

# Energy Consumption Prediction

Climate change is a globally relevant, urgent, and multi-faceted issue heavily impacted by energy policy and infrastructure. Addressing climate change involves mitigation (i.e. mitigating greenhouse gas emissions) and adaptation (i.e. preparing for unavoidable consequences). Mitigation of GHG emissions requires changes to electricity systems, transportation, buildings, industry, and land use.

According to a report issued by the International Energy Agency (IEA), the lifecycle of buildings from construction to demolition were responsible for 37% of global energy-related CO2 emissions in 2020. Yet it is possible to drastically reduce the energy consumption of buildings by a combination of easy-to-implement fixes and state-of-the-art strategies. For example, retrofitted buildings can reduce heating and cooling energy requirements by 50-90 percent. Many of these energy efficiency measures also result in overall cost savings and yield other benefits, such as cleaner air for occupants. This potential can be achieved while maintaining the services that buildings provide.

## Goal

The goal of this competition is to predict the energy consumption using building characteristics and climate and weather variables.

## Data

The WiDS Datathon 2022 focuses on a prediction task involving roughly 100k observations of building energy usage records collected over 7 years and a number of states within the United States. The dataset consists of building characteristics (e.g. floor area, facility type etc), weather data for the location of the building (e.g. annual average temperature, annual total precipitation etc) as well as the energy usage for the building and the given year, measured as Site Energy Usage Intensity (Site EUI). Each row in the data corresponds to the a single building observed in a given year. Your task is to predict the Site EUI for each row, given the characteristics of the building and the weather data for the location of the building.

## Setup

### Load Data and Packages

```
library(gtExtras)
library(gtsummary)
library(tidyverse)
library(tidymodels)

data <- read_csv("data/buildings-data/train.csv")
```

### Clean Data

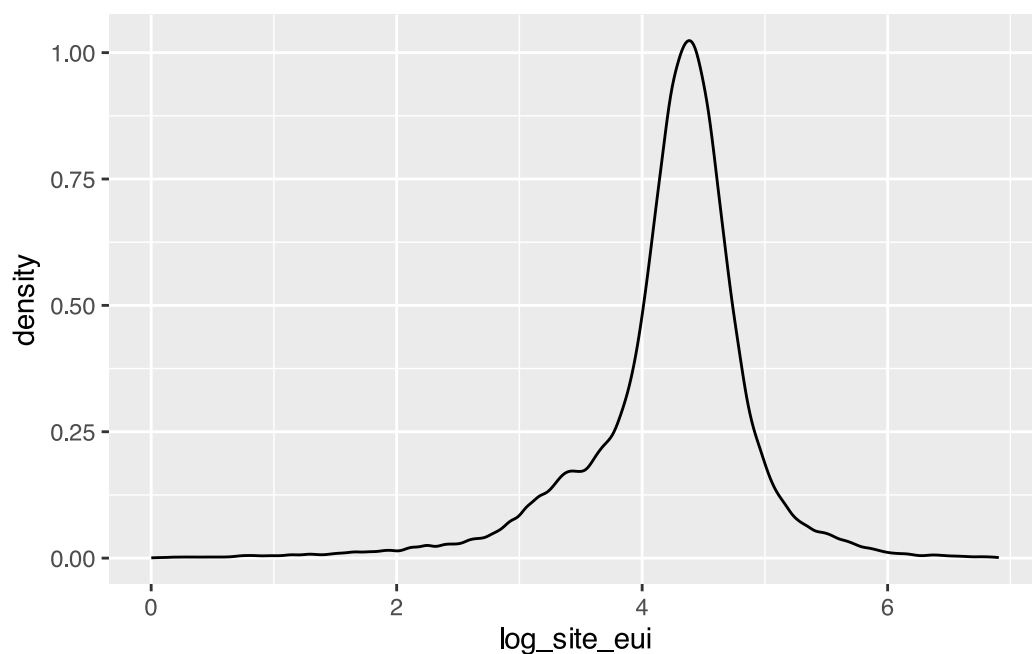
```
data <- data |>
  janitor::clean_names() |>
  mutate(
    state_factor = factor(state_factor),
    building_class = factor(building_class),
    facility_type = factor(facility_type),
    year_built = factor(year_built, ordered = TRUE),
    energy_star_rating = factor(energy_star_rating, ordered = TRUE),
    log_site_eui = log(site_eui)
  )

data |>
  gt_preview() |>
  tab_header(title = "Building Energy Dataset")
```

## Building Energy Dataset

year_	state_factor	building_class	facility_type	year_built	energy_star_rating	log_site_eui
2016	CA	Office	Office	2016	1	1.5
2017	CA	Office	Office	2017	1	1.5
2018	CA	Office	Office	2018	1	1.5
2019	CA	Office	Office	2019	1	1.5
2020	CA	Office	Office	2020	1	1.5
2021	CA	Office	Office	2021	1	1.5
2022	CA	Office	Office	2022	1	1.5
2023	CA	Office	Office	2023	1	1.5
2024	CA	Office	Office	2024	1	1.5
2025	CA	Office	Office	2025	1	1.5
2026	CA	Office	Office	2026	1	1.5
2027	CA	Office	Office	2027	1	1.5
2028	CA	Office	Office	2028	1	1.5
2029	CA	Office	Office	2029	1	1.5
2030	CA	Office	Office	2030	1	1.5
2031	CA	Office	Office	2031	1	1.5
2032	CA	Office	Office	2032	1	1.5
2033	CA	Office	Office	2033	1	1.5
2034	CA	Office	Office	2034	1	1.5
2035	CA	Office	Office	2035	1	1.5
2036	CA	Office	Office	2036	1	1.5
2037	CA	Office	Office	2037	1	1.5
2038	CA	Office	Office	2038	1	1.5
2039	CA	Office	Office	2039	1	1.5
2040	CA	Office	Office	2040	1	1.5
2041	CA	Office	Office	2041	1	1.5
2042	CA	Office	Office	2042	1	1.5
2043	CA	Office	Office	2043	1	1.5
2044	CA	Office	Office	2044	1	1.5
2045	CA	Office	Office	2045	1	1.5
2046	CA	Office	Office	2046	1	1.5
2047	CA	Office	Office	2047	1	1.5
2048	CA	Office	Office	2048	1	1.5
2049	CA	Office	Office	2049	1	1.5
2050	CA	Office	Office	2050	1	1.5
2051	CA	Office	Office	2051	1	1.5
2052	CA	Office	Office	2052	1	1.5
2053	CA	Office	Office	2053	1	1.5
2054	CA	Office	Office	2054	1	1.5
2055	CA	Office	Office	2055	1	1.5
2056	CA	Office	Office	2056	1	1.5
2057	CA	Office	Office	2057	1	1.5
2058	CA	Office	Office	2058	1	1.5
2059	CA	Office	Office	2059	1	1.5
2060	CA	Office	Office	2060	1	1.5
2061	CA	Office	Office	2061	1	1.5
2062	CA	Office	Office	2062	1	1.5
2063	CA	Office	Office	2063	1	1.5
2064	CA	Office	Office	2064	1	1.5
2065	CA	Office	Office	2065	1	1.5
2066	CA	Office	Office	2066	1	1.5
2067	CA	Office	Office	2067	1	1.5
2068	CA	Office	Office	2068	1	1.5
2069	CA	Office	Office	2069	1	1.5
2070	CA	Office	Office	2070	1	1.5
2071	CA	Office	Office	2071	1	1.5
2072	CA	Office	Office	2072	1	1.5
2073	CA	Office	Office	2073	1	1.5
2074	CA	Office	Office	2074	1	1.5
2075	CA	Office	Office	2075	1	1.5
2076	CA	Office	Office	2076	1	1.5
2077	CA	Office	Office	2077	1	1.5
2078	CA	Office	Office	2078	1	1.5
2079	CA	Office	Office	2079	1	1.5
2080	CA	Office	Office	2080	1	1.5
2081	CA	Office	Office	2081	1	1.5
2082	CA	Office	Office	2082	1	1.5
2083	CA	Office	Office	2083	1	1.5
2084	CA	Office	Office	2084	1	1.5
2085	CA	Office	Office	2085	1	1.5
2086	CA	Office	Office	2086	1	1.5
2087	CA	Office	Office	2087	1	1.5
2088	CA	Office	Office	2088	1	1.5
2089	CA	Office	Office	2089	1	1.5
2090	CA	Office	Office	2090	1	1.5
2091	CA	Office	Office	2091	1	1.5
2092	CA	Office	Office	2092	1	1.5
2093	CA	Office	Office	2093	1	1.5
2094	CA	Office	Office	2094	1	1.5
2095	CA	Office	Office	2095	1	1.5
2096	CA	Office	Office	2096	1	1.5
2097	CA	Office	Office	2097	1	1.5
2098	CA	Office	Office	2098	1	1.5
2099	CA	Office	Office	2099	1	1.5
2100	CA	Office	Office	2100	1	1.5

```
data |>
  ggplot(mapping = aes(x = log_site_eui)) +
  geom_density()
```



```
res <- lm(site_eui ~ facility_type, data = data)
summary(res)
```

Call:

```
lm(formula = site_eui ~ facility_type, data = data)
```

Residuals:

Min	1Q	Median	3Q	Max
-317.99	-22.06	-5.52	13.75	909.55

Coefficients:

	Estimate	Std. Error
(Intercept)	31.877	1.182
facility_type5plus_Unit_Building	4.861	1.864
facility_typeCommercial_Other	60.765	1.707
facility_typeCommercial_Unknown	81.275	5.406
facility_typeData_Center	307.858	9.965
facility_typeEducation_College_or_university	76.752	1.975
facility_typeEducation_Other_classroom	37.565	1.443
facility_typeEducation_Preschool_or_daycare	29.097	5.087
facility_typeEducation_Uncategorized	14.296	2.264
facility_typeFood_Sales	104.916	6.258
facility_typeFood_Service_Other	-2.640	12.526
facility_typeFood_Service_Restaurant_or_cafeteria	163.717	6.535
facility_typeFood_Service_Uncategorized	96.925	12.176

facility_typeGrocery_store_or_food_market	209.258	2.701
facility_typeHealth_Care_Inpatient	216.464	2.804
facility_typeHealth_Care_Outpatient_Clinic	71.736	6.972
facility_typeHealth_Care_Outpatient_Uncategorized	158.015	8.650
facility_typeHealth_Care_Uncategorized	152.068	7.296
facility_typeIndustrial	93.468	2.878
facility_typeLaboratory	297.572	5.109
facility_typeLodging_Dormitory_or_fraternity_sorority	49.719	2.313
facility_typeLodging_Hotel	73.058	1.630
facility_typeLodging_Other	89.081	6.053
facility_typeLodging_Uncategorized	34.719	23.024
facility_typeMixed_Use_Commercial_and_Residential	57.653	2.309
facility_typeMixed_Use_Predominantly_Commercial	37.256	3.424
facility_typeMixed_Use_Predominantly_Residential	49.921	17.179
facility_typeMultifamily_Uncategorized	52.002	1.210
facility_typeNursing_Home	99.437	2.196
facility_typeOffice_Bank_or_other_financial	58.019	4.084
facility_typeOffice_Medical_non_diagnostic	84.885	2.704
facility_typeOffice_Mixed_use	50.233	12.176
facility_typeOffice_Uncategorized	45.197	1.268
facility_typeParking_Garage	35.474	3.454
facility_typePublic_Assembly_Drama_theater	49.040	6.258
facility_typePublic_Assembly_Entertainment_culture	87.023	5.043
facility_typePublic_Assembly_Library	73.972	4.233
facility_typePublic_Assembly_Movie_Theater	71.218	8.317
facility_typePublic_Assembly_Other	94.827	4.474
facility_typePublic_Assembly_Recreation	83.301	6.174
facility_typePublic_Assembly_Social_meeting	47.045	5.607
facility_typePublic_Assembly_Stadium	125.165	17.179
facility_typePublic_Assembly_Uncategorized	30.996	10.351
facility_typePublic_Safety_Courthouse	71.305	8.424
facility_typePublic_Safety_Fire_or_police_station	99.246	4.270
facility_typePublic_Safety_Penitentiary	139.028	8.535
facility_typePublic_Safety_Uncategorized	51.832	7.929
facility_typeReligious_worship	12.684	2.832
facility_typeRetail_Enclosed_mall	69.089	4.840
facility_typeRetail_Strip_shopping_mall	78.542	4.979
facility_typeRetail_Uncategorized	49.026	1.933
facility_typeRetail_Vehicle_dealership_showroom	14.764	6.093
facility_typeService_Drycleaning_or_Laundry	10.236	17.179
facility_typeService_Uncategorized	81.689	6.346
facility_typeService_Vehicle_service_repair_shop	105.719	4.533
facility_typeWarehouse_Distribution_or_Shipping_center	7.683	2.403
facility_typeWarehouse_Nonrefrigerated	6.332	1.872
facility_typeWarehouse_Refrigerated	64.648	4.979
facility_typeWarehouse_Selfstorage	-10.288	2.445
facility_typeWarehouse_Uncategorized	4.060	3.067
t value Pr(> t )		

(Intercept)	26.975	< 2e-16	***
facility_type5plus_Unit_Building	2.608	0.009101	**
facility_typeCommercial_Other	35.607	< 2e-16	***
facility_typeCommercial_Unknown	15.035	< 2e-16	***
facility_typeData_Center	30.893	< 2e-16	***
facility_typeEducation_College_or_university	38.866	< 2e-16	***
facility_typeEducation_Other_classroom	26.038	< 2e-16	***
facility_typeEducation_Preschool_or_daycare	5.720	1.07e-08	***
facility_typeEducation_Uncategorized	6.315	2.72e-10	***
facility_typeFood_Sales	16.765	< 2e-16	***
facility_typeFood_Service_Other	-0.211	0.833054	
facility_typeFood_Service_Restaurant_or_cafeteria	25.054	< 2e-16	***
facility_typeFood_Service_Uncategorized	7.960	1.74e-15	***
facility_typeGrocery_store_or_food_market	77.465	< 2e-16	***
facility_typeHealth_Care_Inpatient	77.211	< 2e-16	***
facility_typeHealth_Care_Outpatient_Clinic	10.290	< 2e-16	***
facility_typeHealth_Care_Outpatient_Uncategorized	18.267	< 2e-16	***
facility_typeHealth_Care_Uncategorized	20.843	< 2e-16	***
facility_typeIndustrial	32.481	< 2e-16	***
facility_typeLaboratory	58.244	< 2e-16	***
facility_typeLodging_Dormitory_or_fraternity_sorority	21.499	< 2e-16	***
facility_typeLodging_Hotel	44.824	< 2e-16	***
facility_typeLodging_Other	14.716	< 2e-16	***
facility_typeLodging_Uncategorized	1.508	0.131577	
facility_typeMixed_Use_Commercial_and_Residential	24.971	< 2e-16	***
facility_typeMixed_Use_Predominantly_Commercial	10.881	< 2e-16	***
facility_typeMixed_Use_Predominantly_Residential	2.906	0.003663	**
facility_typeMultifamily_Uncategorized	42.986	< 2e-16	***
facility_typeNursing_Home	45.289	< 2e-16	***
facility_typeOffice_Bank_or_other_financial	14.207	< 2e-16	***
facility_typeOffice_Medical_non_diagnostic	31.395	< 2e-16	***
facility_typeOffice_Mixed_use	4.126	3.70e-05	***
facility_typeOffice_Uncategorized	35.645	< 2e-16	***
facility_typeParking_Garage	10.271	< 2e-16	***
facility_typePublic_Assembly_Drama_theater	7.836	4.69e-15	***
facility_typePublic_Assembly_Entertainment_culture	17.257	< 2e-16	***
facility_typePublic_Assembly_Library	17.475	< 2e-16	***
facility_typePublic_Assembly_Movie_Theater	8.563	< 2e-16	***
facility_typePublic_Assembly_Other	21.197	< 2e-16	***
facility_typePublic_Assembly_Recreation	13.493	< 2e-16	***
facility_typePublic_Assembly_Social_meeting	8.391	< 2e-16	***
facility_typePublic_Assembly_Stadium	7.286	3.23e-13	***
facility_typePublic_Assembly_Uncategorized	2.995	0.002750	**
facility_typePublic_Safety_Courthouse	8.465	< 2e-16	***
facility_typePublic_Safety_Fire_or_police_station	23.242	< 2e-16	***
facility_typePublic_Safety_Penitentiary	16.289	< 2e-16	***
facility_typePublic_Safety_Uncategorized	6.537	6.33e-11	***
facility_typeReligious_worship	4.478	7.54e-06	***

facility_typeRetail_Enclosed_mall	14.274	< 2e-16	***
facility_typeRetail_Strip_shopping_mall	15.775	< 2e-16	***
facility_typeRetail_Uncategorized	25.365	< 2e-16	***
facility_typeRetail_Vehicle_dealership_showroom	2.423	0.015384	*
facility_typeService_Drycleaning_or_Laundry	0.596	0.551299	
facility_typeService_Uncategorized	12.872	< 2e-16	***
facility_typeService_Vehicle_service_repair_shop	23.320	< 2e-16	***
facility_typeWarehouse_Distribution_or_Shipping_center	3.197	0.001387	**
facility_typeWarehouse_Nonrefrigerated	3.383	0.000716	***
facility_typeWarehouse_Refrigerated	12.984	< 2e-16	***
facility_typeWarehouse_Selfstorage	-4.208	2.58e-05	***
facility_typeWarehouse_Uncategorized	1.324	0.185652	

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Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 51.42 on 75697 degrees of freedom

Multiple R-squared: 0.2217, Adjusted R-squared: 0.221

F-statistic: 365.4 on 59 and 75697 DF, p-value: < 2.2e-16

## Bibliography