

LAB_Simple_Linear_Regression

November 27, 2025

1 Simple Linear Regression

Estimated time needed: **15** minutes

1.1 Objectives

After completing this lab you will be able to:

- Use scikit-learn to implement simple Linear Regression
- Create a model, train it, test it and use the model

1.1.1 Importing Needed packages

```
[2]: !pip install scikit-learn  
!pip install matplotlib  
!pip install pandas  
!pip install numpy  
%matplotlib inline
```

Requirement already satisfied: scikit-learn in ./venv/lib/python3.12/site-packages (1.7.2)
Requirement already satisfied: numpy>=1.22.0 in ./venv/lib/python3.12/site-packages (from scikit-learn) (2.3.5)
Requirement already satisfied: scipy>=1.8.0 in ./venv/lib/python3.12/site-packages (from scikit-learn) (1.16.3)
Requirement already satisfied: joblib>=1.2.0 in ./venv/lib/python3.12/site-packages (from scikit-learn) (1.5.2)
Requirement already satisfied: threadpoolctl>=3.1.0 in ./venv/lib/python3.12/site-packages (from scikit-learn) (3.6.0)
Requirement already satisfied: matplotlib in ./venv/lib/python3.12/site-packages (3.10.7)
Requirement already satisfied: contourpy>=1.0.1 in ./venv/lib/python3.12/site-packages (from matplotlib) (1.3.3)
Requirement already satisfied: cycler>=0.10 in ./venv/lib/python3.12/site-packages (from matplotlib) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in ./venv/lib/python3.12/site-packages (from matplotlib) (4.60.1)
Requirement already satisfied: kiwisolver>=1.3.1 in ./venv/lib/python3.12/site-packages (from matplotlib) (1.4.9)

```
Requirement already satisfied: numpy>=1.23 in ./venv/lib/python3.12/site-packages (from matplotlib) (2.3.5)
Requirement already satisfied: packaging>=20.0 in ./venv/lib/python3.12/site-packages (from matplotlib) (25.0)
Requirement already satisfied: pillow>=8 in ./venv/lib/python3.12/site-packages (from matplotlib) (12.0.0)
Requirement already satisfied: pyparsing>=3 in ./venv/lib/python3.12/site-packages (from matplotlib) (3.2.5)
Requirement already satisfied: python-dateutil>=2.7 in ./venv/lib/python3.12/site-packages (from matplotlib) (2.9.0.post0)
Requirement already satisfied: six>=1.5 in ./venv/lib/python3.12/site-packages (from python-dateutil>=2.7->matplotlib) (1.17.0)
Requirement already satisfied: pandas in ./venv/lib/python3.12/site-packages (2.3.3)
Requirement already satisfied: numpy>=1.26.0 in ./venv/lib/python3.12/site-packages (from pandas) (2.3.5)
Requirement already satisfied: python-dateutil>=2.8.2 in ./venv/lib/python3.12/site-packages (from pandas) (2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in ./venv/lib/python3.12/site-packages (from pandas) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in ./venv/lib/python3.12/site-packages (from pandas) (2025.2)
Requirement already satisfied: six>=1.5 in ./venv/lib/python3.12/site-packages (from python-dateutil>=2.8.2->pandas) (1.17.0)
Requirement already satisfied: numpy in ./venv/lib/python3.12/site-packages (2.3.5)
```

```
[3]: import matplotlib.pyplot as plt
      import pandas as pd
      import numpy as np
```

1.1.2 Downloading Data

To download the data, we will use !wget to download it from IBM Object Storage.

```
[4]: !wget -O FuelConsumption.csv https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/IBMDriverSkillsNetwork-ML0101EN-SkillsNetwork/labs/Module%202/data/FuelConsumptionCo2.csv
```



```
--2025-11-27 22:11:45-- https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/IBMDriverSkillsNetwork-ML0101EN-SkillsNetwork/labs/Module%202/data/FuelConsumptionCo2.csv
Resolving cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud (cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud)... 169.63.118.104
Connecting to cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud (cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud)|169.63.118.104|:443...
connected.
HTTP request sent, awaiting response... 200 OK
Length: 72629 (71K) [text/csv]
```

```
Saving to: 'FuelConsumption.csv'
```

```
FuelConsumption.csv 100%[=====] 70.93K 186KB/s in 0.4s
```

```
2025-11-27 22:11:47 (186 KB/s) - 'FuelConsumption.csv' saved [72629/72629]
```

In case you're working **locally** uncomment the below line.

```
[5]: #!curl https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/
    ↵IBMDeveloperSkillsNetwork-ML0101EN-SkillsNetwork/labs/Module%202/data/
    ↵FuelConsumptionCo2.csv -o FuelConsumptionCo2.csv
```

1.2 Understanding the Data

1.2.1 FuelConsumption.csv:

We have downloaded a fuel consumption dataset, **FuelConsumption.csv**, which contains model-specific fuel consumption ratings and estimated carbon dioxide emissions for new light-duty vehicles for retail sale in Canada. [Dataset source](#)

- **MODELYEAR** e.g. 2014
- **MAKE** e.g. Acura
- **MODEL** e.g. ILX
- **VEHICLE CLASS** e.g. SUV
- **ENGINE SIZE** e.g. 4.7
- **CYLINDERS** e.g 6
- **TRANSMISSION** e.g. A6
- **FUEL CONSUMPTION in CITY(L/100 km)** e.g. 9.9
- **FUEL CONSUMPTION in HWY (L/100 km)** e.g. 8.9
- **FUEL CONSUMPTION COMB (L/100 km)** e.g. 9.2
- **CO2 EMISSIONS (g/km)** e.g. 182 → low → 0

1.3 Reading the data in

```
[6]: df = pd.read_csv("FuelConsumptionCo2.csv")

# take a look at the dataset
df.head()
```

```
[6]: MODELYEAR   MAKE      MODEL VEHICLECLASS  ENGINESIZE CYLINDERS \
0       2014     ACURA      ILX    COMPACT        2.0         4
1       2014     ACURA      ILX    COMPACT        2.4         4
2       2014     ACURA  ILX HYBRID    COMPACT        1.5         4
3       2014     ACURA      MDX 4WD    SUV - SMALL      3.5         6
4       2014     ACURA      RDX AWD    SUV - SMALL      3.5         6

TRANSMISSION FUELTYPE  FUELCONSUMPTION_CITY  FUELCONSUMPTION_HWY \
0           AS5          Z                 9.9                  6.7
```

1	M6	Z	11.2	7.7
2	AV7	Z	6.0	5.8
3	AS6	Z	12.7	9.1
4	AS6	Z	12.1	8.7

	FUELCONSUMPTION_COMB	FUELCONSUMPTION_COMB MPG	CO2EMISSIONS
0	8.5	33	196
1	9.6	29	221
2	5.9	48	136
3	11.1	25	255
4	10.6	27	244

1.3.1 Data Exploration

Let's first have a descriptive exploration on our data.

```
[7]: # summarize the data
df.describe()
```

```
[7]:      MODELYEAR  ENGINESIZE  CYLINDERS  FUELCONSUMPTION_CITY \
count    1067.0    1067.000000  1067.000000          1067.000000
mean     2014.0     3.346298    5.794752         13.296532
std      0.0       1.415895    1.797447         4.101253
min     2014.0     1.000000    3.000000         4.600000
25%    2014.0     2.000000    4.000000        10.250000
50%    2014.0     3.400000    6.000000        12.600000
75%    2014.0     4.300000    8.000000        15.550000
max    2014.0     8.400000   12.000000        30.200000

      FUELCONSUMPTION_HWY  FUELCONSUMPTION_COMB  FUELCONSUMPTION_COMB MPG \
count    1067.000000          1067.000000          1067.000000
mean     9.474602           11.580881          26.441425
std      2.794510           3.485595           7.468702
min     4.900000           4.700000          11.000000
25%    7.500000           9.000000          21.000000
50%    8.800000          10.900000          26.000000
75%   10.850000          13.350000          31.000000
max    20.500000          25.800000          60.000000

      CO2EMISSIONS
count  1067.000000
mean   256.228679
std    63.372304
min   108.000000
25%  207.000000
50%  251.000000
75%  294.000000
max  488.000000
```

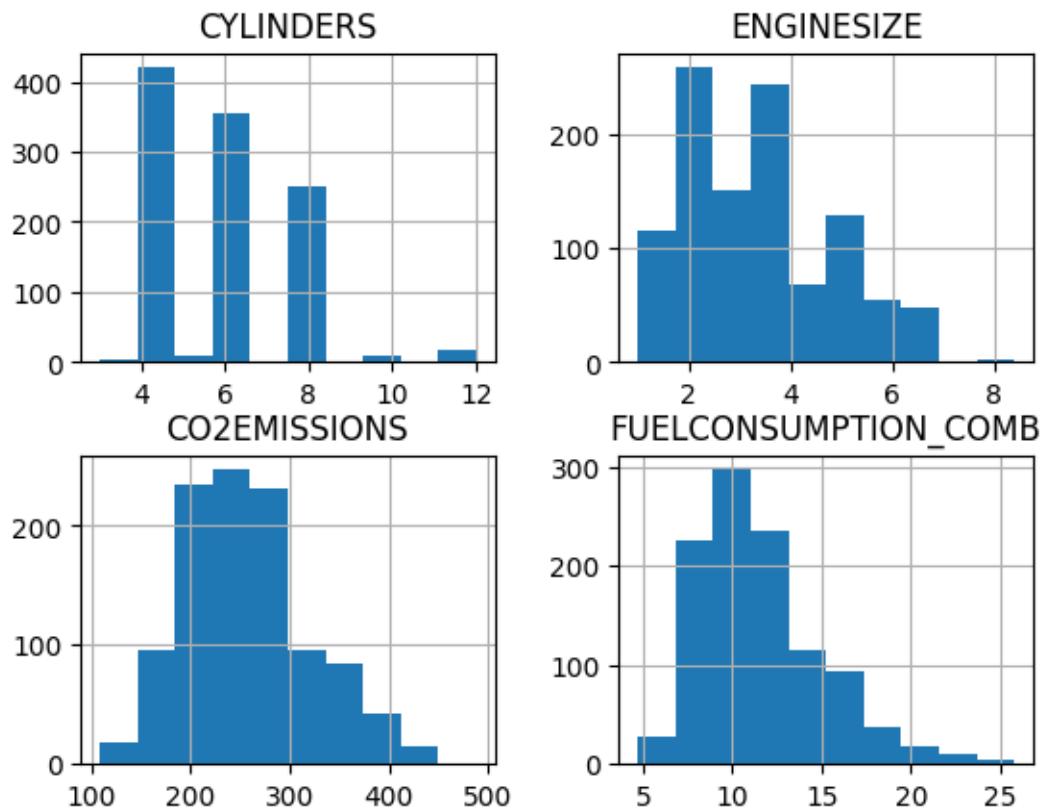
Let's select some features to explore more.

```
[8]: cdf = df[['ENGINESIZE', 'CYLINDERS', 'FUELCONSUMPTION_COMB', 'CO2EMISSIONS']]  
cdf.head(9)
```

```
[8]:   ENGINESIZE  CYLINDERS  FUELCONSUMPTION_COMB  CO2EMISSIONS  
0         2.0          4            8.5           196  
1         2.4          4            9.6           221  
2         1.5          4            5.9           136  
3         3.5          6           11.1           255  
4         3.5          6           10.6           244  
5         3.5          6           10.0           230  
6         3.5          6           10.1           232  
7         3.7          6           11.1           255  
8         3.7          6           11.6           267
```

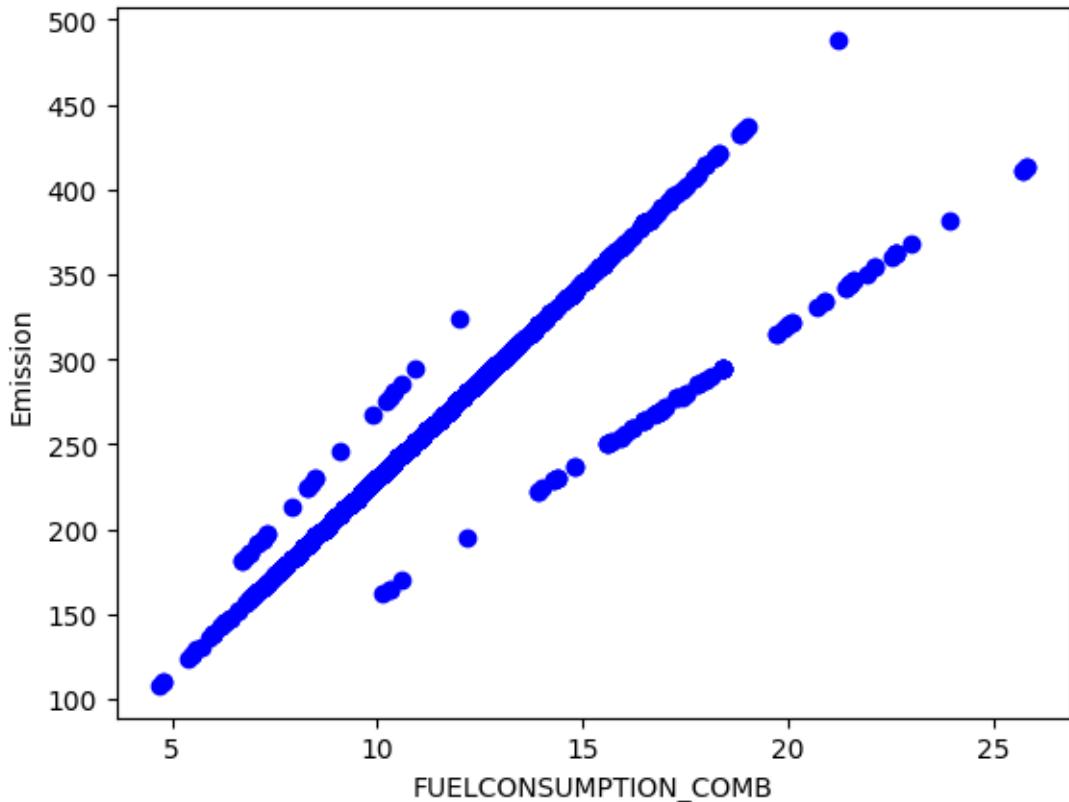
We can plot each of these features:

```
[9]: viz = cdf[['CYLINDERS', 'ENGINESIZE', 'CO2EMISSIONS', 'FUELCONSUMPTION_COMB']]  
viz.hist()  
plt.show()
```

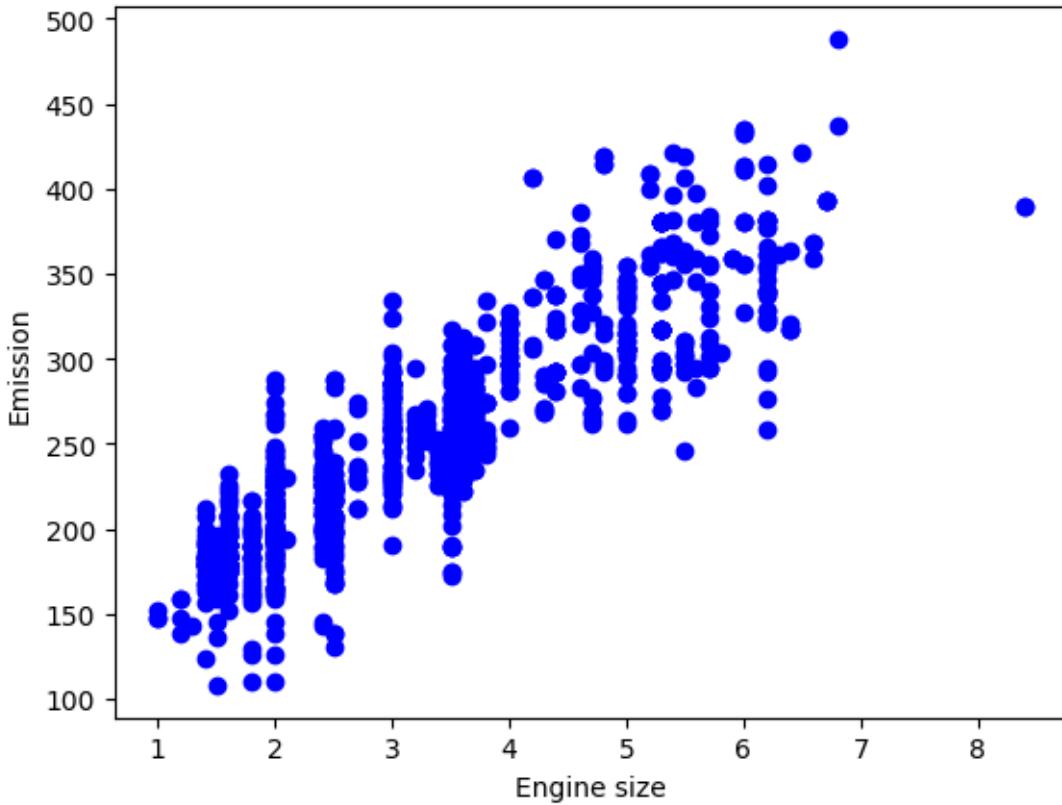


Now, let's plot each of these features against the Emission, to see how linear their relationship is:

```
[10]: plt.scatter(cdf.FUELCONSUMPTION_COMB, cdf.CO2EMISSIONS, color='blue')
plt.xlabel("FUELCONSUMPTION_COMB")
plt.ylabel("Emission")
plt.show()
```



```
[11]: plt.scatter(cdf.ENGINESIZE, cdf.CO2EMISSIONS, color='blue')
plt.xlabel("Engine size")
plt.ylabel("Emission")
plt.show()
```



1.4 Practice

Plot **CYLINDER** vs the Emission, to see how linear is their relationship is:

Creating train and test dataset Train/Test Split involves splitting the dataset into training and testing sets that are mutually exclusive. After which, you train with the training set and test with the testing set. This will provide a more accurate evaluation on out-of-sample accuracy because the testing dataset is not part of the dataset that have been used to train the model. Therefore, it gives us a better understanding of how well our model generalizes on new data.

This means that we know the outcome of each data point in the testing dataset, making it great to test with! Since this data has not been used to train the model, the model has no knowledge of the outcome of these data points. So, in essence, it is truly an out-of-sample testing.

Let's split our dataset into train and test sets. 80% of the entire dataset will be used for training and 20% for testing. We create a mask to select random rows using `np.random.rand()` function:

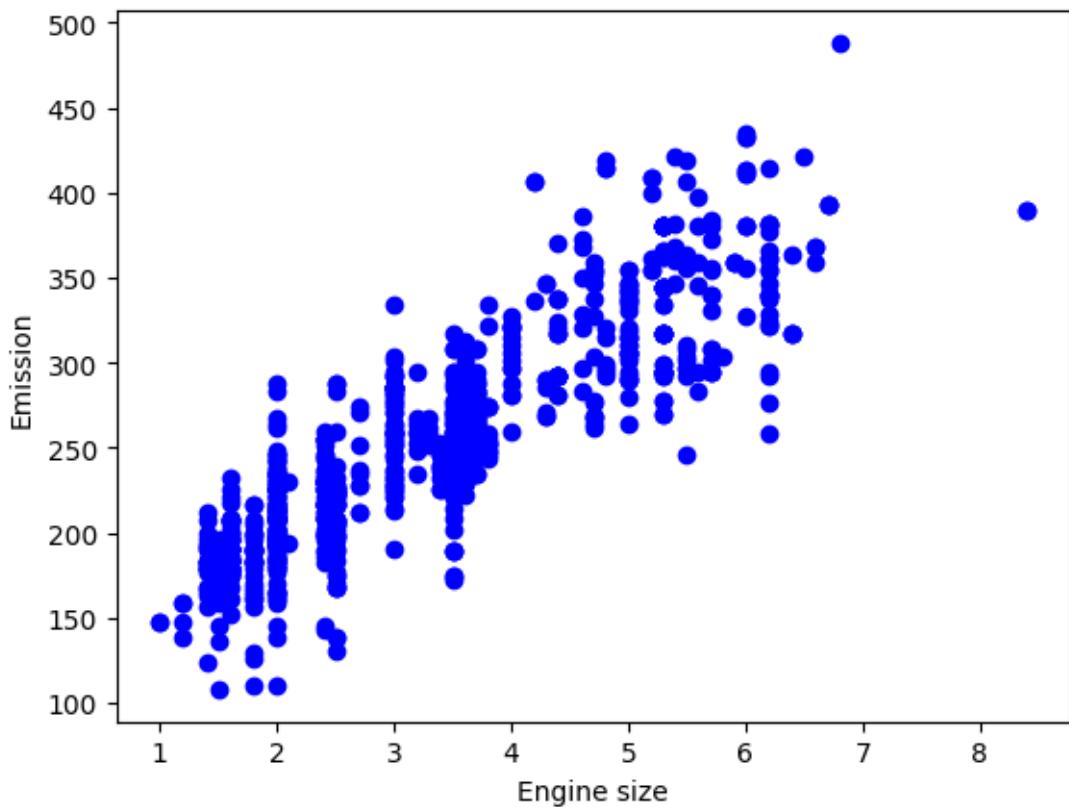
```
[12]: msk = np.random.rand(len(df)) < 0.8
train = cdf[msk]
test = cdf[~msk]
```

1.4.1 Simple Regression Model

Linear Regression fits a linear model with coefficients $B = (B_1, \dots, B_n)$ to minimize the ‘residual sum of squares’ between the actual value y in the dataset, and the predicted value \hat{y} using linear approximation.

Train data distribution

```
[13]: plt.scatter(train.ENGINESIZE, train.CO2EMISSIONS, color='blue')
plt.xlabel("Engine size")
plt.ylabel("Emission")
plt.show()
```



Modeling Using sklearn package to model data.

```
[14]: from sklearn import linear_model
regr = linear_model.LinearRegression()
train_x = np.asarray(train[['ENGINESIZE']])
train_y = np.asarray(train[['CO2EMISSIONS']])
regr.fit(train_x, train_y)
# The coefficients
print ('Coefficients: ', regr.coef_)
```

```
print ('Intercept: ',regr.intercept_)
```

```
Coefficients: [[39.16974953]]
```

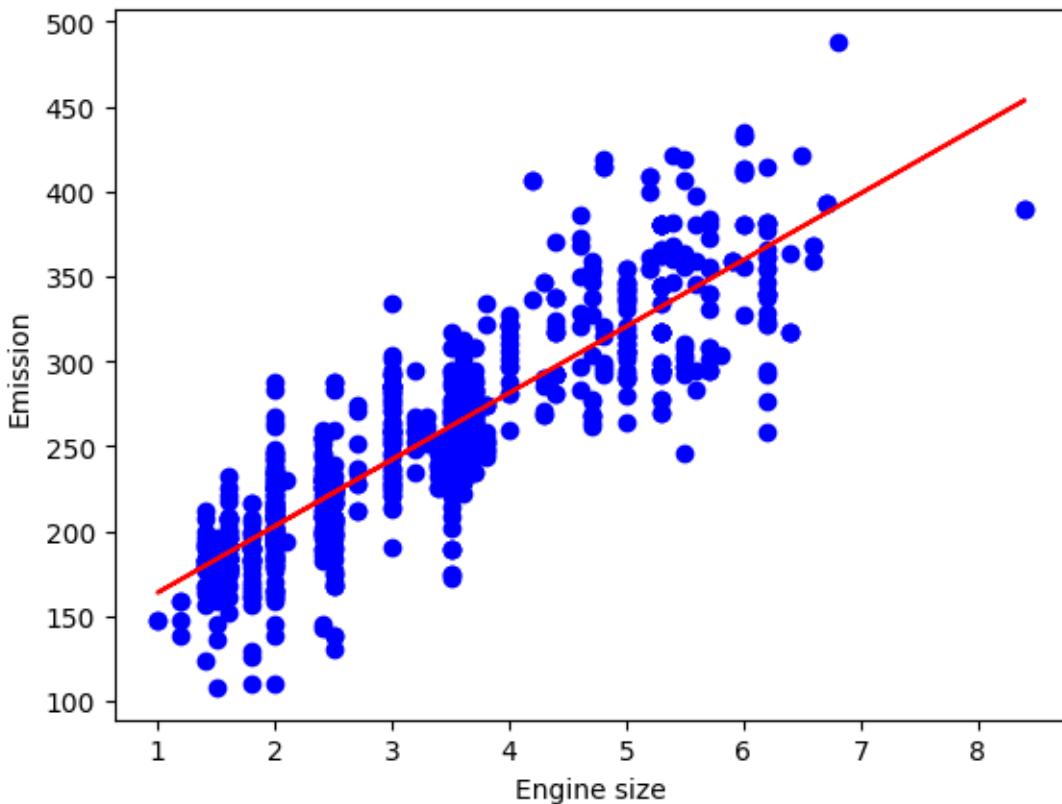
```
Intercept: [124.60375388]
```

As mentioned before, **Coefficient** and **Intercept** in the simple linear regression, are the parameters of the fit line. Given that it is a simple linear regression, with only 2 parameters, and knowing that the parameters are the intercept and slope of the line, sklearn can estimate them directly from our data. Notice that all of the data must be available to traverse and calculate the parameters.

Plot outputs We can plot the fit line over the data:

```
[15]: plt.scatter(train.ENGINESIZE, train.CO2EMISSIONS, color='blue')
plt.plot(train_x, regr.coef_[0]*train_x + regr.intercept_[0], '-r')
plt.xlabel("Engine size")
plt.ylabel("Emission")
```

```
[15]: Text(0, 0.5, 'Emission')
```



Evaluation We compare the actual values and predicted values to calculate the accuracy of a regression model. Evaluation metrics provide a key role in the development of a model, as it provides insight to areas that require improvement.

There are different model evaluation metrics, lets use MSE here to calculate the accuracy of our model based on the test set:

- * Mean Absolute Error: It is the mean of the absolute value of the errors. This is the easiest of the metrics to understand since it's just average error.

- Mean Squared Error (MSE): Mean Squared Error (MSE) is the mean of the squared error. It's more popular than Mean Absolute Error because the focus is geared more towards large errors. This is due to the squared term exponentially increasing larger errors in comparison to smaller ones.
- Root Mean Squared Error (RMSE).
- R-squared is not an error, but rather a popular metric to measure the performance of your regression model. It represents how close the data points are to the fitted regression line. The higher the R-squared value, the better the model fits your data. The best possible score is 1.0 and it can be negative (because the model can be arbitrarily worse).

```
[16]: from sklearn.metrics import r2_score

test_x = np.asarray(test[['ENGINESIZE']])
test_y = np.asarray(test[['CO2EMISSIONS']])
test_y_ = regr.predict(test_x)

print("Mean absolute error: %.2f" % np.mean(np.absolute(test_y_ - test_y)))
print("Residual sum of squares (MSE): %.2f" % np.mean((test_y_ - test_y) ** 2))
print("R2-score: %.2f" % r2_score(test_y , test_y_) )
```

Mean absolute error: 21.37
Residual sum of squares (MSE): 763.24
R2-score: 0.79

1.5 Exercise

Lets see what the evaluation metrics are if we trained a regression model using the FUELCONSUMPTION_COMB feature.

Start by selecting FUELCONSUMPTION_COMB as the train_x data from the train dataframe, then select FUELCONSUMPTION_COMB as the test_x data from the test dataframe

```
[ ]: train_x = #ADD CODE

test_x = #ADD CODE
```

Click here for the solution

```
train_x = train[["FUELCONSUMPTION_COMB"]]

test_x = test[["FUELCONSUMPTION_COMB"]]
```

Now train a Linear Regression Model using the `train_x` you created and the `train_y` created previously

```
[ ]: regr = linear_model.LinearRegression()  
  
#ADD CODE
```

Click here for the solution

```
regr = linear_model.LinearRegression()  
  
regr.fit(train_x, train_y)
```

Find the predictions using the model's `predict` function and the `test_x` data

```
[ ]: #Click here for the solution  
predictions = #ADD CODE
```

Click here for the solution

```
predictions = regr.predict(test_x)
```

Finally use the `predictions` and the `test_y` data and find the Mean Absolute Error value using the `np.absolute` and `np.mean` function like done previously

```
[ ]: #ADD CODE
```

Click here for the solution

```
print("Mean Absolute Error: %.2f" % np.mean(np.absolute(predictions - test_y)))
```

We can see that the MAE is much worse when we train using `ENGINESIZE` than `FUELCONSUMPTION_COMB`