

Anticipating buildings performance

Project



Seattle

Predict energy consumption and
carbon emissions of
non-residential buildings of
Seattle

CONTEXT

- Buildings account for 33% of Seattle's core emissions
- Climate Action Plan for 0 GHG emissions by 2050
- More market value for energy efficiency

MISSION



Find the best model to predict future CO2 emissions and energy consumption for the buildings based on the 2016 report



Evaluate 'ENERGY STAR Score' influence

DATASET

OSEBuildingID	DataYear	BuildingType	PrimaryPropertyType	PropertyName	Address	City	State	ZipCode	TaxParcelIdentificationNumber	...	Electricity(kWh)	Electricity(kBtu)	NaturalGas(therms)	NaturalGas(kBtu)
821	2016	NonResidential	Warehouse	3701 S. Nor...	3701 S. Nor...	Seattle	WA	98118.00	0323049194	...	880501.38	3004271.00	0.00	0.00
20028	2016	Multifamily...	Low-Rise Mu...	53454 - Pac...	4616 22nd A...	Seattle	WA	98105.00	0925049084	...	648716.69	2213421.00	0.00	0.00
23010	2016	Multifamily...	Mid-Rise Mu...	Cedarvale H...	11050 8th A...	Seattle	WA	98125.00	2926049178	...	811777.50	2769785.00	8311.12	8311112.00
26601	2016	NonResidential	Small- and ...	Duncan Buil...	315 2nd Ave...	Seattle	WA	98104.00	5247800720	...	375174.31	1280095.00	6586.82	658682.00
19464	2016	Multifamily...	Mid-Rise Mu...	Ballard Con...	1532 NW 56t...	Seattle	WA	98107.00	0451900000	...	1059638.75	3615487.00	13190.71	1319071.00
21344	2016	Multifamily...	High-Rise M...	SUMMIT AT F...	1200 UNIVER...	Seattle	WA	98101.00	1978200865	...	2083056.38	7107388.00	124186.91	12418691.00
25111	2016	Multifamily...	Low-Rise Mu...	Sierra on G...	11222 Green...	Seattle	WA	98133.00	8911000040	...	169119.00	577034.00	0.00	0.00
25514	2016	Multifamily...	High-Rise M...	Washington ...	1620 43rd A...	Seattle	WA	98112.00	9186700000	...	1067268.75	3641521.00	15936.40	1593640.00
25511	2016	Multifamily...	Low-Rise Mu...	Washington ...	1065 E Pros...	Seattle	WA	98102.00	9178900000	...	71528.80	244056.00	11736.72	1173672.00
21550	2016	NonResidential	Small- and ...	Bayview Buil...	129 1st Ave...	Seattle	WA	98119.00	1992200400	...	140782.50	480350.00	21102.72	2110272.00
23287	2016	Multifamily...	High-Rise M...	Skyline at ...	725 9th Avenue	Seattle	WA	98104.00	8590400825	...	5155959.00	17592132.00	83781.13	8378113.00
26188	2016	Multifamily...	Mid-Rise Mu...	Alley 24	241 Yale Av...	Seattle	WA	98109.00	6849700130	...	809425.12	2761759.00	26650.27	2665027.00
23713	2016	Multifamily...	Low-Rise Mu...	Starliter	8708 Rainie...	Seattle	WA	98118.00	3524049011	...	229514.70	783104.00	0.00	0.00
23251	2016	Multifamily...	Low-Rise Mu...	Sunset Vist...	5451 Califo...	Seattle	WA	98136.00	7625701325	...	158359.70	540323.00	0.00	0.00
27343	2016	Multifamily...	Low-Rise Mu...	Ravenna Woods	2300 NE 89T...	Seattle	WA	98115.00	7181200000	...	365743.81	1247918.00	0.00	0.00

Quick overview

- Data origin: Seattle Open Data (<https://data.seattle.gov/>)
- 3376 entries (=buildings)
- 46 columns
- 13% of missing values

Targets

Greenhouse gas emissions (carbon dioxide, methane, and nitrous oxide gases)

TotalGHGEmissions	total amount
GHGEmissionsIntensity	per square foot

Energy consumption (electricity, natural gas, steam)

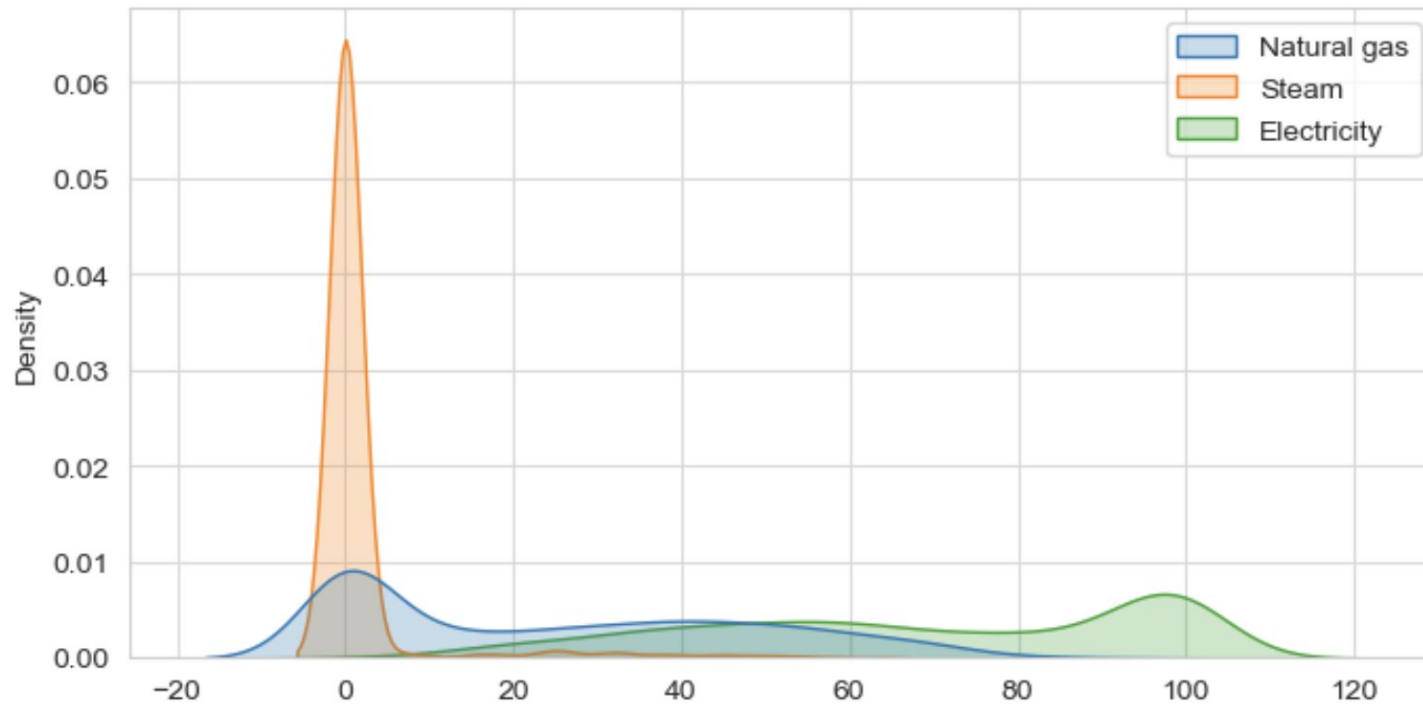
SiteEnergyUseWN(kBtu)	annual amount of energy consumed
SiteEUIWN(kBtu/sf)	energy consumed per square foot

Features

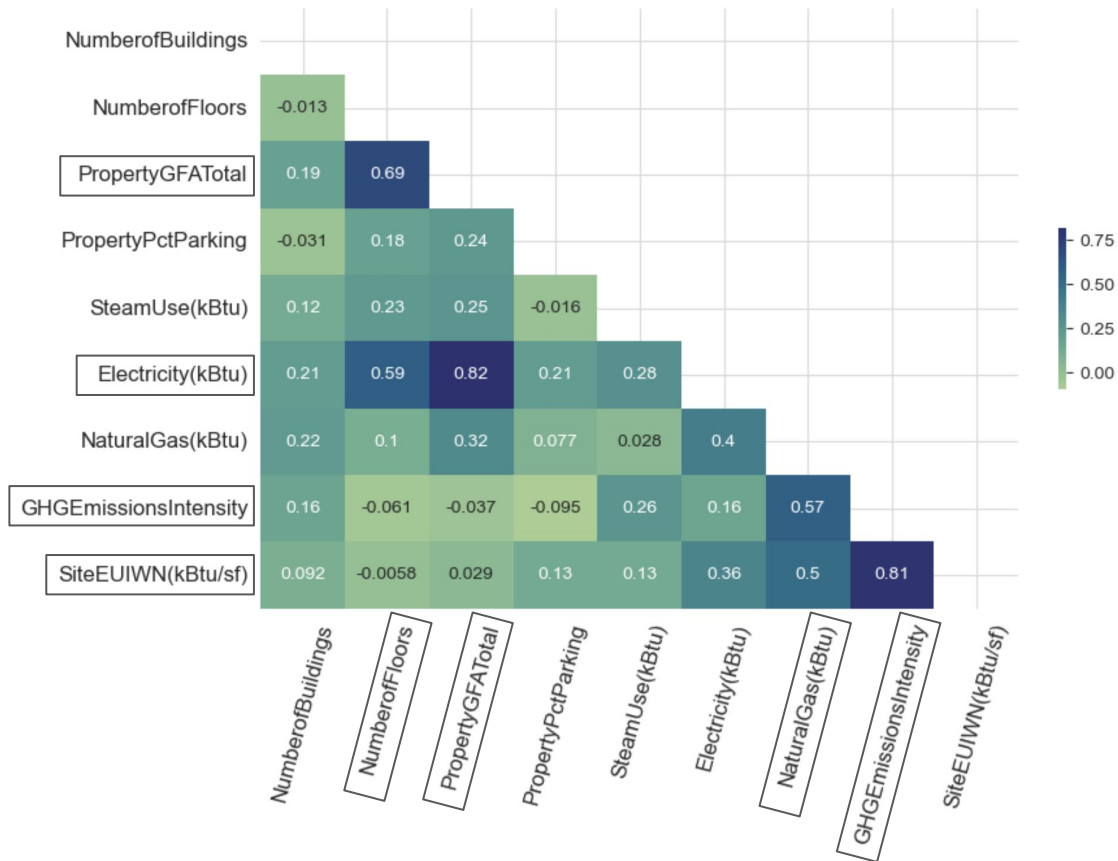
Type	Surface/structure	Location	Age	Resources
BuildingType	PropertyGFATotal	Address	YearBuilt	SteamUse(kBtu)
PrimaryPropertyType	PropertyGFABuilding(s)	City		Electricity(kBtu)
ListOfAllPropertyUseTypes	PropertyGFAParking	State		Electricity(kWh)
LargestPropertyUseType	LargestPropertyUseTypeGFA	ZipCode		NaturalGas(kBtu)
SecondLargestPropertyUseType	SecondLargestPropertyUseTypeGFA	CouncilDistrictCode		NaturalGas(therms)
ThirdLargestPropertyUseType	ThirdLargestPropertyUseTypeGFA	Neighborhood		
	NumberOfBuildings	Latitude		
	NumberOfFloors	Longitude		

*ENERGYSTARScore

Resources distribution (%)



Correlations



FEATURE ENGINEERING

FEATURE ENGINEERING manual

Type	Surface/structure	Location	Age	Resources
Type_Accommodation	NumberofBuildings	Neighborhood	DecadeBuilt	SteamUse(pct)
Type_Entertainment	NumberofFloors			Electricity(pct)
Type_Industry	PropertyGFATotal			NaturalGas(pct)
Type_Medical_facility	PropertyParking(pct)			
Type_Office				
Type_Parking				
Type_School				
Type_Services				
Type_Storage_facility				
Type_Store				
Type_Other				

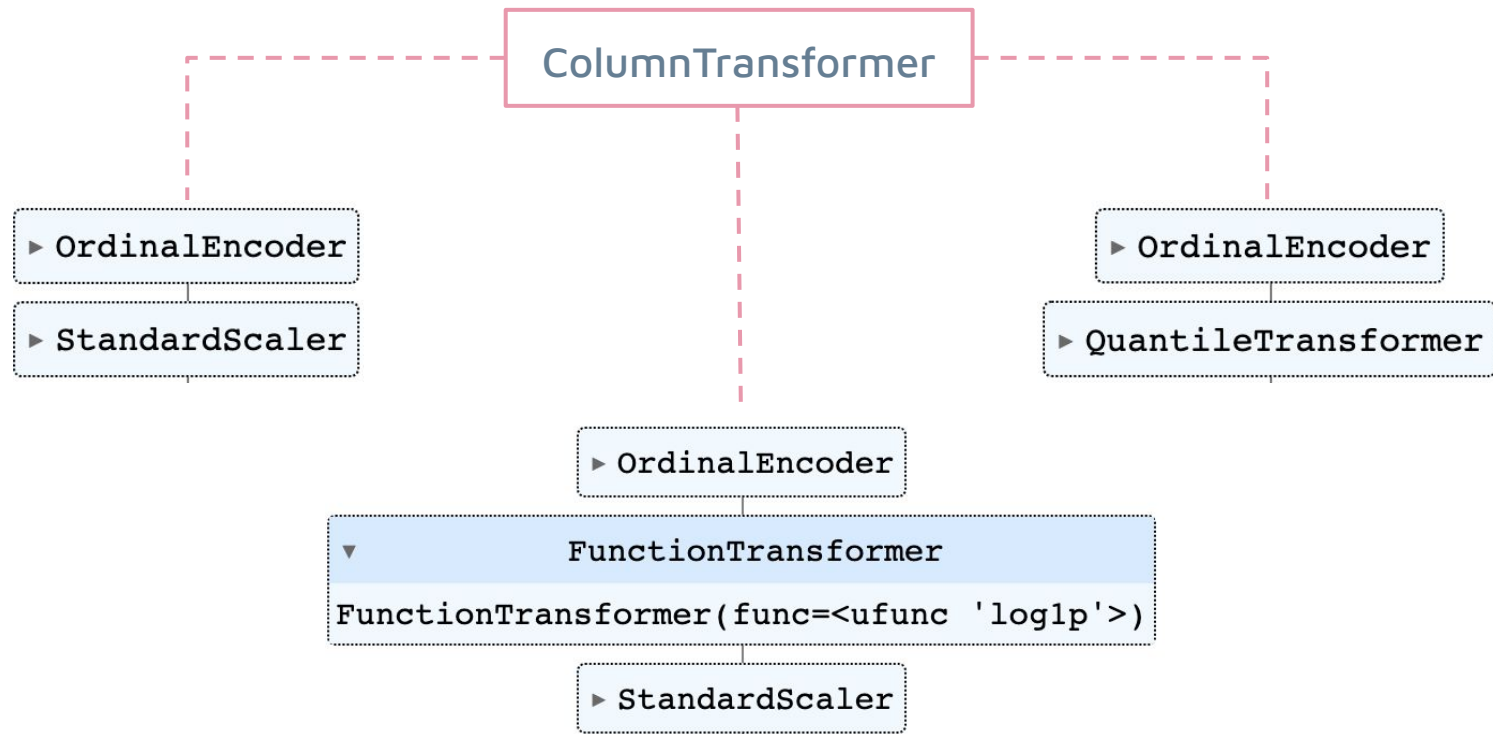
FEATURE ENGINEERING Neighborhood

OneHotEncoder

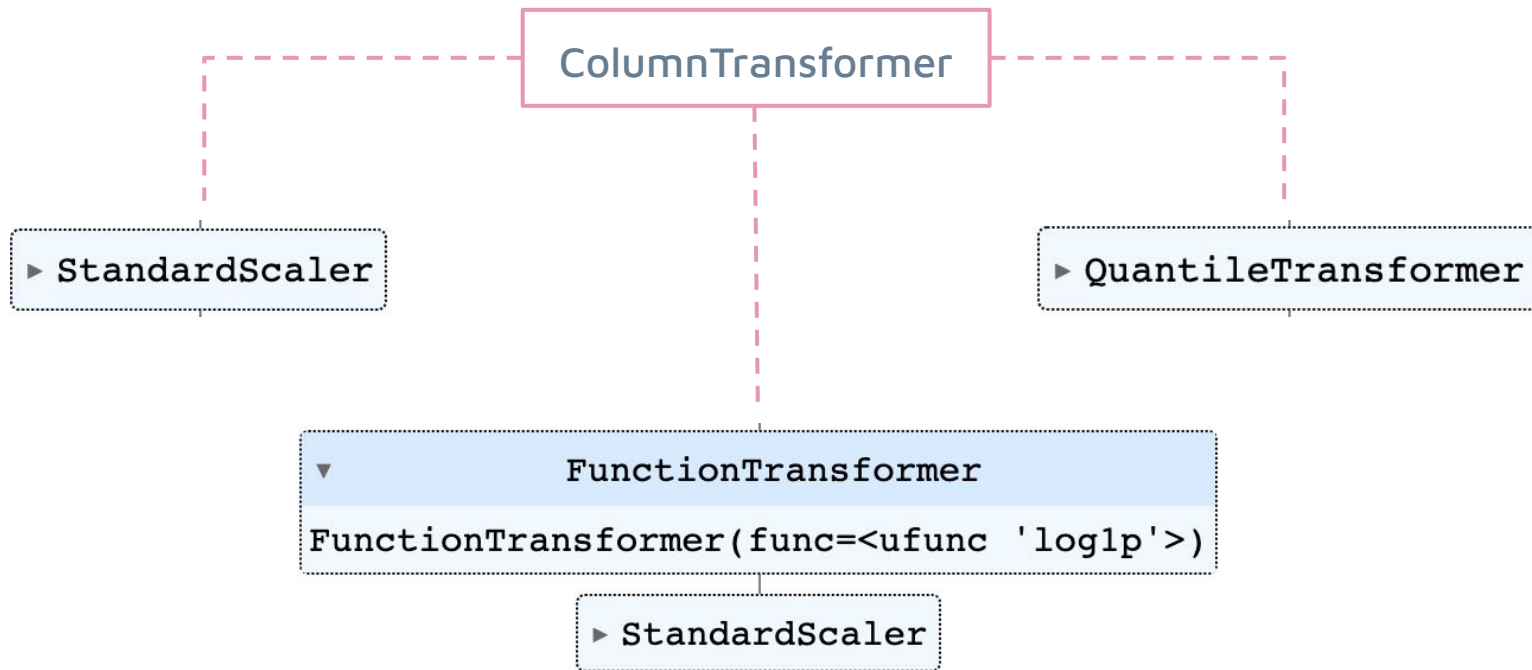
Neighborhood_BALLARD	Neighborhood_CENTRAL	Neighborhood_DELRIDGE	Neighborhood_DOWNTOWN	Neighborhood_EAST	Neighborhood_GREATER DUWAMISH	Neighborhood_LAKE UNION	Neighborhood_MAGNOLIA / QUEEN ANNE	Neighborhood_NORTH
0	0	0	0	0	0	1	0	0
0	0	0	1	0	0	0	0	0
1	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	1	0	0
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0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0
0	0	0	0	1	0	0	0	0

FEATURE ENGINEERING

DecadeBuilt



FEATURE ENGINEERING Numerical values

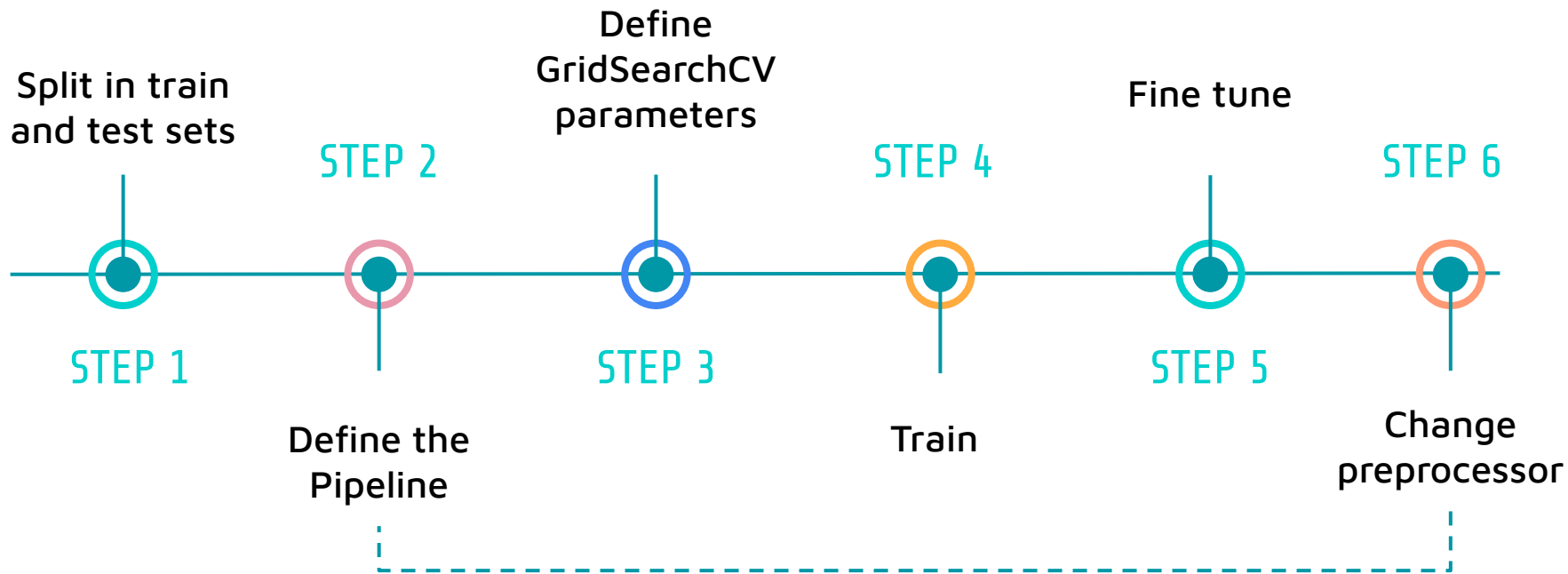


MODELLING

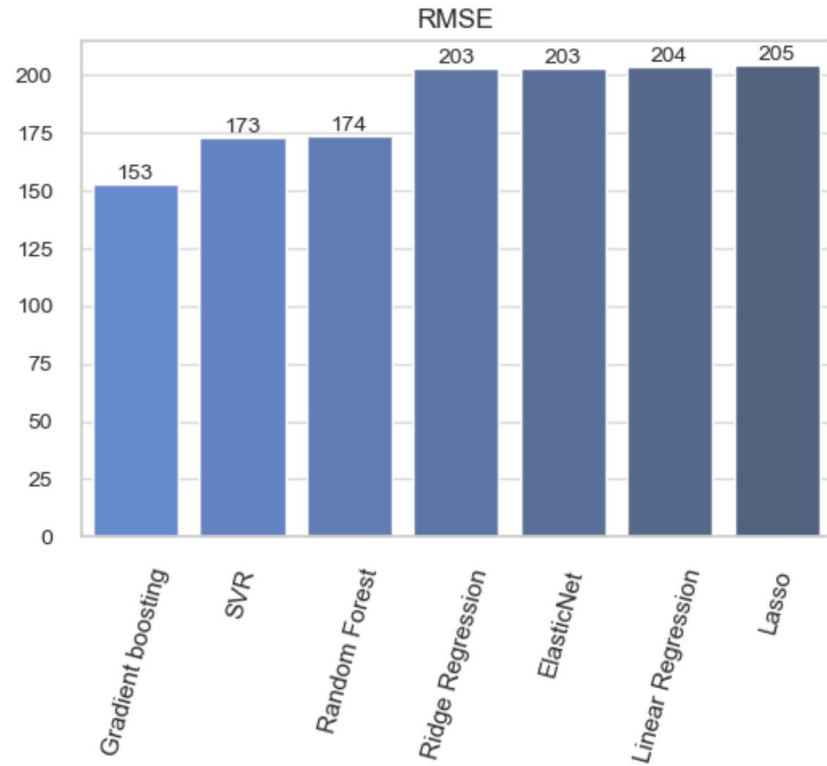
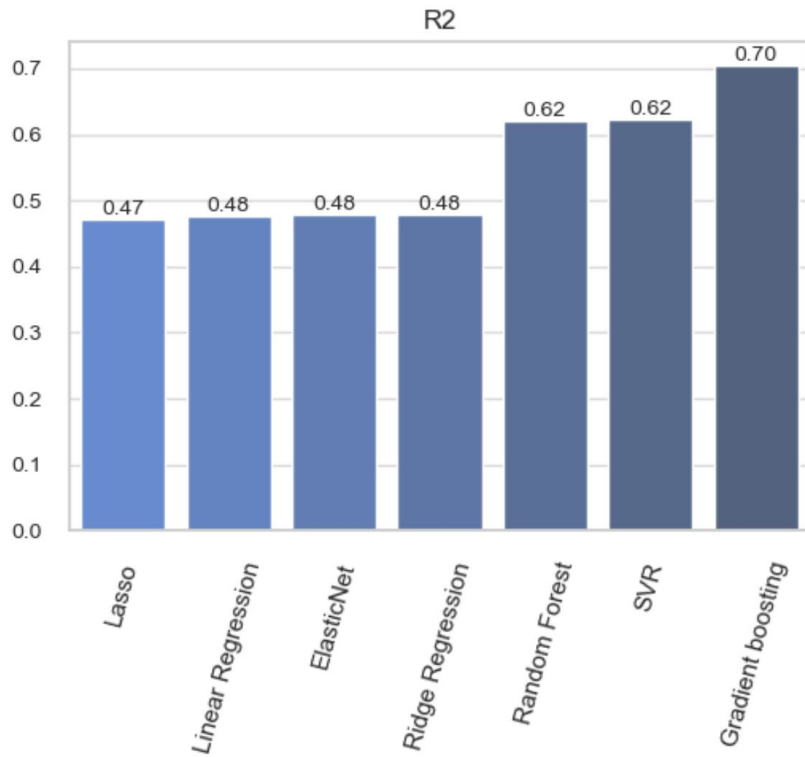
Models

- Linear Regression (baseline)
- Ridge Regression
- Lasso
- Elastic Net
- Support Vector Regression
- Random Forest Regression
- Gradient Boosting

TRAINING PROCESS

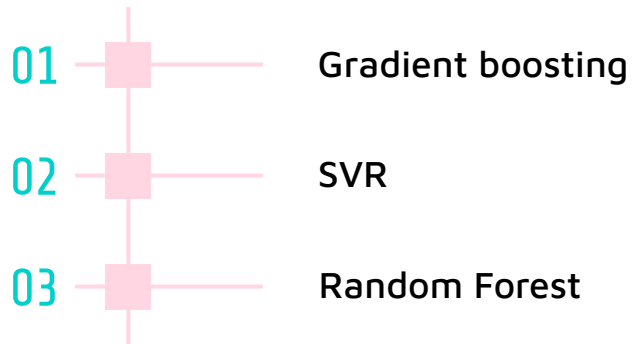


MODELLING TotalGHGEmissions

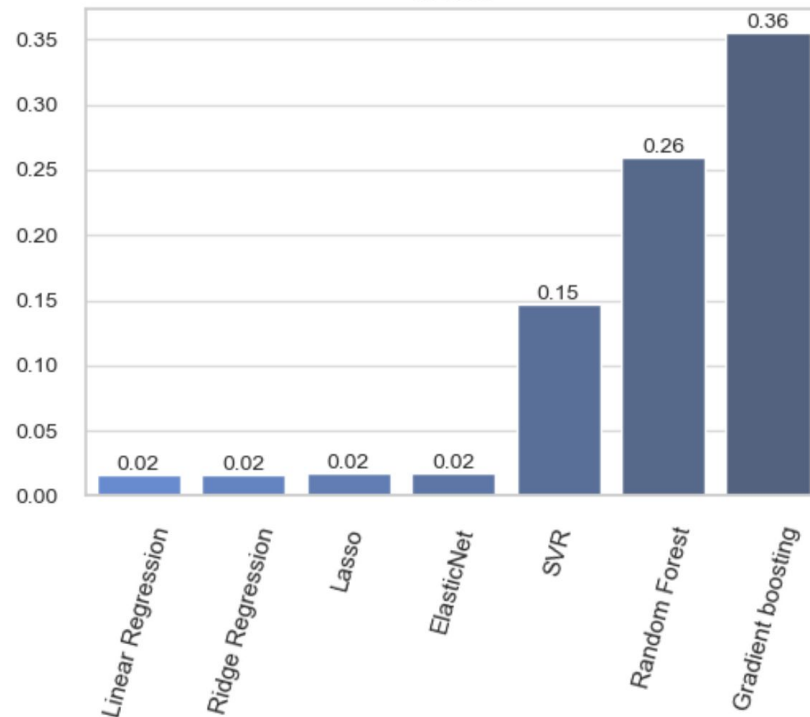


MODELLING TotalGHGEmissions

Best scores

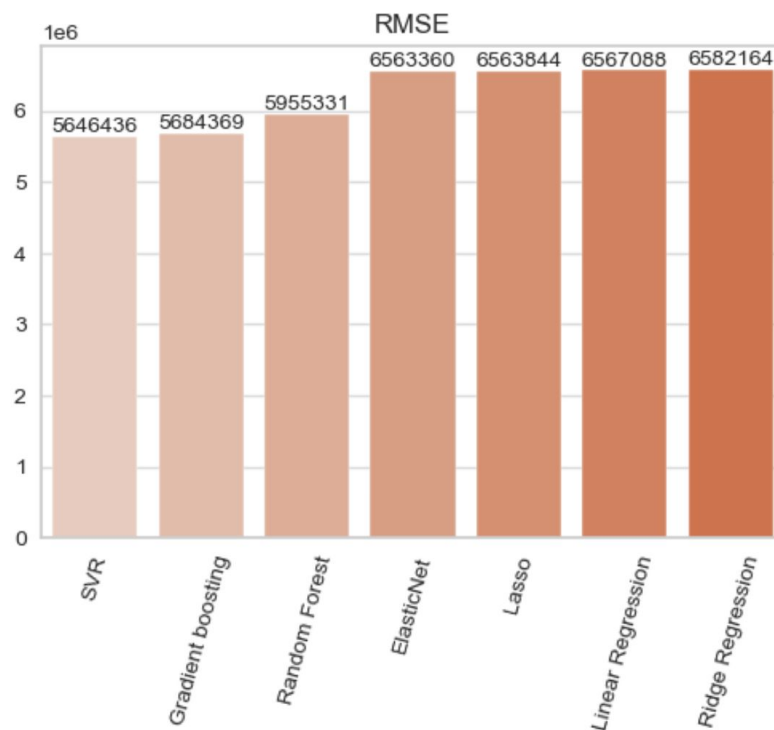
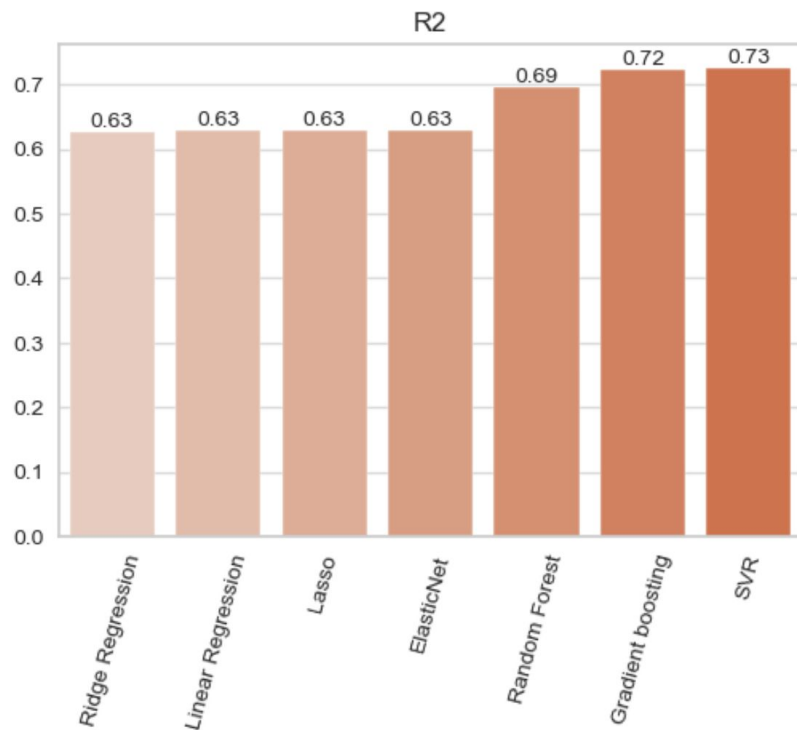


Fit time (seconds)



MODELLING

SiteEnergyUseWN

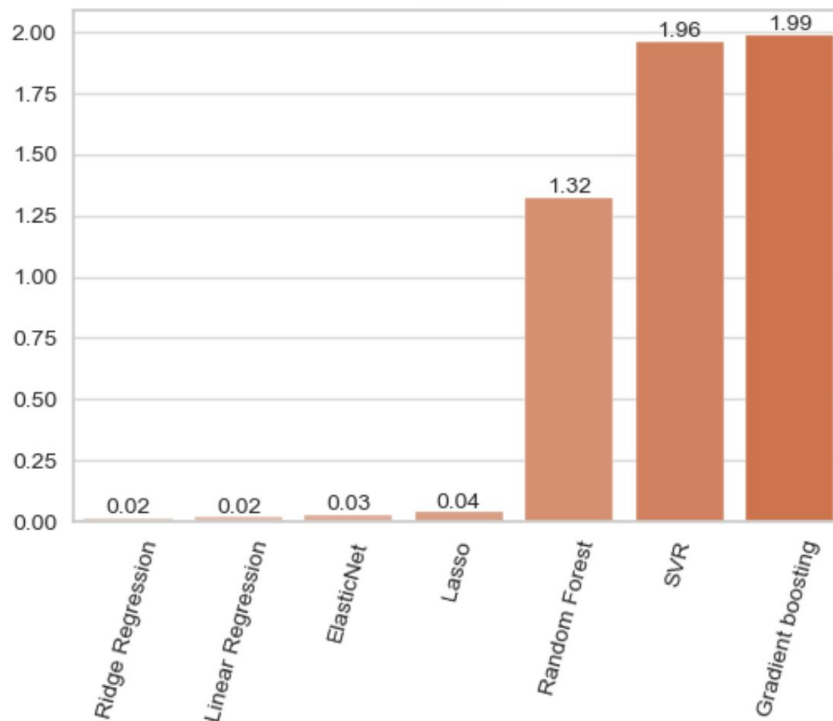


MODELLING SiteEnergyUseWN

Best scores

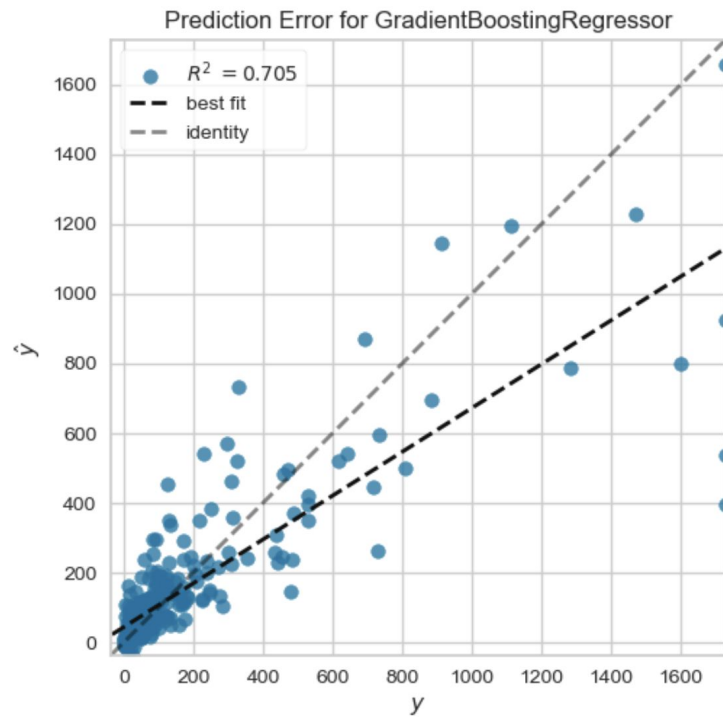
- 01 SVR
- 02 Gradient boosting
- 03 Random Forest

Fit time (seconds)

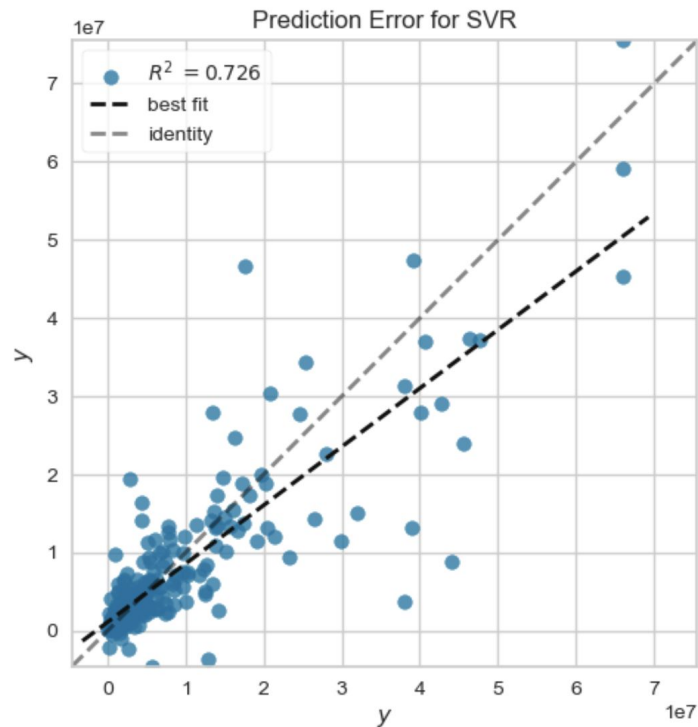


MODELLING Prediction errors

TotalGHGEmissions

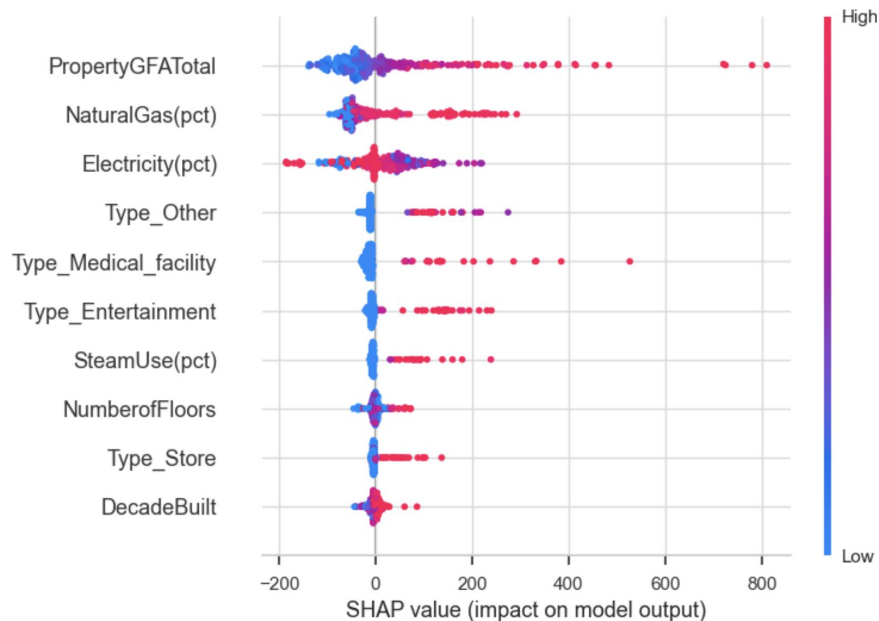


SiteEnergyUseWN

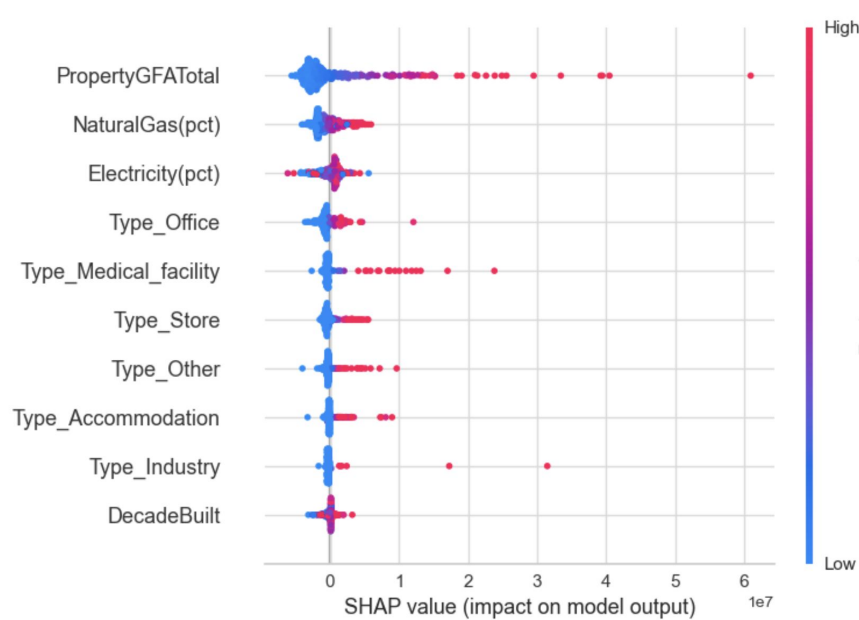


FEATURE IMPORTANCE

TotalGHGEmissions



SiteEnergyUseWN



ENERGYSTARScore

	R2	RMSE	With EnergyStarScore
TotalGHGEmissions	0.712	166	✓
	0.696	170	✗
SiteEnergyUseWN	0.744	6834352	✓
	0.736	6920445	✗

OUTCOMES

	TotalGHGEmissions	SiteEnergyUseWN
Best models	<ul style="list-style-type: none">• Gradient boosting• SVR• Random Forest	<ul style="list-style-type: none">• SVR• Gradient boosting• Random Forest
Features	<ul style="list-style-type: none">• PropertyGFATotal• NaturalGas(pct)• Electricity(pct)• Type_Medical_facility• Type_Store• DecadeBuilt• Type_Other	
ENERGYSTARScore	Small impact	

THANKS!

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