Main_data_Models

2023-12-03

```
library (arrow)
```

```
## Warning: package 'arrow' was built under R version 4.3.2
```

```
##
## Attaching package: 'arrow'
```

```
## The following object is masked from 'package:utils':
##
##     timestamp
```

```
library(arrow)
library(tidyverse)
```

```
## ── Attaching core tidyverse packages ──────────────────────── tidyverse 2.0.0 ──
## ✓ dplyr     1.1.3     ✓ readr     2.1.4
## ✓ forcats   1.0.0     ✓ stringr   1.5.0
## ✓ ggplot2   3.4.4     ✓ tibble    3.2.1
## ✓ lubridate 1.9.2     ✓ tidyr     1.3.0
## ✓ purrr     1.0.2
```

```
## ── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
## ✖ lubridate::duration() masks arrow::duration()
## ✖ dplyr::filter()       masks stats::filter()
## ✖ dplyr::lag()          masks stats::lag()
## ℹ Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to be
come errors
```

```
Merged_Final<-read_parquet("Aggregate_Final_Dataset.parquet")
```

```
str(Merged_Final)
```

```
## tibble [137,040 × 102] (S3: tbl_df/tbl/data.frame)
##  $ in.county                                : chr [1:137040] "G4500010" "G4500010" "G4500
010" "G4500010" ...
##  $ hour                                     : num [1:137040] 0 0 0 0 0 0 0 0 0 0 ...
##  $ Dry Bulb Temperature [°C]                : num [1:137040] 22.4 22.4 22.4 22.4 22.4 ...
##  $ Relative Humidity [%]                    : num [1:137040] 95.2 95.2 95.2 95.2 95.2 ...
##  $ Wind Speed [m/s]                         : num [1:137040] 1.09 1.09 1.09 1.09 1.09 ...
##  $ Wind Direction [Deg]                     : num [1:137040] 126 126 126 126 126 ...
##  $ Global Horizontal Radiation [W/m2]       : num [1:137040] 0 0 0 0 0 0 0 0 0 0 ...
##  $ Direct Normal Radiation [W/m2]           : num [1:137040] 0 0 0 0 0 0 0 0 0 0 ...
##  $ Diffuse Horizontal Radiation [W/m2]      : num [1:137040] 0 0 0 0 0 0 0 0 0 0 ...
##  $ bldg_id                                  : num [1:137040] 410602 465218 473719 29915 1
02598 ...
##  $ in.sqft                                  : num [1:137040] 1220 2176 3301 2663 1690 ...
##  $ in.bathroom_spot_vent_hour               : chr [1:137040] "Hour20" "Hour11" "Hour4" "H
our19" ...
##  $ in.bedrooms                              : num [1:137040] 4 4 5 3 3 4 3 4 3 2 ...
##  $ in.building_america_climate_zone         : chr [1:137040] "Mixed-Humid" "Mixed-Humid"
"Mixed-Humid" "Mixed-Humid" ...
##  $ in.ceiling_fan                           : chr [1:137040] "Standard Efficiency" "Stand
ard Efficiency" "Standard Efficiency" "Standard Efficiency, No usage" ...
##  $ in.city                                  : chr [1:137040] "In another census Place" "N
ot in a census Place" "Not in a census Place" "Not in a census Place" ...
##  $ in.clothes_dryer                         : chr [1:137040] "Electric, 120% Usage" "Gas,
100% Usage" "Electric, 80% Usage" "Propane, 100% Usage" ...
##  $ in.clothes_washer                        : chr [1:137040] "EnergyStar, 120% Usage" "En
ergyStar, 100% Usage" "Standard, 80% Usage" "EnergyStar, 100% Usage" ...
##  $ in.clothes_washer_presence               : chr [1:137040] "Yes" "Yes" "Yes" "Yes" ...
##  $ in.cooking_range                         : chr [1:137040] "Electric, 120% Usage" "Elec
tric, 100% Usage" "Electric, 80% Usage" "Electric, 100% Usage" ...
##  $ in.cooling_setpoint                      : chr [1:137040] "75F" "70F" "75F" "75F" ...
##  $ in.cooling_setpoint_has_offset           : chr [1:137040] "No" "No" "No" "No" ...
##  $ in.cooling_setpoint_offset_magnitude     : chr [1:137040] "0F" "0F" "0F" "0F" ...
##  $ in.cooling_setpoint_offset_period        : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.county_and_puma                       : chr [1:137040] "G4500010, G45001600" "G4500
010, G45001600" "G4500010, G45001600" "G4500010, G45001600" ...
##  $ in.dishwasher                            : chr [1:137040] "290 Rated kWh, 120% Usage"
"318 Rated kWh, 100% Usage" "290 Rated kWh, 80% Usage" "None" ...
##  $ in.ducts                                 : chr [1:137040] "20% Leakage, R-4" "20% Leak
age, R-8" "20% Leakage, R-4" "20% Leakage, R-4" ...
##  $ in.federal_poverty_level                 : chr [1:137040] "300-400%" "150-200%" "400%
+" "400%+" ...
##  $ in.geometry_attic_type                   : chr [1:137040] "Vented Attic" "Vented Atti
c" "Vented Attic" "Vented Attic" ...
##  $ in.geometry_floor_area                   : chr [1:137040] "1000-1499" "2000-2499" "300
0-3999" "2500-2999" ...
##  $ in.geometry_floor_area_bin               : chr [1:137040] "0-1499" "1500-2499" "2500-3
999" "2500-3999" ...
##  $ in.geometry_foundation_type              : chr [1:137040] "Slab" "Slab" "Slab" "Slab"
...
##  $ in.geometry_garage                       : chr [1:137040] "None" "2 Car" "2 Car" "Non
e" ...
##  $ in.geometry_stories                      : num [1:137040] 1 1 2 1 2 2 1 2 1 1 ...
##  $ in.geometry_stories_low_rise             : num [1:137040] 1 1 2 1 2 2 1 2 1 1 ...
```

```
##  $ in.geometry_wall_exterior_finish          : chr [1:137040] "Wood, Medium/Dark" "Brick,
Medium/Dark" "Vinyl, Light" "Aluminum, Light" ...
##  $ in.geometry_wall_type                     : chr [1:137040] "Wood Frame" "Wood Frame" "W
ood Frame" "Steel Frame" ...
##  $ in.has_pv                                 : chr [1:137040] "No" "No" "No" "No" ...
##  $ in.heating_fuel                           : chr [1:137040] "Electricity" "Electricity"
"Propane" "Electricity" ...
##  $ in.heating_setpoint                       : chr [1:137040] "70F" "72F" "65F" "55F" ...
##  $ in.heating_setpoint_has_offset            : chr [1:137040] "Yes" "Yes" "No" "No" ...
##  $ in.heating_setpoint_offset_magnitude      : chr [1:137040] "3F" "3F" "0F" "0F" ...
##  $ in.heating_setpoint_offset_period         : chr [1:137040] "Night" "Day and Night -4h"
"None" "None" ...
##  $ in.hot_water_fixtures                     : chr [1:137040] "200% Usage" "100% Usage" "5
0% Usage" "100% Usage" ...
##  $ in.hvac_cooling_efficiency                : chr [1:137040] "AC, SEER 15" "Heat Pump" "A
C, SEER 13" "Heat Pump" ...
##  $ in.hvac_cooling_partial_space_conditioning: chr [1:137040] "100% Conditioned" "100% Con
ditioned" "100% Conditioned" "100% Conditioned" ...
##  $ in.hvac_cooling_type                      : chr [1:137040] "Central AC" "Heat Pump" "Ce
ntral AC" "Heat Pump" ...
##  $ in.hvac_has_ducts                         : chr [1:137040] "Yes" "Yes" "Yes" "Yes" ...
##  $ in.hvac_has_zonal_electric_heating        : chr [1:137040] "No" "No" "No" "No" ...
##  $ in.hvac_heating_efficiency                : chr [1:137040] "Electric Furnace, 100% AFU
E" "ASHP, SEER 13, 7.7 HSPF" "Fuel Furnace, 80% AFUE" "ASHP, SEER 13, 7.7 HSPF" ...
##  $ in.hvac_heating_type                      : chr [1:137040] "Ducted Heating" "Ducted Hea
t Pump" "Ducted Heating" "Ducted Heat Pump" ...
##  $ in.hvac_heating_type_and_fuel             : chr [1:137040] "Electricity Electric Furnac
e" "Electricity ASHP" "Propane Fuel Furnace" "Electricity ASHP" ...
##  $ in.income                                 : chr [1:137040] "45000-49999" "50000-59999"
"160000-179999" "80000-99999" ...
##  $ in.income_recs_2015                       : chr [1:137040] "40000-59999" "40000-59999"
"140000+" "80000-99999" ...
##  $ in.income_recs_2020                       : chr [1:137040] "40000-59999" "40000-59999"
"150000+" "60000-99999" ...
##  $ in.infiltration                           : chr [1:137040] "15 ACH50" "25 ACH50" "4 ACH
50" "15 ACH50" ...
##  $ in.insulation_ceiling                     : chr [1:137040] "R-30" "R-30" "R-7" "R-30"
...
##  $ in.insulation_floor                       : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.insulation_foundation_wall             : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.insulation_rim_joist                   : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.insulation_roof                        : chr [1:137040] "Unfinished, Uninsulated" "U
nfinished, Uninsulated" "Unfinished, Uninsulated" "Unfinished, Uninsulated" ...
##  $ in.insulation_slab                        : chr [1:137040] "Uninsulated" "2ft R10 Unde
r, Horizontal" "Uninsulated" "Uninsulated" ...
##  $ in.insulation_wall                        : chr [1:137040] "Wood Stud, Uninsulated" "Wo
od Stud, R-15" "Wood Stud, Uninsulated" "Wood Stud, R-11" ...
##  $ in.lighting                               : chr [1:137040] "100% Incandescent" "100% In
candescent" "100% LED" "100% CFL" ...
##  $ in.misc_extra_refrigerator                : chr [1:137040] "EF 15.9" "None" "None" "Non
e" ...
##  $ in.misc_freezer                           : chr [1:137040] "None" "EF 12, National Aver
age" "None" "EF 12, National Average" ...
```

```
##  $ in.misc_gas_fireplace                     : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.misc_gas_grill                         : chr [1:137040] "Gas Grill" "None" "None" "N
one" ...
##  $ in.misc_gas_lighting                      : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.misc_hot_tub_spa                       : chr [1:137040] "None" "None" "None" "Electr
ic" ...
##  $ in.misc_pool                              : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.misc_pool_heater                       : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.misc_pool_pump                         : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.misc_well_pump                         : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.occupants                              : chr [1:137040] "1" "5" "4" "2" ...
##  $ in.orientation                            : chr [1:137040] "West" "South" "East" "Nort
h" ...
##  $ in.plug_load_diversity                    : chr [1:137040] "200%" "100%" "50%" "100%"
...
##  $ in.puma                                   : chr [1:137040] "G45001600" "G45001600" "G45
001600" "G45001600" ...
##  $ in.puma_metro_status                      : chr [1:137040] "Not/partially in metro are
a" "Not/partially in metro area" "Not/partially in metro area" "Not/partially in metro area"
...
##  $ in.pv_orientation                         : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.pv_system_size                         : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.range_spot_vent_hour                   : chr [1:137040] "Hour9" "Hour19" "Hour2" "Ho
ur16" ...
##  $ in.reeds_balancing_area                   : num [1:137040] 95 95 95 95 95 95 95 95 95 9
5 ...
##  $ in.refrigerator                           : chr [1:137040] "EF 17.6, 100% Usage" "EF 1
7.6, 100% Usage" "EF 17.6, 100% Usage" "EF 17.6, 100% Usage" ...
##  $ in.roof_material                          : chr [1:137040] "Composition Shingles" "Wood
Shingles" "Composition Shingles" "Composition Shingles" ...
##  $ in.tenure                                 : chr [1:137040] "Owner" "Renter" "Owner" "Ow
ner" ...
##  $ in.usage_level                            : chr [1:137040] "High" "Medium" "Low" "Mediu
m" ...
##  $ in.vacancy_status                         : chr [1:137040] "Occupied" "Occupied" "Occup
ied" "Vacant" ...
##  $ in.vintage                                : chr [1:137040] "1960s" "2000s" "1970s" "199
0s" ...
##  $ in.vintage_acs                            : chr [1:137040] "1960-79" "2000-09" "1960-7
9" "1980-99" ...
##  $ in.water_heater_efficiency                : chr [1:137040] "Electric Standard" "Electri
c Standard" "Electric Standard" "Electric Standard" ...
##  $ in.water_heater_fuel                      : chr [1:137040] "Electricity" "Electricity"
"Electricity" "Electricity" ...
##  $ in.weather_file_city                      : chr [1:137040] "Greenwood Co" "Greenwood C
o" "Greenwood Co" "Greenwood Co" ...
##  $ in.weather_file_latitude                  : num [1:137040] 34.2 34.2 34.2 34.2 34.2 ...
##  $ in.weather_file_longitude                 : num [1:137040] -82.2 -82.2 -82.2 -82.2 -82.
```

```
2 ...
##  $ in.window_areas                          : chr [1:137040] "F18 B18 L18 R18" "F12 B12 L
12 R12" "F12 B12 L12 R12" "F30 B30 L30 R30" ...
##  $ in.windows                               : chr [1:137040] "Single, Clear, Metal" "Doub
le, Clear, Metal, Air" "Double, Low-E, Non-metal, Air, M-Gain" "Double, Clear, Non-metal, Ai
r" ...
##  $ upgrade.water_heater_efficiency          : chr [1:137040] "Electric Heat Pump, 66 gal,
3.35 UEF" "Electric Heat Pump, 66 gal, 3.35 UEF" "Electric Heat Pump, 80 gal, 3.45 UEF" "Elec
tric Heat Pump, 50 gal, 3.45 UEF" ...
##  $ upgrade.clothes_dryer                    : chr [1:137040] "Electric, Premium, Heat Pum
p, Ventless, 120% Usage" "Electric, Premium, Heat Pump, Ventless, 100% Usage" "Electric, Prem
ium, Heat Pump, Ventless, 80% Usage" "Electric, Premium, Heat Pump, Ventless, 100% Usage" ...
##   [list output truncated]
```

```
# cols_1<-c('in.sqft',
# 'in.bedrooms',
# 'in.building_america_climate_zone',
# 'in.ceiling_fan',
# 'in.cooling_setpoint',
# 'in.cooling_setpoint_has_offset',
# 'in.cooling_setpoint_offset_magnitude',
# 'in.cooling_setpoint_offset_period',
# 'in.ducts',
# 'in.geometry_foundation_type',
# 'in.geometry_wall_type',
# 'in.has_pv',
# 'in.heating_fuel',
# 'in.hot_water_fixtures',
# 'in.hvac_cooling_partial_space_conditioning',
# 'in.hvac_cooling_type',
# 'in.hvac_heating_type',
# 'in.hvac_heating_type_and_fuel',
# 'in.insulation_ceiling',
# 'in.insulation_wall',
# 'in.lighting',
# 'in.misc_extra_refrigerator',
# 'in.misc_freezer',
# 'in.misc_pool_pump',
# 'in.occupants',
# 'in.pv_system_size',
# 'in.refrigerator',
# 'in.roof_material',
# 'in.usage_level',
# 'in.vacancy_status',
# 'in.water_heater_efficiency',
# 'in.water_heater_fuel',
# 'Final_Energy_KWH'
# )
#
# Subset_V1<-Merged_Final[,cols_1]
```

```
# str(Subset_V1)
# non_numeric_cols <- sapply(Subset_V1, function(x) !is.numeric(x))
# Subset_V1[non_numeric_cols] <- lapply(Subset_V1[non_numeric_cols], as.factor)
# str(Subset_V1)
#
#
#
# # Example assuming 'energy_consumption' is the target variable
# model_lm <- lm( Final_Energy_KWH~ ., data = Subset_V1)
# summary(model_lm)
```

1. This is the first version of the Model, it has around 35 variables and we used linear regression on energy here. Here we analyzed using the P value which coloumns were significant and which ones weren't.

Some columns include environmental variables like 'Dry Bulb Temperature [°C]', 'Relative Humidity [%]', and 'Global Horizontal Radiation [W/m2]'. It also includes building-specific attributes like 'in.sqft', 'in.bedrooms', 'in.building_america_climate_zone', and other features related to appliances, HVAC systems, insulation, energy consumption ('Final_Energy_KWH'), among others.

```
cols_2<-c(
'Dry Bulb Temperature [°C]',
'Relative Humidity [%]',
'Global Horizontal Radiation [W/m2]',
'in.sqft',
'in.bedrooms',
'in.building_america_climate_zone',
'in.ceiling_fan',
'in.cooling_setpoint',
'in.cooling_setpoint_has_offset',
'in.cooling_setpoint_offset_magnitude',
'in.clothes_dryer',
'in.clothes_washer',
'in.ducts',
'in.geometry_foundation_type',
'in.geometry_wall_type',
'in.has_pv',
'in.heating_fuel',
'in.hot_water_fixtures',
'in.hvac_cooling_partial_space_conditioning',
'in.hvac_cooling_type',
'in.hvac_heating_type',
'in.insulation_ceiling',
'in.insulation_wall',
'in.lighting',
'in.misc_extra_refrigerator',
'in.misc_freezer',
'in.misc_pool_pump',
'in.occupants',
'in.pv_system_size',
'in.refrigerator',
'in.roof_material',
'in.usage_level',
'in.vacancy_status',
'in.water_heater_efficiency',
'in.water_heater_fuel',
'Final_Energy_KWH'
)

Subset_V2<-Merged_Final[,cols_2]
```

Observations :

Interpretation of coefficients: For instance, Dry Bulb Temperature [°C], Relative Humidity [%], and Global Horizontal Radiation [W/m2] have extremely low p-values (close to zero), suggesting a high level of significance in predicting Final_Energy_KWH.

Multiple R-squared: This indicates the proportion of variance in the dependent variable that is explained by the independent variables in the model. A value of 0.6603 suggests that approximately 66.03% of the variance in the dependent variable is accounted for by the independent variables.

Adjusted R-squared: Similar to R-squared, but adjusted for the number of predictors in the model. It penalizes for adding unnecessary variables. In your case, it's 0.6599, indicating the same information but adjusted for the number of predictors.

```
str(Subset_V2)
```

```
## tibble [137,040 × 36] (S3: tbl_df/tbl/data.frame)
##  $ Dry Bulb Temperature [°C]                 : num [1:137040] 22.4 22.4 22.4 22.4 22.4 ...
##  $ Relative Humidity [%]                     : num [1:137040] 95.2 95.2 95.2 95.2 95.2 ...
##  $ Global Horizontal Radiation [W/m2]        : num [1:137040] 0 0 0 0 0 0 0 0 0 0 ...
##  $ in.sqft                                   : num [1:137040] 1220 2176 3301 2663 1690 ...
##  $ in.bedrooms                               : num [1:137040] 4 4 5 3 3 4 3 4 3 2 ...
##  $ in.building_america_climate_zone          : Factor w/ 2 levels "Hot-Humid","Mixed-Humi
d": 2 2 2 2 2 2 2 2 2 2 ...
##  $ in.ceiling_fan                            : Factor w/ 3 levels "None","Standard Efficie
ncy",..: 2 2 2 3 2 2 2 3 2 2 ...
##  $ in.cooling_setpoint                       : Factor w/ 11 levels "60F","62F","65F",..: 8
6 8 8 10 10 7 6 8 7 ...
##  $ in.cooling_setpoint_has_offset            : Factor w/ 2 levels "No","Yes": 1 1 1 1 2 1
2 2 1 1 ...
##  $ in.cooling_setpoint_offset_magnitude      : Factor w/ 4 levels "0F","2F","5F",..: 1 1 1
1 4 1 4 4 1 1 ...
##  $ in.clothes_dryer                          : Factor w/ 10 levels "Electric, 100% Usag
e",..: 2 4 3 8 3 2 1 1 1 1 ...
##  $ in.clothes_washer                         : Factor w/ 7 levels "EnergyStar, 100% Usag
e",..: 2 1 7 1 7 6 5 5 1 5 ...
##  $ in.ducts                                  : Factor w/ 14 levels "0% Leakage, Uninsulate
d",..: 6 8 6 6 13 10 2 13 9 2 ...
##  $ in.geometry_foundation_type               : Factor w/ 6 levels "Ambient","Heated Baseme
nt",..: 3 3 3 3 5 3 3 6 6 1 ...
##  $ in.geometry_wall_type                     : Factor w/ 4 levels "Brick","Concrete",..: 4
4 4 3 4 1 4 1 4 4 ...
##  $ in.has_pv                                 : Factor w/ 2 levels "No","Yes": 1 1 1 1 1 1
1 1 1 1 ...
##  $ in.heating_fuel                           : Factor w/ 6 levels "Electricity",..: 1 1 6
1 3 1 1 1 3 3 ...
##  $ in.hot_water_fixtures                     : Factor w/ 3 levels "100% Usage","200% Usag
e",..: 2 1 3 1 3 2 1 1 1 1 ...
##  $ in.hvac_cooling_partial_space_conditioning: Factor w/ 6 levels "100% Conditioned",..: 1
1 1 1 1 1 1 1 1 ...
##  $ in.hvac_cooling_type                      : Factor w/ 4 levels "Central AC","Heat Pum
p",..: 1 2 1 2 1 2 1 2 1 1 ...
##  $ in.hvac_heating_type                      : Factor w/ 4 levels "Ducted Heat Pump",..: 2
1 2 1 2 1 2 1 2 2 ...
##  $ in.insulation_ceiling                     : Factor w/ 8 levels "None","R-13",..: 4 4 7
4 4 7 2 2 4 5 ...
##  $ in.insulation_wall                        : Factor w/ 15 levels "Brick, 12-in, 3-wythe,
R-11",..: 15 12 15 11 13 5 14 5 15 15 ...
##  $ in.lighting                               : Factor w/ 3 levels "100% CFL","100% Incande
scent",..: 2 2 3 1 1 2 3 1 3 3 ...
##  $ in.misc_extra_refrigerator                : Factor w/ 7 levels "EF 10.2","EF 10.5",..:
3 7 7 7 4 7 7 4 7 7 ...
##  $ in.misc_freezer                           : Factor w/ 2 levels "EF 12, National Averag
e",..: 2 1 2 1 2 2 2 2 2 2 ...
##  $ in.misc_pool_pump                         : Factor w/ 2 levels "1.0 HP Pump",..: 2 2 2
2 2 2 2 2 2 2 ...
##  $ in.occupants                              : Factor w/ 10 levels "1","10+","2",..: 1 6 5
3 3 3 3 8 3 3 ...
##  $ in.pv_system_size                         : Factor w/ 8 levels "1.0 kWDC","11.0 kWD
C",..: 8 8 8 8 8 8 8 8 8 8 ...
##  $ in.refrigerator                           : Factor w/ 7 levels "EF 10.2, 100% Usag
```

```
e",..: 4 4 4 4 4 4 4 4 5 4 ...
##  $ in.roof_material                          : Factor w/ 7 levels "Asphalt Shingles, Mediu
m",..: 2 7 2 2 1 2 2 5 2 2 ...
##  $ in.usage_level                            : Factor w/ 3 levels "High","Low","Medium": 1
3 2 3 2 1 3 3 3 3 ...
##  $ in.vacancy_status                         : Factor w/ 2 levels "Occupied","Vacant": 1 1
1 2 1 1 1 2 1 1 ...
##  $ in.water_heater_efficiency                : Factor w/ 12 levels "Electric Heat Pump, 80
gal",..: 3 3 3 3 8 3 12 3 7 7 ...
##  $ in.water_heater_fuel                      : Factor w/ 5 levels "Electricity",..: 1 1 1
1 3 1 5 1 3 3 ...
##  $ Final_Energy_KWH                          : num [1:137040] 24.9 36.19 17.28 1
```

```
# Example assuming 'energy_consumption' is the target variable
model_lm_2 <- lm( Final_Energy_KWH~ ., data = Subset_V2)
summary(model_lm_2)
```

```
##
## Call:
## lm(formula = Final_Energy_KWH ~ ., data = Subset_V2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -158.492   -6.910   -1.128    5.297  189.168
##
## Coefficients: (13 not defined because of singularities)
##                                                    Estimate Std. Error
## (Intercept)                                       8.139e+00  3.085e+00
## `Dry Bulb Temperature [°C]`                       2.641e+00  5.138e-02
## `Relative Humidity [%]`                          -4.472e-01  1.282e-02
## `Global Horizontal Radiation [W/m2]`             -1.484e-02  2.498e-04
## in.sqft                                           6.347e-03  3.037e-05
## in.bedrooms                                       4.810e-01  4.908e-02
## in.building_america_climate_zoneMixed-Humid      -8.259e-01  1.286e-01
## in.ceiling_fanStandard Efficiency                 4.347e-01  8.466e-02
## in.ceiling_fanStandard Efficiency, No usage       1.347e+00  2.286e-01
## in.cooling_setpoint62F                           -3.483e+00  6.837e-01
## in.cooling_setpoint65F                           -5.291e+00  4.246e-01
## in.cooling_setpoint67F                           -9.243e+00  5.329e-01
## in.cooling_setpoint68F                           -8.625e+00  3.841e-01
## in.cooling_setpoint70F                           -1.049e+01  3.746e-01
## in.cooling_setpoint72F                           -1.227e+01  3.744e-01
## in.cooling_setpoint75F                           -1.530e+01  3.736e-01
## in.cooling_setpoint76F                           -1.647e+01  3.864e-01
## in.cooling_setpoint78F                           -1.852e+01  3.766e-01
## in.cooling_setpoint80F                           -2.122e+01  4.198e-01
## in.cooling_setpoint_has_offsetYes                 2.241e+00  1.706e-01
## in.cooling_setpoint_offset_magnitude2F           -2.472e+00  1.821e-01
## in.cooling_setpoint_offset_magnitude5F           -9.242e-01  1.977e-01
## in.cooling_setpoint_offset_magnitude9F                   NA         NA
## in.clothes_dryerElectric, 120% Usage              1.262e+00  6.721e-01
## in.clothes_dryerElectric, 80% Usage               1.576e+00  7.132e-01
## in.clothes_dryerGas, 100% Usage                  -3.675e-01  2.326e-01
## in.clothes_dryerGas, 120% Usage                   1.091e+00  7.360e-01
## in.clothes_dryerGas, 80% Usage                    2.019e+00  7.708e-01
## in.clothes_dryerNone                              3.540e-01  3.985e-01
## in.clothes_dryerPropane, 100% Usage              -1.546e+00  4.870e-01
## in.clothes_dryerPropane, 120% Usage               2.023e+00  1.053e+00
## in.clothes_dryerPropane, 80% Usage                2.033e+00  9.498e-01
## in.clothes_washerEnergyStar, 120% Usage          -3.833e-01  9.241e-01
## in.clothes_washerEnergyStar, 80% Usage           -2.738e+00  9.163e-01
## in.clothes_washerNone                            -1.161e+00  5.328e-01
## in.clothes_washerStandard, 100% Usage             8.311e-01  1.051e-01
## in.clothes_washerStandard, 120% Usage             1.067e+00  9.306e-01
## in.clothes_washerStandard, 80% Usage             -2.243e+00  9.238e-01
## in.ducts10% Leakage, R-4                          3.940e+00  1.596e+00
## in.ducts10% Leakage, R-6                          6.251e-01  1.612e+00
## in.ducts10% Leakage, R-8                          2.560e+00  1.598e+00
## in.ducts10% Leakage, Uninsulated                  1.890e+00  1.597e+00
## in.ducts20% Leakage, R-4                          3.858e+00  1.594e+00
## in.ducts20% Leakage, R-6                          7.509e-01  1.602e+00
## in.ducts20% Leakage, R-8                          2.228e+00  1.595e+00
```

```
## in.occupants5                                          60.943  < 2e-16 ***
## in.occupants6                                          45.777  < 2e-16 ***
## in.occupants7                                          44.281  < 2e-16 ***
## in.occupants8                                          29.868  < 2e-16 ***
## in.occupants9                                          21.036  < 2e-16 ***
## in.pv_system_size11.0 kWDC                            -25.131  < 2e-16 ***
## in.pv_system_size13.0 kWDC                            -23.669  < 2e-16 ***
## in.pv_system_size3.0 kWDC                              -7.484 7.27e-14 ***
## in.pv_system_size5.0 kWDC                             -12.768  < 2e-16 ***
## in.pv_system_size7.0 kWDC                             -16.904  < 2e-16 ***
## in.pv_system_size9.0 kWDC                             -21.716  < 2e-16 ***
## in.pv_system_sizeNone                                      NA       NA
## in.refrigeratorEF 10.5, 100% Usage                     -1.190 0.234050
## in.refrigeratorEF 15.9, 100% Usage                     -4.600 4.22e-06 ***
## in.refrigeratorEF 17.6, 100% Usage                     -4.735 2.20e-06 ***
## in.refrigeratorEF 19.9, 100% Usage                     -6.053 1.43e-09 ***
## in.refrigeratorEF 6.7, 100% Usage                       3.099 0.001943 **
## in.refrigeratorNone                                    -4.320 1.56e-05 ***
## in.roof_materialComposition Shingles                    2.016 0.043828 *
## in.roof_materialMetal, Dark                             3.248 0.001163 **
## in.roof_materialSlate                                  -0.037 0.970203
## in.roof_materialTile, Clay or Ceramic                  -0.226 0.821557
## in.roof_materialTile, Concrete                          0.341 0.732866
## in.roof_materialWood Shingles                           2.614 0.008948 **
## in.usage_levelLow                                          NA       NA
## in.usage_levelMedium                                       NA       NA
## in.vacancy_statusVacant                              -100.338  < 2e-16 ***
## in.water_heater_efficiencyElectric Premium              0.788 0.430966
## in.water_heater_efficiencyElectric Standard            -0.196 0.844893
## in.water_heater_efficiencyElectric Tankless             7.360 1.85e-13 ***
## in.water_heater_efficiencyFuel Oil Standard            -1.901 0.057244 .
## in.water_heater_efficiencyNatural Gas Premium           0.055 0.955997
## in.water_heater_efficiencyNatural Gas Standard         -0.115 0.908582
## in.water_heater_efficiencyNatural Gas Tankless          3.745 0.000181 ***
## in.water_heater_efficiencyOther Fuel                    0.742 0.458248
## in.water_heater_efficiencyPropane Premium              -1.217 0.223569
## in.water_heater_efficiencyPropane Standard             -0.003 0.997506
## in.water_heater_efficiencyPropane Tankless             -0.053 0.957641
## in.water_heater_fuelFuel Oil                               NA       NA
## in.water_heater_fuelNatural Gas                            NA       NA
## in.water_heater_fuelOther Fuel                             NA       NA
## in.water_heater_fuelPropane                                NA       NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 13.02 on 136898 degrees of freedom
## Multiple R-squared:  0.6603, Adjusted R-squared:  0.6599
## F-statistic:  1887 on 141 and 136898 DF,  p-value: < 2.2e-16
```

#Model 3

Coloums contain : It contains many columns from cols_2, such as environmental variables, building-specific attributes, and energy-related features. Additionally, cols_3 introduces new variables like ‘in.county’, ‘hour’, ‘in.insulation_slab’, ‘Wind Speed [m/s]’, and a couple of others that were not present in cols_2.

```
cols_3<-c(
  'Dry Bulb Temperature [°C]',
   'Relative Humidity [%]',
  'in.county',
  'hour',
  'Global Horizontal Radiation [W/m2]',
  'in.sqft',
'in.bedrooms',
'in.building_america_climate_zone',
'in.ceiling_fan',
'in.cooling_setpoint',
'in.cooling_setpoint_has_offset',
'in.cooling_setpoint_offset_magnitude',
#-----------
'in.clothes_dryer',
'in.clothes_washer',
'in.insulation_slab',
'Wind Speed [m/s]',
#-------------------
'in.ducts',
'in.geometry_foundation_type',
'in.geometry_wall_type',
'in.has_pv',
'in.heating_fuel',
'in.hot_water_fixtures',
'in.hvac_cooling_partial_space_conditioning',
'in.hvac_cooling_type',
'in.hvac_heating_type',
#'in.hvac_heating_type_and_fuel',
'in.insulation_ceiling',
'in.insulation_wall',
'in.lighting',
'in.misc_extra_refrigerator',
'in.misc_freezer',
'in.misc_pool_pump',
'in.occupants',
'in.pv_system_size',
'in.refrigerator',
'in.roof_material',
'in.usage_level',
'in.vacancy_status',
'in.water_heater_efficiency',
'in.water_heater_fuel',
'Final_Energy_KWH'
)

Subset_V3<-Merged_Final[,cols_3]
```

```
str(Subset_V3)
```

```
## tibble [137,040 × 40] (S3: tbl_df/tbl/data.frame)
##  $ Dry Bulb Temperature [°C]                 : num [1:137040] 22.4 22.4 22.4 22.4 22.4 ...
##  $ Relative Humidity [%]                     : num [1:137040] 95.2 95.2 95.2 95.2 95.2 ...
##  $ in.county                                 : chr [1:137040] "G4500010" "G4500010" "G4500
010" "G4500010" ...
##  $ hour                                      : num [1:137040] 0 0 0 0 0 0 0 0 0 0 ...
##  $ Global Horizontal Radiation [W/m2]        : num [1:137040] 0 0 0 0 0 0 0 0 0 0 ...
##  $ in.sqft                                   : num [1:137040] 1220 2176 3301 2663 1690 ...
##  $ in.bedrooms                               : num [1:137040] 4 4 5 3 3 4 3 4 3 2 ...
##  $ in.building_america_climate_zone          : chr [1:137040] "Mixed-Humid" "Mixed-Humid"
"Mixed-Humid" "Mixed-Humid" ...
##  $ in.ceiling_fan                            : chr [1:137040] "Standard Efficiency" "Stand
ard Efficiency" "Standard Efficiency" "Standard Efficiency, No usage" ...
##  $ in.cooling_setpoint                       : chr [1:137040] "75F" "70F" "75F" "75F" ...
##  $ in.cooling_setpoint_has_offset            : chr [1:137040] "No" "No" "No" "No" ...
##  $ in.cooling_setpoint_offset_magnitude      : chr [1:137040] "0F" "0F" "0F" "0F" ...
##  $ in.clothes_dryer                          : chr [1:137040] "Electric, 120% Usage" "Gas,
100% Usage" "Electric, 80% Usage" "Propane, 100% Usage" ...
##  $ in.clothes_washer                         : chr [1:137040] "EnergyStar, 120% Usage" "En
ergyStar, 100% Usage" "Standard, 80% Usage" "EnergyStar, 100% Usage" ...
##  $ in.insulation_slab                        : chr [1:137040] "Uninsulated" "2ft R10 Unde
r, Horizontal" "Uninsulated" "Uninsulated" ...
##  $ Wind Speed [m/s]                          : num [1:137040] 1.09 1.09 1.09 1.09 1.09 ...
##  $ in.ducts                                  : chr [1:137040] "20% Leakage, R-4" "20% Leak
age, R-8" "20% Leakage, R-4" "20% Leakage, R-4" ...
##  $ in.geometry_foundation_type               : chr [1:137040] "Slab" "Slab" "Slab" "Slab"
...
##  $ in.geometry_wall_type                     : chr [1:137040] "Wood Frame" "Wood Frame" "W
ood Frame" "Steel Frame" ...
##  $ in.has_pv                                 : chr [1:137040] "No" "No" "No" "No" ...
##  $ in.heating_fuel                           : chr [1:137040] "Electricity" "Electricity"
"Propane" "Electricity" ...
##  $ in.hot_water_fixtures                     : chr [1:137040] "200% Usage" "100% Usage" "5
0% Usage" "100% Usage" ...
##  $ in.hvac_cooling_partial_space_conditioning: chr [1:137040] "100% Conditioned" "100% Con
ditioned" "100% Conditioned" "100% Conditioned" ...
##  $ in.hvac_cooling_type                      : chr [1:137040] "Central AC" "Heat Pump" "Ce
ntral AC" "Heat Pump" ...
##  $ in.hvac_heating_type                      : chr [1:137040] "Ducted Heating" "Ducted Hea
t Pump" "Ducted Heating" "Ducted Heat Pump" ...
##  $ in.insulation_ceiling                     : chr [1:137040] "R-30" "R-30" "R-7" "R-30"
...
##  $ in.insulation_wall                        : chr [1:137040] "Wood Stud, Uninsulated" "Wo
od Stud, R-15" "Wood Stud, Uninsulated" "Wood Stud, R-11" ...
##  $ in.lighting                               : chr [1:137040] "100% Incandescent" "100% In
candescent" "100% LED" "100% CFL" ...
##  $ in.misc_extra_refrigerator                : chr [1:137040] "EF 15.9" "None" "None" "Non
e" ...
##  $ in.misc_freezer                           : chr [1:137040] "None" "EF 12, National Aver
age" "None" "EF 12, National Average" ...
##  $ in.misc_pool_pump                         : chr [1:137040] "None" "None" "None" "None"
...
##  $ in.occupants                              : chr [1:137040] "1" "5" "4" "2" ...
##  $ in.pv_system_size                         : chr [1:137040] "None" "None" "None" "None"
...
```

```
##  $ in.refrigerator                          : chr [1:137040] "EF 17.6, 100% Usage" "EF 1
7.6, 100% Usage" "EF 17.6, 100% Usage" "EF 17.6, 100% Usage" ...
##  $ in.roof_material                         : chr [1:137040] "Composition Shingles" "Wood
Shingles" "Composition Shingles" "Composition Shingles" ...
##  $ in.usage_level                           : chr [1:137040] "High" "Medium" "Low" "Mediu
m" ...
##  $ in.vacancy_status                        : chr [1:137040] "Occupied" "Occupied" "Occup
ied" "Vacant" ...
##  $ in.water_heater_efficiency               : chr [1:137040] "Electric Standard" "Electri
c Standard" "Electric Standard" "Electric Standard" ...
##  $ in.water_heater_fuel                     : chr [1:137040] "Electricity" "Electricity"
"Electricity" "Electricity" ...
##  $ Final_Energy_KWH                         : num [1:137040] 24.9 36 19 17 28.1 ...
```

```
non_numeric_cols <- sapply(Subset_V3, function(x) !is.numeric(x))
Subset_V3[non_numeric_cols] <- lapply(Subset_V3[non_numeric_cols], as.factor)
str(Subset_V3)
```

```
## tibble [137,040 × 40] (S3: tbl_df/tbl/data.frame)
##  $ Dry Bulb Temperature [°C]                 : num [1:137040] 22.4 22.4 22.4 22.4 22.4 ...
##  $ Relative Humidity [%]                     : num [1:137040] 95.2 95.2 95.2 95.2 95.2 ...
##  $ in.county                                 : Factor w/ 46 levels "G4500010","G450003
0",..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ hour                                      : num [1:137040] 0 0 0 0 0 0 0 0 0 0 ...
##  $ Global Horizontal Radiation [W/m2]        : num [1:137040] 0 0 0 0 0 0 0 0 0 0 ...
##  $ in.sqft                                   : num [1:137040] 1220 2176 3301 2663 1690 ...
##  $ in.bedrooms                               : num [1:137040] 4 4 5 3 3 4 3 4 3 2 ...
##  $ in.building_america_climate_zone          : Factor w/ 2 levels "Hot-Humid","Mixed-Humi
d": 2 2 2 2 2 2 2 2 2 2 ...
##  $ in.ceiling_fan                            : Factor w/ 3 levels "None","Standard Efficie
ncy",..: 2 2 2 3 2 2 2 3 2 2 ...
##  $ in.cooling_setpoint                       : Factor w/ 11 levels "60F","62F","65F",..: 8
6 8 8 10 10 7 6 8 7 ...
##  $ in.cooling_setpoint_has_offset            : Factor w/ 2 levels "No","Yes": 1 1 1 1 2 1
2 2 1 1 ...
##  $ in.cooling_setpoint_offset_magnitude      : Factor w/ 4 levels "0F","2F","5F",..: 1 1 1
1 4 1 4 4 1 1 ...
##  $ in.clothes_dryer                          : Factor w/ 10 levels "Electric, 100% Usag
e",..: 2 4 3 8 3 2 1 1 1 1 ...
##  $ in.clothes_washer                         : Factor w/ 7 levels "EnergyStar, 100% Usag
e",..: 2 1 7 1 7 6 5 5 1 5 ...
##  $ in.insulation_slab                        : Factor w/ 6 levels "2ft R10 Perimeter, Vert
ical",..: 6 2 6 6 5 6 6 5 5 5 ...
##  $ Wind Speed [m/s]                          : num [1:137040] 1.09 1.09 1.09 1.09 1.09 ...
##  $ in.ducts                                  : Factor w/ 14 levels "0% Leakage, Uninsulate
d",..: 6 8 6 6 13 10 2 13 9 2 ...
##  $ in.geometry_foundation_type               : Factor w/ 6 levels "Ambient","Heated Baseme
nt",..: 3 3 3 3 5 3 3 6 6 1 ...
##  $ in.geometry_wall_type                     : Factor w/ 4 levels "Brick","Concrete",..: 4
4 4 3 4 1 4 1 4 4 ...
##  $ in.has_pv                                 : Factor w/ 2 levels "No","Yes": 1 1 1 1 1 1
1 1 1 1 ...
##  $ in.heating_fuel                           : Factor w/ 6 levels "Electricity",..: 1 1 6
1 3 1 1 1 3 3 ...
##  $ in.hot_water_fixtures                     : Factor w/ 3 levels "100% Usage","200% Usag
e",..: 2 1 3 1 3 2 1 1 1 1 ...
##  $ in.hvac_cooling_partial_space_conditioning: Factor w/ 6 levels "100% Conditioned",..: 1
1 1 1 1 1 1 1 1 1 ...
##  $ in.hvac_cooling_type                      : Factor w/ 4 levels "Central AC","Heat Pum
p",..: 1 2 1 2 1 2 1 2 1 1 ...
##  $ in.hvac_heating_type                      : Factor w/ 4 levels "Ducted Heat Pump",..: 2
1 2 1 2 1 2 1 2 2 ...
##  $ in.insulation_ceiling                     : Factor w/ 8 levels "None","R-13",..: 4 4 7
4 4 7 2 2 4 5 ...
##  $ in.insulation_wall                        : Factor w/ 15 levels "Brick, 12-in, 3-wythe,
R-11",..: 15 12 15 11 13 5 14 5 15 15 ...
##  $ in.lighting                               : Factor w/ 3 levels "100% CFL","100% Incande
scent",..: 2 2 3 1 1 2 3 1 3 3 ...
##  $ in.misc_extra_refrigerator                : Factor w/ 7 levels "EF 10.2","EF 10.5",..:
3 7 7 7 4 7 7 4 7 7 ...
##  $ in.misc_freezer                           : Factor w/ 2 levels "EF 12, National Averag
e",..: 2 1 2 1 2 2 2 2 2 2 ...
##  $ in.misc_pool_pump                         : Factor w/ 2 levels "1.0 HP Pump",..: 2 2 2
```

```
2 2 2 2 2 2 2 ...
##  $ in.occupants                          : Factor w/ 10 levels "1","10+","2",..: 1 6 5
3 3 3 3 8 3 3 ...
##  $ in.pv_system_size                     : Factor w/ 8 levels "1.0 kWDC","11.0 kWD
C",..: 8 8 8 8 8 8 8 8 8 ...
##  $ in.refrigerator                       : Factor w/ 7 levels "EF 10.2, 100% Usag
e",..: 4 4 4 4 4 4 4 4 5 4 ...
##  $ in.roof_material                      : Factor w/ 7 levels "Asphalt Shingles, Mediu
m",..: 2 7 2 2 1 2 2 5 2 2 ...
##  $ in.usage_level                        : Factor w/ 3 levels "High","Low","Medium": 1
3 2 3 2 1 3 3 3 3 ...
##  $ in.vacancy_status                     : Factor w/ 2 levels "Occupied","Vacant": 1 1
1 2 1 1 1 2 1 1 ...
##  $ in.water_heater_efficiency            : Factor w/ 12 levels "Electric Heat Pump, 80
gal",..: 3 3 3 3 8 3 12 3 7 7 ...
##  $ in.water_heater_fuel                  : Factor w/ 5 levels "Electricity",..: 1 1 1
1 3 1 5 1 3 3 ...
##  $ Final_Energy_KWH                      : num [1:137040] 24.9 36.19 17.28 1
```

Observations :

Multiple R-squared: This value (0.6823) represents the proportion of variance in the dependent variable (in this case, Final_Energy_KWH) that is explained by the independent variables included in the model. It ranges between 0 and 1, where 1 indicates that all variability in the response variable is explained by the predictors.

Adjusted R-squared: Similar to R-squared, but adjusted for the number of predictors in the model. It penalizes the addition of irrelevant predictors that do not improve the model significantly. In your case, it's 0.6818, slightly lower than the Multiple R-squared due to the adjustment for the number of predictors.

```
# Example assuming 'energy_consumption' is the target variable
model_lm_3 <- lm( Final_Energy_KWH~ ., data = Subset_V3)
summary(model_lm_3)
```

```
##
## Call:
## lm(formula = Final_Energy_KWH ~ ., data = Subset_V3)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -157.908   -6.464   -1.105    4.906  187.829
##
## Coefficients: (15 not defined because of singularities)
##                                                    Estimate Std. Error
## (Intercept)                                       8.221e+01  7.272e+00
## `Dry Bulb Temperature [°C]`                       1.538e-01  1.600e-01
## `Relative Humidity [%]`                          -7.067e-01  3.725e-02
## in.countyG4500030                                 1.344e-01  5.452e-01
## in.countyG4500050                                -1.649e+00  9.585e-01
## in.countyG4500070                                -5.319e+00  5.307e-01
## in.countyG4500090                                -1.480e+00  7.590e-01
## in.countyG4500110                                -3.638e+00  7.299e-01
## in.countyG4500130                                 2.257e+00  6.676e-01
## in.countyG4500150                                -5.014e+00  6.006e-01
## in.countyG4500170                                -2.824e+00  8.129e-01
## in.countyG4500190                                -4.544e+00  5.850e-01
## in.countyG4500210                                 4.701e+00  5.986e-01
## in.countyG4500230                                 9.592e-01  6.526e-01
## in.countyG4500250                                -8.846e+00  6.560e-01
## in.countyG4500270                                -6.914e+00  6.558e-01
## in.countyG4500290                                 4.600e+00  7.685e-01
## in.countyG4500310                                -6.400e+00  5.721e-01
## in.countyG4500330                                -9.242e+00  6.666e-01
## in.countyG4500350                                -5.263e+00  6.116e-01
## in.countyG4500370                                 7.911e-01  6.877e-01
## in.countyG4500390                                -1.598e+00  6.516e-01
## in.countyG4500410                                -6.789e+00  5.378e-01
## in.countyG4500430                                -1.079e+01  6.009e-01
## in.countyG4500450                                -3.867e+00  5.092e-01
## in.countyG4500470                                 4.067e-01  5.585e-01
## in.countyG4500490                                 2.654e+00  8.910e-01
## in.countyG4500510                                -1.177e+01  5.551e-01
## in.countyG4500530                                 7.181e-01  8.190e-01
## in.countyG4500550                                -6.822e+00  5.757e-01
## in.countyG4500570                                -9.116e+00  6.258e-01
## in.countyG4500590                                 1.286e+00  5.618e-01
## in.countyG4500610                                -5.967e+00  7.864e-01
## in.countyG4500630                                -4.695e+00  5.387e-01
## in.countyG4500650                                 1.110e+00  7.811e-01
## in.countyG4500670                                -7.766e+00  7.168e-01
## in.countyG4500690                                -8.200e+00  6.580e-01
## in.countyG4500710                                -5.575e+00  6.253e-01
## in.countyG4500730                                -8.132e-01  5.616e-01
## in.countyG4500750                                -3.000e+00  5.486e-01
## in.countyG4500770                                -2.313e+00  5.529e-01
## in.countyG4500790                                -2.349e+00  5.214e-01
## in.countyG4500810                                -2.680e-01  7.377e-01
## in.countyG4500830                                -4.479e+00  5.144e-01
## in.countyG4500850                                -5.997e+00  5.481e-01
```

```
## in.pv_system_size5.0 kWDC                                  -12.192  < 2e-16 ***
## in.pv_system_size7.0 kWDC                                  -16.889  < 2e-16 ***
## in.pv_system_size9.0 kWDC                                  -21.640  < 2e-16 ***
## in.pv_system_sizeNone                                           NA       NA
## in.refrigeratorEF 10.5, 100% Usage                          -0.958 0.338152
## in.refrigeratorEF 15.9, 100% Usage                          -4.479 7.52e-06 ***
## in.refrigeratorEF 17.6, 100% Usage                          -4.281 1.86e-05 ***
## in.refrigeratorEF 19.9, 100% Usage                          -5.691 1.26e-08 ***
## in.refrigeratorEF 6.7, 100% Usage                            3.642 0.000271 ***
## in.refrigeratorNone                                         -4.530 5.92e-06 ***
## in.roof_materialComposition Shingles                         2.070 0.038456 *
## in.roof_materialMetal, Dark                                  3.727 0.000194 ***
## in.roof_materialSlate                                        0.959 0.337496
## in.roof_materialTile, Clay or Ceramic                       -0.989 0.322724
## in.roof_materialTile, Concrete                               0.555 0.578902
## in.roof_materialWood Shingles                                2.829 0.004675 **
## in.usage_levelLow                                               NA       NA
## in.usage_levelMedium                                            NA       NA
## in.vacancy_statusVacant                                   -102.611  < 2e-16 ***
## in.water_heater_efficiencyElectric Premium                   1.276 0.202133
## in.water_heater_efficiencyElectric Standard                  0.170 0.865336
## in.water_heater_efficiencyElectric Tankless                  7.973 1.56e-15 ***
## in.water_heater_efficiencyFuel Oil Standard                 -1.703 0.088597 .
## in.water_heater_efficiencyNatural Gas Premium               -0.074 0.940918
## in.water_heater_efficiencyNatural Gas Standard               0.059 0.953329
## in.water_heater_efficiencyNatural Gas Tankless               3.272 0.001067 **
## in.water_heater_efficiencyOther Fuel                         1.150 0.250173
## in.water_heater_efficiencyPropane Premium                   -1.463 0.143392
## in.water_heater_efficiencyPropane Standard                   0.494 0.621319
## in.water_heater_efficiencyPropane Tankless                  -0.723 0.469791
## in.water_heater_fuelFuel Oil                                    NA       NA
## in.water_heater_fuelNatural Gas                                 NA       NA
## in.water_heater_fuelOther Fuel                                  NA       NA
## in.water_heater_fuelPropane                                     NA       NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 12.59 on 136848 degrees of freedom
## Multiple R-squared:  0.6823, Adjusted R-squared:  0.6818
## F-statistic:  1539 on 191 and 136848 DF,  p-value: < 2.2e-16
```

XGBoost :

The decision to use XGBoost (Extreme Gradient Boosting) over linear regression due to various factors:

1.Complexity and Non-linearity: Linear regression assumes a linear relationship between the independent and dependent variables. If your data has complex, non-linear relationships, XGBoost, being a tree-based ensemble method, can capture these non-linearities more effectively than linear regression.

2.Feature Interactions: XGBoost can capture interactions between variables better than linear regression. Linear regression assumes that the effect of an independent variable is constant, whereas XGBoost can handle interactions between variables more flexibly.

3.Performance: If your primary goal is predictive accuracy and the linear model isn't performing well on your dataset (based on metrics like RMSE, MAE, etc.), XGBoost or other tree-based methods might yield better results.

4.Handling of Large Datasets: XGBoost is often more scalable and efficient for larger datasets compared to traditional linear regression models.

5.Feature Importance: XGBoost provides a feature importance score, which can help identify the most significant variables influencing the target compared to linear regression.

6.Model Interpretability: Linear regression models are more interpretable since they directly show the relationship between variables and the target. XGBoost, being a more complex model, is generally less interpretable.

In summary, while linear regression provides simple interpretability and assumes a linear relationship between variables, XGBoost can handle non-linear relationships and interactions, making it a powerful algorithm for predictive tasks, especially when the data is complex or when high predictive accuracy is needed.

Final Model

```
library(arrow)
library(tidyverse)



cols_4<-c('hour',
          'in.county',
          'Dry Bulb Temperature [°C]','Relative Humidity [%]','Wind Speed [m/s]',
          'Wind Direction [Deg]','Direct Normal Radiation [W/m2]','Diffuse Horizontal Radiati
on [W/m2]',
          'Global Horizontal Radiation [W/m2]', 'in.sqft',
          'in.bedrooms',
          'in.building_america_climate_zone',
          'in.ceiling_fan',
          'in.clothes_dryer',
          'in.clothes_washer',
          'in.cooling_setpoint',
          'in.cooling_setpoint_has_offset',
          'in.cooling_setpoint_offset_magnitude',
          'in.dishwasher',
          'in.ducts',
          'in.geometry_foundation_type',
          'in.geometry_wall_type',
          'in.geometry_stories',
          'in.has_pv',
          'in.heating_fuel',
          'in.hot_water_fixtures',
          'in.hvac_cooling_partial_space_conditioning',
          'in.hvac_cooling_type',
          'in.hvac_heating_type',
          'in.hvac_heating_type_and_fuel',
          'in.infiltration',
          'in.insulation_ceiling',
          'in.insulation_wall',
          'in.lighting',
          'in.misc_extra_refrigerator',
          'in.misc_freezer',
          'in.misc_pool_pump',
          'in.occupants',
          'in.pv_system_size',
          'in.refrigerator',
          'in.roof_material',
          'in.usage_level',
          'in.vacancy_status',
          'in.water_heater_efficiency',
          'in.water_heater_fuel',
          'Final_Energy_KWH'

)

Subset_V4<-Merged_Final[,cols_4]

non_numeric_cols <- sapply(Subset_V4, function(x) !is.numeric(x))
Subset_V4[non_numeric_cols] <- lapply(Subset_V4[non_numeric_cols], as.factor)
```

```
#xGBoost Model
set.seed(123)

# Split data into training and test sets (e.g., 80% training, 20% test)
train_indices <- sample(1:nrow(Subset_V4), size = 0.7 * nrow(Subset_V4))
train_data <- Subset_V4[train_indices, ]
test_data <- Subset_V4[-train_indices, ]
```

XGBoost is also effective at handling non-linear relationships between predictor and target variables, which is important for our analysis. Additionally, it demonstrates robustness against outliers, a valuable feature considering the presence of airbases, airports, and similar data points. Moreover, XGBoost is more focused on making predictions rather than drawing inferences, aligning well with the project's prediction-oriented objectives. Furthermore, XGBoost provides feature importance scores, allowing us to pinpoint the variables that exert the most significant influence on the prediction, aiding in identifying key drivers of Final Energy Consumption

```
library (xgboost)
```

```
## Warning: package 'xgboost' was built under R version 4.3.2
```

```
##
## Attaching package: 'xgboost'
```

```
## The following object is masked from 'package:dplyr':
##
##     slice
```

```
# Convert training data to DMatrix format
dtrain <- xgb.DMatrix(data = data.matrix(train_data[, -which(names(train_data) == "Final_Ener
gy_KWH")]),
                      label = train_data$Final_Energy_KWH)

params <- list(
  objective = "reg:squarederror",
  eta = 0.1,
  max_depth = 8,
  subsample = 0.5,
  colsample_bytree = 0.5
)

nrounds <- 3000  # Number of boosting rounds. Adjust based on your dataset and needs

xgb_model <- xgboost(params = params, data = dtrain, nrounds = nrounds)
```

```
## [2968]   train-rmse:1.006519
## [2969]   train-rmse:1.006065
## [2970]   train-rmse:1.005599
## [2971]   train-rmse:1.005191
## [2972]   train-rmse:1.004762
## [2973]   train-rmse:1.004264
## [2974]   train-rmse:1.003765
## [2975]   train-rmse:1.003328
## [2976]   train-rmse:1.003082
## [2977]   train-rmse:1.002697
## [2978]   train-rmse:1.002335
## [2979]   train-rmse:1.001887
## [2980]   train-rmse:1.001607
## [2981]   train-rmse:1.001198
## [2982]   train-rmse:1.000703
## [2983]   train-rmse:1.000167
## [2984]   train-rmse:0.999723
## [2985]   train-rmse:0.999183
## [2986]   train-rmse:0.998777
## [2987]   train-rmse:0.998336
## [2988]   train-rmse:0.997923
## [2989]   train-rmse:0.997582
## [2990]   train-rmse:0.997263
## [2991]   train-rmse:0.996861
## [2992]   train-rmse:0.996386
## [2993]   train-rmse:0.995986
## [2994]   train-rmse:0.995568
## [2995]   train-rmse:0.995237
## [2996]   train-rmse:0.994799
## [2997]   train-rmse:0.994577
## [2998]   train-rmse:0.994053
## [2999]   train-rmse:0.993743
## [3000]   train-rmse:0.993360
```

```
#summary(xgb_model)


# Assuming you have a trained XGBoost model 'xgb_model' and a test set 'test_data'

# Predict on the test set
dtest <- xgb.DMatrix(data = data.matrix(test_data[, -which(names(test_data) == "Final_Energy_
KWH")]))
predictions1 <- predict(xgb_model, dtest)
```

RMSE (Root Mean Squared Error): 6.31186571704705

RMSE is a measure of the average deviation of predicted values from the actual observed values. It represents the square root of the average of the squared differences between predicted and actual values.

In this case, the RMSE value of approximately 6.31 suggests that, on average, the predictions of the model are around 6.31 units away from the actual values.

An R-squared value of approximately 0.919 (or 91.9%) indicates that roughly 91.9% of the variance in the dependent variable is accounted for by the independent variables in the model, suggesting that the model explains a large portion of the variability in the target energy variable.

Overall, We believe the model has reasonably good performance: the RMSE shows that the predictions are relatively close to the actual values on average, while the high R-squared value indicates that a significant amount of the variance in the target variable is captured by the model.

```
# Compute RMSE
rmse <- sqrt(mean((predictions1 - test_data$Final_Energy_KWH)^2))
print(paste("RMSE:", rmse))
```

```
## [1] "RMSE: 6.31186571704705"
```

```
# Compute R-squared
SST <- sum((test_data$Final_Energy_KWH - mean(test_data$Final_Energy_KWH))^2)
SSR <- sum((predictions1 - test_data$Final_Energy_KWH)^2)
r_squared <- 1 - SSR/SST
print(paste("R-squared:", r_squared))
```

```
## [1] "R-squared: 0.918774005776453"
```

```
#range(predictions1-test_data$Final_Energy_KWH)
#summary(predictions1-test_data$Final_Energy_KWH)
# Visualize feature importance
```

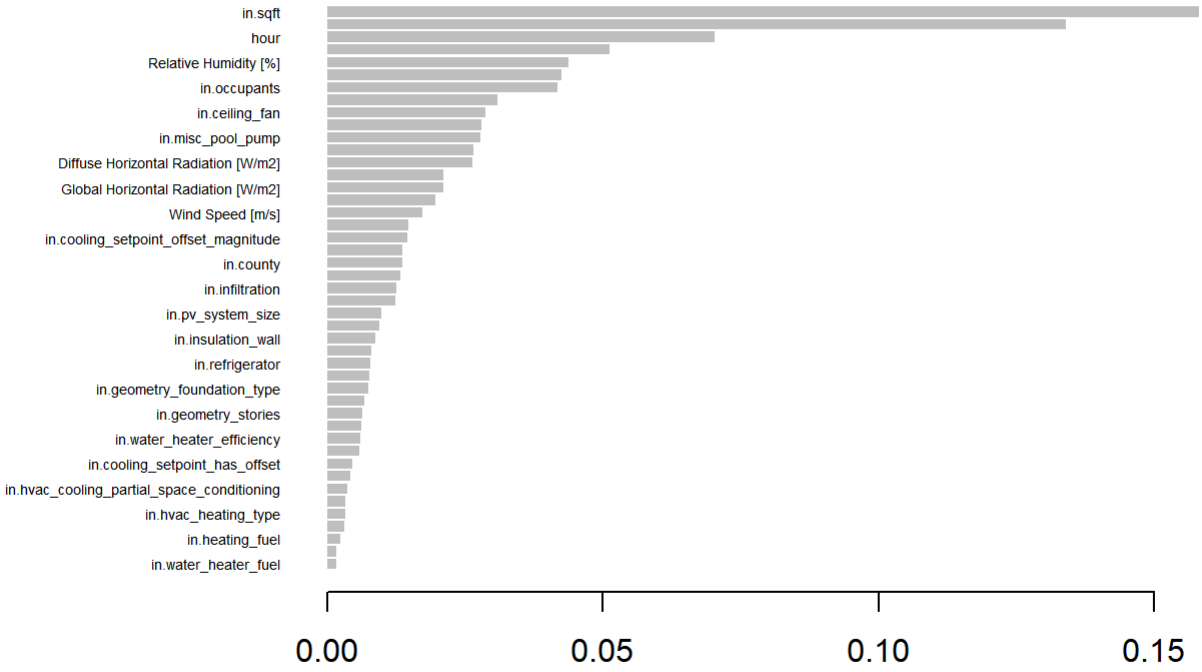
This gives us the variables the model thinks are most relevant for energy consumption. Size first, ceiling fan, infiltration, pv size and so on are the major contributing factors (these are all the factors we can control). Apart from this most of the weather factors are also the front runner for energy consumption.

```
importance_matrix <- xgb.importance(model = xgb_model)
print(importance_matrix)
```

```
##                                     Feature        Gain       Cover
##  1:                                 in.sqft 0.158177489 0.033965064
##  2:                  Dry Bulb Temperature [°C] 0.134084002 0.069716993
##  3:                                    hour 0.070327063 0.034350854
##  4:                        in.vacancy_status 0.051136147 0.004614631
##  5:                    Relative Humidity [%] 0.043782236 0.066849953
##  6:                      in.cooling_setpoint 0.042394795 0.030129696
##  7:                             in.occupants 0.041805860 0.027784610
##  8:                           in.usage_level 0.030905286 0.007420890
##  9:                           in.ceiling_fan 0.028719415 0.009261957
## 10:                     in.hot_water_fixtures 0.028027720 0.007087027
## 11:                         in.misc_pool_pump 0.027747947 0.008502793
## 12:                                in.has_pv 0.026476178 0.002185749
## 13:       Diffuse Horizontal Radiation [W/m2] 0.026324658 0.037677688
## 14:                               in.lighting 0.021123791 0.013279487
## 15:        Global Horizontal Radiation [W/m2] 0.021013058 0.034260479
## 16:                               in.bedrooms 0.019538042 0.016220458
## 17:                          Wind Speed [m/s] 0.017243818 0.073707550
## 18:            Direct Normal Radiation [W/m2] 0.014680574 0.047107451
## 19:      in.cooling_setpoint_offset_magnitude 0.014570460 0.028221685
## 20:                           in.clothes_dryer 0.013617540 0.012943325
## 21:                                 in.county 0.013545079 0.044087776
## 22:                                  in.ducts 0.013262754 0.034186903
## 23:                           in.infiltration 0.012573600 0.036375677
## 24:                       Wind Direction [Deg] 0.012256148 0.067447838
## 25:                          in.pv_system_size 0.009841358 0.004205402
## 26:                          in.clothes_washer 0.009336975 0.020165367
## 27:                        in.insulation_wall 0.008691952 0.026202826
## 28:                     in.insulation_ceiling 0.007876470 0.021353204
## 29:                           in.refrigerator 0.007766143 0.017650896
## 30:                in.misc_extra_refrigerator 0.007600425 0.015955038
## 31:               in.geometry_foundation_type 0.007442659 0.015981068
## 32:                              in.dishwasher 0.006719948 0.018027180
## 33:                       in.geometry_stories 0.006332543 0.008442002
## 34:                          in.roof_material 0.006110545 0.015426848
## 35:                in.water_heater_efficiency 0.005955791 0.016615164
## 36:              in.hvac_heating_type_and_fuel 0.005696044 0.014423808
## 37:             in.cooling_setpoint_has_offset 0.004577795 0.010023987
## 38:                         in.hvac_cooling_type 0.004103965 0.006512882
## 39: in.hvac_cooling_partial_space_conditioning 0.003673111 0.007434931
## 40:                           in.misc_freezer 0.003274584 0.006725249
## 41:                       in.hvac_heating_type 0.003263433 0.007528100
## 42:                     in.geometry_wall_type 0.003083014 0.006954731
## 43:                           in.heating_fuel 0.002250814 0.005583242
## 44:           in.building_america_climate_zone 0.001539205 0.003679797
## 45:                       in.water_heater_fuel 0.001529566 0.003721744
##                                     Feature        Gain       Cover
##       Frequency
##  1: 0.037852894
##  2: 0.059497254
##  3: 0.042519669
##  4: 0.003675853
##  5: 0.053061512
##  6: 0.035223430
##  7: 0.028204529
```

```
##  8: 0.008260176
##  9: 0.014616464
## 10: 0.008645451
## 11: 0.008014320
## 12: 0.001238277
## 13: 0.029687163
## 14: 0.016442398
## 15: 0.024659099
## 16: 0.023501775
## 17: 0.052799165
## 18: 0.035152971
## 19: 0.022974083
## 20: 0.020424072
## 21: 0.042084922
## 22: 0.039597875
## 23: 0.040128565
## 24: 0.049109820
## 25: 0.001383692
## 26: 0.026628949
## 27: 0.028186539
## 28: 0.026143232
## 29: 0.019782447
## 30: 0.017565242
## 31: 0.018145403
## 32: 0.023800101
## 33: 0.011036555
## 34: 0.019449641
## 35: 0.017051042
## 36: 0.015827757
## 37: 0.012625627
## 38: 0.009873234
## 39: 0.009867238
## 40: 0.009252596
## 41: 0.009356036
## 42: 0.009628877
## 43: 0.009528435
## 44: 0.002636960
## 45: 0.004858663
##       Frequency
```

```
# Visualize feature importance
xgb.plot.importance(importance_matrix)
```



Plotting a graph of energy consumption with a 5 degree celcius increase in temperature

```
Test_Optimied_Variables <-Subset_V4
#Test_Optimied_Variables$in.insulation_wall<-"Brick, 12-in, 3-wythe, R-7"
#Test_Optimied_Variables$in.hvac_cooling_partial_space_conditioning<-"40% Conditioned"
#Test_Optimied_Variables$in.usage_level<-"Low"
Test_Optimied_Variables$`Dry Bulb Temperature [°C]`<-Test_Optimied_Variables$`Dry Bulb Temper
ature [°C]`+5

dtest2 <- xgb.DMatrix(data = data.matrix(Test_Optimied_Variables[, -which(names(test_data) ==
"Final_Energy_KWH")]))

predictions1 <- predict(xgb_model, dtest2)
#actual vs predicted reduced due to upgrades
df_new = data.frame(predictions1,Subset_V4$Final_Energy_KWH)
#df_new
#sum(predictions1)
#sum(Subset_V4$Final_Energy_KWH)


data <- data.frame(
  Category = rep(c("Predicted Energy", "Current Energy"),each=nrow(predictions1)),
  Energy_Value = c(predictions1, test_data$Final_Energy_KWH)
)
```

```
## Warning in rep(c("Predicted Energy", "Current Energy"), each =
## nrow(predictions1)): first element used of 'each' argument
```

```
Test_Optimied_Variables$predictions1<-predictions1

#glimpse(Test_Optimied_Variables)
```

```
# Load necessary libraries
library(ggplot2)
library(dplyr)
library(maps)
```

```
##
## Attaching package: 'maps'
```

```
## The following object is masked from 'package:purrr':
##
##     map
```

```
#install.packages("mapdata")
library(mapdata)
```

```
## Warning: package 'mapdata' was built under R version 4.3.2
```

```
#install.packages("ggrepel")
library(ggrepel)
```

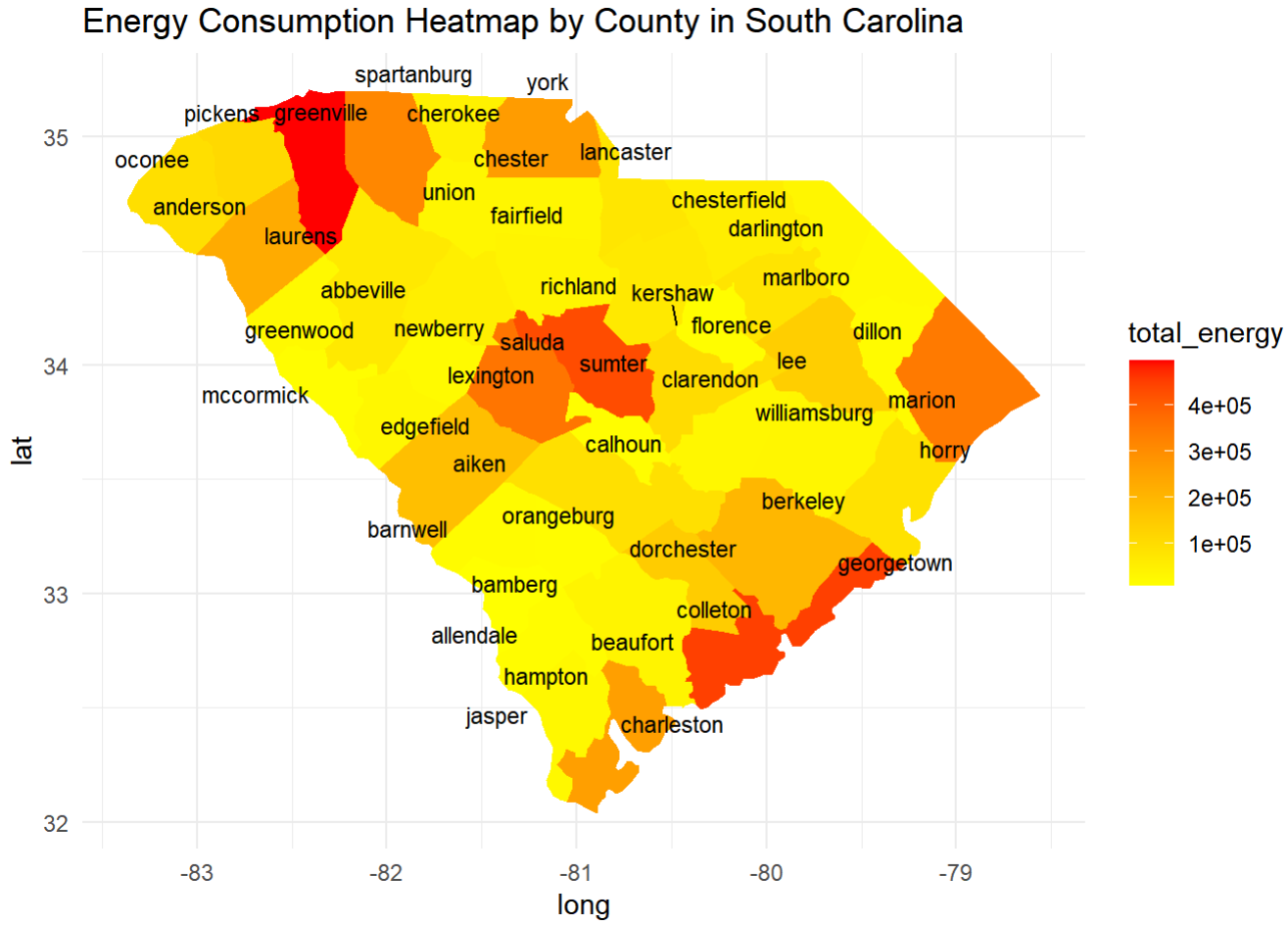
```
## Warning: package 'ggrepel' was built under R version 4.3.2
```

```
 ICPSRNAM = c("ABBEVILLE", "AIKEN", "ALLENDALE", "ANDERSON", "BAMBERG", "BARNWELL", "BEAUFOR
T", "BERKELEY", "CALHOUN", "CHARLESTON",
               "CHEROKEE", "CHESTER", "CHESTERFIELD", "CLARENDON", "COLLETON", "DARLINGTON",
"DILLON", "DORCHESTER", "EDGEFIELD",
               "FAIRFIELD", "FLORENCE", "GEORGETOWN", "GREENVILLE", "GREENWOOD", "HAMPTON",
"HORRY", "JASPER", "KERSHAW", "LANCASTER",
               "LAURENS", "LEE", "LEXINGTON", "MARION", "MARLBORO", "MCCORMICK", "NEWBERRY",
"OCONEE", "ORANGEBURG", "PICKENS",
               "RICHLAND", "SALUDA", "SPARTANBURG", "SUMTER", "UNION", "WILLIAMSBURG", "YOR
K")

  GISJOIN = c("G4500010", "G4500030", "G4500050", "G4500070", "G4500090", "G4500110", "G45001
30", "G4500150", "G4500170", "G4500190",
              "G4500210", "G4500230", "G4500250", "G4500270", "G4500290", "G4500310", "G45003
30", "G4500350", "G4500370", "G4500390",
              "G4500410", "G4500430", "G4500450", "G4500470", "G4500490", "G4500510", "G45005
30", "G4500550", "G4500570", "G4500590",
              "G4500610", "G4500630", "G4500670", "G4500690", "G4500650", "G4500710", "G45007
30", "G4500750", "G4500770", "G4500790",
              "G4500810", "G4500830", "G4500850", "G4500870", "G4500890", "G4500910")
# Calculate total energy by county
List_Name<-data.frame(tolower(ICPSRNAM),(GISJOIN))
#List_Name
energy_data <- Subset_V4 %>%
  group_by(in.county) %>%
  summarize(total_energy = sum(Final_Energy_KWH, na.rm = TRUE))
energy_data$County_name<-List_Name$tolower.ICPSRNAM.[match(energy_data$in.county,List_Name$X.
GISJOIN.)]


county_map <- map_data("county", region = "south carolina")
county_map$subregion<-tolower(county_map$subregion)
energy_data$in.county<-tolower(energy_data$in.county)

# Merge energy data with the county map
merged_data <- merge(county_map, energy_data, by.x = "subregion", by.y = "County_name", all.x
= TRUE)
#merged_data
# Create the heatmap
```

Observations :

This map is inline with the building density we saw in the extrapolation part of this project. The energy consumption is highest for greenville followed by the others like horry, colleton, georgetown!

```
ggplot(merged_data, aes(x = long, y = lat, group = group, fill = total_energy)) +
  geom_polygon() +
  scale_fill_gradient(low = "yellow", high = "red") +
  labs(title = "Energy Consumption Heatmap by County in South Carolina") +
  theme_minimal() +

  # Add labels using geom_text_repel
  geom_text_repel(
    data = merged_data[!duplicated(merged_data$subregion), ], # Select only unique subregions
    aes(label = subregion),
    color = "black",
    size = 3,
    box.padding = unit(0.2, "lines") # Adjust the label padding if needed
  )
```

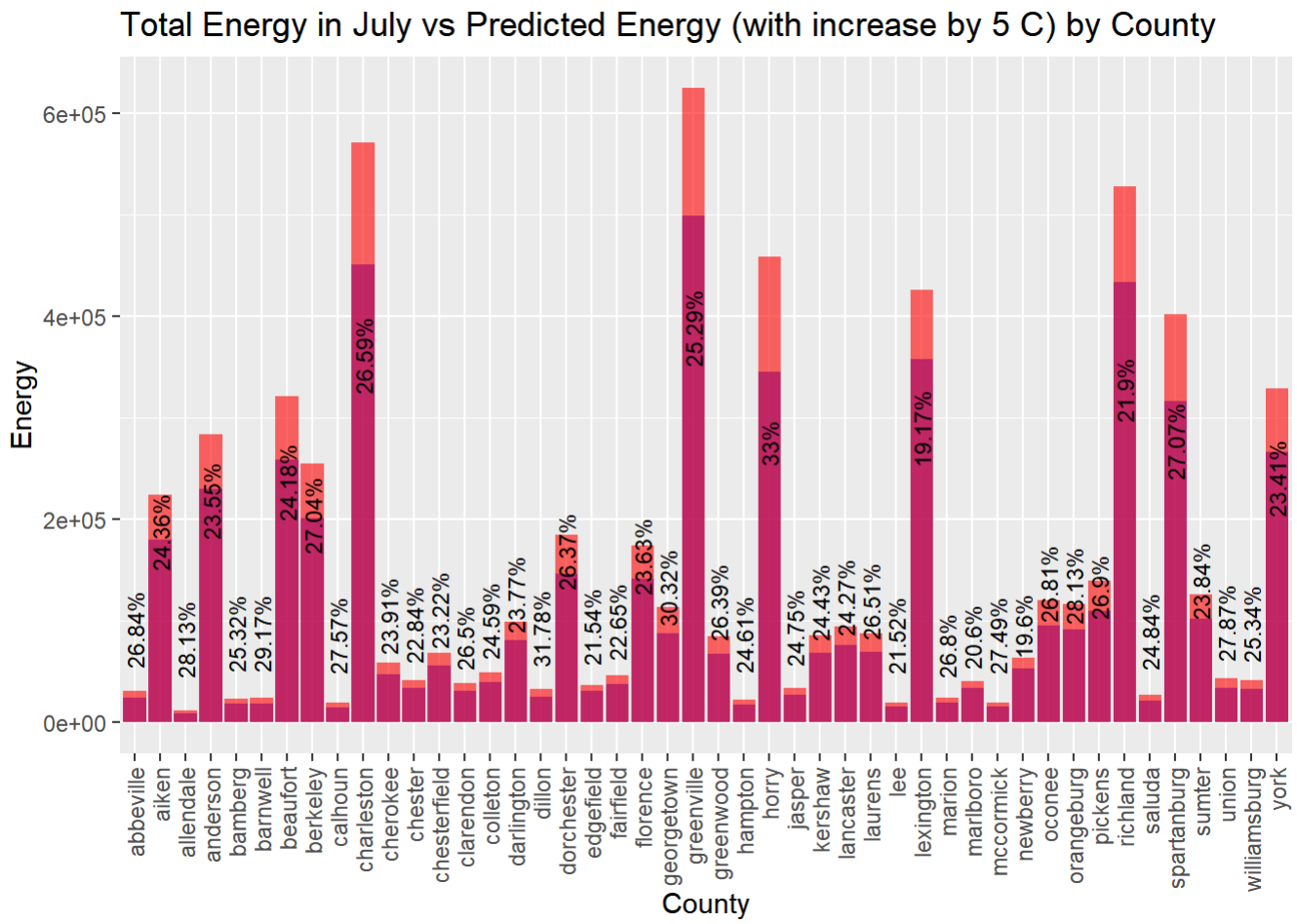


This graph shows a county wise increse in energy consumption when there is temperature increase, we see horry has the hightest percentage increasase of more than 30% but greenville still has had thehigest increse magnitutde wise as it is 25%.

```
Summarize_Predictions<-Test_Optimied_Variables %>%group_by(in.county) %>%
  summarize(total_energy = sum(Final_Energy_KWH, na.rm = TRUE),predicted_energy=sum(predictio
ns1,na.rm=TRUE))

Summarize_Predictions$County_name<-List_Name$tolower.ICPSRNAM.[match(Summarize_Predictions$i
n.county,List_Name$X.GISJOIN.)]
head(Summarize_Predictions)
```

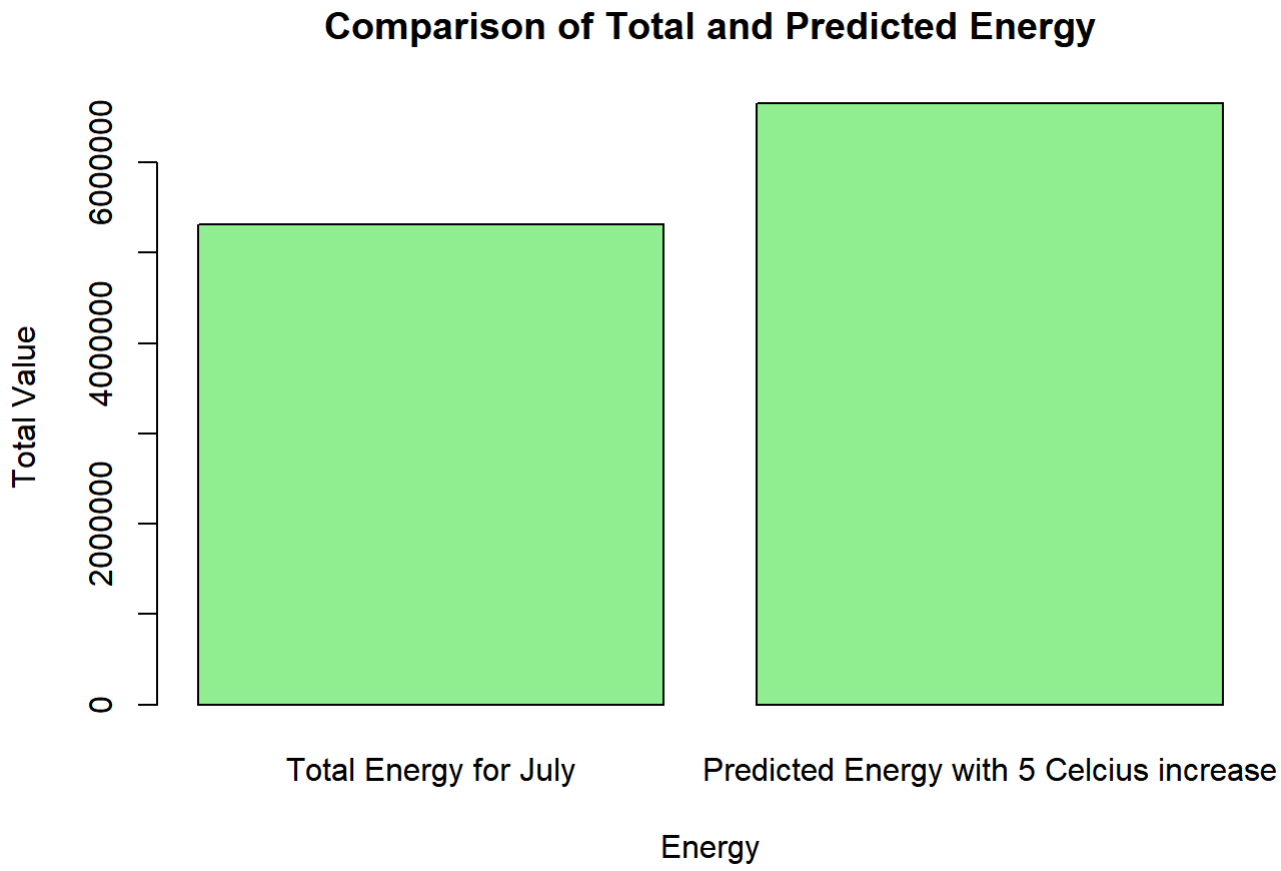
```
## # A tibble: 6 × 4
##   in.county total_energy predicted_energy County_name
##   <fct>            <dbl>            <dbl> <chr>
## 1 G4500010        24115.           30588. abbeville
## 2 G4500030       179654.          223416. aiken
## 3 G4500050         8800.           11275. allendale
## 4 G4500070       229560.          283613. anderson
## 5 G4500090        18221.           22834. bamberg
## 6 G4500110        18339.           23688. barnwell
```

```
#str(Summarize_Predictions)
#
#
# library(ggplot2)
#
# # Create a bar plot
# ggplot(data = Summarize_Predictions, aes(x = in.county)) +
#   geom_bar(aes(y = total_energy), stat = "identity", fill = "blue", alpha = 0.6) +
#   geom_bar(aes(y = predicted_energy), stat = "identity", fill = "red", alpha = 0.6) +
#   labs(title = "Total Energy in July vs Predicted Energy (with increase by 5 C) by County",
#        x = "County", y = "Energy") +
#   theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust = 1))
#



# Calculate percentage difference
Summarize_Predictions$percentage_diff <- ( (Summarize_Predictions$predicted_energy -Summarize
_Predictions$total_energy)/Summarize_Predictions$total_energy) * 100

# Create a bar plot with percentage difference labels
ggplot(data = Summarize_Predictions, aes(x = County_name)) +
  geom_bar(aes(y = total_energy), stat = "identity", fill = "blue", alpha = 0.6) +
  geom_bar(aes(y = predicted_energy), stat = "identity", fill = "red", alpha = 0.6) +
  geom_text(aes(y = pmax(predicted_energy, total_energy),
                label = paste0(round(percentage_diff, 2), "%")),
            position = position_stack(vjust = 0.5),
            size = 3,
            color = "black",
            angle = 90,
            hjust = -0.5) +
  labs(title = "Total Energy in July vs Predicted Energy (with increase by 5 C) by County",
       x = "County", y = "Energy") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust = 1))
```



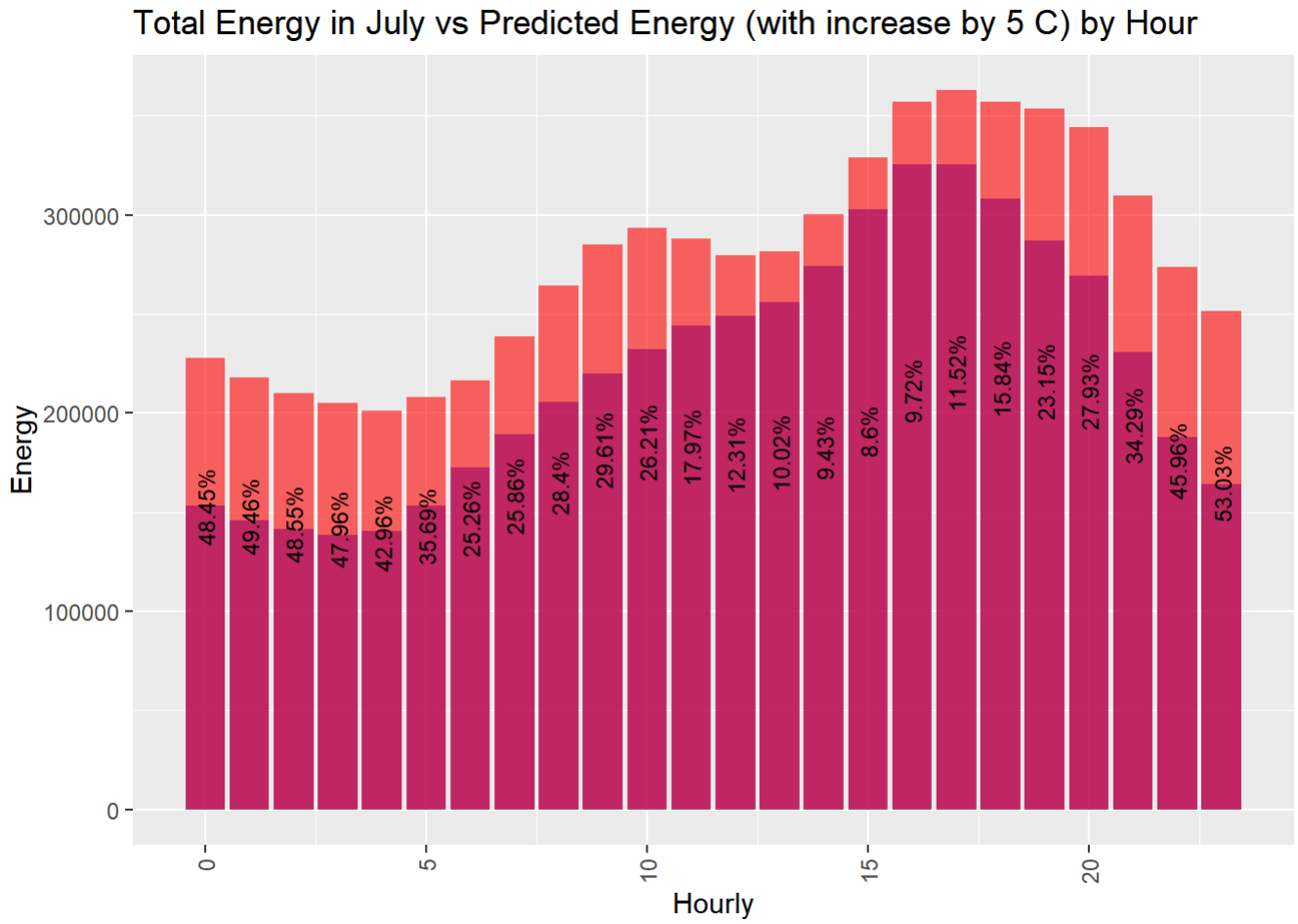
This graph shows total increase ecpected in july

```
sum_energy<-sum(Summarize_Predictions$total_energy)
Predicted<-sum(Summarize_Predictions$predicted_energy)
values <- c(sum_energy, Predicted)

options(scipen = 999)
# Creating a bar plot
barplot(values, names.arg = c("Total Energy for July", "Predicted Energy with 5 Celcius incre
ase"), col = "lightgreen",
        xlab = "Energy", ylab = "Total Value", main = "Comparison of Total and Predicted Ener
gy")
```



This graph illustrates the hourly temperature increase throughout the month of July. We see the enrgy consumtion peak at round 4pm and then it starts to come down from there. Even with increse in temperature the pattern has not changed ,just the magnitutde of consumption has increased.

```
Predictions_hour<-Test_Optimied_Variables %>%group_by(hour) %>%
  summarize(total_energy = sum(Final_Energy_KWH, na.rm = TRUE),predicted_energy=sum(predictio
ns1,na.rm=TRUE))

# Calculate percentage difference
Predictions_hour$percentage_diff <- ((Predictions_hour$predicted_energy - Predictions_hour$to
tal_energy) / Predictions_hour$total_energy) * 100

#since temp increse people keep appliances on often
ggplot(data = Predictions_hour, aes(x = hour)) +
  geom_bar(aes(y = total_energy), stat = "identity", fill = "blue", alpha = 0.6) +
  geom_bar(aes(y = predicted_energy), stat = "identity", fill = "red", alpha = 0.6) +
  geom_text(aes(y = pmax(predicted_energy, total_energy),
                label = paste0(round(percentage_diff, 2), "%")),
            position = position_stack(vjust = 0.5),
            size = 3,
            color = "black",
            angle = 90,
            hjust = -0.5) +
  labs(title = "Total Energy in July vs Predicted Energy (with increase by 5 C) by Hour",
       x = "Hourly", y = "Energy") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust = 1))
```



To conclude we see a considerable increase in the total consumption. The value jumps from 5.3 Million to 7.2 Million which is around 40% more than before.

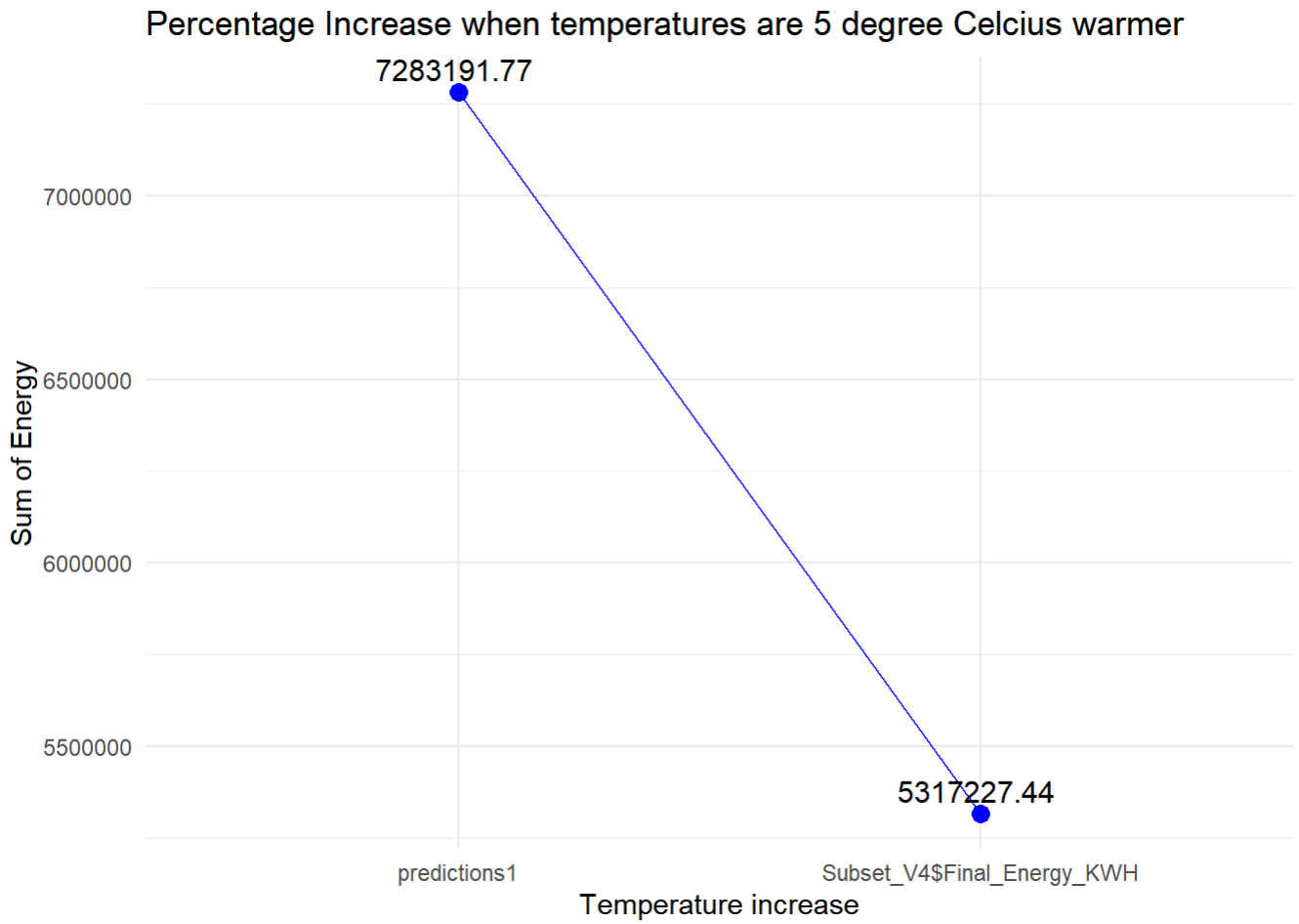
```
Test_Optimied_Variables_reduce <-Subset_V4
Test_Optimied_Variables_reduce$`Dry Bulb Temperature [°C]`<-Test_Optimied_Variables$`Dry Bulb
Temperature [°C]`+5
#Test_Optimied_Variables_reduce$in.ceiling_fan<-"Standard Efficiency, No usage"
#Test_Optimied_Variables$in.insulation_wall<-"Brick, 12-in, 3-wythe, R-7"
#Test_Optimied_Variables$in.hvac_cooling_partial_space_conditioning<-"40% Conditioned"
# Test_Optimied_Variables$in.usage_level<-"Low"
#Test_Optimied_Variables_reduce$in.pv_system_size<-"1.0 kWDC"

# Assuming 'Test_Optimized_Variables_reduce' is your dataset

# Replace "none" with "1kw" in the 'in.pv_system_size' column
#Test_Optimied_Variables_reduce$in.pv_system_size <- ifelse(Test_Optimied_Variables_reduce$i
n.pv_system_size == "None" , "1.0 kWDC",Test_Optimied_Variables_reduce$in.pv_system_size)

#unique(Test_Optimied_Variables_reduce$in.hvac_cooling_type)
#Test_Optimied_Variables_reduce$in.hvac_cooling_type<-"Central AC"
#Test_Optimied_Variables_reduce$in.hvac_cooling_partial_space_conditioning<-"40% Conditioned"
#Test_Optimied_Variables_reduce$in.ducts<-"None"
#Test_Optimied_Variables_reduce$in.hot_water_fixtures<-"50% Usage"
dtest2 <- xgb.DMatrix(data = data.matrix(Test_Optimied_Variables_reduce[, -which(names(test_d
ata) == "Final_Energy_KWH")]))

predictions1 <- predict(xgb_model, dtest2)
#actual vs predicted reduced due to upgrades
df_new = data.frame(predictions1,Subset_V4$Final_Energy_KWH)
#df_new
sum(predictions1)
```

```
## [1] 7283192
```

```
sum(Subset_V4$Final_Energy_KWH)
```

```
## [1] 5317227
```

```
Test_Optimied_Variables$predictions1<-predictions1
# Calculate the sum of predictions1 and Subset_V4$Final_Energy_KWH
sum_predictions <- sum(predictions1)
sum_final_energy <- sum(Subset_V4$Final_Energy_KWH)

# Calculate the percentage increase
percent_increase <- ((sum_final_energy - sum_predictions) / sum_predictions) * 100

# Create a data frame for plotting
data <- data.frame(
  Variable = c("predictions1", "Subset_V4$Final_Energy_KWH"),
  Sum = c(sum_predictions, sum_final_energy)
)

# Load necessary libraries
library(ggplot2)

# Create a line plot
ggplot(data, aes(x = Variable, y = Sum, group = 1)) +
  geom_line(color = "blue") +
  geom_point(color = "blue", size = 3) +
  geom_text(aes(label = paste(round(Sum, 2), "")), vjust = -0.5, size = 4) +
  labs(title = "Percentage Increase when temperatures are 5 degree Celcius warmer",
       x = "Temperature increase",
       y = "Sum of Energy") +
  theme_minimal()
```

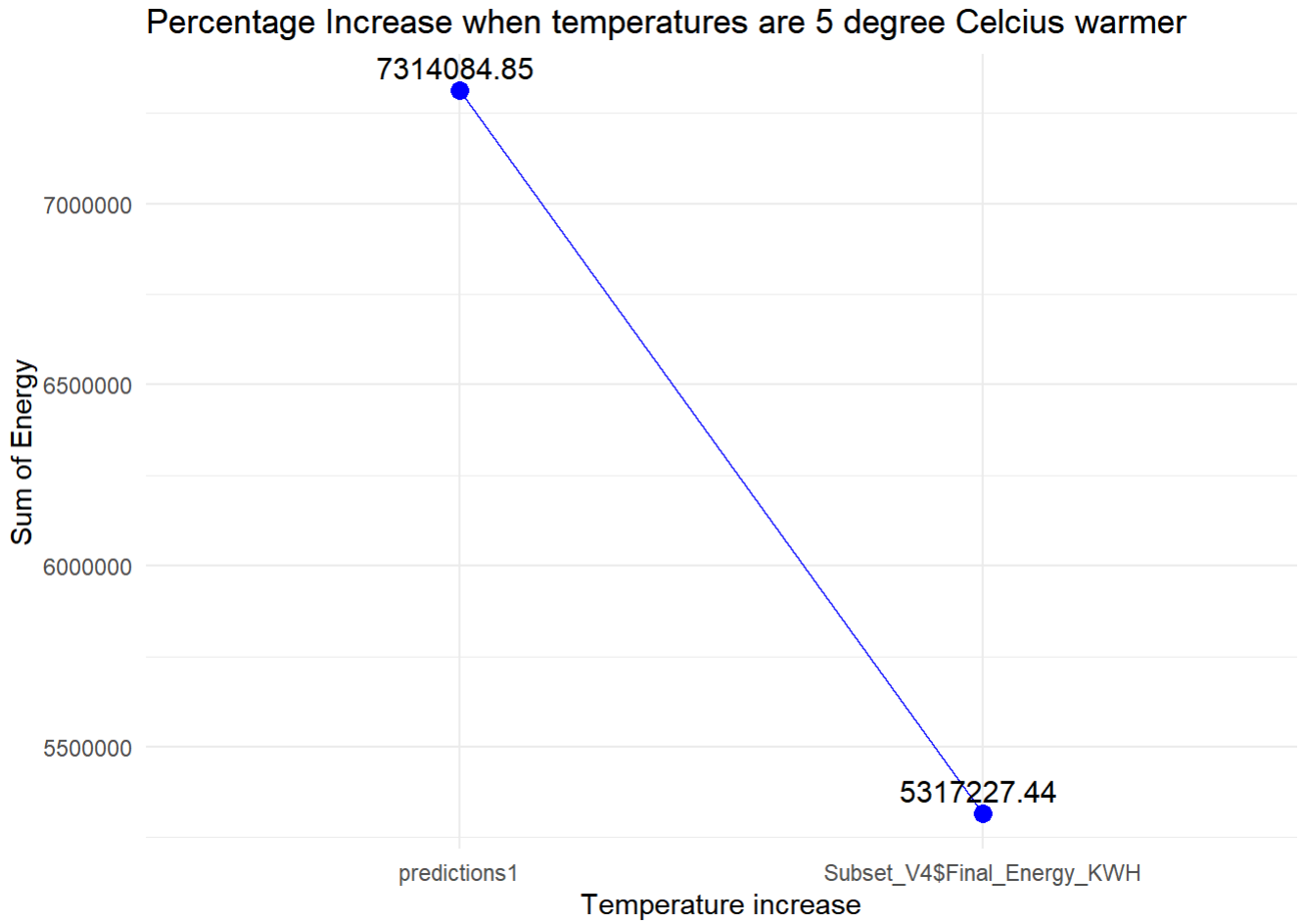


To try and reduce this consumption we have tried to simulate how we can ring the energy consumption down with increased temperatures. We see that reducing ceiling fan usage along with water fixtures is not making a

major difference. With the inconvenience of altering the efficient all across south Carolina the dip in usage is almost insignificant.

```
Test_Optimied_Variables_reduce <-Subset_V4
Test_Optimied_Variables_reduce$`Dry Bulb Temperature [°C]`<-Test_Optimied_Variables$`Dry Bulb
Temperature [°C]`+5
Test_Optimied_Variables_reduce$in.ceiling_fan<-"Standard Efficiency, No usage"
#Test_Optimied_Variables$in.insulation_wall<-"Brick, 12-in, 3-wythe, R-7"
#Test_Optimied_Variables$in.hvac_cooling_partial_space_conditioning<-"40% Conditioned"
# Test_Optimied_Variables$in.usage_level<-"Low"
#Test_Optimied_Variables_reduce$in.cooling_setpoint<-"80F"
#Test_Optimied_Variables_reduce$in.pv_system_size<-"1.0 kWDC"

# Assuming 'Test_Optimized_Variables_reduce' is your dataset

# Replace "none" with "1kw" in the 'in.pv_system_size' column
#Test_Optimied_Variables_reduce$in.pv_system_size <- ifelse(Test_Optimied_Variables_reduce$i
n.pv_system_size == "None" , "1.0 kWDC",Test_Optimied_Variables_reduce$in.pv_system_size)

#unique(Test_Optimied_Variables_reduce$in.hvac_cooling_type)
#Test_Optimied_Variables_reduce$in.hvac_cooling_type<-"Central AC"
#Test_Optimied_Variables_reduce$in.hvac_cooling_partial_space_conditioning<-"40% Conditioned"
#Test_Optimied_Variables_reduce$in.ducts<-"None"
Test_Optimied_Variables_reduce$in.hot_water_fixtures<-"50% Usage"
dtest2 <- xgb.DMatrix(data = data.matrix(Test_Optimied_Variables_reduce[, -which(names(test_d
ata) == "Final_Energy_KWH")]))

predictions1 <- predict(xgb_model, dtest2)
#actual vs predicted reduced due to upgrades
df_new = data.frame(predictions1,Subset_V4$Final_Energy_KWH)
#df_new
#sum(predictions1)
#sum(Subset_V4$Final_Energy_KWH)

Test_Optimied_Variables$predictions1<-predictions1
# Calculate the sum of predictions1 and Subset_V4$Final_Energy_KWH
sum_predictions <- sum(predictions1)
Final_temp_increase <-sum_predictions
sum_final_energy <- sum(Subset_V4$Final_Energy_KWH)

# Calculate the percentage increase
percent_increase <- ((sum_final_energy - sum_predictions) / sum_predictions) * 100

# Create a data frame for plotting
data <- data.frame(
  Variable = c("predictions1", "Subset_V4$Final_Energy_KWH"),
  Sum = c(sum_predictions, sum_final_energy)
)

# Load necessary libraries
library(ggplot2)

# Create a line plot
ggplot(data, aes(x = Variable, y = Sum, group = 1)) +
  geom_line(color = "blue") +
  geom_point(color = "blue", size = 3) +
  geom_text(aes(label = paste(round(Sum, 2), "")), vjust = -0.5, size = 4) +
  labs(title = "Percentage Increase when temperatures are 5 degree Celcius warmer",
```

```
      x = "Temperature increase",
      y = "Sum of Energy") +
theme_minimal()
```



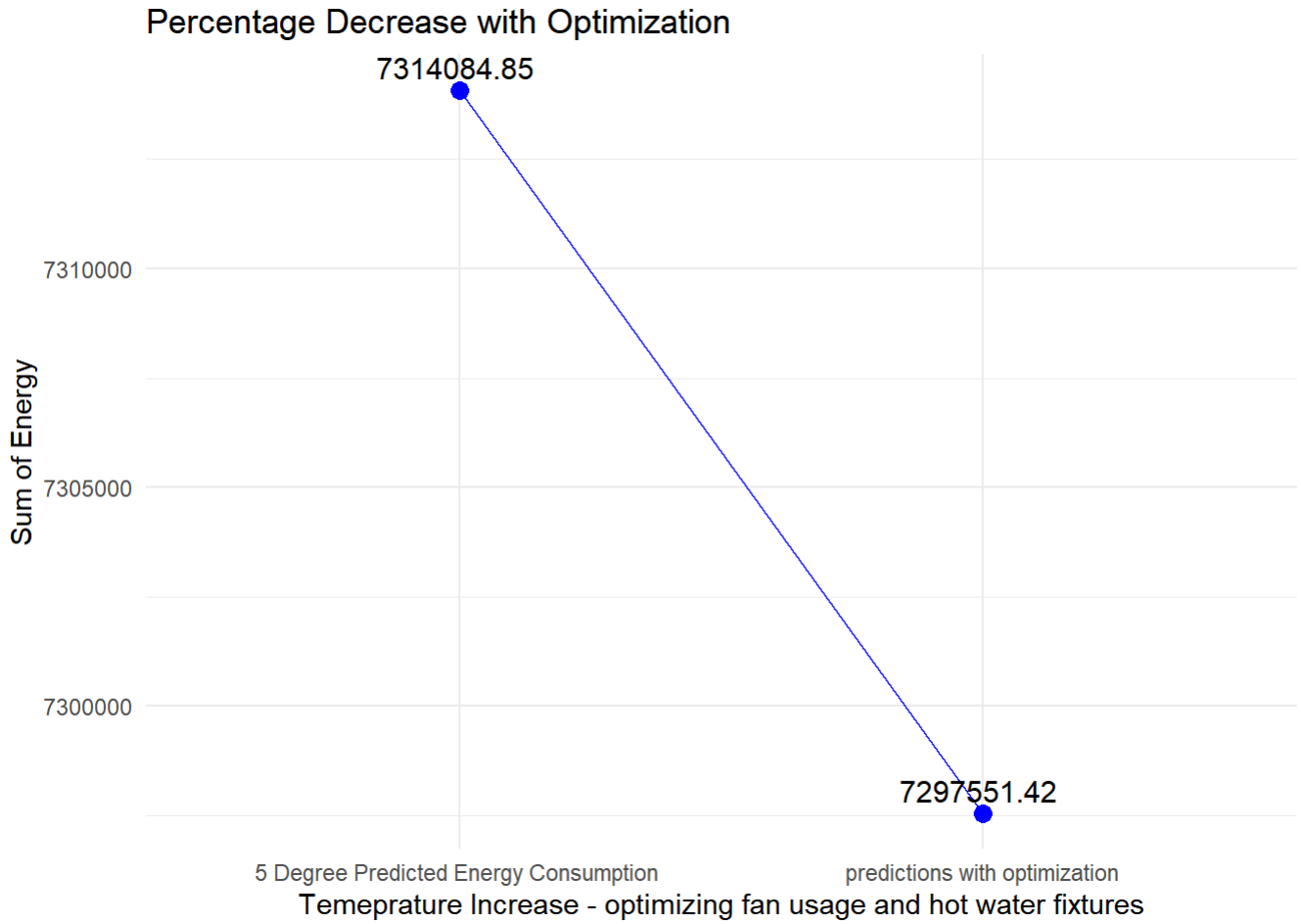
When we turned the ceiling fan to optimal efficiency, the hot water fixtures and ACH levels to most optimised energy usages.While the observed decrease stood at approximately 1% despite alterations in three key factors, a deeper exploration into the logistics of these changes uncovered consequential insights.

This would be more cost effective if it was implementable. Each state has a minimum ACh that it needs the building to maintain. It is roughly 4ACH.

For a 1% decrease in energy consumption we would have to set it to 15ACH which is so much higher than required by law. This approach would be cost effective but not logical.

```
Test_Optimied_Variables_reduce <-Subset_V4
Test_Optimied_Variables_reduce$`Dry Bulb Temperature [°C]`<-Test_Optimied_Variables$`Dry Bulb
Temperature [°C]`+5
Test_Optimied_Variables_reduce$in.ceiling_fan<-"Standard Efficiency, No usage"
#Test_Optimied_Variables$in.insulation_wall<-"Brick, 12-in, 3-wythe, R-7"
#Test_Optimied_Variables$in.hvac_cooling_partial_space_conditioning<-"40% Conditioned"
# Test_Optimied_Variables$in.usage_level<-"Low"
#Test_Optimied_Variables_reduce$in.cooling_setpoint<-"80F"
#Test_Optimied_Variables_reduce$in.pv_system_size<-"1.0 kWDC"

# Assuming 'Test_Optimized_Variables_reduce' is your dataset

# Replace "none" with "1kw" in the 'in.pv_system_size' column
#Test_Optimied_Variables_reduce$in.pv_system_size <- ifelse(Test_Optimied_Variables_reduce$i
n.pv_system_size == "None" , "1.0 kWDC",Test_Optimied_Variables_reduce$in.pv_system_size)

#unique(Test_Optimied_Variables_reduce$in.hvac_cooling_type)
#Test_Optimied_Variables_reduce$in.hvac_cooling_type<-"Central AC"
#Test_Optimied_Variables_reduce$in.hvac_cooling_partial_space_conditioning<-"40% Conditioned"
#Test_Optimied_Variables_reduce$in.ducts<-"None"
Test_Optimied_Variables_reduce$in.infiltration<-"ACH50 15"

Test_Optimied_Variables_reduce$in.hot_water_fixtures<-"50% Usage"
dtest2 <- xgb.DMatrix(data = data.matrix(Test_Optimied_Variables_reduce[, -which(names(test_d
ata) == "Final_Energy_KWH")]))

predictions1 <- predict(xgb_model, dtest2)
#actual vs predicted reduced due to upgrades
df_new = data.frame(predictions1,Final_temp_increase )
#df_new
#sum(predictions1)
#sum(Subset_V4$Final_Energy_KWH)

Test_Optimied_Variables$predictions1<-predictions1
# Calculate the sum of predictions1 and Subset_V4$Final_Energy_KWH
sum_predictions <- sum(predictions1)
sum_final_energy <- Final_temp_increase

# Calculate the percentage increase
percent_increase <- ((sum_final_energy - sum_predictions) / sum_predictions) * 100

# Create a data frame for plotting
data <- data.frame(
  Variable = c("predictions with optimization", "5 Degree Predicted Energy Consumption "),
  Sum = c(sum_predictions, sum_final_energy)
)

# Load necessary libraries
library(ggplot2)

# Create a line plot
ggplot(data, aes(x = Variable, y = Sum, group = 1)) +
  geom_line(color = "blue") +
  geom_point(color = "blue", size = 3) +
  geom_text(aes(label = paste(round(Sum, 2), "")), vjust = -0.5, size = 4) +
```

```
  labs(title = "Percentage Decrease with Optimization",
       x = "Temeprature Increase - optimizing fan usage and hot water fixtures",
       y = "Sum of Energy") +
  theme_minimal()
```



To make it easier to reduce energy we looked at the size of solar panels installed. Instead of increasing the sizes of solar panels in buildings with already existing solar panels. We recommended the buildings with no solar panels to install the smallest one of “1KwDC”. This not only brugh the usage down, but is predicting a lower consumption than the usage in July of 2018.

```
Test_Optimied_Variables_reduce <-Subset_V4
Test_Optimied_Variables_reduce$`Dry Bulb Temperature [°C]`<-Test_Optimied_Variables$`Dry Bulb
Temperature [°C]`+5
#Test_Optimied_Variables_reduce$in.ceiling_fan<-"Standard Efficiency, No usage"
#Test_Optimied_Variables$in.insulation_wall<-"Brick, 12-in, 3-wythe, R-7"
#Test_Optimied_Variables$in.hvac_cooling_partial_space_conditioning<-"40% Conditioned"
# Test_Optimied_Variables$in.usage_level<-"Low"
#Test_Optimied_Variables_reduce$in.cooling_setpoint<-"80F"
#Test_Optimied_Variables_reduce$in.pv_system_size<-"1.0 kWDC"

# Assuming 'Test_Optimized_Variables_reduce' is your dataset

# Replace "none" with "1kw" in the 'in.pv_system_size' column
Test_Optimied_Variables_reduce$in.pv_system_size <- ifelse(Test_Optimied_Variables_reduce$in.
pv_system_size == "None" , "1.0 kWDC",Test_Optimied_Variables_reduce$in.pv_system_size)

#unique(Test_Optimied_Variables_reduce$in.hvac_cooling_type)
#Test_Optimied_Variables_reduce$in.hvac_cooling_type<-"Central AC"
#Test_Optimied_Variables_reduce$in.hvac_cooling_partial_space_conditioning<-"40% Conditioned"
#Test_Optimied_Variables_reduce$in.ducts<-"None"
#Test_Optimied_Variables_reduce$in.infiltration<-"ACH50 15"

#Test_Optimied_Variables_reduce$in.hot_water_fixtures<-"50% Usage"
dtest2 <- xgb.DMatrix(data = data.matrix(Test_Optimied_Variables_reduce[, -which(names(test_d
ata) == "Final_Energy_KWH")]))

predictions1 <- predict(xgb_model, dtest2)
#actual vs predicted reduced due to upgrades
df_new = data.frame(predictions1,Final_temp_increase )
#df_new
#sum(predictions1)
#sum(Subset_V4$Final_Energy_KWH)

Test_Optimied_Variables$predictions1<-predictions1
# Calculate the sum of predictions1 and Subset_V4$Final_Energy_KWH
sum_predictions <- sum(predictions1)
sum_final_energy <- Final_temp_increase

# Calculate the percentage increase
percent_increase <- ((sum_final_energy - sum_predictions) / sum_predictions) * 100

# Create a data frame for plotting
data <- data.frame(
  Variable = c("predictions with optimization", "5 Degree Predicted Energy Consumption "),
  Sum = c(sum_predictions, sum_final_energy)
)
```

Furthermore, the scalability and modularity of solar panel installations render them adaptable to various building sizes and energy requirements, making them a versatile and cost-efficient solution. In contrast, altering house insulation or upgrading appliance efficiency, while viable strategies, might involve more intricate and expensive modifications.

```
# Load necessary libraries
library(ggplot2)

# Create a line plot
ggplot(data, aes(x = Variable, y = Sum, group = 1)) +
  geom_line(color = "blue") +
  geom_point(color = "blue", size = 3) +
  geom_text(aes(label = paste(round(Sum, 2), "")), vjust = -0.5, size = 4) +
  labs(title = "Percentage Decrease with Optimization",
       x = "Temeprature Increase - optimizing PV usage",
       y = "Sum of Energy") +
  theme_minimal()
```