⚙ Environment Setup and Data Loading (Alternate Version)

- Installs specific versions of essential libraries to ensure compatibility and reproducibility:
  - `tensorflow==2.12.0`
  - `scikit-learn==1.2.2`
  - `matplotlib==3.7.1`
  - `pandas==2.0.3`
  - `numpy==1.23.5`
- Imports the necessary libraries for data handling, preprocessing, modeling, and visualization.
- Loads the EV charging dataset from the local path (`EVChargingStationUsage.csv`) into a pandas DataFrame for further processing.

 This setup block is particularly useful when running the notebook on a fresh environment or outside Google Colab.

```
# Import Libraries
!pip install tensorflow==2.12.0
!pip install scikit-learn==1.2.2
!pip install matplotlib==3.7.1
!pip install pandas==2.0.3
!pip install numpy==1.23.5
import pandas as pd
import numpy as np
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import MinMaxScaler, LabelEncoder
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import LSTM, Dense, Dropout
import matplotlib.pyplot as plt


# from google.colab import drive
# drive.mount('/content/drive')
data_path = 'EVChargingStationUsage.csv'
data = pd.read_csv(data_path)
data
```

```
Collecting tensorflow==2.12.0
  Downloading tensorflow-2.12.0-cp310-cp310-
macosx_10_15_x86_64.whl.metadata (3.2 kB)
Collecting absl-py>=1.0.0 (from tensorflow==2.12.0)
  Downloading absl_py-2.3.1-py3-none-any.whl.metadata (3.3 kB)
Collecting astunparse>=1.6.0 (from tensorflow==2.12.0)
  Downloading astunparse-1.6.3-py2.py3-none-any.whl.metadata (4.4 kB)
Collecting flatbuffers>=2.0 (from tensorflow==2.12.0)
  Downloading flatbuffers-25.2.10-py2.py3-none-any.whl.metadata (875
bytes)
```

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Collecting gast<=0.4.0,>=0.2.1 (from tensorflow==2.12.0)
  Downloading gast-0.4.0-py3-none-any.whl.metadata (1.1 kB)
Collecting google-pasta>=0.1.1 (from tensorflow==2.12.0)
  Downloading google_pasta-0.2.0-py3-none-any.whl.metadata (814 bytes)
Collecting h5py>=2.9.0 (from tensorflow==2.12.0)
  Downloading h5py-3.14.0-cp310-cp310-macosx_10_9_x86_64.whl.metadata
(2.7 kB)
Collecting jax>=0.3.15 (from tensorflow==2.12.0)
  Downloading jax-0.6.2-py3-none-any.whl.metadata (13 kB)
Collecting libclang>=13.0.0 (from tensorflow==2.12.0)
  Downloading libclang-18.1.1-py2.py3-none-
macosx_10_9_x86_64.whl.metadata (5.2 kB)
Collecting numpy<1.24,>=1.22 (from tensorflow==2.12.0)
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(2.3 kB)
Collecting opt-einsum>=2.3.2 (from tensorflow==2.12.0)
  Downloading opt_einsum-3.4.0-py3-none-any.whl.metadata (6.3 kB)
Requirement already satisfied: packaging in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
tensorflow==2.12.0) (24.0)
Collecting protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.21.4,!
=4.21.5,<5.0.0dev,>=3.20.3 (from tensorflow==2.12.0)
  Downloading protobuf-4.25.8-cp37-abi3-
macosx_10_9_universal2.whl.metadata (541 bytes)
Requirement already satisfied: setuptools in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
tensorflow==2.12.0) (69.5.1)
Requirement already satisfied: six>=1.12.0 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
tensorflow==2.12.0) (1.17.0)
Collecting termcolor>=1.1.0 (from tensorflow==2.12.0)
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Requirement already satisfied: typing-extensions>=3.6.6 in
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tensorflow==2.12.0) (4.14.1)
Collecting wrapt<1.15,>=1.11.0 (from tensorflow==2.12.0)
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Collecting tensorflow-estimator<2.13,>=2.12.0 (from
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any.whl.metadata (1.3 kB)
Collecting keras<2.13,>=2.12.0 (from tensorflow==2.12.0)
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tensorflow==2.12.0)
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macosx_10_14_x86_64.whl.metadata (14 kB)
Requirement already satisfied: wheel<1.0,>=0.23.0 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
astunparse>=1.6.0->tensorflow==2.12.0) (0.43.0)
INFO: pip is looking at multiple versions of jax to determine which
version is compatible with other requirements. This could take a
while.
Collecting jax>=0.3.15 (from tensorflow==2.12.0)
  Downloading jax-0.6.1-py3-none-any.whl.metadata (13 kB)
  Downloading jax-0.6.0-py3-none-any.whl.metadata (22 kB)
  Downloading jax-0.5.3-py3-none-any.whl.metadata (22 kB)
  Downloading jax-0.5.2-py3-none-any.whl.metadata (22 kB)
  Downloading jax-0.5.1-py3-none-any.whl.metadata (22 kB)
  Downloading jax-0.5.0-py3-none-any.whl.metadata (22 kB)
  Downloading jax-0.4.38-py3-none-any.whl.metadata (22 kB)
Collecting jaxlib<=0.4.38,>=0.4.38 (from jax>=0.3.15-
>tensorflow==2.12.0)
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macosx_10_14_x86_64.whl.metadata (1.0 kB)
Collecting ml_dtypes>=0.4.0 (from jax>=0.3.15->tensorflow==2.12.0)
  Downloading ml_dtypes-0.5.3-cp310-cp310-
macosx_10_9_universal2.whl.metadata (8.9 kB)
INFO: pip is still looking at multiple versions of jax to determine
which version is compatible with other requirements. This could take a
while.
Collecting jax>=0.3.15 (from tensorflow==2.12.0)
  Downloading jax-0.4.37-py3-none-any.whl.metadata (22 kB)
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>tensorflow==2.12.0)
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macosx_10_14_x86_64.whl.metadata (1.0 kB)
Collecting jax>=0.3.15 (from tensorflow==2.12.0)
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  Downloading jax-0.4.35-py3-none-any.whl.metadata (22 kB)
Collecting jaxlib<=0.4.35,>=0.4.34 (from jax>=0.3.15-
>tensorflow==2.12.0)
  Downloading jaxlib-0.4.35-cp310-cp310-
macosx_10_14_x86_64.whl.metadata (983 bytes)
Collecting jax>=0.3.15 (from tensorflow==2.12.0)
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Collecting jaxlib<=0.4.34,>=0.4.34 (from jax>=0.3.15-
>tensorflow==2.12.0)
  Downloading jaxlib-0.4.34-cp310-cp310-
macosx_10_14_x86_64.whl.metadata (983 bytes)
Collecting jax>=0.3.15 (from tensorflow==2.12.0)
  Downloading jax-0.4.33-py3-none-any.whl.metadata (22 kB)
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Collecting jaxlib<=0.4.33,>=0.4.33 (from jax>=0.3.15-
>tensorflow==2.12.0)
  Downloading jaxlib-0.4.33-cp310-cp310-
macosx_10_14_x86_64.whl.metadata (983 bytes)
INFO: This is taking longer than usual. You might need to provide the
dependency resolver with stricter constraints to reduce runtime. See
https://pip.pypa.io/warnings/backtracking for guidance. If you want to
abort this run, press Ctrl + C.
Collecting jax>=0.3.15 (from tensorflow==2.12.0)
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Collecting jaxlib<=0.4.31,>=0.4.30 (from jax>=0.3.15-
>tensorflow==2.12.0)
  Downloading jaxlib-0.4.31-cp310-cp310-
macosx_10_14_x86_64.whl.metadata (983 bytes)
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>tensorflow==2.12.0)
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macosx_10_14_x86_64.whl.metadata (1.0 kB)
Collecting scipy>=1.9 (from jax>=0.3.15->tensorflow==2.12.0)
  Using cached scipy-1.15.3-cp310-cp310-
macosx_14_0_x86_64.whl.metadata (61 kB)
Collecting google-auth<3,>=1.6.3 (from tensorboard<2.13,>=2.12-
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kB)
Collecting google-auth-oauthlib<1.1,>=0.5 (from
tensorboard<2.13,>=2.12->tensorflow==2.12.0)
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any.whl.metadata (2.7 kB)
Collecting markdown>=2.6.8 (from tensorboard<2.13,>=2.12-
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  Downloading markdown-3.8.2-py3-none-any.whl.metadata (5.1 kB)
Requirement already satisfied: requests<3,>=2.21.0 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
tensorboard<2.13,>=2.12->tensorflow==2.12.0) (2.31.0)
Collecting tensorboard-data-server<0.8.0,>=0.7.0 (from
tensorboard<2.13,>=2.12->tensorflow==2.12.0)
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macosx_10_9_x86_64.whl.metadata (1.1 kB)
Collecting werkzeug>=1.0.1 (from tensorboard<2.13,>=2.12-
>tensorflow==2.12.0)
  Using cached werkzeug-3.1.3-py3-none-any.whl.metadata (3.7 kB)
Collecting cachetools<6.0,>=2.0.0 (from google-auth<3,>=1.6.3-
>tensorboard<2.13,>=2.12->tensorflow==2.12.0)
  Downloading cachetools-5.5.2-py3-none-any.whl.metadata (5.4 kB)
Collecting pyasn1-modules>=0.2.1 (from google-auth<3,>=1.6.3-
>tensorboard<2.13,>=2.12->tensorflow==2.12.0)
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  Downloading pyasn1_modules-0.4.2-py3-none-any.whl.metadata (3.5 kB)
Collecting rsa<5,>=3.1.4 (from google-auth<3,>=1.6.3-
>tensorboard<2.13,>=2.12->tensorflow==2.12.0)
  Downloading rsa-4.9.1-py3-none-any.whl.metadata (5.6 kB)
Collecting requests-oauthlib>=0.7.0 (from google-auth-
oauthlib<1.1,>=0.5->tensorboard<2.13,>=2.12->tensorflow==2.12.0)
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(11 kB)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
requests<3,>=2.21.0->tensorboard<2.13,>=2.12->tensorflow==2.12.0)
(3.3.2)
Requirement already satisfied: idna<4,>=2.5 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
requests<3,>=2.21.0->tensorboard<2.13,>=2.12->tensorflow==2.12.0)
(3.6)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
requests<3,>=2.21.0->tensorboard<2.13,>=2.12->tensorflow==2.12.0)
(2.2.1)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
requests<3,>=2.21.0->tensorboard<2.13,>=2.12->tensorflow==2.12.0)
(2025.8.3)
Collecting MarkupSafe>=2.1.1 (from werkzeug>=1.0.1-
>tensorboard<2.13,>=2.12->tensorflow==2.12.0)
  Using cached MarkupSafe-3.0.2-cp310-cp310-
macosx_10_9_universal2.whl.metadata (4.0 kB)
Collecting pyasn1<0.7.0,>=0.6.1 (from pyasn1-modules>=0.2.1->google-
auth<3,>=1.6.3->tensorboard<2.13,>=2.12->tensorflow==2.12.0)
  Using cached pyasn1-0.6.1-py3-none-any.whl.metadata (8.4 kB)
Collecting oauthlib>=3.0.0 (from requests-oauthlib>=0.7.0->google-
auth-oauthlib<1.1,>=0.5->tensorboard<2.13,>=2.12->tensorflow==2.12.0)
  Downloading oauthlib-3.3.1-py3-none-any.whl.metadata (7.9 kB)
Downloading tensorflow-2.12.0-cp310-cp310-macosx_10_15_x86_64.whl
(230.1 MB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 230.1/230.1 MB 15.7 MB/s eta
0:00:0000:0100:01
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 135.8/135.8 kB 2.7 MB/s eta
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acosx_11_0_universal2.whl (11.0 MB)
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acosx_10_9_x86_64.whl (3.3 MB)
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━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 2.0/2.0 MB 34.0 MB/s eta
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━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1.7/1.7 MB 30.4 MB/s eta
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acosx_10_9_x86_64.whl (26.5 MB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 26.5/26.5 MB 45.4 MB/s eta
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py-1.23.5-cp310-cp310-macosx_10_9_x86_64.whl (18.1 MB)
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-3.4.0-py3-none-any.whl (71 kB)
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acosx_10_9_universal2.whl (394 kB)
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━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 5.6/5.6 MB 36.5 MB/s eta
0:00:0000:0100:01
ator-2.12.0-py2.py3-none-any.whl (440 kB)
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0:00:00a 0:00:01
color-3.1.0-py3-none-any.whl (7.7 kB)
Downloading wrapt-1.14.1-cp310-cp310-macosx_10_9_x86_64.whl (35 kB)
Downloading google_auth-2.40.3-py2.py3-none-any.whl (216 kB)
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acosx_10_14_x86_64.whl (83.5 MB)
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arkdown-3.8.2-py3-none-any.whl (106 kB)
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0:00:00
l_dtypes-0.5.3-cp310-cp310-macosx_10_9_universal2.whl (667 kB)
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acosx_14_0_x86_64.whl (25.1 MB)
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0:00:0000:0100:01
acosx_10_9_x86_64.whl (4.8 MB)
Using cached werkzeug-3.1.3-py3-none-any.whl (224 kB)
Downloading cachetools-5.5.2-py3-none-any.whl (10 kB)
Using cached MarkupSafe-3.0.2-cp310-cp310-macosx_10_9_universal2.whl
(14 kB)
Downloading pyasn1_modules-0.4.2-py3-none-any.whl (181 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 181.3/181.3 kB 6.3 MB/s eta
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━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 160.1/160.1 kB 5.5 MB/s eta
0:00:00
color, tensorflow-io-gcs-filesystem, tensorflow-estimator,
```

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tensorboard-data-server, pyasn1, protobuf, opt-einsum, oauthlib,
numpy, MarkupSafe, markdown, keras, grpcio, google-pasta, gast,
cachetools, astunparse, absl-py, werkzeug, scipy, rsa, requests-
oauthlib, pyasn1-modules, ml_dtypes, h5py, jaxlib, google-auth, jax,
google-auth-oauthlib, tensorboard, tensorflow
Successfully installed MarkupSafe-3.0.2 absl-py-2.3.1 astunparse-1.6.3
cachetools-5.5.2 flatbuffers-25.2.10 gast-0.4.0 google-auth-2.40.3
google-auth-oauthlib-1.0.0 google-pasta-0.2.0 grpcio-1.74.0 h5py-
3.14.0 jax-0.4.30 jaxlib-0.4.30 keras-2.12.0 libclang-18.1.1 markdown-
3.8.2 ml_dtypes-0.5.3 numpy-1.23.5 oauthlib-3.3.1 opt-einsum-3.4.0
protobuf-4.25.8 pyasn1-0.6.1 pyasn1-modules-0.4.2 requests-oauthlib-
2.0.0 rsa-4.9.1 scipy-1.15.3 tensorboard-2.12.3 tensorboard-data-
server-0.7.2 tensorflow-2.12.0 tensorflow-estimator-2.12.0 tensorflow-
io-gcs-filesystem-0.37.1 termcolor-3.1.0 werkzeug-3.1.3 wrapt-1.14.1
Collecting scikit-learn==1.2.2
  Downloading scikit_learn-1.2.2-cp310-cp310-
macosx_10_9_x86_64.whl.metadata (11 kB)
Requirement already satisfied: numpy>=1.17.3 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
scikit-learn==1.2.2) (1.23.5)
Requirement already satisfied: scipy>=1.3.2 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
scikit-learn==1.2.2) (1.15.3)
Collecting joblib>=1.1.1 (from scikit-learn==1.2.2)
  Using cached joblib-1.5.1-py3-none-any.whl.metadata (5.6 kB)
Collecting threadpoolctl>=2.0.0 (from scikit-learn==1.2.2)
  Using cached threadpoolctl-3.6.0-py3-none-any.whl.metadata (13 kB)
Downloading scikit_learn-1.2.2-cp310-cp310-macosx_10_9_x86_64.whl (9.1
MB)
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atplotlib==3.7.1
  Downloading matplotlib-3.7.1-cp310-cp310-
macosx_10_12_x86_64.whl.metadata (5.6 kB)
Collecting contourpy>=1.0.1 (from matplotlib==3.7.1)
  Downloading contourpy-1.3.2-cp310-cp310-
macosx_10_9_x86_64.whl.metadata (5.5 kB)
Collecting cycler>=0.10 (from matplotlib==3.7.1)
  Using cached cycler-0.12.1-py3-none-any.whl.metadata (3.8 kB)
Collecting fonttools>=4.22.0 (from matplotlib==3.7.1)
  Downloading fonttools-4.59.0-cp310-cp310-
macosx_10_9_x86_64.whl.metadata (107 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 107.9/107.9 kB 2.4 MB/s eta
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 matplotlib==3.7.1)
  Downloading kiwisolver-1.4.8-cp310-cp310-
macosx_10_9_x86_64.whl.metadata (6.2 kB)
```

```
Requirement already satisfied: numpy>=1.20 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
matplotlib==3.7.1) (1.23.5)
Requirement already satisfied: packaging>=20.0 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
matplotlib==3.7.1) (24.0)
Collecting pillow>=6.2.0 (from matplotlib==3.7.1)
  Using cached pillow-11.3.0-cp310-cp310-
macosx_10_10_x86_64.whl.metadata (9.0 kB)
Collecting pyparsing>=2.3.1 (from matplotlib==3.7.1)
  Downloading pyparsing-3.2.3-py3-none-any.whl.metadata (5.0 kB)
Requirement already satisfied: python-dateutil>=2.7 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
matplotlib==3.7.1) (2.9.0.post0)
Requirement already satisfied: six>=1.5 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
python-dateutil>=2.7->matplotlib==3.7.1) (1.17.0)
Downloading matplotlib-3.7.1-cp310-cp310-macosx_10_12_x86_64.whl (7.4
MB)
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acosx_10_9_x86_64.whl (268 kB)
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acosx_10_9_x86_64.whl (66 kB)
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Downloading pyparsing-3.2.3-py3-none-any.whl (111 kB)
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atplotlib
Successfully installed contourpy-1.3.2 cycler-0.12.1 fonttools-4.59.0
kiwisolver-1.4.8 matplotlib-3.7.1 pillow-11.3.0 pyparsing-3.2.3
Collecting pandas==2.0.3
  Downloading pandas-2.0.3-cp310-cp310-macosx_10_9_x86_64.whl.metadata
(18 kB)
Requirement already satisfied: python-dateutil>=2.8.2 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
pandas==2.0.3) (2.9.0.post0)
Collecting pytz>=2020.1 (from pandas==2.0.3)
  Using cached pytz-2025.2-py2.py3-none-any.whl.metadata (22 kB)
Collecting tzdata>=2022.1 (from pandas==2.0.3)
  Using cached tzdata-2025.2-py2.py3-none-any.whl.metadata (1.4 kB)
Requirement already satisfied: numpy>=1.21.0 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
```

```
pandas==2.0.3) (1.23.5)
Requirement already satisfied: six>=1.5 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages (from
python-dateutil>=2.8.2->pandas==2.0.3) (1.17.0)
Downloading pandas-2.0.3-cp310-cp310-macosx_10_9_x86_64.whl (11.8 MB)
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ent already satisfied: numpy==1.23.5 in
/usr/local/Caskroom/mambaforge/base/lib/python3.10/site-packages
(1.23.5)

2025-08-08 11:55:41.480651: I
tensorflow/core/platform/cpu_feature_guard.cc:182] This TensorFlow
binary is optimized to use available CPU instructions in performance-
critical operations.
To enable the following instructions: AVX2 AVX512F AVX512_VNNI FMA, in
other operations, rebuild TensorFlow with the appropriate compiler
flags.
/var/folders/2w/yw9nf3h9675_h3zz3_cgs11r0000gn/T/ipykernel_9085/723177
589.py:19: DtypeWarning: Columns (29,30,32) have mixed types. Specify
dtype option on import or set low_memory=False.
  data = pd.read_csv(data_path)
```

	Station Name	MAC Address	\
0	PALO ALTO CA / HAMILTON #1	000D:6F00:015A:9D76	
1	PALO ALTO CA / HAMILTON #1	000D:6F00:015A:9D76	
2	PALO ALTO CA / HAMILTON #1	000D:6F00:015A:9D76	
3	PALO ALTO CA / HAMILTON #1	000D:6F00:015A:9D76	
4	PALO ALTO CA / HAMILTON #1	000D:6F00:015A:9D76	
...	...	...	
259410	PALO ALTO CA / TED THOMPSON #3	0024:B100:0002:9F81	
259411	PALO ALTO CA / WEBSTER #1	0024:B100:0002:4233	
259412	PALO ALTO CA / MPL #4	0024:B100:0003:CD37	
259413	PALO ALTO CA / WEBSTER #1	0024:B100:0002:4233	
259414	PALO ALTO CA / CAMBRIDGE #4	0024:B100:0003:3A0A	

	Org Name	Start Date	Start Time	Zone	\
0	City of Palo Alto	7/29/2011	20:17	PDT	
1	City of Palo Alto	7/30/2011	0:00	PDT	
2	City of Palo Alto	7/30/2011	8:16	PDT	
3	City of Palo Alto	7/30/2011	14:51	PDT	
4	City of Palo Alto	7/30/2011	18:51	PDT	
...	...	...		...	
259410	City of Palo Alto	12/31/2020	16:39	PST	
259411	City of Palo Alto	12/31/2020	16:48	PST	
259412	City of Palo Alto	12/31/2020	17:28	PST	

```
259413  City of Palo Alto   12/31/2020 17:49              PST
259414  City of Palo Alto   12/31/2020 18:19              PST

                End Date End Time Zone Transaction Date (Pacific Time)
\
0        7/29/2011 23:20           PDT                  7/29/2011 23:20

1         7/30/2011 0:02           PDT                   7/30/2011 0:02

2        7/30/2011 12:34           PDT                  7/30/2011 12:34

3        7/30/2011 16:55           PDT                  7/30/2011 16:55

4        7/30/2011 20:03           PDT                  7/30/2011 20:03

...                  ...           ...                             ...

259410  12/31/2020 17:14           PST                 12/31/2020 17:16

259411  12/31/2020 20:31           PST                 12/31/2020 20:32

259412    1/1/2021 10:56           PST                   1/1/2021 10:57

259413  12/31/2020 21:55           PST                 12/31/2020 21:56

259414  12/31/2020 19:01           PST                 12/31/2020 19:02


       Total Duration (hh:mm:ss) Charging Time (hh:mm:ss)  ...
Longitude  \
0                       3:03:32                  1:54:03  ... -
122.160309
1                       0:02:06                  0:01:54  ... -
122.160309
2                       4:17:32                  4:17:28  ... -
122.160309
3                       2:03:24                  2:02:58  ... -
122.160309
4                       1:11:24                  0:43:54  ... -
122.160309
...                         ...                      ...  ...
...
259410                  0:35:44                  0:35:18  ... -
122.144043
259411                  3:43:01                  2:14:04  ... -
122.158272
259412                 17:28:14                  5:08:12  ... -
122.113510
259413                  4:05:34                  3:53:42  ... -
122.158272
```

```
259414                   0:42:07                  0:41:44  ... -
122.146034

        Currency   Fee             Ended By  Plug In Event Id  \
0            USD  0.00  Plug Out at Vehicle                 3
1            USD  0.00            Customer                 4
2            USD  0.00  Plug Out at Vehicle                 5
3            USD  0.00            Customer                 6
4            USD  0.00  Plug Out at Vehicle                 7
...          ...   ...                 ...               ...
259410       USD  0.42  Plug Out at Vehicle              2369
259411       USD  4.69  Plug Out at Vehicle              7255
259412       USD  6.82  Plug Out at Vehicle               455
259413       USD  2.75  Plug Out at Vehicle              7256
259414       USD  0.36  Plug Out at Vehicle              2302

       Driver Postal Code  User ID              County    System
S/N  \
0                 95124.0   3284.0                 NaN           NaN

1                 94301.0   4169.0                 NaN           NaN

2                 94301.0   4169.0                 NaN           NaN

3                 94302.0   2545.0                 NaN           NaN

4                 94043.0   3765.0                 NaN           NaN

...                   ...      ...                 ...           ...

259410            94301.0  2024201                 NaN  1.745410e+11

259411            94541.0   242661  Santa Clara County  1.336410e+11

259412            94306.0   449995  Santa Clara County  2.002410e+11

259413            94552.0   804075  Santa Clara County  1.336410e+11

259414            94305.0  2022651  Santa Clara County  1.852410e+11


        Model Number
0                NaN
1                NaN
2                NaN
3                NaN
4                NaN
...              ...
259410  CT4020-HD-GW
259411  CT4020-HD-GW
259412  CT4010-HD-GW
```

```
259413  CT4020-HD-GW
259414  CT4020-HD-GW

[259415 rows x 33 columns]
```

Feature Selection Based on Correlation

This step performs advanced preprocessing to prepare the dataset for feature selection:

- **Removes duplicate columns** (if any) related to previously computed time-in-seconds fields.
- **Converts all datetime columns** into numeric timestamp format (`int64`) for compatibility with correlation and modeling.
- **Encodes non-numeric categorical columns** using `LabelEncoder` to make them numeric and usable in correlation analysis.
- **Computes the correlation matrix** for all numeric columns, focusing on how each feature correlates with `Energy (kWh)`.
- **Filters and selects features** that have a correlation coefficient greater than 0.5 with the target variable, assuming they have predictive power.
- **Prints** the sorted correlation values and the final list of relevant features for modeling.

This is a useful technique for reducing dimensionality and retaining only the most impactful variables for training.

```
# Remove additional columns if they already exist
# columns_to_remove = ["Charging Time (hh:mm:ss) (seconds)", "Total
Duration (hh:mm:ss) (seconds)"]
# data = data.drop(columns=[col for col in columns_to_remove if col in
data.columns], errors='ignore')

# Convert datetime columns to numeric timestamps
datetime_columns = [col for col in data.columns if "Date" in col or
"Time" in col]
for col in datetime_columns:
    if col in data.columns:
        data[col] = pd.to_datetime(data[col],
errors='coerce').astype('int64', errors='ignore')

# Encode non-numeric columns
non_numeric_columns =
data.select_dtypes(include=['object']).columns.tolist()
for col in non_numeric_columns:
    le = LabelEncoder()
    data[col] = le.fit_transform(data[col].astype(str))

# Calculate the correlation matrix for numeric columns
correlation_matrix = data.corr(numeric_only=True)
correlation_with_energy = correlation_matrix["Energy
(kWh)"].sort_values(ascending=False)
```

```python
# Filter features with correlation > 0.5
relevant_features = correlation_with_energy[correlation_with_energy >
0.5].index.tolist()

# Display the correlation factors and relevant features
print("Correlation with Energy (kWh):")
print(correlation_with_energy)
print("\nRelevant Features:")
print(relevant_features)
```

```
C:\Users\Subhamyu.Nepal\AppData\Local\Temp\
ipykernel_17960\4145061786.py:9: UserWarning: Could not infer format,
so each element will be parsed individually, falling back to
`dateutil`. To ensure parsing is consistent and as-expected, please
specify a format.
  data[col] = pd.to_datetime(data[col],
errors='coerce').astype('int64', errors='ignore')
C:\Users\Subhamyu.Nepal\AppData\Local\Temp\
ipykernel_17960\4145061786.py:9: UserWarning: Could not infer format,
so each element will be parsed individually, falling back to
`dateutil`. To ensure parsing is consistent and as-expected, please
specify a format.
  data[col] = pd.to_datetime(data[col],
errors='coerce').astype('int64', errors='ignore')
C:\Users\Subhamyu.Nepal\AppData\Local\Temp\
ipykernel_17960\4145061786.py:9: UserWarning: Could not infer format,
so each element will be parsed individually, falling back to
`dateutil`. To ensure parsing is consistent and as-expected, please
specify a format.
  data[col] = pd.to_datetime(data[col],
errors='coerce').astype('int64', errors='ignore')

Correlation with Energy (kWh):
Energy (kWh)                        1.000000
GHG Savings (kg)                    1.000000
Gasoline Savings (gallons)          1.000000
Charging Time (hh:mm:ss)            0.871576
Total Duration (hh:mm:ss)           0.584751
Fee                                 0.521298
Port Type                           0.103145
Station Name                        0.095423
Start Date                          0.089981
Org Name                            0.065510
Ended By                            0.053452
MAC Address                         0.044920
End Date                            0.039576
Plug In Event Id                    0.035849
Latitude                            0.033891
Transaction Date (Pacific Time)     0.020471
```

```
Longitude                           0.007940
Driver Postal Code                  0.002980
EVSE ID                             0.002193
Port Number                         0.001983
User ID                            -0.000971
Address 1                          -0.014890
System S/N                         -0.016161
Currency                           -0.024318
Postal Code                        -0.027035
Model Number                       -0.042902
County                             -0.059161
Plug Type                          -0.103343
Start Time Zone                          NaN
End Time Zone                            NaN
City                                     NaN
State/Province                           NaN
Country                                  NaN
Name: Energy (kWh), dtype: float64

Relevant Features:
['Energy (kWh)', 'GHG Savings (kg)', 'Gasoline Savings (gallons)',
'Charging Time (hh:mm:ss)', 'Total Duration (hh:mm:ss)', 'Fee']
```

Visualize Feature Correlations with Heatmap

- Creates a **correlation heatmap** using `seaborn` to visually explore relationships between numeric features.
- Uses the `"Reds"` colormap to emphasize stronger correlations in deeper red shades.
- Enhancements include:
  - Larger figure size for better readability.
  - Square cells with borders (`linewidths=0.5`).
  - Rotated axis labels for clarity.
- Helps identify:
  - Strongly correlated variables (redundant features).
  - Features with strong linear relationship to the target (`Energy (kWh)`).

This visual diagnostic is key for feature selection, multicollinearity detection, and understanding dataset structure.

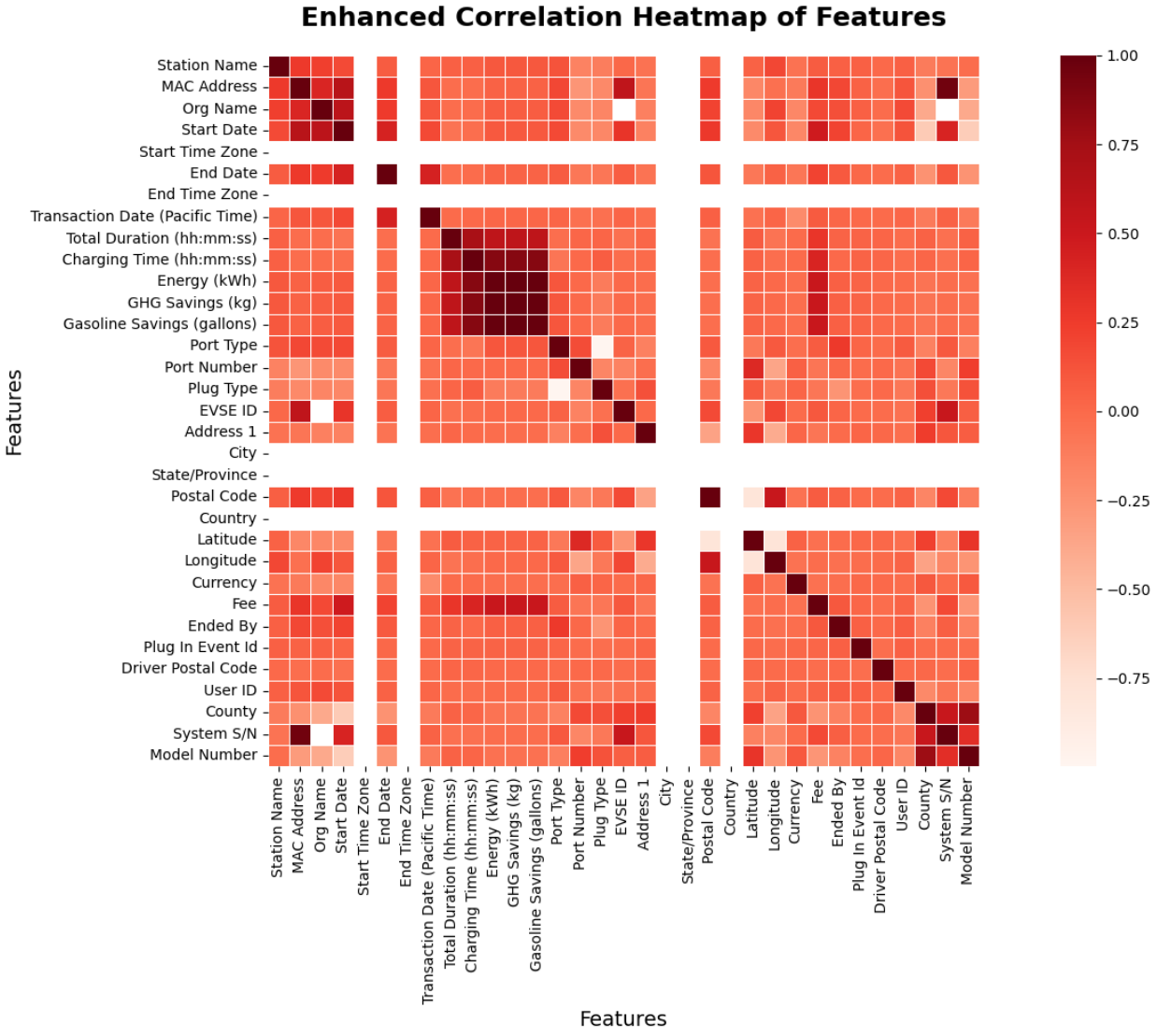
```
import seaborn as sns


plt.figure(figsize=(16, 10))
heatmap = sns.heatmap(
    correlation_matrix,
    annot=False,  # Remove correlation factors
    cmap="Reds",  # Use the "Reds" colormap for a red theme
    cbar=True,
```

```
    linewidths=0.5,
    square=True
)

# Add titles and labels
plt.title("Enhanced Correlation Heatmap of Features", fontsize=18,
fontweight='bold', pad=20)
plt.xlabel("Features", fontsize=14)
plt.ylabel("Features", fontsize=14)
plt.xticks(fontsize=10, rotation=90)  # Set rotation to 90 for
vertical text
plt.yticks(fontsize=10, rotation=0)

# Show the heatmap
plt.tight_layout()
plt.show()
```


Enhanced Correlation Heatmap of Features
Features
Station Name
MAC Address
Org Name
Start Date
Start Time Zone
End Date
End Time Zone
Transaction Date (Pacific Time)
Total Duration (hh:mm:ss)
Charging Time (hh:mm:ss)
Energy (kWh)
GHG Savings (kg)
Gasoline Savings (gallons)
Port Type
Port Number
Plug Type
EVSE ID
Address 1
City
State/Province
Postal Code
Country
Latitude
Longitude
Currency
Fee
Ended By
Plug In Event Id
Driver Postal Code
User ID
County
System S/N
Model Number
Features
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75