>                    <int>
##  1 Greenville Greenvil        960
##  2 Charleston Muni            793
##  3 Columbia Owens Apt         483
##  4 Myrtle Beach Civ           471
##  5 Columbia Metro             388
##  6 Beaufort Mcas              322
##  7 Rock Hill York Co          315
##  8 Florence Rgnl              300
##  9 Anderson Rgnl              246
## 10 Shaw Afb Sumter            245
## 11 Oconee Co Rgnl             244
## 12 Greenwood Co               240
## 13 Augusta Bush Field         205
```

```
## 14 Orangeburg Muni            176
## 15 Monroe Airport             158
## 16 Maxton                      70
## 17 Rutherfordton               62
## 18 Daniel Field                32
```

```
barplot <- ggplot(homes_per_city, aes(x = reorder(in.weather_file_city, num_homes), y = num_homes)) +
  geom_bar(stat = "identity", fill = "lightblue") +
  labs(
    title = "Number of Homes per City - July 2018",
    x = "City",
    y = "Number of Homes"
  ) +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))

print(barplot)
```




```
##############################################################################
# 3. Summarize Metrics per City
##############################################################################
combined_data$EUI <- combined_data$Total_Energy_Consumption / combined_data$in.sqft

summary_metrics <- function(x) {
  c( Min = min(x, na.rm = TRUE),
```

```
    Max = max(x, na.rm = TRUE))
}

city_summary <- aggregate(cbind(in.sqft, Total_Energy_Consumption) ~ in.weather_file_city,
                          data = combined_data,
                          FUN = summary_metrics)

city_summary <- do.call(data.frame, city_summary)
colnames(city_summary) <- c("City", "Min_Size_Sq_Ft", "Max_Size_Sq_Ft",
                            "Min_Total_Energy_Consumption", "Max_Total_Energy_Consumption")

city_summary[, -1] <- round(city_summary[, -1], 2)

cat("Summary Table 1: Home Metrics per City (Average, Min, Max)\n")
```

```
## Summary Table 1: Home Metrics per City (Average, Min, Max)
```

```
print(city_summary)
```

```
##                   City Min_Size_Sq_Ft Max_Size_Sq_Ft
## 1        Anderson Rgnl            328           8194
## 2   Augusta Bush Field            328           8194
## 3        Beaufort Mcas            328           8194
## 4      Charleston Muni            328           8194
## 5       Columbia Metro            633           8194
## 6   Columbia Owens Apt            633           8194
## 7         Daniel Field            885           8194
## 8        Florence Rgnl            328           8194
## 9  Greenville Greenvil            328           8194
## 10        Greenwood Co            633           8194
## 11              Maxton            328           8194
## 12      Monroe Airport            328           8194
## 13    Myrtle Beach Civ            328           8194
## 14      Oconee Co Rgnl            328           8194
## 15     Orangeburg Muni            328           8194
## 16   Rock Hill York Co            328           8194
## 17       Rutherfordton            328           3301
## 18     Shaw Afb Sumter            328           8194
##    Min_Total_Energy_Consumption Max_Total_Energy_Consumption
## 1                        -24.96                        86.71
## 2                        -25.86                       100.36
## 3                        -11.87                       112.96
## 4                        -36.04                       116.42
## 5                        -24.17                       115.27
## 6                          0.90                       106.01
## 7                          9.93                        61.09
## 8                          3.07                        90.29
## 9                        -32.48                       113.40
## 10                       -39.34                        81.86
## 11                         3.02                        81.11
## 12                       -44.59                        89.09
## 13                       -31.69                       113.56
```

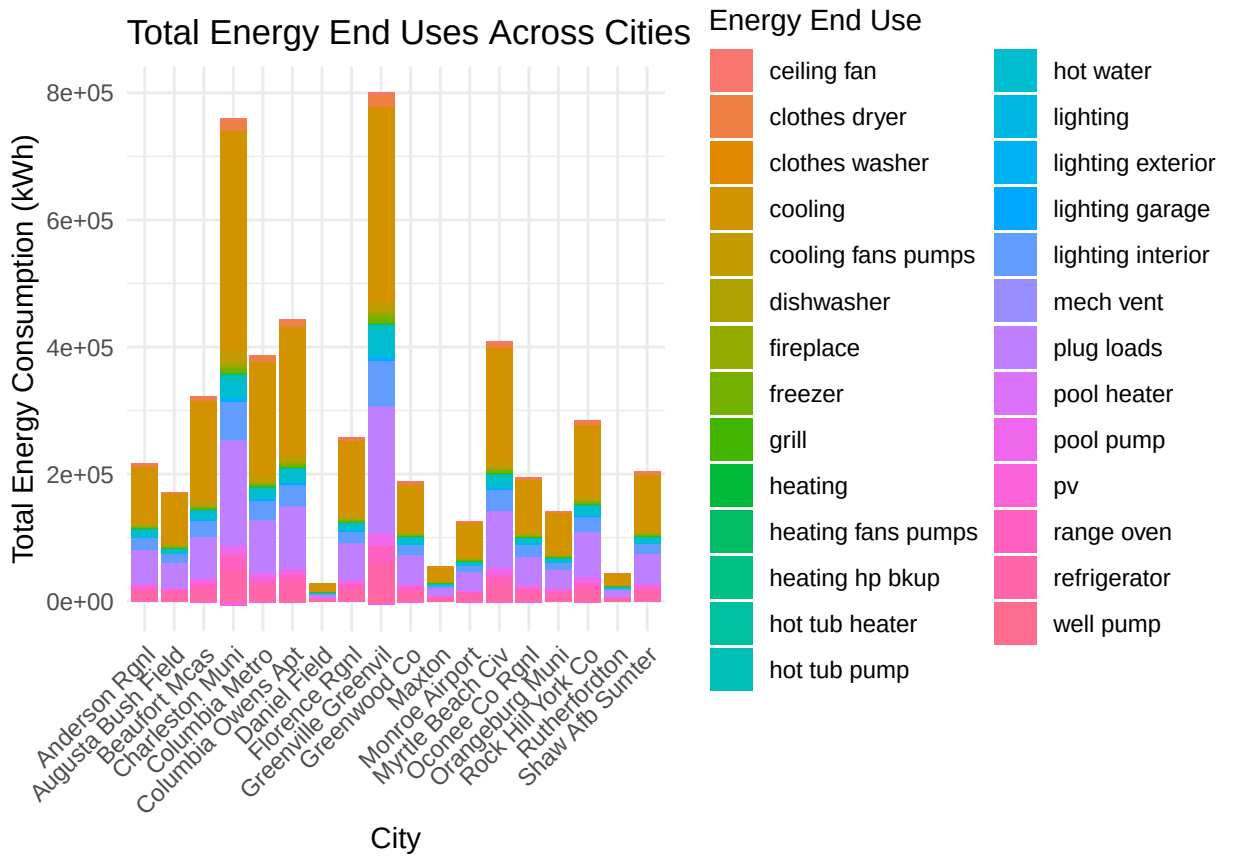
```
## 14                      -39.19                      109.56
## 15                      -19.13                       94.85
## 16                      -22.06                      105.73
## 17                        2.69                       63.79
## 18                      -19.40                       70.40
```

```
################################################################################
# 3. Summarize Energy End Use per City
################################################################################
# Load required library
library(ggplot2)
library(dplyr)
library(tidyr)

# Simplify column names in combined_data
colnames(combined_data) <- gsub("out\\.(electricity|fuel_oil|natural_gas|propane)\\.", "", colnames(comb
colnames(combined_data) <- gsub("\\.energy_consumption", "", colnames(combined_data))
colnames(combined_data) <- gsub("_", " ", colnames(combined_data)) # Replace underscores with spaces

# List of energy consumption columns (after simplification)
energy_columns <- c(
  "ceiling fan",
  "clothes dryer",
  "clothes washer",
  "cooling fans pumps",
  "cooling",
  "dishwasher",
  "freezer",
  "heating fans pumps",
  "heating hp bkup",
  "heating",
  "hot tub heater",
  "hot tub pump",
  "hot water",
  "lighting exterior",
  "lighting garage",
  "lighting interior",
  "mech vent",
  "plug loads",
  "pool heater",
  "pool pump",
  "pv",
  "range oven",
  "refrigerator",
  "well pump",
  "heating hp bkup",
  "heating",
  "hot water",
  "clothes dryer",
  "fireplace",
  "grill",
  "heating hp bkup",
  "heating",
  "hot tub heater",
```

```
  "hot water",
  "lighting",
  "pool heater",
  "range oven",
  "clothes dryer",
  "heating hp bkup",
  "heating",
  "hot water",
  "range oven"
)

# energy consumption by city
city_energy_totals <- combined_data %>%
  select(`in.weather file city`, all_of(energy_columns)) %>%
  group_by(`in.weather file city`) %>%
  summarise(across(everything(), sum, na.rm = TRUE))
```

```
## Warning: There was 1 warning in ‘summarise()‘.
## i In argument: ‘across(everything(), sum, na.rm = TRUE)‘.
## i In group 1: ‘in.weather file city = "Anderson Rgnl"‘.
## Caused by warning:
## ! The ‘...‘ argument of ‘across()‘ is deprecated as of dplyr 1.1.0.
## Supply arguments directly to ‘.fns‘ through an anonymous function instead.
##
##   # Previously
##   across(a:b, mean, na.rm = TRUE)
##
##   # Now
##   across(a:b, \(x) mean(x, na.rm = TRUE))
```

```
# data trasnformation to use in plot
city_energy_totals_long <- city_energy_totals %>%
  pivot_longer(cols = -`in.weather file city`,  # Use all columns except the city column
               names_to = "Energy_End_Use",
               values_to = "Total_Consumption")

# energy end use breakdown plot per city
ggplot(city_energy_totals_long, aes(x = `in.weather file city`, y = Total_Consumption, fill = Energy_En
  geom_bar(stat = "identity") +
  labs(
    title = "Total Energy End Uses Across Cities",
    x = "City",
    y = "Total Energy Consumption (kWh)",
    fill = "Energy End Use"
  ) +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))
```




```
################################################################################
# 4. Summarize End Use Percentage
################################################################################

# Calculate total energy consumption per city for normalization

# total energy consumption across all cities
total_end_use_percentages <- combined_data %>%
  select(all_of(energy_columns)) %>%
  summarise(across(everything(), sum, na.rm = TRUE)) %>%
  mutate(Total_Energy = rowSums(across(everything()), na.rm = TRUE)) %>%
  mutate(across(everything(), ~ (. / Total_Energy) * 100, .names = "percent_{col}")) %>%
  select(starts_with("percent"))

# Reshape the data into a two-column format
total_end_use_percentages_long <- total_end_use_percentages %>%
  pivot_longer(cols = everything(),
               names_to = "Energy_End_Use",
               values_to = "Percentage") %>%
  mutate(
    Energy_End_Use = gsub("percent_out\\.(electricity|fuel_oil|natural_gas|propane)\\.", "", Energy_End
    Energy_End_Use = gsub("\\.energy_consumption", "", Energy_End_Use),
    Energy_End_Use = gsub("_", " ", Energy_End_Use),
    Percentage = round(Percentage, 2)  # Round to 2 decimal places
  )
```

```r
print(total_end_use_percentages_long)
```

```
## # A tibble: 28 x 2
##    Energy_End_Use              Percentage
##    <chr>                            <dbl>
##  1 percent ceiling fan               0.46
##  2 percent clothes dryer             2.3
##  3 percent clothes washer            0.24
##  4 percent cooling fans pumps        2.4
##  5 percent cooling                  43.1
##  6 percent dishwasher                0.4
##  7 percent freezer                   1.27
##  8 percent heating fans pumps        0
##  9 percent heating hp bkup           0
## 10 percent heating                   0.01
## # i 18 more rows
```

```r
################################################################################
# 4. Summarize HVAC Type vs Overall Energy Use
################################################################################

# Ensure all column names in combined_data are unique and syntactically valid
colnames(combined_data) <- make.names(colnames(combined_data), unique = TRUE)

hvac_cooling_summary <- combined_data %>%
  group_by(`bldg.id`, `in.hvac.cooling.type`) %>%
  summarise(
    Home_Count = n_distinct(bldg.id),
    # Count the number of unique homes for each building and HVAC type
    Total_Cooling_Energy = sum(cooling, na.rm = TRUE),
    # Total cooling energy for this group
    Cooling_Efficiency_Labels = paste(unique(`in.hvac.cooling.efficiency`), collapse = ", ")
    # Efficiency rating type for each cooling equipment per home
  ) %>%
  ungroup() %>%
  group_by(`in.hvac.cooling.type`) %>%
  summarise(
    Total_Homes = sum(Home_Count),
    # Total number of homes with each HVAC type
    Total_Cooling_Energy = sum(Total_Cooling_Energy, na.rm = TRUE),
    Cooling_Efficiency_Labels = paste(unique(Cooling_Efficiency_Labels), collapse = ", ")
  ) %>%
  mutate(
    Percentage_Cooling = (Total_Cooling_Energy / sum(Total_Cooling_Energy, na.rm = TRUE)) * 100
  ) %>%
  select(`in.hvac.cooling.type`, Total_Homes, Percentage_Cooling, Cooling_Efficiency_Labels)
```

```
## `summarise()` has grouped output by 'bldg.id'. You can override using the
## `.groups` argument.
```

```r
hvac_cooling_summary <- hvac_cooling_summary %>%
  mutate(Percentage_Cooling = round(Percentage_Cooling, 2)) # clean up data
```

```r
print(hvac_cooling_summary)
```

```
## # A tibble: 4 x 4
##   in.hvac.cooling.type Total_Homes Percentage_Cooling Cooling_Efficiency_Labels
##   <chr>                      <int>              <dbl> <chr>
## 1 Central AC                  3710              67.2  AC, SEER 15, AC, SEER 13,~
## 2 Heat Pump                   1244              22.7  Heat Pump
## 3 None                         125               1.78 None
## 4 Room AC                      631               8.3  Room AC, EER 10.7, Room A~
```

```r
################################################################################
# Hourly Data Import and Cleaning
################################################################################
library(data.table)
library(dplyr)

housing_file <- "~/Downloads/filtered_housing_data.csv"
weather_hourly_file <- "~/Downloads/combined_july_weather_data.csv"
energy_hourly_file <- "~/Downloads/combined_energy_usage_data.csv"
output_hourly_file <- "~/Downloads/final_hourly_combined_data.csv"

housing_data <- fread(housing_file)
weather_hourly_data <- fread(weather_hourly_file)
energy_hourly_data <- fread(energy_hourly_file)

colnames(housing_data) <- make.names(colnames(housing_data), unique = TRUE)
colnames(weather_hourly_data) <- make.names(colnames(weather_hourly_data), unique = TRUE)
colnames(energy_hourly_data) <- make.names(colnames(energy_hourly_data), unique = TRUE)

# Add `in.county` to energy data by matching `bldg_id` from housing data
if ("bldg_id" %in% colnames(housing_data) && "bldg_id" %in% colnames(energy_hourly_data)) {
  message("Adding `in.county` column to energy data...")
  energy_hourly_data <- merge(
    energy_hourly_data,
    housing_data[, .(bldg_id, in.county)],
    by = "bldg_id",
    all.x = TRUE
  )
} else {
  stop("`bldg_id` column is missing in housing or energy data.")
}
```

```
## Adding ‘in.county‘ column to energy data...
```

```r
# Add `date` column to weather_hourly_data if it only has `date_time`
if ("date_time" %in% colnames(weather_hourly_data)) {
  message("Extracting `date` from `date_time` in weather_hourly_data...")
  weather_hourly_data[, date := as.Date(date_time, format = "%Y-%m-%d %H:%M:%S")]
} else {
  stop("`date_time` column is missing in weather_hourly_data.")
}
```

```
## Extracting ‘date‘ from ‘date_time‘ in weather_hourly_data...
```

```
# Standardize `date` columns
message("Standardizing `date` column formats...")
```

```
## Standardizing ‘date‘ column formats...
```

```
if ("date" %in% colnames(weather_hourly_data)) {
  weather_hourly_data[, date := as.Date(as.character(date), format = "%Y-%m-%d")]
}
if ("date" %in% colnames(energy_hourly_data)) {
  energy_hourly_data[, date := as.Date(as.character(date), format = "%Y-%m-%d")]
}

message("Deduplicating data...") # without it causes an error on merge
```

```
## Deduplicating data...
```

```
weather_hourly_data <- unique(weather_hourly_data, by = c("date", "in.county"))
energy_hourly_data <- unique(energy_hourly_data, by = c("date", "in.county"))

# Merge energy and weather data
if (all(c("date", "in.county") %in% colnames(weather_hourly_data)) &&
    all(c("date", "in.county") %in% colnames(energy_hourly_data))) {
  message("Combining energy and weather data...")
  combined_hourly_data <- merge(
    energy_hourly_data,
    weather_hourly_data,
    by = c("date", "in.county"),
    all.x = TRUE,
    allow.cartesian = TRUE # Allow Cartesian join if needed
  )
} else {
  stop("Required keys (`date`, `in.county`) are missing in weather or energy data.")
}
```

```
## Combining energy and weather data...
```

```
# add housing data with the combined dataset
if ("bldg_id" %in% colnames(combined_hourly_data) && "bldg_id" %in% colnames(housing_data)) {
  message("Adding housing data to the combined dataset...")
  combined_hourly_data <- merge(
    combined_hourly_data,
    housing_data, # Merge all columns of housing_data
    by = "bldg_id",
    all.x = TRUE
  )
} else {
  stop("`bldg_id` column is missing in combined or housing data.")
}
```

```
## Adding housing data to the combined dataset...
```

```r
# output hourly combinded data set
fwrite(combined_hourly_data, output_hourly_file)
message("Final combined data saved to: ", output_hourly_file)
```

```
## Final combined data saved to: ~/Downloads/final_hourly_combined_data.csv
```

```r
print(head(combined_hourly_data))
```

```
## Key: <bldg_id>
##    bldg_id       date in.county.x
##      <int>     <Date>      <char>
## 1:      65 2018-07-01    G4500910
## 2:      65 2018-07-02    G4500910
## 3:      65 2018-07-03    G4500910
## 4:      65 2018-07-04    G4500910
## 5:      65 2018-07-05    G4500910
## 6:      65 2018-07-06    G4500910
##    out.electricity.ceiling_fan.energy_consumption
##                                             <num>
## 1:                                          0.005
## 2:                                          0.009
## 3:                                          0.009
## 4:                                          0.009
## 5:                                          0.009
## 6:                                          0.006
##    out.electricity.clothes_dryer.energy_consumption
##                                               <num>
## 1:                                            0.000
## 2:                                            0.000
## 3:                                            0.000
## 4:                                            0.677
## 5:                                            0.000
## 6:                                            0.000
##    out.electricity.clothes_washer.energy_consumption
##                                                <num>
## 1:                                             0.000
## 2:                                             0.000
## 3:                                             0.000
## 4:                                             0.184
## 5:                                             0.000
## 6:                                             0.000
##    out.electricity.cooling_fans_pumps.energy_consumption
##                                                    <num>
## 1:                                                 0.017
## 2:                                                 0.023
## 3:                                                 0.024
## 4:                                                 0.053
## 5:                                                 0.016
## 6:                                                 0.028
##    out.electricity.cooling.energy_consumption
##                                         <num>
## 1:                                      0.316
```

```
## 2:                                       0.386
## 3:                                       0.377
## 4:                                       0.760
## 5:                                       0.299
## 6:                                       0.451
##    out.electricity.dishwasher.energy_consumption
##                                             <num>
## 1:                                              0
## 2:                                              0
## 3:                                              0
## 4:                                              0
## 5:                                              0
## 6:                                              0
##    out.electricity.freezer.energy_consumption
##                                         <num>
## 1:                                      0.037
## 2:                                      0.044
## 3:                                      0.044
## 4:                                      0.044
## 5:                                      0.044
## 6:                                      0.044
##    out.electricity.heating_fans_pumps.energy_consumption
##                                                    <num>
## 1:                                                     0
## 2:                                                     0
## 3:                                                     0
## 4:                                                     0
## 5:                                                     0
## 6:                                                     0
##    out.electricity.heating_hp_bkup.energy_consumption
##                                                 <int>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.electricity.heating.energy_consumption
##                                         <num>
## 1:                                          0
## 2:                                          0
## 3:                                          0
## 4:                                          0
## 5:                                          0
## 6:                                          0
##    out.electricity.hot_tub_heater.energy_consumption
##                                                 <num>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.electricity.hot_tub_pump.energy_consumption
```

```
##                                            <num>
## 1:                                             0
## 2:                                             0
## 3:                                             0
## 4:                                             0
## 5:                                             0
## 6:                                             0
##    out.electricity.hot_water.energy_consumption
##                                           <num>
## 1:                                        0.004
## 2:                                        0.004
## 3:                                        0.238
## 4:                                        0.004
## 5:                                        0.215
## 6:                                        0.004
##    out.electricity.lighting_exterior.energy_consumption
##                                                   <num>
## 1:                                                0.012
## 2:                                                0.021
## 3:                                                0.021
## 4:                                                0.021
## 5:                                                0.021
## 6:                                                0.021
##    out.electricity.lighting_garage.energy_consumption
##                                                 <num>
## 1:                                              0.008
## 2:                                              0.013
## 3:                                              0.013
## 4:                                              0.013
## 5:                                              0.013
## 6:                                              0.013
##    out.electricity.lighting_interior.energy_consumption
##                                                   <num>
## 1:                                                0.031
## 2:                                                0.198
## 3:                                                0.227
## 4:                                                0.221
## 5:                                                0.221
## 6:                                                0.086
##    out.electricity.mech_vent.energy_consumption
##                                           <num>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.electricity.plug_loads.energy_consumption
##                                           <num>
## 1:                                        0.226
## 2:                                        0.240
## 3:                                        0.244
## 4:                                        0.241
## 5:                                        0.241
```

```
## 6:                                          0.235
##    out.electricity.pool_heater.energy_consumption
##                                             <num>
## 1:                                                0
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.electricity.pool_pump.energy_consumption
##                                           <num>
## 1:                                               0
## 2:                                               0
## 3:                                               0
## 4:                                               0
## 5:                                               0
## 6:                                               0
##    out.electricity.pv.energy_consumption
##                                    <num>
## 1:                                     0
## 2:                                     0
## 3:                                     0
## 4:                                     0
## 5:                                     0
## 6:                                     0
##    out.electricity.range_oven.energy_consumption
##                                             <num>
## 1:                                                0
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.electricity.refrigerator.energy_consumption
##                                                <num>
## 1:                                             0.210
## 2:                                             0.239
## 3:                                             0.239
## 4:                                             0.239
## 5:                                             0.239
## 6:                                             0.239
##    out.electricity.well_pump.energy_consumption
##                                           <num>
## 1:                                               0
## 2:                                               0
## 3:                                               0
## 4:                                               0
## 5:                                               0
## 6:                                               0
##    out.fuel_oil.heating_hp_bkup.energy_consumption
##                                              <int>
## 1:                                                0
## 2:                                                0
## 3:                                                0
```

```
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.fuel_oil.heating.energy_consumption
##                                       <int>
## 1:                                        0
## 2:                                        0
## 3:                                        0
## 4:                                        0
## 5:                                        0
## 6:                                        0
##    out.fuel_oil.hot_water.energy_consumption
##                                         <int>
## 1:                                          0
## 2:                                          0
## 3:                                          0
## 4:                                          0
## 5:                                          0
## 6:                                          0
##    out.natural_gas.clothes_dryer.energy_consumption
##                                               <int>
## 1:                                                0
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.natural_gas.fireplace.energy_consumption
##                                           <num>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.natural_gas.grill.energy_consumption
##                                       <num>
## 1:                                        0
## 2:                                        0
## 3:                                        0
## 4:                                        0
## 5:                                        0
## 6:                                        0
##    out.natural_gas.heating_hp_bkup.energy_consumption
##                                                 <int>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.natural_gas.heating.energy_consumption
##                                         <int>
## 1:                                          0
```

```
## 2:                                          0
## 3:                                          0
## 4:                                          0
## 5:                                          0
## 6:                                          0
##    out.natural_gas.hot_tub_heater.energy_consumption
##                                                <num>
## 1:                                                 0
## 2:                                                 0
## 3:                                                 0
## 4:                                                 0
## 5:                                                 0
## 6:                                                 0
##    out.natural_gas.hot_water.energy_consumption
##                                           <int>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.natural_gas.lighting.energy_consumption
##                                          <num>
## 1:                                           0
## 2:                                           0
## 3:                                           0
## 4:                                           0
## 5:                                           0
## 6:                                           0
##    out.natural_gas.pool_heater.energy_consumption
##                                             <num>
## 1:                                              0
## 2:                                              0
## 3:                                              0
## 4:                                              0
## 5:                                              0
## 6:                                              0
##    out.natural_gas.range_oven.energy_consumption
##                                            <int>
## 1:                                             0
## 2:                                             0
## 3:                                             0
## 4:                                             0
## 5:                                             0
## 6:                                             0
##    out.propane.clothes_dryer.energy_consumption
##                                           <int>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.propane.heating_hp_bkup.energy_consumption
```

```
##                                          <int>
## 1:                                           0
## 2:                                           0
## 3:                                           0
## 4:                                           0
## 5:                                           0
## 6:                                           0
##    out.propane.heating.energy_consumption
##                                     <int>
## 1:                                      0
## 2:                                      0
## 3:                                      0
## 4:                                      0
## 5:                                      0
## 6:                                      0
##    out.propane.hot_water.energy_consumption
##                                       <int>
## 1:                                        0
## 2:                                        0
## 3:                                        0
## 4:                                        0
## 5:                                        0
## 6:                                        0
##    out.propane.range_oven.energy_consumption                time
##                                        <int>              <POSc>
## 1:                                         0 2018-07-01 04:00:00
## 2:                                         0 2018-07-02 01:00:00
## 3:                                         0 2018-07-03 01:00:00
## 4:                                         0 2018-07-04 01:00:00
## 5:                                         0 2018-07-05 01:00:00
## 6:                                         0 2018-07-06 01:00:00
##              date_time Dry.Bulb.Temperature...C. Relative.Humidity....
##                 <POSc>                   <num>                  <num>
## 1: 2018-07-01 01:00:00                   25.00                  87.61
## 2: 2018-07-02 01:00:00                   23.87                  94.83
## 3: 2018-07-03 01:00:00                   23.30                 100.00
## 4: 2018-07-04 01:00:00                   26.10                  82.07
## 5: 2018-07-05 01:00:00                   25.60                  81.51
## 6: 2018-07-06 01:00:00                   24.40                  90.81
##    Wind.Speed..m.s. Wind.Direction..Deg. Global.Horizontal.Radiation..W.m2.
##               <num>                <num>                                <num>
## 1:                0                62.31                                    0
## 2:                0                 0.00                                    0
## 3:                0                82.31                                    0
## 4:                0                 0.00                                    0
## 5:                0                26.92                                    0
## 6:                0                 0.00                                    0
##    Direct.Normal.Radiation..W.m2. Diffuse.Horizontal.Radiation..W.m2. in.sqft
##                             <num>                                <num>   <int>
## 1:                              0                                    0     885
## 2:                              0                                    0     885
## 3:                              0                                    0     885
## 4:                              0                                    0     885
## 5:                              0                                    0     885
```

```
## 6:                              0                                     0     885
##    in.bedrooms in.county.y in.geometry_wall_type in.has_pv   in.income
##          <int>      <char>                <char>    <char>      <char>
## 1:           3    G4500910            Wood Frame        No 10000-14999
## 2:           3    G4500910            Wood Frame        No 10000-14999
## 3:           3    G4500910            Wood Frame        No 10000-14999
## 4:           3    G4500910            Wood Frame        No 10000-14999
## 5:           3    G4500910            Wood Frame        No 10000-14999
## 6:           3    G4500910            Wood Frame        No 10000-14999
##    in.occupants     in.roof_material in.tenure in.usage_level in.vacancy_status
##          <char>               <char>    <char>         <char>            <char>
## 1:           3 Composition Shingles    Renter         Medium          Occupied
## 2:           3 Composition Shingles    Renter         Medium          Occupied
## 3:           3 Composition Shingles    Renter         Medium          Occupied
## 4:           3 Composition Shingles    Renter         Medium          Occupied
## 5:           3 Composition Shingles    Renter         Medium          Occupied
## 6:           3 Composition Shingles    Renter         Medium          Occupied
##    in.vintage in.weather_file_city in.hvac_cooling_efficiency
##        <char>               <char>                    <char>
## 1:      1950s    Rock Hill York Co                AC, SEER 15
## 2:      1950s    Rock Hill York Co                AC, SEER 15
## 3:      1950s    Rock Hill York Co                AC, SEER 15
## 4:      1950s    Rock Hill York Co                AC, SEER 15
## 5:      1950s    Rock Hill York Co                AC, SEER 15
## 6:      1950s    Rock Hill York Co                AC, SEER 15
##    in.hvac_cooling_partial_space_conditioning in.hvac_cooling_type
##                                        <char>              <char>
## 1:                          100% Conditioned           Central AC
## 2:                          100% Conditioned           Central AC
## 3:                          100% Conditioned           Central AC
## 4:                          100% Conditioned           Central AC
## 5:                          100% Conditioned           Central AC
## 6:                          100% Conditioned           Central AC
##    upgrade.hvac_cooling_efficiency in.cooling_setpoint
##                             <char>              <char>
## 1:                      Heat Pump                 72F
## 2:                      Heat Pump                 72F
## 3:                      Heat Pump                 72F
## 4:                      Heat Pump                 72F
## 5:                      Heat Pump                 72F
## 6:                      Heat Pump                 72F
##    in.cooling_setpoint_has_offset in.cooling_setpoint_offset_magnitude
##                            <char>                                <char>
## 1:                             No                                    0F
## 2:                             No                                    0F
## 3:                             No                                    0F
## 4:                             No                                    0F
## 5:                             No                                    0F
## 6:                             No                                    0F
##    in.cooling_setpoint_offset_period
##                               <char>
## 1:                              None
## 2:                              None
## 3:                              None
```

```
## 4:                              None
## 5:                              None
## 6:                              None
```

```
print(tail(combined_hourly_data))
```

```
## Key: <bldg_id>
##    bldg_id       date in.county.x
##      <int>     <Date>      <char>
## 1:  103412 2018-07-26    G4500810
## 2:  103412 2018-07-27    G4500810
## 3:  103412 2018-07-28    G4500810
## 4:  103412 2018-07-29    G4500810
## 5:  103412 2018-07-30    G4500810
## 6:  103412 2018-07-31    G4500810
##    out.electricity.ceiling_fan.energy_consumption
##                                             <num>
## 1:                                          0.012
## 2:                                          0.009
## 3:                                          0.012
## 4:                                          0.015
## 5:                                          0.009
## 6:                                          0.009
##    out.electricity.clothes_dryer.energy_consumption
##                                               <num>
## 1:                                                0
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.electricity.clothes_washer.energy_consumption
##                                                 <num>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.electricity.cooling_fans_pumps.energy_consumption
##                                                    <num>
## 1:                                                 0.016
## 2:                                                 0.016
## 3:                                                 0.020
## 4:                                                 0.020
## 5:                                                 0.008
## 6:                                                 0.018
##    out.electricity.cooling.energy_consumption
##                                         <num>
## 1:                                      0.333
## 2:                                      0.326
## 3:                                      0.398
## 4:                                      0.420
## 5:                                      0.180
```

```
## 6:                                      0.369
##    out.electricity.dishwasher.energy_consumption
##                                            <num>
## 1:                                             0
## 2:                                             0
## 3:                                             0
## 4:                                             0
## 5:                                             0
## 6:                                             0
##    out.electricity.freezer.energy_consumption
##                                         <num>
## 1:                                      0.044
## 2:                                      0.044
## 3:                                      0.044
## 4:                                      0.044
## 5:                                      0.044
## 6:                                      0.044
##    out.electricity.heating_fans_pumps.energy_consumption
##                                                    <num>
## 1:                                                     0
## 2:                                                     0
## 3:                                                     0
## 4:                                                     0
## 5:                                                     0
## 6:                                                     0
##    out.electricity.heating_hp_bkup.energy_consumption
##                                                 <int>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.electricity.heating.energy_consumption
##                                         <num>
## 1:                                          0
## 2:                                          0
## 3:                                          0
## 4:                                          0
## 5:                                          0
## 6:                                          0
##    out.electricity.hot_tub_heater.energy_consumption
##                                                 <num>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.electricity.hot_tub_pump.energy_consumption
##                                               <num>
## 1:                                                0
## 2:                                                0
## 3:                                                0
```

```
## 4:                                                 0
## 5:                                                 0
## 6:                                                 0
##    out.electricity.hot_water.energy_consumption
##                                           <num>
## 1:                                        0.004
## 2:                                        0.242
## 3:                                        0.004
## 4:                                        0.004
## 5:                                        0.204
## 6:                                        0.004
##    out.electricity.lighting_exterior.energy_consumption
##                                                   <num>
## 1:                                                0.025
## 2:                                                0.025
## 3:                                                0.025
## 4:                                                0.025
## 5:                                                0.025
## 6:                                                0.025
##    out.electricity.lighting_garage.energy_consumption
##                                                 <num>
## 1:                                              0.013
## 2:                                              0.013
## 3:                                              0.013
## 4:                                              0.013
## 5:                                              0.013
## 6:                                              0.013
##    out.electricity.lighting_interior.energy_consumption
##                                                   <num>
## 1:                                                0.454
## 2:                                                0.253
## 3:                                                0.454
## 4:                                                0.606
## 5:                                                0.313
## 6:                                                0.313
##    out.electricity.mech_vent.energy_consumption
##                                           <num>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.electricity.plug_loads.energy_consumption
##                                           <num>
## 1:                                        0.282
## 2:                                        0.275
## 3:                                        0.282
## 4:                                        0.291
## 5:                                        0.279
## 6:                                        0.279
##    out.electricity.pool_heater.energy_consumption
##                                             <num>
## 1:                                              0
```

```
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.electricity.pool_pump.energy_consumption
##                                           <num>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.electricity.pv.energy_consumption
##                                   <num>
## 1:                                    0
## 2:                                    0
## 3:                                    0
## 4:                                    0
## 5:                                    0
## 6:                                    0
##    out.electricity.range_oven.energy_consumption
##                                             <num>
## 1:                                              0
## 2:                                              0
## 3:                                              0
## 4:                                              0
## 5:                                              0
## 6:                                              0
##    out.electricity.refrigerator.energy_consumption
##                                                <num>
## 1:                                             0.117
## 2:                                             0.117
## 3:                                             0.117
## 4:                                             0.117
## 5:                                             0.117
## 6:                                             0.117
##    out.electricity.well_pump.energy_consumption
##                                           <num>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.fuel_oil.heating_hp_bkup.energy_consumption
##                                               <int>
## 1:                                                0
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.fuel_oil.heating.energy_consumption
```

```
##                                     <int>
## 1:                                      0
## 2:                                      0
## 3:                                      0
## 4:                                      0
## 5:                                      0
## 6:                                      0
##    out.fuel_oil.hot_water.energy_consumption
##                                        <int>
## 1:                                         0
## 2:                                         0
## 3:                                         0
## 4:                                         0
## 5:                                         0
## 6:                                         0
##    out.natural_gas.clothes_dryer.energy_consumption
##                                               <int>
## 1:                                                0
## 2:                                                0
## 3:                                                0
## 4:                                                0
## 5:                                                0
## 6:                                                0
##    out.natural_gas.fireplace.energy_consumption
##                                           <num>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.natural_gas.grill.energy_consumption
##                                       <num>
## 1:                                        0
## 2:                                        0
## 3:                                        0
## 4:                                        0
## 5:                                        0
## 6:                                        0
##    out.natural_gas.heating_hp_bkup.energy_consumption
##                                                 <int>
## 1:                                                  0
## 2:                                                  0
## 3:                                                  0
## 4:                                                  0
## 5:                                                  0
## 6:                                                  0
##    out.natural_gas.heating.energy_consumption
##                                         <int>
## 1:                                          0
## 2:                                          0
## 3:                                          0
## 4:                                          0
## 5:                                          0
```

```
## 6:                                          0
##    out.natural_gas.hot_tub_heater.energy_consumption
##                                                <num>
## 1:                                                 0
## 2:                                                 0
## 3:                                                 0
## 4:                                                 0
## 5:                                                 0
## 6:                                                 0
##    out.natural_gas.hot_water.energy_consumption
##                                           <int>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.natural_gas.lighting.energy_consumption
##                                          <num>
## 1:                                           0
## 2:                                           0
## 3:                                           0
## 4:                                           0
## 5:                                           0
## 6:                                           0
##    out.natural_gas.pool_heater.energy_consumption
##                                              <num>
## 1:                                               0
## 2:                                               0
## 3:                                               0
## 4:                                               0
## 5:                                               0
## 6:                                               0
##    out.natural_gas.range_oven.energy_consumption
##                                             <int>
## 1:                                              0
## 2:                                              0
## 3:                                              0
## 4:                                              0
## 5:                                              0
## 6:                                              0
##    out.propane.clothes_dryer.energy_consumption
##                                           <int>
## 1:                                            0
## 2:                                            0
## 3:                                            0
## 4:                                            0
## 5:                                            0
## 6:                                            0
##    out.propane.heating_hp_bkup.energy_consumption
##                                             <int>
## 1:                                              0
## 2:                                              0
## 3:                                              0
```

```
## 4:                                          0
## 5:                                          0
## 6:                                          0
##    out.propane.heating.energy_consumption
##                                     <int>
## 1:                                      0
## 2:                                      0
## 3:                                      0
## 4:                                      0
## 5:                                      0
## 6:                                      0
##    out.propane.hot_water.energy_consumption
##                                       <int>
## 1:                                        0
## 2:                                        0
## 3:                                        0
## 4:                                        0
## 5:                                        0
## 6:                                        0
##    out.propane.range_oven.energy_consumption                time
##                                        <int>              <POSc>
## 1:                                         0 2018-07-26 01:00:00
## 2:                                         0 2018-07-27 01:00:00
## 3:                                         0 2018-07-28 01:00:00
## 4:                                         0 2018-07-29 01:00:00
## 5:                                         0 2018-07-30 01:00:00
## 6:                                         0 2018-07-31 01:00:00
##              date_time Dry.Bulb.Temperature...C. Relative.Humidity....
##                 <POSc>                    <num>                 <num>
## 1: 2018-07-26 01:00:00                     21.7                100.00
## 2: 2018-07-27 01:00:00                     21.7                 96.39
## 3: 2018-07-28 01:00:00                     21.7                 96.39
## 4: 2018-07-29 01:00:00                     22.2                 93.49
## 5: 2018-07-30 01:00:00                     21.1                100.00
## 6: 2018-07-31 01:00:00                     23.9                 90.22
##    Wind.Speed..m.s. Wind.Direction..Deg. Global.Horizontal.Radiation..W.m2.
##               <num>                <num>                                <num>
## 1:              1.5               260.00                                    0
## 2:              0.0                60.00                                    0
## 3:              0.0                 0.00                                    0
## 4:              2.1                20.00                                    0
## 5:              0.0                33.33                                    0
## 6:              3.1               200.00                                    0
##    Direct.Normal.Radiation..W.m2. Diffuse.Horizontal.Radiation..W.m2. in.sqft
##                             <num>                                <num>   <int>
## 1:                              0                                    0    1690
## 2:                              0                                    0    1690
## 3:                              0                                    0    1690
## 4:                              0                                    0    1690
## 5:                              0                                    0    1690
## 6:                              0                                    0    1690
##    in.bedrooms in.county.y in.geometry_wall_type in.has_pv   in.income
##          <int>      <char>                <char>    <char>      <char>
## 1:           4    G4500810            Wood Frame        No 60000-69999
```

```
## 2:           4    G4500810            Wood Frame        No 60000-69999
## 3:           4    G4500810            Wood Frame        No 60000-69999
## 4:           4    G4500810            Wood Frame        No 60000-69999
## 5:           4    G4500810            Wood Frame        No 60000-69999
## 6:           4    G4500810            Wood Frame        No 60000-69999
##    in.occupants     in.roof_material in.tenure in.usage_level in.vacancy_status
##          <char>               <char>    <char>         <char>            <char>
## 1:            3 Composition Shingles     Owner         Medium          Occupied
## 2:            3 Composition Shingles     Owner         Medium          Occupied
## 3:            3 Composition Shingles     Owner         Medium          Occupied
## 4:            3 Composition Shingles     Owner         Medium          Occupied
## 5:            3 Composition Shingles     Owner         Medium          Occupied
## 6:            3 Composition Shingles     Owner         Medium          Occupied
##    in.vintage in.weather_file_city in.hvac_cooling_efficiency
##        <char>              <char>                     <char>
## 1:      1990s         Greenwood Co                  Heat Pump
## 2:      1990s         Greenwood Co                  Heat Pump
## 3:      1990s         Greenwood Co                  Heat Pump
## 4:      1990s         Greenwood Co                  Heat Pump
## 5:      1990s         Greenwood Co                  Heat Pump
## 6:      1990s         Greenwood Co                  Heat Pump
##    in.hvac_cooling_partial_space_conditioning in.hvac_cooling_type
##                                        <char>               <char>
## 1:                          100% Conditioned            Heat Pump
## 2:                          100% Conditioned            Heat Pump
## 3:                          100% Conditioned            Heat Pump
## 4:                          100% Conditioned            Heat Pump
## 5:                          100% Conditioned            Heat Pump
## 6:                          100% Conditioned            Heat Pump
##    upgrade.hvac_cooling_efficiency in.cooling_setpoint
##                             <char>              <char>
## 1:                      Heat Pump                 75F
## 2:                      Heat Pump                 75F
## 3:                      Heat Pump                 75F
## 4:                      Heat Pump                 75F
## 5:                      Heat Pump                 75F
## 6:                      Heat Pump                 75F
##    in.cooling_setpoint_has_offset in.cooling_setpoint_offset_magnitude
##                            <char>                                <char>
## 1:                            Yes                                    2F
## 2:                            Yes                                    2F
## 3:                            Yes                                    2F
## 4:                            Yes                                    2F
## 5:                            Yes                                    2F
## 6:                            Yes                                    2F
##    in.cooling_setpoint_offset_period
##                               <char>
## 1:           Day and Night Setup -5h
## 2:           Day and Night Setup -5h
## 3:           Day and Night Setup -5h
## 4:           Day and Night Setup -5h
## 5:           Day and Night Setup -5h
## 6:           Day and Night Setup -5h
```

```r
str(combined_hourly_data)
```

```
## Classes 'data.table' and 'data.frame':   1426 obs. of  75 variables:
##  $ bldg_id                                              : int  65 65 65 65 65 65 65 65 65 65 ...
##  $ date                                                 : Date, format: "2018-07-01" "2018-07-02" ..
##  $ in.county.x                                          : chr  "G4500910" "G4500910" "G4500910" "G450
##  $ out.electricity.ceiling_fan.energy_consumption       : num  0.005 0.009 0.009 0.009 0.009 0.006 0
##  $ out.electricity.clothes_dryer.energy_consumption     : num  0 0 0 0.677 0 0 0 0.143 0 0 ...
##  $ out.electricity.clothes_washer.energy_consumption    : num  0 0 0 0.184 0 0 0 0 0 0 ...
##  $ out.electricity.cooling_fans_pumps.energy_consumption: num  0.017 0.023 0.024 0.053 0.016 0.028 0
##  $ out.electricity.cooling.energy_consumption           : num  0.316 0.386 0.377 0.76 0.299 0.451 0.1
##  $ out.electricity.dishwasher.energy_consumption        : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.freezer.energy_consumption           : num  0.037 0.044 0.044 0.044 0.044 0.044 0
##  $ out.electricity.heating_fans_pumps.energy_consumption: num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.heating_hp_bkup.energy_consumption   : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.heating.energy_consumption           : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.hot_tub_heater.energy_consumption    : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.hot_tub_pump.energy_consumption      : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.hot_water.energy_consumption         : num  0.004 0.004 0.238 0.004 0.215 0.004 0
##  $ out.electricity.lighting_exterior.energy_consumption : num  0.012 0.021 0.021 0.021 0.021 0.021 0
##  $ out.electricity.lighting_garage.energy_consumption   : num  0.008 0.013 0.013 0.013 0.013 0.013 0
##  $ out.electricity.lighting_interior.energy_consumption : num  0.031 0.198 0.227 0.221 0.221 0.086 0
##  $ out.electricity.mech_vent.energy_consumption         : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.plug_loads.energy_consumption        : num  0.226 0.24 0.244 0.241 0.241 0.235 0.1
##  $ out.electricity.pool_heater.energy_consumption       : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.pool_pump.energy_consumption         : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.pv.energy_consumption                : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.range_oven.energy_consumption        : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.electricity.refrigerator.energy_consumption      : num  0.21 0.239 0.239 0.239 0.239 0.239 0.1
##  $ out.electricity.well_pump.energy_consumption         : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.fuel_oil.heating_hp_bkup.energy_consumption      : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.fuel_oil.heating.energy_consumption              : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.fuel_oil.hot_water.energy_consumption            : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.clothes_dryer.energy_consumption     : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.fireplace.energy_consumption         : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.grill.energy_consumption             : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.heating_hp_bkup.energy_consumption   : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.heating.energy_consumption           : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.hot_tub_heater.energy_consumption    : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.hot_water.energy_consumption         : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.lighting.energy_consumption          : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.pool_heater.energy_consumption       : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.natural_gas.range_oven.energy_consumption        : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.clothes_dryer.energy_consumption         : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.heating_hp_bkup.energy_consumption       : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.heating.energy_consumption               : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.hot_water.energy_consumption             : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ out.propane.range_oven.energy_consumption            : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ time                                                 : POSIXct, format: "2018-07-01 04:00:00" "20
##  $ date_time                                            : POSIXct, format: "2018-07-01 01:00:00" "20
##  $ Dry.Bulb.Temperature...C.                            : num  25 23.9 23.3 26.1 25.6 ...
##  $ Relative.Humidity....                                : num  87.6 94.8 100 82.1 81.5 ...
##  $ Wind.Speed..m.s.                                     : num  0 0 0 0 0 0 0 2.6 1.5 0 ...
```

```
##  $ Wind.Direction..Deg.                                    : num  62.3 0 82.3 0 26.9 ...
##  $ Global.Horizontal.Radiation..W.m2.                      : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ Direct.Normal.Radiation..W.m2.                          : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ Diffuse.Horizontal.Radiation..W.m2.                     : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ in.sqft                                                 : int  885 885 885 885 885 885 885 885 885 88
##  $ in.bedrooms                                             : int  3 3 3 3 3 3 3 3 3 3 ...
##  $ in.county.y                                             : chr  "G4500910" "G4500910" "G4500910" "G450
##  $ in.geometry_wall_type                                   : chr  "Wood Frame" "Wood Frame" "Wood Frame
##  $ in.has_pv                                               : chr  "No" "No" "No" "No" ...
##  $ in.income                                               : chr  "10000-14999" "10000-14999" "10000-149
##  $ in.occupants                                            : chr  "3" "3" "3" "3" ...
##  $ in.roof_material                                        : chr  "Composition Shingles" "Composition Sh
##  $ in.tenure                                               : chr  "Renter" "Renter" "Renter" "Renter" .
##  $ in.usage_level                                          : chr  "Medium" "Medium" "Medium" "Medium" .
##  $ in.vacancy_status                                       : chr  "Occupied" "Occupied" "Occupied" "Occu
##  $ in.vintage                                              : chr  "1950s" "1950s" "1950s" "1950s" ...
##  $ in.weather_file_city                                    : chr  "Rock Hill York Co" "Rock Hill York Co
##  $ in.hvac_cooling_efficiency                              : chr  "AC, SEER 15" "AC, SEER 15" "AC, SEER
##  $ in.hvac_cooling_partial_space_conditioning              : chr  "100% Conditioned" "100% Conditioned"
##  $ in.hvac_cooling_type                                    : chr  "Central AC" "Central AC" "Central AC
##  $ upgrade.hvac_cooling_efficiency                         : chr  "Heat Pump" "Heat Pump" "Heat Pump" "H
##  $ in.cooling_setpoint                                     : chr  "72F" "72F" "72F" "72F" ...
##  $ in.cooling_setpoint_has_offset                          : chr  "No" "No" "No" "No" ...
##  $ in.cooling_setpoint_offset_magnitude                    : chr  "0F" "0F" "0F" "0F" ...
##  $ in.cooling_setpoint_offset_period                       : chr  "None" "None" "None" "None" ...
##  - attr(*, ".internal.selfref")=<externalptr>
##  - attr(*, "sorted")= chr "bldg_id"
```

```r
################################################################################
# DATA CLEANING (HOURLY)
################################################################################

# Analyze missing values
analyze_missing_values <- function(data) {
  missing_summary <- colSums(is.na(data))
  missing_table <- data.frame(
    Column = names(missing_summary),
    Missing_Values = missing_summary,
    Total_Values = nrow(data),
    Percentage_Missing = (missing_summary / nrow(data)) * 100
  )
  print(missing_table)
}
analyze_missing_values(combined_hourly_data)
```

```
##
## bldg_id                                                                    I
## date
## in.county.x                                                                in.c
## out.electricity.ceiling_fan.energy_consumption              out.electricity.ceiling_fan.energy_consu
## out.electricity.clothes_dryer.energy_consumption           out.electricity.clothes_dryer.energy_consu
## out.electricity.clothes_washer.energy_consumption         out.electricity.clothes_washer.energy_consu
## out.electricity.cooling_fans_pumps.energy_consumption out.electricity.cooling_fans_pumps.energy_consu
## out.electricity.cooling.energy_consumption                    out.electricity.cooling.energy_consu
```

```
## out.electricity.dishwasher.energy_consumption                out.electricity.dishwasher.energy_consu
## out.electricity.freezer.energy_consumption                      out.electricity.freezer.energy_consu
## out.electricity.heating_fans_pumps.energy_consumption out.electricity.heating_fans_pumps.energy_consu
## out.electricity.heating_hp_bkup.energy_consumption      out.electricity.heating_hp_bkup.energy_consu
## out.electricity.heating.energy_consumption                      out.electricity.heating.energy_consu
## out.electricity.hot_tub_heater.energy_consumption        out.electricity.hot_tub_heater.energy_consu
## out.electricity.hot_tub_pump.energy_consumption            out.electricity.hot_tub_pump.energy_consu
## out.electricity.hot_water.energy_consumption                out.electricity.hot_water.energy_consu
## out.electricity.lighting_exterior.energy_consumption   out.electricity.lighting_exterior.energy_consu
## out.electricity.lighting_garage.energy_consumption      out.electricity.lighting_garage.energy_consu
## out.electricity.lighting_interior.energy_consumption   out.electricity.lighting_interior.energy_consu
## out.electricity.mech_vent.energy_consumption                out.electricity.mech_vent.energy_consu
## out.electricity.plug_loads.energy_consumption               out.electricity.plug_loads.energy_consu
## out.electricity.pool_heater.energy_consumption             out.electricity.pool_heater.energy_consu
## out.electricity.pool_pump.energy_consumption                out.electricity.pool_pump.energy_consu
## out.electricity.pv.energy_consumption                              out.electricity.pv.energy_consu
## out.electricity.range_oven.energy_consumption              out.electricity.range_oven.energy_consu
## out.electricity.refrigerator.energy_consumption           out.electricity.refrigerator.energy_consu
## out.electricity.well_pump.energy_consumption                out.electricity.well_pump.energy_consu
## out.fuel_oil.heating_hp_bkup.energy_consumption           out.fuel_oil.heating_hp_bkup.energy_consu
## out.fuel_oil.heating.energy_consumption                         out.fuel_oil.heating.energy_consu
## out.fuel_oil.hot_water.energy_consumption                    out.fuel_oil.hot_water.energy_consu
## out.natural_gas.clothes_dryer.energy_consumption         out.natural_gas.clothes_dryer.energy_consu
## out.natural_gas.fireplace.energy_consumption                out.natural_gas.fireplace.energy_consu
## out.natural_gas.grill.energy_consumption                    out.natural_gas.grill.energy_consu
## out.natural_gas.heating_hp_bkup.energy_consumption      out.natural_gas.heating_hp_bkup.energy_consu
## out.natural_gas.heating.energy_consumption                  out.natural_gas.heating.energy_consu
## out.natural_gas.hot_tub_heater.energy_consumption        out.natural_gas.hot_tub_heater.energy_consu
## out.natural_gas.hot_water.energy_consumption                out.natural_gas.hot_water.energy_consu
## out.natural_gas.lighting.energy_consumption                 out.natural_gas.lighting.energy_consu
## out.natural_gas.pool_heater.energy_consumption            out.natural_gas.pool_heater.energy_consu
## out.natural_gas.range_oven.energy_consumption             out.natural_gas.range_oven.energy_consu
## out.propane.clothes_dryer.energy_consumption              out.propane.clothes_dryer.energy_consu
## out.propane.heating_hp_bkup.energy_consumption            out.propane.heating_hp_bkup.energy_consu
## out.propane.heating.energy_consumption                          out.propane.heating.energy_consu
## out.propane.hot_water.energy_consumption                     out.propane.hot_water.energy_consu
## out.propane.range_oven.energy_consumption                   out.propane.range_oven.energy_consu
## time
## date_time                                                                                    da
## Dry.Bulb.Temperature...C.                                                          Dry.Bulb.Temperatu
## Relative.Humidity....                                                                  Relative.Humidi
## Wind.Speed..m.s.                                                                            Wind.Speed
## Wind.Direction..Deg.                                                                    Wind.Direction
## Global.Horizontal.Radiation..W.m2.                                        Global.Horizontal.Radiation
## Direct.Normal.Radiation..W.m2.                                              Direct.Normal.Radiation
## Diffuse.Horizontal.Radiation..W.m2.                                      Diffuse.Horizontal.Radiation
## in.sqft                                                                                      i
## in.bedrooms                                                                                in.be
## in.county.y                                                                                in.co
## in.geometry_wall_type                                                                 in.geometry_wal
## in.has_pv                                                                                    in
## in.income                                                                                    in
## in.occupants                                                                               in.occ
## in.roof_material                                                                         in.roof_ma
```

```
## in.tenure                                                                   in
## in.usage_level                                                              in.usag
## in.vacancy_status                                                           in.vacancy
## in.vintage                                                                  in.
## in.weather_file_city                                                        in.weather_fi
## in.hvac_cooling_efficiency                                                  in.hvac_cooling_eff
## in.hvac_cooling_partial_space_conditioning              in.hvac_cooling_partial_space_condi
## in.hvac_cooling_type                                                        in.hvac_cooli
## upgrade.hvac_cooling_efficiency                                   upgrade.hvac_cooling_eff
## in.cooling_setpoint                                                         in.cooling_s
## in.cooling_setpoint_has_offset                                      in.cooling_setpoint_has
## in.cooling_setpoint_offset_magnitude                          in.cooling_setpoint_offset_ma
## in.cooling_setpoint_offset_period                                in.cooling_setpoint_offset
##                                                        Missing_Values
## bldg_id                                                             0
## date                                                                0
## in.county.x                                                         0
## out.electricity.ceiling_fan.energy_consumption                      0
## out.electricity.clothes_dryer.energy_consumption                    0
## out.electricity.clothes_washer.energy_consumption                   0
## out.electricity.cooling_fans_pumps.energy_consumption               0
## out.electricity.cooling.energy_consumption                          0
## out.electricity.dishwasher.energy_consumption                       0
## out.electricity.freezer.energy_consumption                          0
## out.electricity.heating_fans_pumps.energy_consumption               0
## out.electricity.heating_hp_bkup.energy_consumption                  0
## out.electricity.heating.energy_consumption                          0
## out.electricity.hot_tub_heater.energy_consumption                   0
## out.electricity.hot_tub_pump.energy_consumption                     0
## out.electricity.hot_water.energy_consumption                        0
## out.electricity.lighting_exterior.energy_consumption                0
## out.electricity.lighting_garage.energy_consumption                  0
## out.electricity.lighting_interior.energy_consumption                0
## out.electricity.mech_vent.energy_consumption                        0
## out.electricity.plug_loads.energy_consumption                       0
## out.electricity.pool_heater.energy_consumption                      0
## out.electricity.pool_pump.energy_consumption                        0
## out.electricity.pv.energy_consumption                               0
## out.electricity.range_oven.energy_consumption                       0
## out.electricity.refrigerator.energy_consumption                     0
## out.electricity.well_pump.energy_consumption                        0
## out.fuel_oil.heating_hp_bkup.energy_consumption                     0
## out.fuel_oil.heating.energy_consumption                             0
## out.fuel_oil.hot_water.energy_consumption                           0
## out.natural_gas.clothes_dryer.energy_consumption                    0
## out.natural_gas.fireplace.energy_consumption                        0
## out.natural_gas.grill.energy_consumption                            0
## out.natural_gas.heating_hp_bkup.energy_consumption                  0
## out.natural_gas.heating.energy_consumption                          0
## out.natural_gas.hot_tub_heater.energy_consumption                   0
## out.natural_gas.hot_water.energy_consumption                        0
## out.natural_gas.lighting.energy_consumption                         0
## out.natural_gas.pool_heater.energy_consumption                      0
## out.natural_gas.range_oven.energy_consumption                       0
```

```
## out.propane.clothes_dryer.energy_consumption                        0
## out.propane.heating_hp_bkup.energy_consumption                      0
## out.propane.heating.energy_consumption                              0
## out.propane.hot_water.energy_consumption                            0
## out.propane.range_oven.energy_consumption                           0
## time                                                                0
## date_time                                                           0
## Dry.Bulb.Temperature...C.                                           0
## Relative.Humidity....                                               0
## Wind.Speed..m.s.                                                    0
## Wind.Direction..Deg.                                                0
## Global.Horizontal.Radiation..W.m2.                                  0
## Direct.Normal.Radiation..W.m2.                                      0
## Diffuse.Horizontal.Radiation..W.m2.                                 0
## in.sqft                                                             0
## in.bedrooms                                                         0
## in.county.y                                                         0
## in.geometry_wall_type                                               0
## in.has_pv                                                           0
## in.income                                                           0
## in.occupants                                                        0
## in.roof_material                                                    0
## in.tenure                                                           0
## in.usage_level                                                      0
## in.vacancy_status                                                   0
## in.vintage                                                          0
## in.weather_file_city                                                0
## in.hvac_cooling_efficiency                                          0
## in.hvac_cooling_partial_space_conditioning                          0
## in.hvac_cooling_type                                                0
## upgrade.hvac_cooling_efficiency                                     0
## in.cooling_setpoint                                                 0
## in.cooling_setpoint_has_offset                                      0
## in.cooling_setpoint_offset_magnitude                                0
## in.cooling_setpoint_offset_period                                   0
##                                                          Total_Values
## bldg_id                                                          1426
## date                                                             1426
## in.county.x                                                      1426
## out.electricity.ceiling_fan.energy_consumption                   1426
## out.electricity.clothes_dryer.energy_consumption                 1426
## out.electricity.clothes_washer.energy_consumption                1426
## out.electricity.cooling_fans_pumps.energy_consumption            1426
## out.electricity.cooling.energy_consumption                       1426
## out.electricity.dishwasher.energy_consumption                    1426
## out.electricity.freezer.energy_consumption                       1426
## out.electricity.heating_fans_pumps.energy_consumption            1426
## out.electricity.heating_hp_bkup.energy_consumption               1426
## out.electricity.heating.energy_consumption                       1426
## out.electricity.hot_tub_heater.energy_consumption                1426
## out.electricity.hot_tub_pump.energy_consumption                  1426
## out.electricity.hot_water.energy_consumption                     1426
## out.electricity.lighting_exterior.energy_consumption             1426
## out.electricity.lighting_garage.energy_consumption               1426
```

```
## out.electricity.lighting_interior.energy_consumption          1426
## out.electricity.mech_vent.energy_consumption                  1426
## out.electricity.plug_loads.energy_consumption                 1426
## out.electricity.pool_heater.energy_consumption                1426
## out.electricity.pool_pump.energy_consumption                  1426
## out.electricity.pv.energy_consumption                         1426
## out.electricity.range_oven.energy_consumption                 1426
## out.electricity.refrigerator.energy_consumption               1426
## out.electricity.well_pump.energy_consumption                  1426
## out.fuel_oil.heating_hp_bkup.energy_consumption               1426
## out.fuel_oil.heating.energy_consumption                       1426
## out.fuel_oil.hot_water.energy_consumption                     1426
## out.natural_gas.clothes_dryer.energy_consumption              1426
## out.natural_gas.fireplace.energy_consumption                  1426
## out.natural_gas.grill.energy_consumption                      1426
## out.natural_gas.heating_hp_bkup.energy_consumption            1426
## out.natural_gas.heating.energy_consumption                    1426
## out.natural_gas.hot_tub_heater.energy_consumption             1426
## out.natural_gas.hot_water.energy_consumption                  1426
## out.natural_gas.lighting.energy_consumption                   1426
## out.natural_gas.pool_heater.energy_consumption                1426
## out.natural_gas.range_oven.energy_consumption                 1426
## out.propane.clothes_dryer.energy_consumption                  1426
## out.propane.heating_hp_bkup.energy_consumption                1426
## out.propane.heating.energy_consumption                        1426
## out.propane.hot_water.energy_consumption                      1426
## out.propane.range_oven.energy_consumption                     1426
## time                                                          1426
## date_time                                                     1426
## Dry.Bulb.Temperature...C.                                     1426
## Relative.Humidity....                                         1426
## Wind.Speed..m.s.                                              1426
## Wind.Direction..Deg.                                          1426
## Global.Horizontal.Radiation..W.m2.                            1426
## Direct.Normal.Radiation..W.m2.                                1426
## Diffuse.Horizontal.Radiation..W.m2.                           1426
## in.sqft                                                       1426
## in.bedrooms                                                   1426
## in.county.y                                                   1426
## in.geometry_wall_type                                         1426
## in.has_pv                                                     1426
## in.income                                                     1426
## in.occupants                                                  1426
## in.roof_material                                              1426
## in.tenure                                                     1426
## in.usage_level                                                1426
## in.vacancy_status                                             1426
## in.vintage                                                    1426
## in.weather_file_city                                          1426
## in.hvac_cooling_efficiency                                    1426
## in.hvac_cooling_partial_space_conditioning                    1426
## in.hvac_cooling_type                                          1426
## upgrade.hvac_cooling_efficiency                               1426
## in.cooling_setpoint                                           1426
```

```
## in.cooling_setpoint_has_offset                                    1426
## in.cooling_setpoint_offset_magnitude                              1426
## in.cooling_setpoint_offset_period                                 1426
##                                                    Percentage_Missing
## bldg_id                                                             0
## date                                                                0
## in.county.x                                                         0
## out.electricity.ceiling_fan.energy_consumption                      0
## out.electricity.clothes_dryer.energy_consumption                    0
## out.electricity.clothes_washer.energy_consumption                   0
## out.electricity.cooling_fans_pumps.energy_consumption               0
## out.electricity.cooling.energy_consumption                          0
## out.electricity.dishwasher.energy_consumption                       0
## out.electricity.freezer.energy_consumption                          0
## out.electricity.heating_fans_pumps.energy_consumption               0
## out.electricity.heating_hp_bkup.energy_consumption                  0
## out.electricity.heating.energy_consumption                          0
## out.electricity.hot_tub_heater.energy_consumption                   0
## out.electricity.hot_tub_pump.energy_consumption                     0
## out.electricity.hot_water.energy_consumption                        0
## out.electricity.lighting_exterior.energy_consumption                0
## out.electricity.lighting_garage.energy_consumption                  0
## out.electricity.lighting_interior.energy_consumption                0
## out.electricity.mech_vent.energy_consumption                        0
## out.electricity.plug_loads.energy_consumption                       0
## out.electricity.pool_heater.energy_consumption                      0
## out.electricity.pool_pump.energy_consumption                        0
## out.electricity.pv.energy_consumption                               0
## out.electricity.range_oven.energy_consumption                       0
## out.electricity.refrigerator.energy_consumption                     0
## out.electricity.well_pump.energy_consumption                        0
## out.fuel_oil.heating_hp_bkup.energy_consumption                     0
## out.fuel_oil.heating.energy_consumption                             0
## out.fuel_oil.hot_water.energy_consumption                           0
## out.natural_gas.clothes_dryer.energy_consumption                    0
## out.natural_gas.fireplace.energy_consumption                        0
## out.natural_gas.grill.energy_consumption                            0
## out.natural_gas.heating_hp_bkup.energy_consumption                  0
## out.natural_gas.heating.energy_consumption                          0
## out.natural_gas.hot_tub_heater.energy_consumption                   0
## out.natural_gas.hot_water.energy_consumption                        0
## out.natural_gas.lighting.energy_consumption                         0
## out.natural_gas.pool_heater.energy_consumption                      0
## out.natural_gas.range_oven.energy_consumption                       0
## out.propane.clothes_dryer.energy_consumption                        0
## out.propane.heating_hp_bkup.energy_consumption                      0
## out.propane.heating.energy_consumption                              0
## out.propane.hot_water.energy_consumption                            0
## out.propane.range_oven.energy_consumption                           0
## time                                                                0
## date_time                                                           0
## Dry.Bulb.Temperature...C.                                           0
## Relative.Humidity....                                               0
## Wind.Speed..m.s.                                                    0
```

```
## Wind.Direction..Deg.                                                    0
## Global.Horizontal.Radiation..W.m2.                                      0
## Direct.Normal.Radiation..W.m2.                                          0
## Diffuse.Horizontal.Radiation..W.m2.                                     0
## in.sqft                                                                 0
## in.bedrooms                                                             0
## in.county.y                                                             0
## in.geometry_wall_type                                                   0
## in.has_pv                                                               0
## in.income                                                               0
## in.occupants                                                            0
## in.roof_material                                                        0
## in.tenure                                                               0
## in.usage_level                                                          0
## in.vacancy_status                                                       0
## in.vintage                                                              0
## in.weather_file_city                                                    0
## in.hvac_cooling_efficiency                                              0
## in.hvac_cooling_partial_space_conditioning                              0
## in.hvac_cooling_type                                                    0
## upgrade.hvac_cooling_efficiency                                         0
## in.cooling_setpoint                                                     0
## in.cooling_setpoint_has_offset                                          0
## in.cooling_setpoint_offset_magnitude                                    0
## in.cooling_setpoint_offset_period                                       0
```

```
  # # Check for missing columns and notify the user
  # missing_columns <- setdiff(electricity_load_columns, colnames(combined_hourly_data))
  # if (length(missing_columns) > 0) {
  #   message("Warning: The following load columns are missing and will be treated as 0: ",
  #           paste(missing_columns, collapse = ", "))
  #   combined_hourly_data[, (missing_columns) := 0]  # Add missing columns as 0
  # }

# Initial data inspection
cat("Initial number of rows in combined_hourly_data:", nrow(combined_hourly_data), "\n")
```

```
## Initial number of rows in combined_hourly_data: 1426
```

```
# Filter out rows where `in.has_pv` is "yes"
if ("in.has_pv" %in% colnames(combined_hourly_data)) {
  combined_hourly_data <- combined_hourly_data[combined_hourly_data$in.has_pv != "yes", ]
  cat("After removing rows with PV systems, rows left:", nrow(combined_hourly_data), "\n")
} else {
  cat("Column `in.has_pv` not found in combined_hourly_data. Skipping this filter.\n")
}
```

```
## After removing rows with PV systems, rows left: 1426
```

```
# Remove all renters
if ("in.tenure" %in% colnames(combined_hourly_data)) {
  combined_hourly_data <- combined_hourly_data[combined_hourly_data$in.tenure != "renter", ]
```

```
  cat("After removing renters, rows left:", nrow(combined_hourly_data), "\n")
} else {
  cat("Column `in.tenure` not found in combined_hourly_data. Skipping this filter.\n")
}
```

```
## After removing renters, rows left: 1426
```

```
# Remove all vacancies
if ("in.vacancy_status" %in% colnames(combined_hourly_data)) {
  combined_hourly_data <- combined_hourly_data[combined_hourly_data$in.vacancy_status != "vacant", ]
  cat("After removing vacant properties, rows left:", nrow(combined_hourly_data), "\n")
} else {
  cat("Column `in.vacancy_status` not found in combined_hourly_data. Skipping this filter.\n")
}
```

```
## After removing vacant properties, rows left: 1426
```

```
# Check if combined_hourly_data is empty
if (nrow(combined_hourly_data) == 0) {
  cat("No data available after filtering. Please review the filtering criteria.\n")
  stop("Dataset is empty. Aborting further analysis.")
} else {
  cat("Rows with PV systems, renters, and vacant properties have been removed from the combined_hourly_
}
```

```
## Rows with PV systems, renters, and vacant properties have been removed from the combined_hourly_data
```

```
# total energy consumption column added

# Add Total Energy Consumption column by summing all electricity-related variables

if (exists("combined_hourly_data")) {
  # Identify columns that match the pattern for electricity-related energy consumption
  electricity_columns <- grep("^out\\.electricity\\..*\\.energy_consumption$", colnames(combined_hourly_

  # Check if any electricity-related columns are found
  if (length(electricity_columns) > 0) {
    # Add Total Energy Consumption column
    combined_hourly_data[, Total_Energy_Consumption := rowSums(.SD, na.rm = TRUE), .SDcols = electricity
    message("Total Energy Consumption column added successfully.")
  } else {
    message("No electricity-related energy consumption columns found in combined_hourly_data.")
  }
} else {
  message("`combined_hourly_data` does not exist. Skipping addition of Total Energy Consumption column.
}
```

```
## Total Energy Consumption column added successfully.
```

```r
# Add Total Energy Consumption column by summing all electricity-related variables

if (exists("combined_hourly_data")) {
  # Identify columns that match the pattern for electricity-related energy consumption
  electricity_columns <- grep("^out\\.electricity\\..*\\.energy_consumption$", colnames(combined_hourly_

  # Check if any electricity-related columns are found
  if (length(electricity_columns) > 0) {
    # Add Total Energy Consumption column
    combined_hourly_data[, Total_Energy_Consumption := rowSums(.SD, na.rm = TRUE), .SDcols = electricity
    message("Total Energy Consumption column added successfully.")

    # Calculate the sum of the Total Energy Consumption column
    total_energy_consumed <- sum(combined_hourly_data$Total_Energy_Consumption, na.rm = TRUE)
    message("The total energy consumption across all rows: ", total_energy_consumed, " kWh (or equivalen
  } else {
    message("No electricity-related energy consumption columns found in combined_hourly_data.")
  }
} else {
  message("`combined_hourly_data` does not exist. Skipping addition of Total Energy Consumption column.
}
```

```
## Total Energy Consumption column added successfully.
```

```
## The total energy consumption across all rows: 2056.868 kWh (or equivalent units).
```

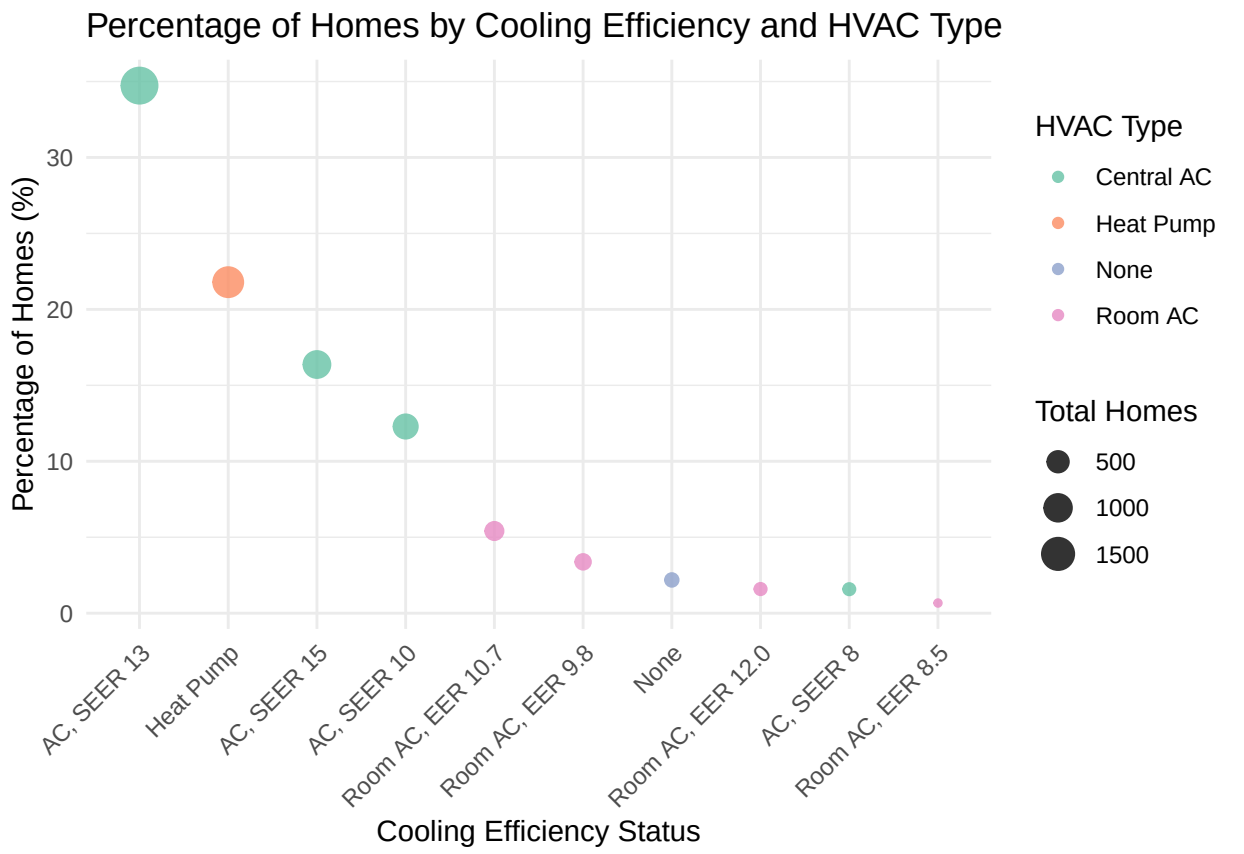
```r
# Efficiency count
# Summarize data by cooling efficiency
hvac_efficiency_summary <- combined_data %>%
  group_by(`in.hvac.cooling.efficiency`) %>%
  summarise(
    Total_Homes = n_distinct(bldg.id),  # Count unique homes for each efficiency status
    Total_Cooling_Energy = sum(cooling, na.rm = TRUE),  # Total cooling energy for each efficiency stat
    HVAC_Types = paste(unique(`in.hvac.cooling.type`), collapse = ", ")  # List all HVAC types associat
  ) %>%
  mutate(
    Percentage_Housing_Stock = (Total_Homes / sum(Total_Homes)) * 100,  # Calculate percentage of housi
    Percentage_Cooling_Energy = (Total_Cooling_Energy / sum(Total_Cooling_Energy)) * 100  # Calculate p
  ) %>%
  arrange(desc(Total_Homes))  # Sort by total homes

# Round percentages for clarity
hvac_efficiency_summary <- hvac_efficiency_summary %>%
  mutate(
    Percentage_Housing_Stock = round(Percentage_Housing_Stock, 2),
    Percentage_Cooling_Energy = round(Percentage_Cooling_Energy, 2)
  )

# Display the table
library(knitr)
library(ggplot2)
```

```
# Create scatter plot for HVAC types and percentage of homes
kable(hvac_efficiency_summary, caption = "HVAC Efficiency Summary: Total Homes, Housing Stock, and Cooli
```

Table 1: HVAC Efficiency Summary: Total Homes, Housing Stock, and Cooling Energy Percentages

in.hvac.cooling.efficiency	Total_Homes	Total_Cooling_Energy	HVAC_Types	Percentage_Housing_Stock	Percentage_Cooling_Energy
AC, SEER 13	1983	770749.51	Central AC	34.73	35.79
Heat Pump	1244	488226.59	Heat Pump	21.79	22.67
AC, SEER 15	935	373668.07	Central AC	16.37	17.35
AC, SEER 10	702	269797.22	Central AC	12.29	12.53
Room AC, EER 10.7	309	87248.94	Room AC	5.41	4.05
Room AC, EER 9.8	193	54571.78	Room AC	3.38	2.53
None	125	38277.99	None	2.19	1.78
Room AC, EER 12.0	91	26106.17	Room AC	1.59	1.21
AC, SEER 8	90	34028.89	Central AC	1.58	1.58
Room AC, EER 8.5	38	10794.82	Room AC	0.67	0.50

```
ggplot(hvac_efficiency_summary, aes(x = reorder(`in.hvac.cooling.efficiency`, -Percentage_Housing_Stock)
  geom_point(aes(color = HVAC_Types, size = Total_Homes), alpha = 0.8) +  # Points scaled by Total Home
  labs(
    title = "Percentage of Homes by Cooling Efficiency and HVAC Type",
    x = "Cooling Efficiency Status",
    y = "Percentage of Homes (%)",
    color = "HVAC Type",
    size = "Total Homes"
  ) +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1)) +
  scale_color_brewer(palette = "Set2")
```




```
##############################################################################
# Model Development
##############################################################################


# Identify the time of day with the highest average energy usage for July

# Ensure the dataset contains only July data
combined_hourly_data <- combined_hourly_data[month(date) == 7, ]
message("Filtered dataset to include only July records.")
```

```
## Filtered dataset to include only July records.
```

```
# Aggregate energy usage by hour
combined_hourly_data[, hour := hour(date_time)] # Extract the hour from the date_time column
peak_hour <- combined_hourly_data[, .(average_energy = mean(Total_Energy_Consumption, na.rm = TRUE)), by

# Filter data for the identified peak hour
peak_data <- combined_hourly_data[hour == peak_hour$hour]
message("The hour with the highest energy usage in July is: ", peak_hour$hour)
```

```
## The hour with the highest energy usage in July is: 1
```

```r
# Ensure that `date_time` is treated as a POSIXct variable
if (!inherits(peak_data$date_time, "POSIXct")) {
  peak_data$date_time <- as.POSIXct(peak_data$date_time, format = "%Y-%m-%d %H:%M:%S")
}
message("Confirmed and formatted the 'date_time' column.")
```

```
## Confirmed and formatted the 'date_time' column.
```

```r
################################################################################
# Model 1 - Temperature and Cooling-Related Loads Only
################################################################################

message("Building Model 1 - Temperature and Cooling-Related Loads...")
```

```
## Building Model 1 - Temperature and Cooling-Related Loads...
```

```r
model_1 <- lm(
  out.electricity.cooling.energy_consumption ~ Dry.Bulb.Temperature...C. +
    out.electricity.cooling_fans_pumps.energy_consumption +
    out.electricity.ceiling_fan.energy_consumption,
  data = peak_data
)

message("Model 1 Summary:")
```

```
## Model 1 Summary:
```

```r
print(summary(model_1))
```

```
##
## Call:
## lm(formula = out.electricity.cooling.energy_consumption ~ Dry.Bulb.Temperature...C. +
##     out.electricity.cooling_fans_pumps.energy_consumption + out.electricity.ceiling_fan.energy_consu
##     data = peak_data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.20304 -0.05249 -0.01191  0.04751  0.30857
##
## Coefficients:
##                                                    Estimate Std. Error
## (Intercept)                                       -0.148821   0.026364
## Dry.Bulb.Temperature...C.                          0.013183   0.001116
## out.electricity.cooling_fans_pumps.energy_consumption 11.922488   0.045962
## out.electricity.ceiling_fan.energy_consumption     1.186672   0.371548
##                                                   t value Pr(>|t|)
## (Intercept)                                        -5.645 1.99e-08 ***
## Dry.Bulb.Temperature...C.                          11.816  < 2e-16 ***
## out.electricity.cooling_fans_pumps.energy_consumption 259.397  < 2e-16 ***
## out.electricity.ceiling_fan.energy_consumption       3.194  0.00143 **
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.07523 on 1422 degrees of freedom
## Multiple R-squared:  0.9816, Adjusted R-squared:  0.9816
## F-statistic: 2.528e+04 on 3 and 1422 DF,  p-value: < 2.2e-16
```

```
message("Model 1 is Complete.")
```

```
## Model 1 is Complete.
```

```
################################################################################
# Model 2 - Major Load Users
################################################################################

message("Building Model 2 - Major Load Users...")
```

```
## Building Model 2 - Major Load Users...
```

```
model_2 <- lm(
  out.electricity.cooling.energy_consumption ~ Dry.Bulb.Temperature...C. +
    out.electricity.cooling_fans_pumps.energy_consumption +
    out.electricity.plug_loads.energy_consumption +
    out.electricity.lighting_interior.energy_consumption +
    date_time,
  data = peak_data
)

message("Model 2 Summary:")
```

```
## Model 2 Summary:
```

```
print(summary(model_2))
```

```
##
## Call:
## lm(formula = out.electricity.cooling.energy_consumption ~ Dry.Bulb.Temperature...C. +
##     out.electricity.cooling_fans_pumps.energy_consumption + out.electricity.plug_loads.energy_consump
##     out.electricity.lighting_interior.energy_consumption + date_time,
##     data = peak_data)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.204515 -0.051885 -0.007333  0.044897  0.286448
##
## Coefficients:
##                                                  Estimate Std. Error
## (Intercept)                                     2.799e+00  3.960e+00
## Dry.Bulb.Temperature...C.                       1.363e-02  1.117e-03
## out.electricity.cooling_fans_pumps.energy_consumption  1.194e+01  4.527e-02
## out.electricity.plug_loads.energy_consumption          6.529e-02  1.291e-02
## out.electricity.lighting_interior.energy_consumption   2.334e-02  9.212e-03
```

```
## date_time                                                -1.940e-09  2.583e-09
##                                                          t value Pr(>|t|)
## (Intercept)                                                0.707   0.4798
## Dry.Bulb.Temperature...C.                                 12.202  < 2e-16 ***
## out.electricity.cooling_fans_pumps.energy_consumption 263.749  < 2e-16 ***
## out.electricity.plug_loads.energy_consumption           5.056 4.83e-07 ***
## out.electricity.lighting_interior.energy_consumption    2.534   0.0114 *
## date_time                                                -0.751   0.4527
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.07438 on 1420 degrees of freedom
## Multiple R-squared:  0.982,  Adjusted R-squared:  0.982
## F-statistic: 1.553e+04 on 5 and 1420 DF,  p-value: < 2.2e-16
```

```
message("Model 2 is Complete.")
```

```
## Model 2 is Complete.
```

```
################################################################################
# Model 3 - Temperature and Date/Time
################################################################################

message("Building Model 3 - Temperature and Date/Time...")
```

```
## Building Model 3 - Temperature and Date/Time...
```

```
model_3 <- lm(
  out.electricity.cooling.energy_consumption ~ Dry.Bulb.Temperature...C. +
    date_time,
  data = peak_data
)

message("Model 3 Summary:")
```

```
## Model 3 Summary:
```

```
print(summary(model_3))
```

```
##
## Call:
## lm(formula = out.electricity.cooling.energy_consumption ~ Dry.Bulb.Temperature...C. +
##     date_time, data = peak_data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.81722 -0.30011 -0.16136  0.08158  2.41974
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                -2.516e+00  2.843e+01  -0.089    0.929
```

```
## Dry.Bulb.Temperature...C.  7.717e-02  7.836e-03   9.848   <2e-16 ***
## date_time                  8.671e-10  1.854e-08   0.047    0.963
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.536 on 1423 degrees of freedom
## Multiple R-squared:  0.06488,    Adjusted R-squared:  0.06356
## F-statistic: 49.36 on 2 and 1423 DF,  p-value: < 2.2e-16
```

```
message("Model 3 is Complete.")
```

```
## Model 3 is Complete.
```

```
################################################################################
# Model 4 - All Factors
################################################################################

message("Building Model 4 - All Factors...")
```

```
## Building Model 4 - All Factors...
```

```
model_4 <- lm(
  out.electricity.cooling.energy_consumption ~ Dry.Bulb.Temperature...C. +
    out.electricity.cooling_fans_pumps.energy_consumption +
    out.electricity.plug_loads.energy_consumption +
    out.electricity.lighting_interior.energy_consumption +
    out.electricity.ceiling_fan.energy_consumption +
    date_time,
  data = peak_data
)

message("Model 4 Summary:")
```

```
## Model 4 Summary:
```

```
print(summary(model_4))
```

```
##
## Call:
## lm(formula = out.electricity.cooling.energy_consumption ~ Dry.Bulb.Temperature...C. +
##     out.electricity.cooling_fans_pumps.energy_consumption + out.electricity.plug_loads.energy_consump
##     out.electricity.lighting_interior.energy_consumption + out.electricity.ceiling_fan.energy_consump
##     date_time, data = peak_data)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.204644 -0.052029 -0.007982  0.045678  0.288674
##
## Coefficients:
##                                                    Estimate Std. Error
## (Intercept)                                       2.873e+00  3.963e+00
```

```
## Dry.Bulb.Temperature...C.                                1.361e-02  1.117e-03
## out.electricity.cooling_fans_pumps.energy_consumption  1.193e+01  4.604e-02
## out.electricity.plug_loads.energy_consumption          6.357e-02  1.327e-02
## out.electricity.lighting_interior.energy_consumption   2.163e-02  9.694e-03
## out.electricity.ceiling_fan.energy_consumption         2.316e-01  4.093e-01
## date_time                                             -1.989e-09  2.585e-09
##                                                      t value Pr(>|t|)
## (Intercept)                                            0.725   0.4686
## Dry.Bulb.Temperature...C.                             12.178  < 2e-16 ***
## out.electricity.cooling_fans_pumps.energy_consumption 259.238  < 2e-16 ***
## out.electricity.plug_loads.energy_consumption           4.790 1.84e-06 ***
## out.electricity.lighting_interior.energy_consumption    2.232   0.0258 *
## out.electricity.ceiling_fan.energy_consumption          0.566   0.5716
## date_time                                              -0.769   0.4418
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.07439 on 1419 degrees of freedom
## Multiple R-squared:  0.982,  Adjusted R-squared:  0.982
## F-statistic: 1.293e+04 on 6 and 1419 DF,  p-value: < 2.2e-16
```

```
message("Model 4 is Complete.")
```

```
## Model 4 is Complete.
```

```
################################################################################
# Model Development - Model 2 Only
################################################################################

library(ggplot2)
library(tidyr)
library(dplyr)

plot_data <- peak_data %>%
  select(
    out.electricity.cooling.energy_consumption,
    Dry.Bulb.Temperature...C.,
    out.electricity.cooling_fans_pumps.energy_consumption,
    out.electricity.lighting_interior.energy_consumption,
    out.electricity.ceiling_fan.energy_consumption
  ) %>%
  pivot_longer(
    cols = -out.electricity.cooling.energy_consumption,
    names_to = "Predictor",
    values_to = "Value"
  )

# Update Labels
label_mapping <- c(
  "Dry.Bulb.Temperature...C." = "Temperature (°C)",
  "out.electricity.cooling_fans_pumps.energy_consumption" = "Cooling Fans & Pumps",
  "out.electricity.lighting_interior.energy_consumption" = "Lighting Interior",
  "out.electricity.ceiling_fan.energy_consumption" = "Ceiling Fan",
```

```
  "out.electricity.plug_loads.energy_consumption" = "Plug Loads"
)
plot_data <- plot_data %>%
  mutate(Predictor = recode(Predictor, !!!label_mapping))

# Plot model
ggplot(plot_data, aes(x = Value, y = out.electricity.cooling.energy_consumption)) +
  geom_point(alpha = 0.6, color = "blue") +
  geom_smooth(method = "lm", color = "red", se = FALSE) +
  facet_wrap(~ Predictor, scales = "free_x") +
  labs(
    title = "Scatter Plots of Predictors vs Cooling Energy Consumption",
    x = "Predictor Value",
    y = "Cooling Energy Consumption (kWh)"
  ) +
  theme_minimal() +
  theme(
    strip.text = element_text(size = 10),
    axis.text.x = element_text(angle = 45, hjust = 1)
  )
```

```
## `geom_smooth()` using formula = 'y ~ x'
```