Predictive Emission Monitoring Systems (PEMS) of CO and NO_X

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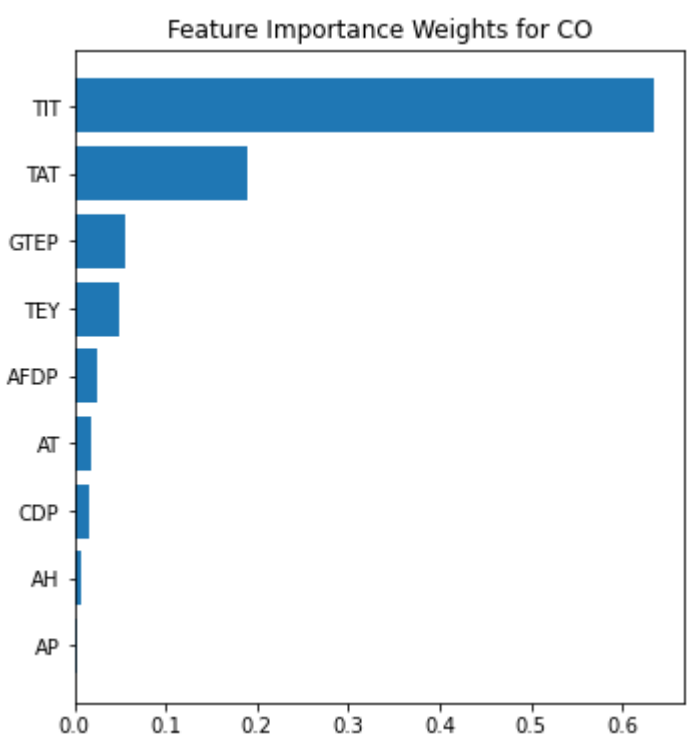
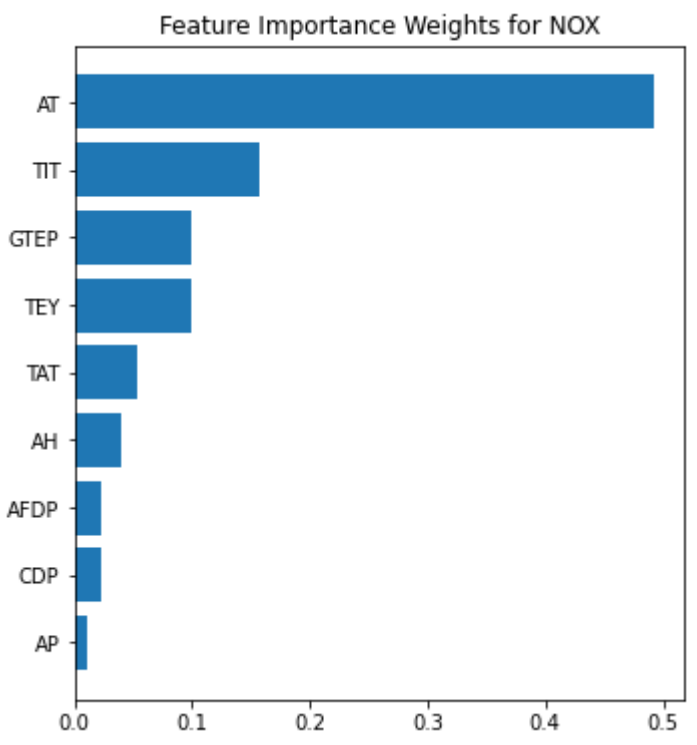
Contents

Data Preparation

- Load .csv file of each year
- Add Datetime column to every year's dataframe
- Concat to make it one big pandas.Dataframe
- Save it as a .parquet file

Feature Selection Criteria





	CO	NOX
AT	-0.174	-0.558
AP	0.067	0.192
AH	0.107	0.165
AFDP	-0.448	-0.188
GTEP	-0.519	-0.202
TIT	-0.706	-0.214
TAT	0.058	-0.093
TEY	-0.57	-0.116
CDP	-0.551	-0.171

CEN/TS 17198:2018

Stationary source emissions - Predictive Emission Monitoring Systems (PEMS) - Applicability, execution and quality assurance

CEN/TS 17198:2018 (E)

Table A.1 — PEMS summary

PEMS output			PEMS range		Average	Unit
No.	Description	Tag. no.	min	max	value	
1	NO_X	SteamBoiler_NO_X	55	100	75	mg/m^3 at 3 % O_2

PEMS input sensor (PIS)			Operating envelope		Nominal	Unit
No.	Description	Tag. no.	Min	Max	value	
1	Air/fuel ratio Total	AirFuelRatio_total	9	14	11	–
2	Natural gas to burner 2	NaturalGas_burner2	0	5000	3250	m^3/h
3	Refinery gas total	RefineryGasFlow_total	0	2000	500	m^3/h
4	Natural gas to burner 1	NaturalGas_burner1	2000	5000	3250	m^3/h
5	Fuel burner 1+2 vs. total	FuelRatio_burner1+2	0,45	1,00	0,67	–
6	Combustion air temperature	CombustionAirTemp	0	25,0	14,0	°C

Uncertainty check	Value	Unit
Maximum range	100	mg/m^3
Uncertainty maximum range (at 95 % confidence level)	4,5	mg/m^3
Uncertainty PEMS at maximum range (at 95 % confidence level)	4,5	%
Maximum permissible uncertainty	20	%
PEMS compliant with requirement?	yes	

Uncertainty Check of NOX Emission

$C_m(i)$ - is the concentration measured in the field of the i^{th} value pair.

$C_p(i)$ - is the concentration measured in the field of the i^{th} value pair.

Δ_i – is the deviation between the emission concentration measured in the field and the concentration predicted by the field of the i^{th} value pair.

$$\Delta_i = C_m(i) - C_p(i)$$

Δ_m – is the mean the relative deviations

$$\Delta_m = \frac{1}{n}\sum_{i=1}^{n}\Delta_i = 4.57\ mg/m^3$$

u_{model} - is the standard uncertainty of the emission model.

$$u_{\text{model}} = \sqrt{\frac{\sum(\Delta_i - \Delta_m)^2}{n-1}} = 4$$

u_{input} - is the standard uncertainty due to deviations in the PEMS input sensors.

*u_{other} - is the standard uncertainty due to parameters not included in the PEMS.

u_{PEMS} - is the standard uncertainty of the PEMS.

$$u_{\text{PEMS}} = \sqrt{\left({u_{\text{model}}}^2 + {u_{\text{input}}}^2 + {u_{\text{other}}}^2\right)}$$
$$= \sqrt{(4^2)} = 4$$

c_{PEMS} - is the concentration range of the PEMS.

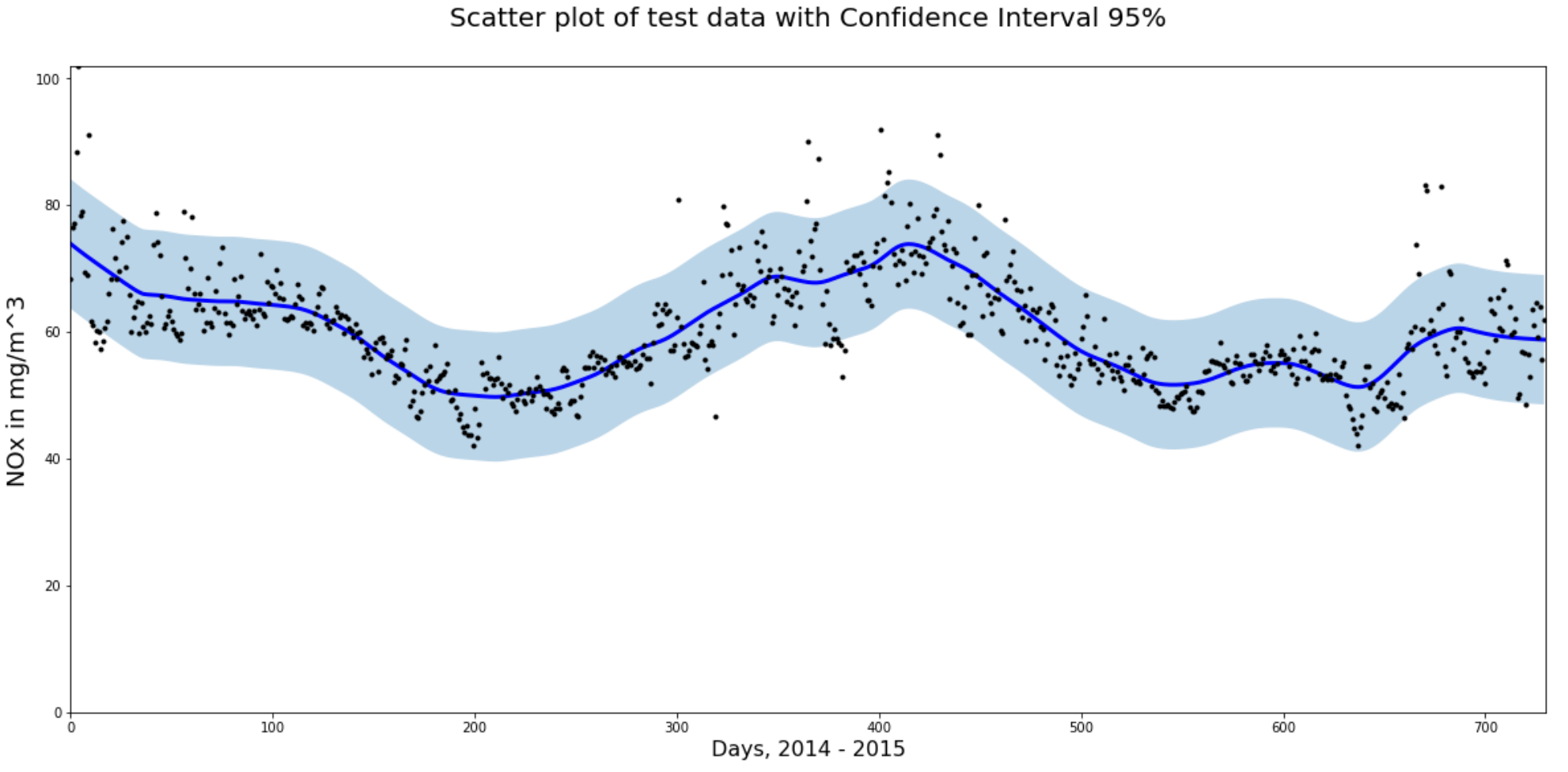
U_{PEMS} - is the relative expanded uncertainty of the PEMS.

$$U_{\text{PEMS}} = 1.96 \times \frac{u_{\text{PEMS}}}{c_{\text{PEMS}}}$$
$$= 1.96 \times \frac{4}{48.92\ mg/m^3} = 0.081 = 8.1\%$$

* Uncertainty of Parameters not included in PEMS have no impact

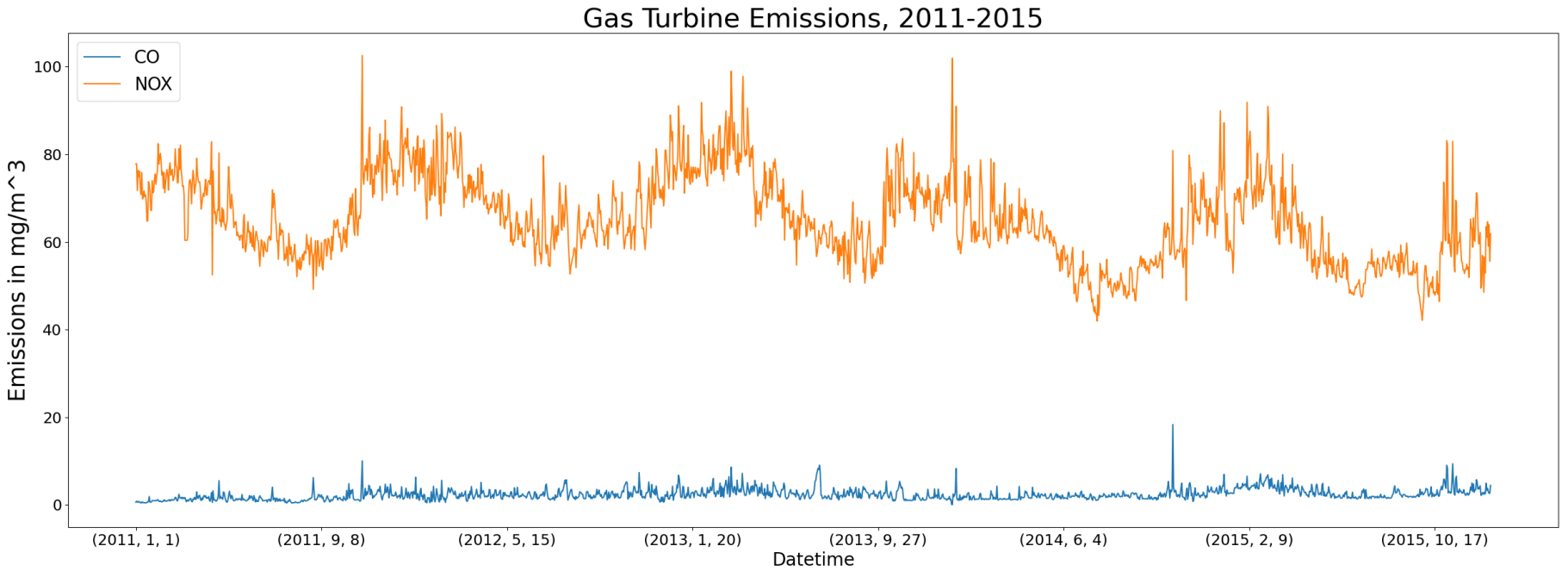
Uncertainty Check of NOX Emission

- Maximum range: 119.83 mg/m^3
- Range of PEMS: 48.92 mg/m^3
- Uncertainty range at 95%: 4 mg/m^3
- Uncertainty PEMS at Range 95% (at 95% Confidence Level): 8.1%
- Maximum Permissable Uncertainty: 20%
- PEMS compliant with requirement? **Yes**


Scatter plot of test data with Confidence Interval 95%
NOx in mg/m^3
Days, 2014 - 2015
0
20
40
60
80
100
0
100
200
300
400
500
600
700

Emission of CO and NO_X during years 2011-2015

Average measurement of CO: 2,37 mg/m^3
Average measurement of NO_X : 65,3 mg/m^3



Prediction

- Data from years 2011-2013 to train our model
- Data from years 2014 and 2015 to test our model

Model trained on data from 2011-2013 to predict CO emissions

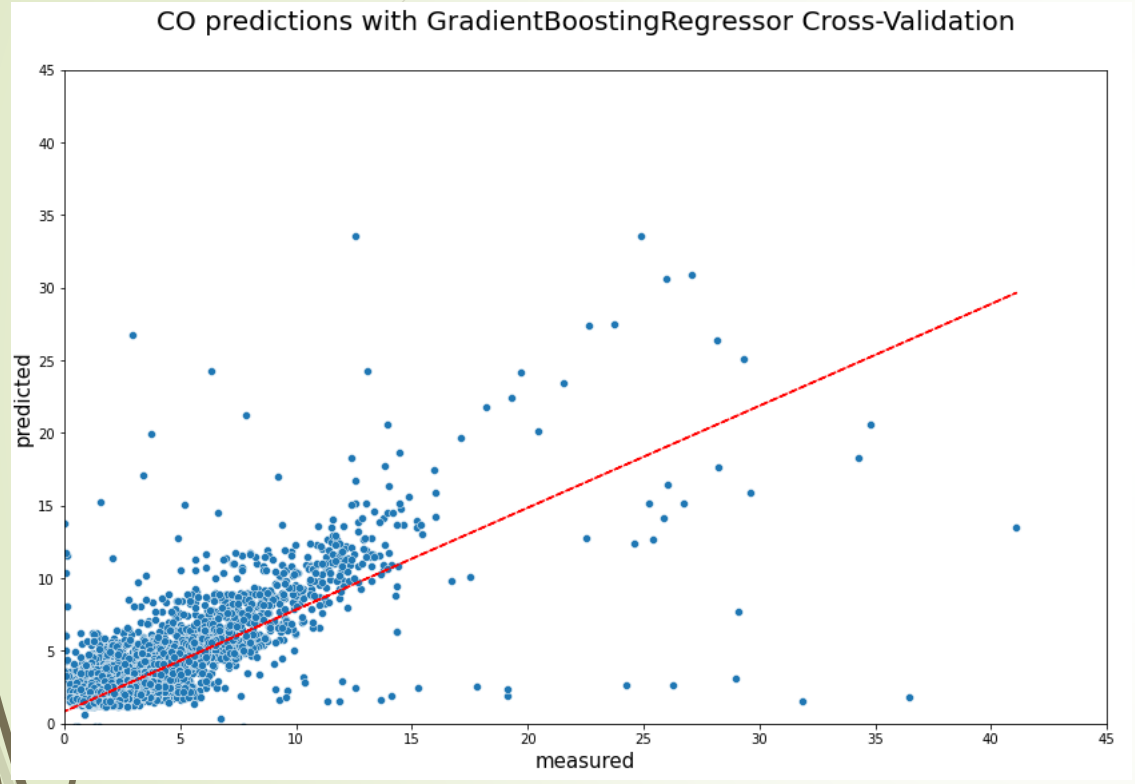
Model: MLPRegressor

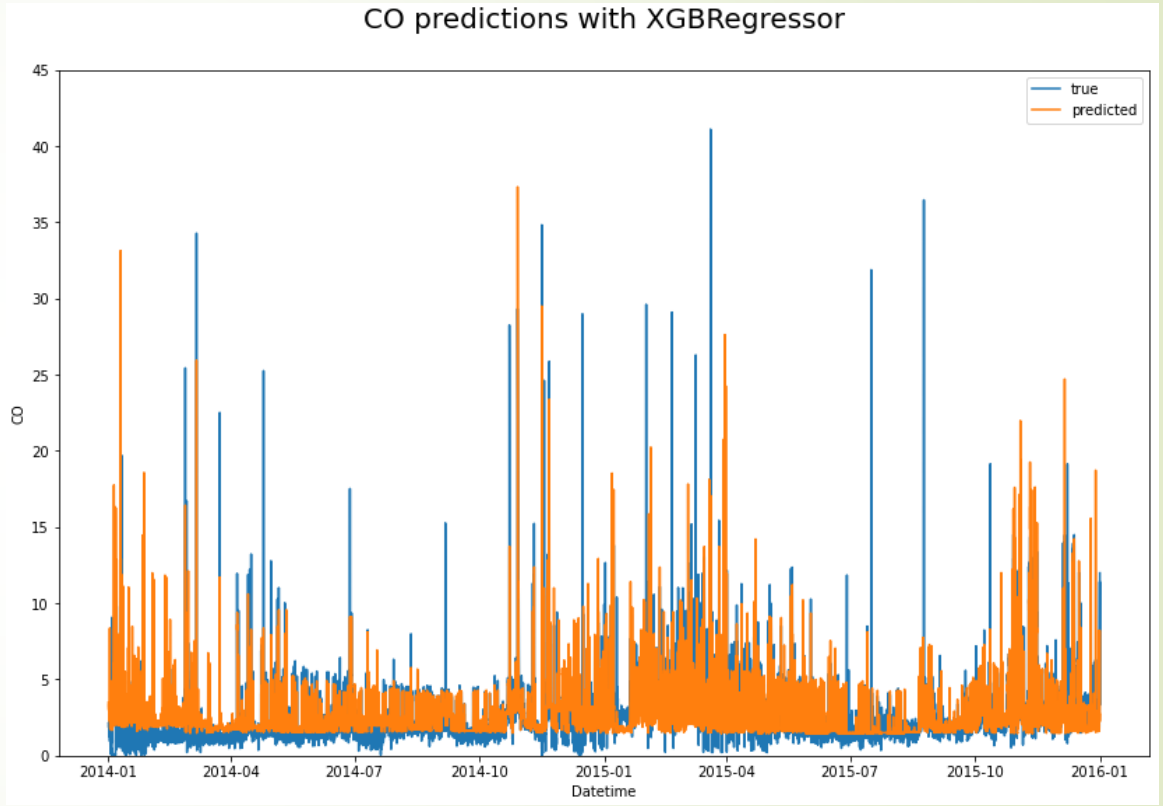
	Test Data
R^2 score	0.52
MAE	1.02
$MAPE$	103.01
$RMSE$	1.51

Model: GradientBoostingRegressor with Cross validation

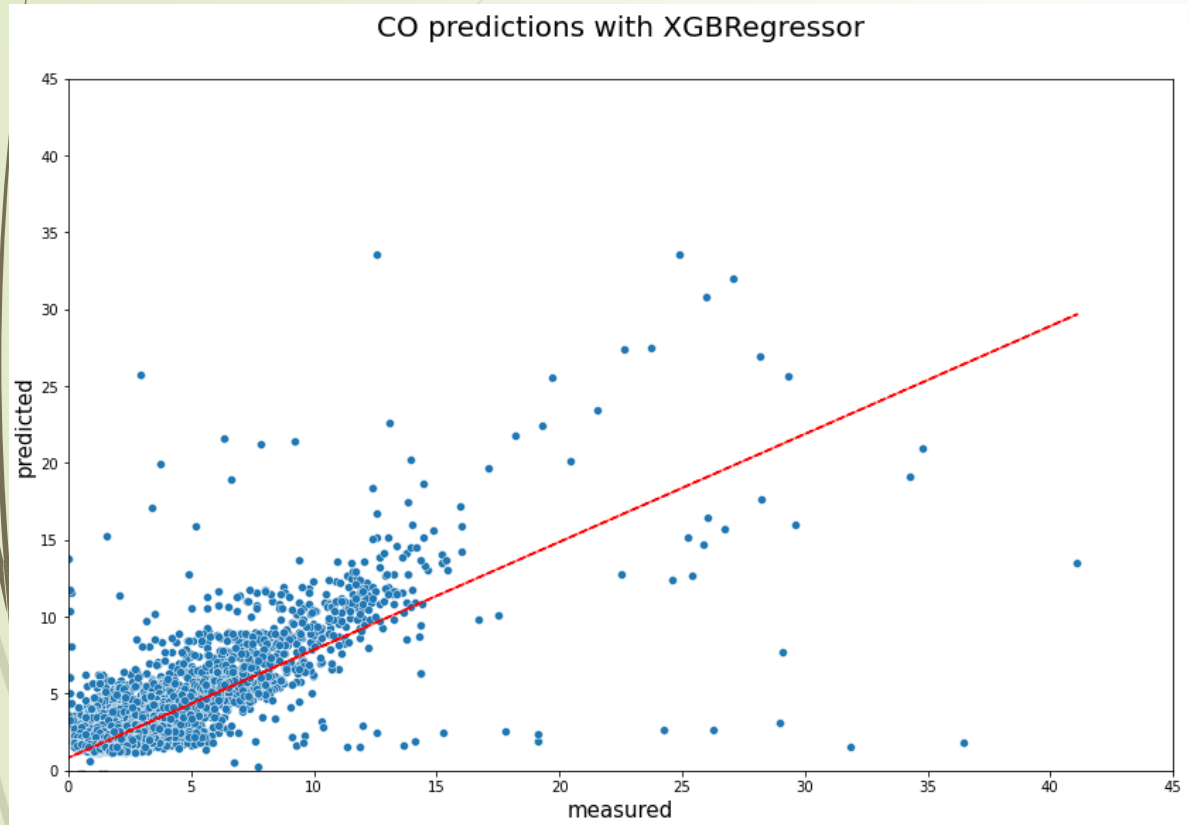
	Training Data	Test Data
R^2 score	0.71	0.74
MAE	0.6	0.53
$MAPE$	0.75	0.76
$RMSE$	1.22	1.09

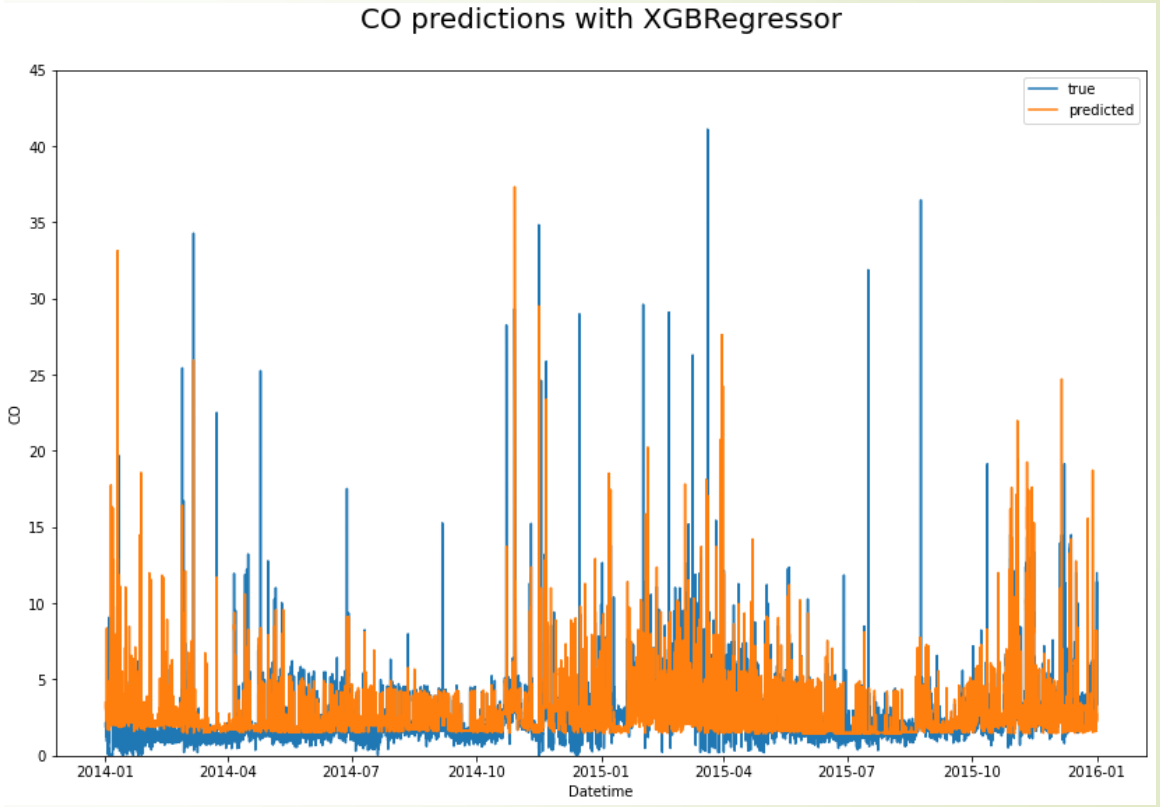
Plotting true values against predicted values





Plotting true values against predicted values





Model trained on data from 2011-2013 to predict NO_X emissions

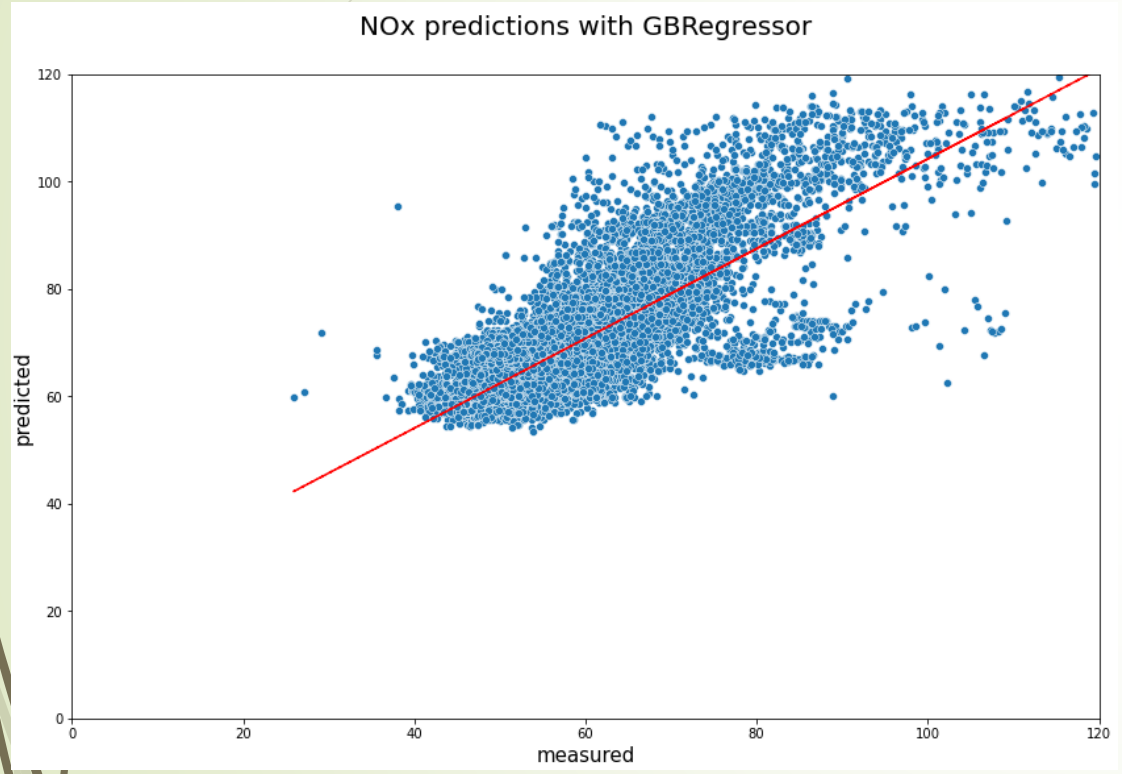
Model: MLPRegressor

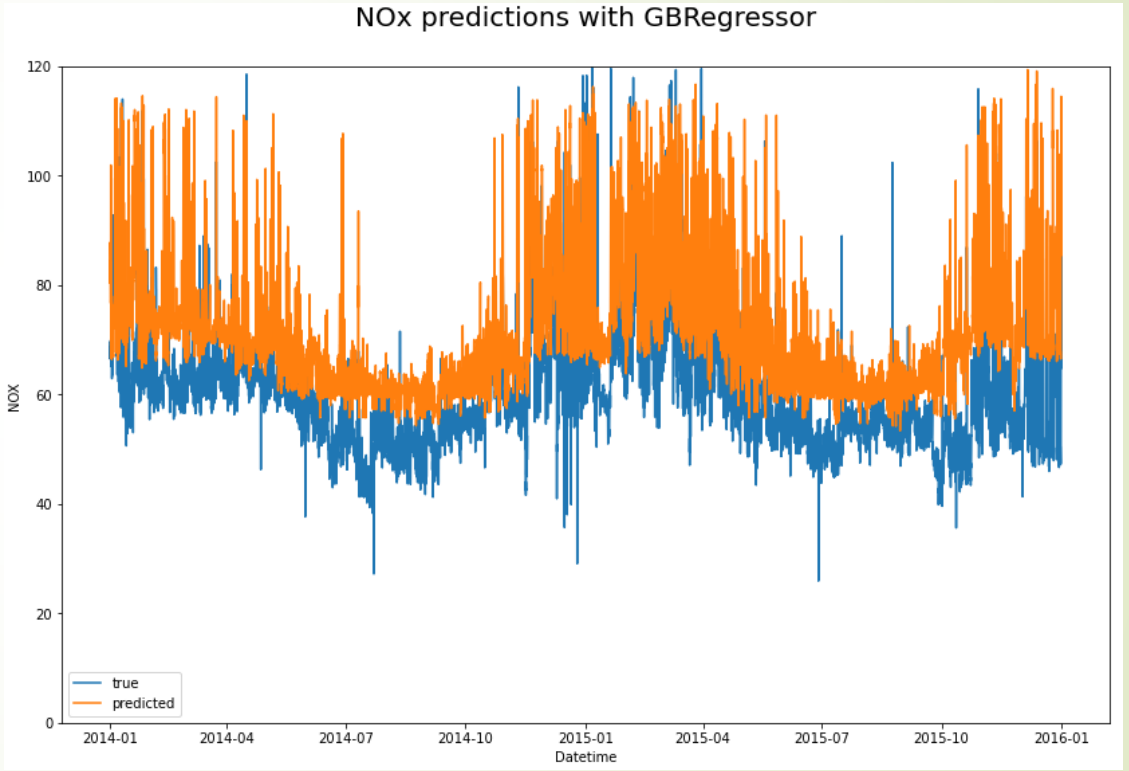
	Test Data
R^2 score	0.4
MAE	10.87
$MAPE$	18.51
$RMSE$	12.54

Model: GradientBoostingRegressor with Cross validation

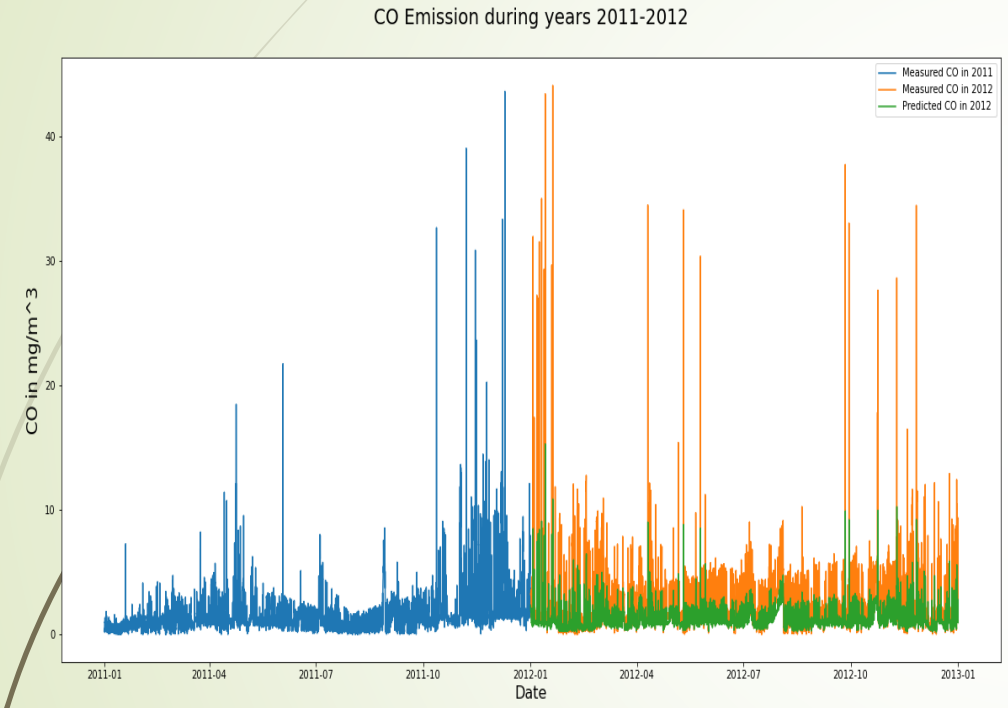
	Training Data	Test Data
R^2 score	0.73	0.72
MAE	4.17	3.87
$MAPE$	0.6	0.64
$RMSE$	5.73	5.51

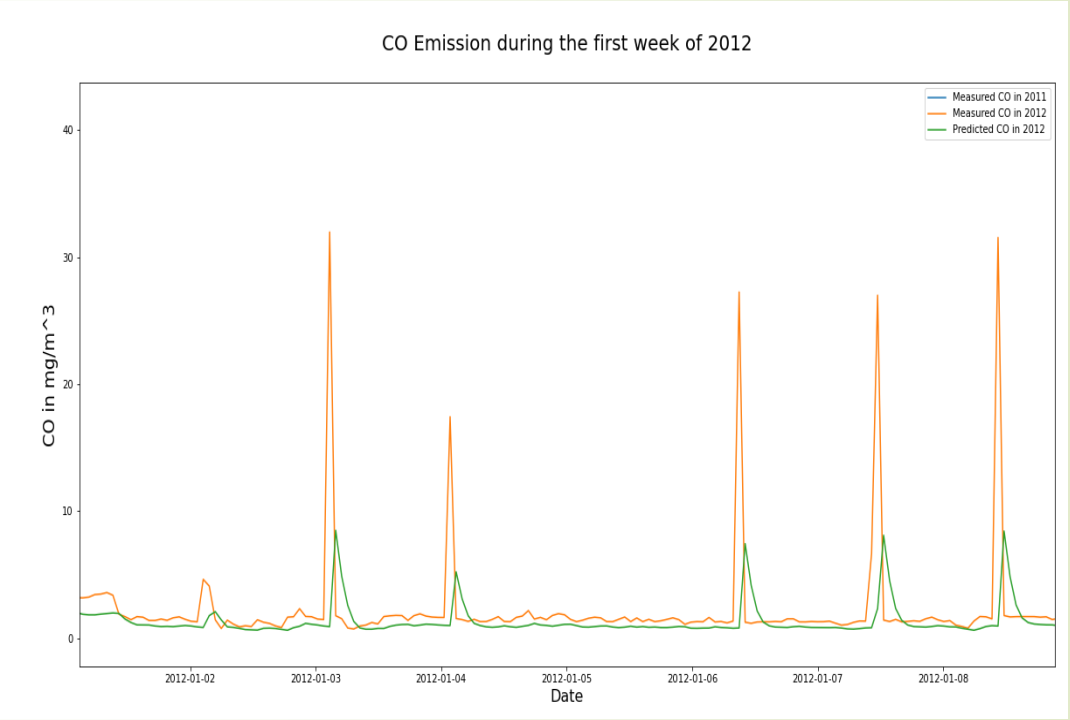
Plotting true values against predicted values



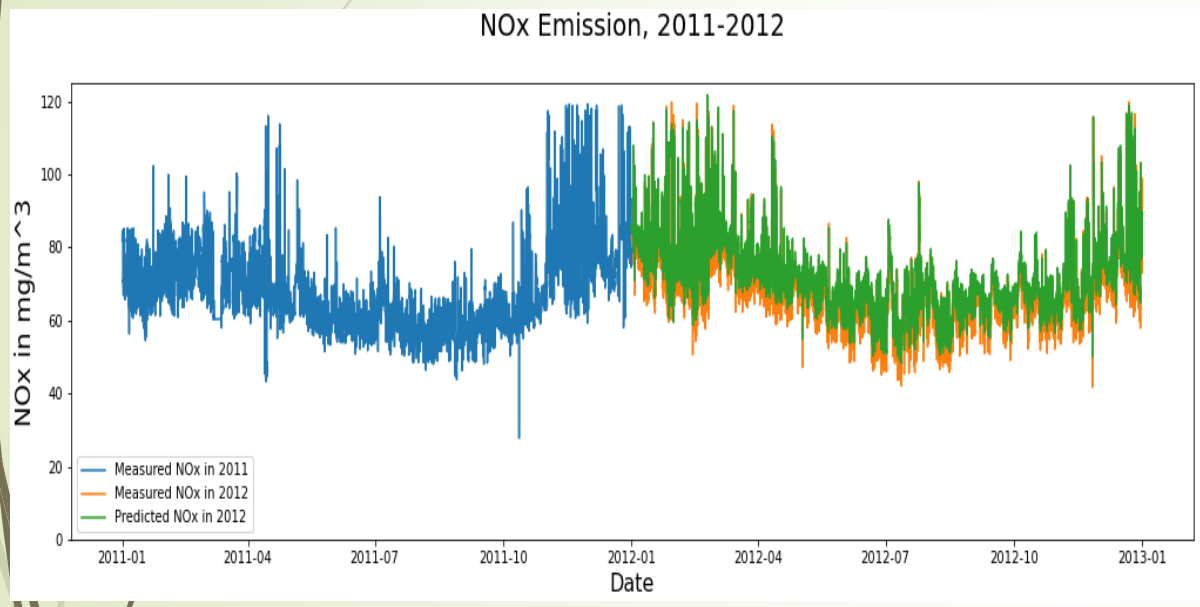


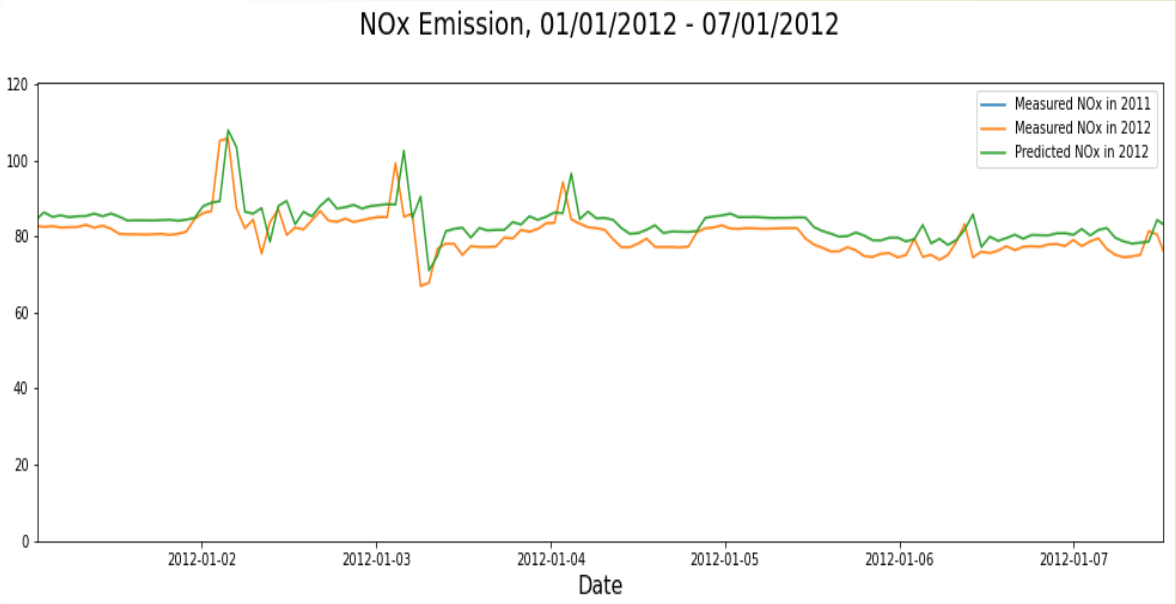
Using in case of sensor failure (CO)



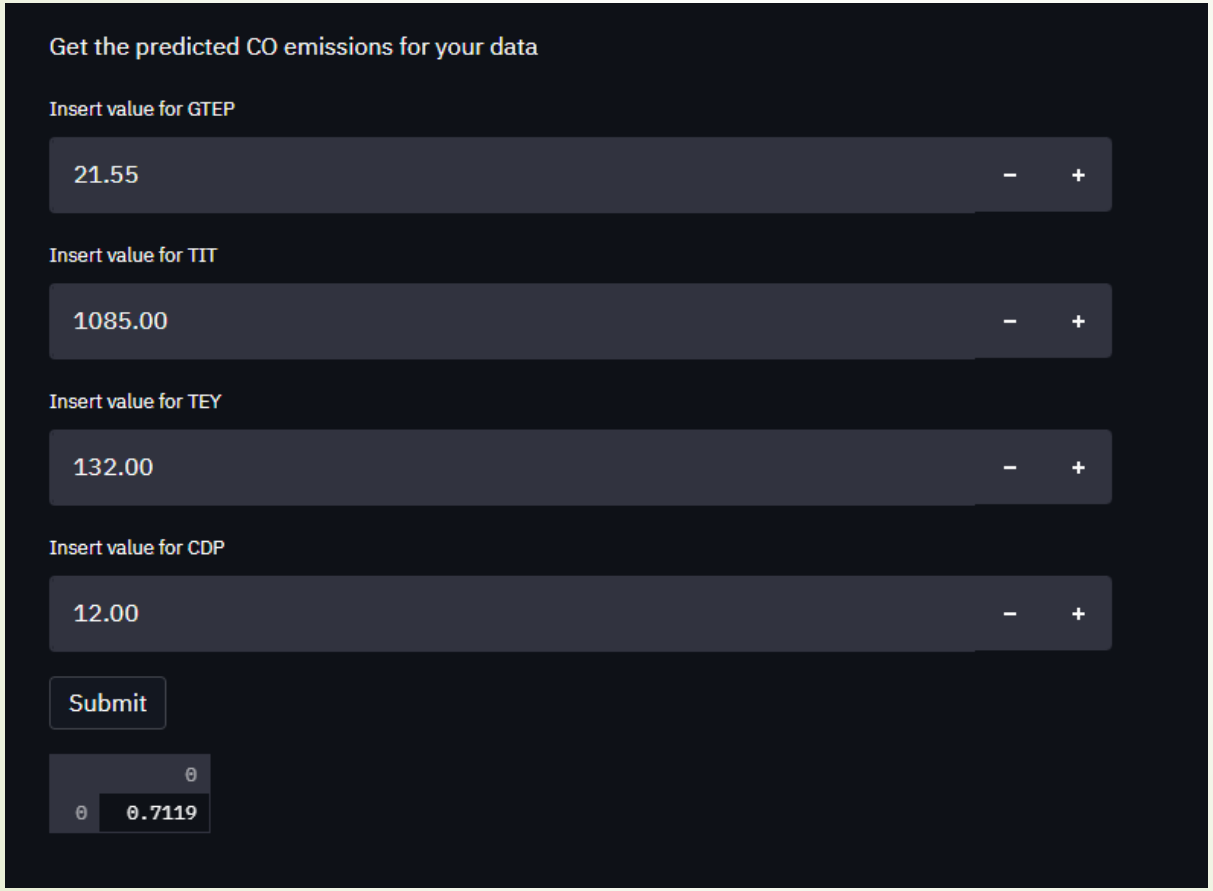


Using in case of sensor failure (NO_X)





Streamlit


Get the predicted CO emissions for your data
Insert value for GTEP
21.55
Insert value for TIT
1085.00
Insert value for TEY
132.00
Insert value for CDP
12.00
Submit
0
0 0.7119

Vielen Dank für Ihre Aufmerksamkeit