EDA

Loading the data

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
```

Setting the style

```
pd.set_option('display.max_columns',20)
pd.set_option('display.max_rows',200)
sns.set_style('whitegrid')
%matplotlib inline
```

Load the data

```
df=pd.read_csv('../data/raw/IEA Global EV Data 2024.csv', header=0)
df.head()
df.info()
df.describe(include='all')
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 12654 entries, 0 to 12653
Data columns (total 8 columns):
 #   Column      Non-Null Count  Dtype
---  ------      --------------  -----
 0   region      12654 non-null  object
 1   category    12654 non-null  object
 2   parameter   12654 non-null  object
 3   mode        12654 non-null  object
 4   powertrain  12654 non-null  object
 5   year        12654 non-null  int64
 6   unit        12654 non-null  object
 7   value       12654 non-null  float64
dtypes: float64(1), int64(1), object(6)
memory usage: 791.0+ KB
```

```
       region    category parameter   mode powertrain          year
unit  \
count   12654       12654     12654  12654      12654  12654.000000
12654
unique     54           3         8      5          6           NaN
6
top     World  Historical  EV stock   Cars         EV           NaN
Vehicles
freq     1250        9174      3470   4706       4894           NaN
```

```
6842
mean       NaN          NaN        NaN    NaN         NaN   2019.822112
NaN
std        NaN          NaN        NaN    NaN         NaN      5.476494
NaN
min        NaN          NaN        NaN    NaN         NaN   2010.000000
NaN
25%        NaN          NaN        NaN    NaN         NaN   2016.000000
NaN
50%        NaN          NaN        NaN    NaN         NaN   2020.000000
NaN
75%        NaN          NaN        NaN    NaN         NaN   2022.000000
NaN
max        NaN          NaN        NaN    NaN         NaN   2035.000000
NaN
```

```
                value
count   1.265400e+04
unique           NaN
top              NaN
freq             NaN
mean    4.273742e+05
std     6.860498e+06
min     1.200000e-06
25%     2.000000e+00
50%     1.300000e+02
75%     5.500000e+03
max     4.400000e+08
```

Data Cleaning

```
#Print the sum of missing values in each column
df.isnull().sum().sort_values(ascending=False)
```

```
region         0
category       0
parameter      0
mode           0
powertrain     0
year           0
unit           0
value          0
dtype: int64
```

```
#Print and drop the duplicate values
df[df.duplicated()]
df=df.drop_duplicates() #if exists

df.dtypes
```

```
region          object
category        object
parameter       object
mode            object
powertrain      object
year             int64
unit            object
value          float64
dtype: object
```

```
df.head(10)
```

```
      region    category        parameter  mode powertrain  year
unit  \
0  Australia  Historical  EV stock share  Cars         EV  2011
percent
1  Australia  Historical  EV sales share  Cars         EV  2011
percent
2  Australia  Historical        EV sales  Cars        BEV  2011
Vehicles
3  Australia  Historical        EV stock  Cars        BEV  2011
Vehicles
4  Australia  Historical        EV stock  Cars        BEV  2012
Vehicles
5  Australia  Historical        EV sales  Cars        BEV  2012
Vehicles
6  Australia  Historical  EV sales share  Cars         EV  2012
percent
7  Australia  Historical  EV stock share  Cars         EV  2012
percent
8  Australia  Historical        EV stock  Cars       PHEV  2012
Vehicles
9  Australia  Historical        EV sales  Cars       PHEV  2012
Vehicles

       value
0    0.00039
1    0.00650
2   49.00000
3   49.00000
4  220.00000
5  170.00000
6    0.03000
7    0.00240
8   80.00000
9   80.00000
```

```
#Define all data types
df['region']=df['region'].astype('object')
df['category']=df['category'].astype('category')
```

```
df['parameter']=df['parameter'].astype('category')
df['mode']=df['mode'].astype('category')
df['powertrain']=df['powertrain'].astype('category')
df['year']=pd.to_datetime(df['year'],format='%Y').dt.year
df['unit']=df['unit'].astype('category')
df['value']=df['value'].astype('float')
```

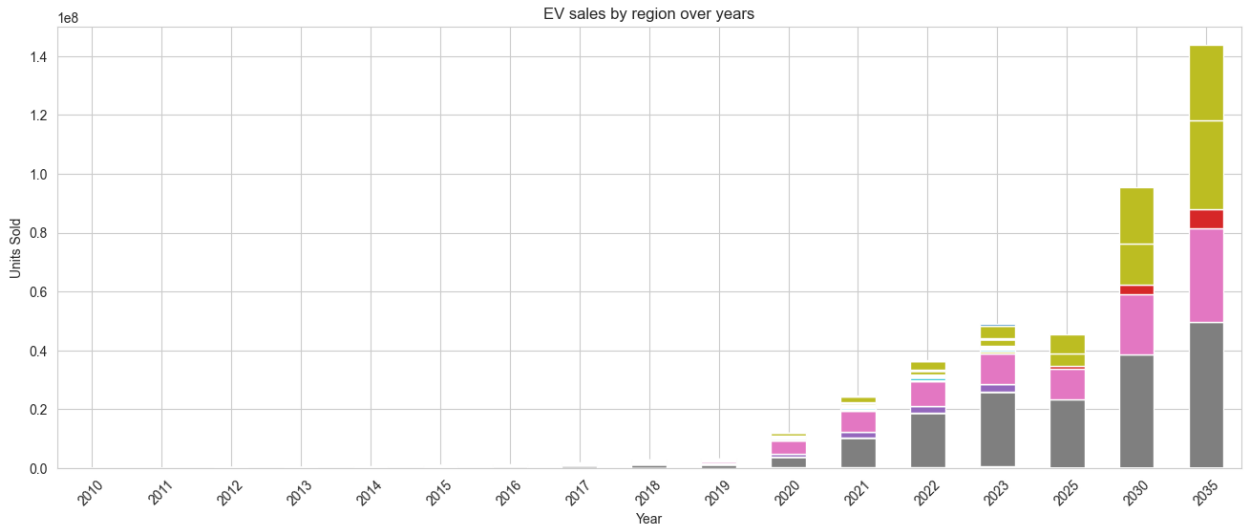
Prepare data to visualize

```
#Vehicle sales by Region
reqcols=df[['region','year','unit','value','parameter']]
reqcols=reqcols[(reqcols['unit'] == 'Vehicles') &
(reqcols['parameter'] == 'EV sales') & (reqcols['region'] != 'World')]
vsbr=reqcols.groupby(['region','year'])
vsbr=vsbr[['value']].agg('sum')
vsbr=vsbr.sort_values(['region','year'])

#Vehicle powertrain share
reqcols=df[df['category']=='Historical']
reqcols=df[['powertrain','value']]
vps=reqcols.groupby(['powertrain'],observed=True)
vps=vps[['value']].agg('sum')

#Vehicle powertrain over years
reqcols=df[df['category']=='Historical']
reqcols=df[['region','year','unit','value','parameter','powertrain']]
reqcols=reqcols[(reqcols['region'] != 'World')]
vpoy=reqcols.groupby(['powertrain','year'], observed=True)
vpoy=vpoy[['value']].agg('sum').reset_index()
vpoy=vpoy.sort_values(['powertrain','year'])

#Projection-STEPS of EVs
reqcols=df[df['category']=='Projection-STEPS']
reqcols=df[['region','year','unit','value','parameter','powertrain','m
ode']]
reqcols=reqcols[(reqcols['region'] != 'World') &
(reqcols['parameter']=='EV sales')]
POE = reqcols.groupby(['mode', 'powertrain', 'year'], observed=True)
['value'].agg('sum').reset_index()

# Share of projection-STEPS of EVs
reqcols=df[df['category']=='Projection-STEPS']
reqcols=df[['powertrain','value']]
SPOE=reqcols.groupby(['powertrain'],observed=True)
SPOE=SPOE[['value']].agg('sum')

#Projection of Global Electricity demand of EVs
reqcols=df[df['category']=='Projection-STEPS']
reqcols=reqcols[reqcols['parameter']=='Electricity demand']
```

```
POED=reqcols[['region','year','value']]
POED=POED.groupby(['region','year']).agg('sum').reset_index()
```

Visualization

```
#Vehicle sales by Region
plotdata=vsbr.reset_index().pivot(index='year',values='value',columns=
'region')
plot=plotdata.plot(kind='bar',stacked=True, legend=False,
figsize=(16,6),ylim=(0,150000000))
plt.xlabel('Year')
plt.ylabel('Units Sold')
plt.xticks(rotation=45)
plt.title('EV sales by region over years')

Text(0.5, 1.0, 'EV sales by region over years')
```



China has been the largest EV market, contributing more than 50% of global EV sales by 2023.

Europe shows strong adoption post-2017, driven by policy support.

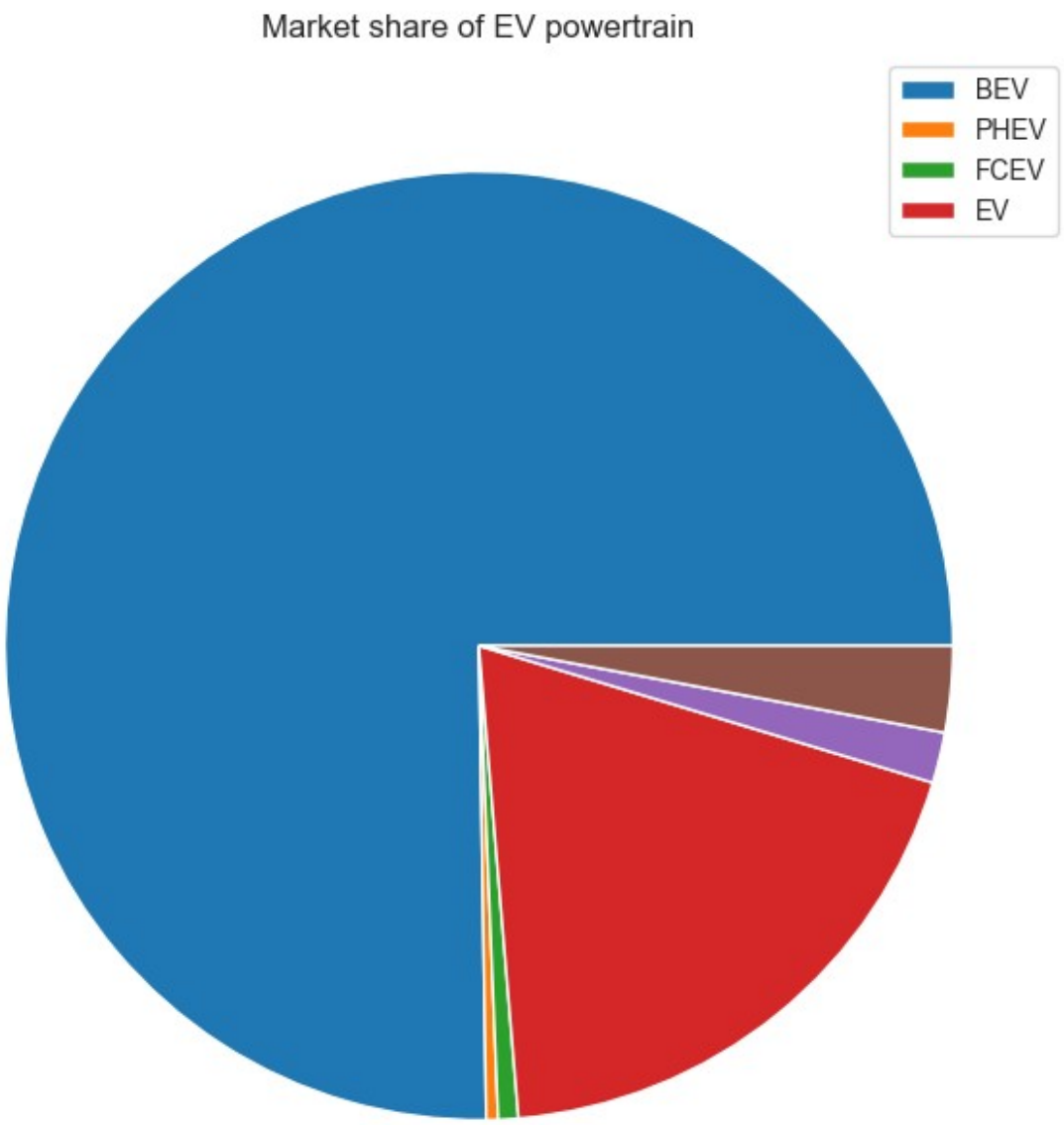
North America lags behind China & Europe but still shows steady growth.

Emerging markets (India, Brazil, etc.) have small but accelerating adoption.

Takeaway: EV growth is unevenly distributed, with China and Europe leading global adoption.

```
#Vehicle powertrain share
plotdata=vps['value'].plot(kind='pie', labels=None, figsize=(12,8))
plt.ylabel(None)
plt.title('Market share of EV powertrain')
labels=['BEV', 'PHEV', 'FCEV', 'EV']
plt.legend(loc='best', labels=labels)
```

```
<matplotlib.legend.Legend at 0x15560cf7f10>
```



Battery Electric Vehicles (BEVs) dominate the EV landscape (~70–80% of sales).

Plug-in Hybrid EVs (PHEVs) have a noticeable but smaller share.

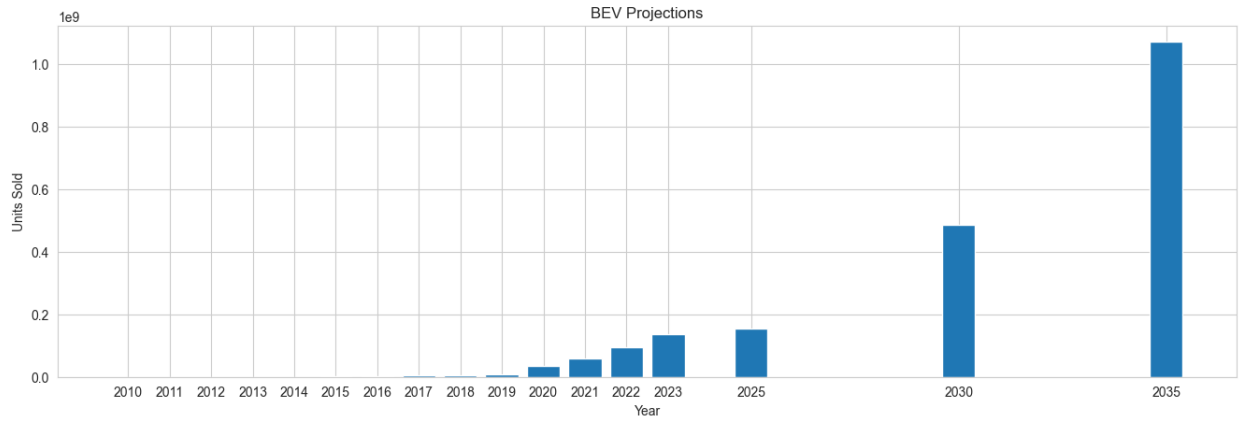
Fuel Cell EVs (FCEVs) remain negligible.

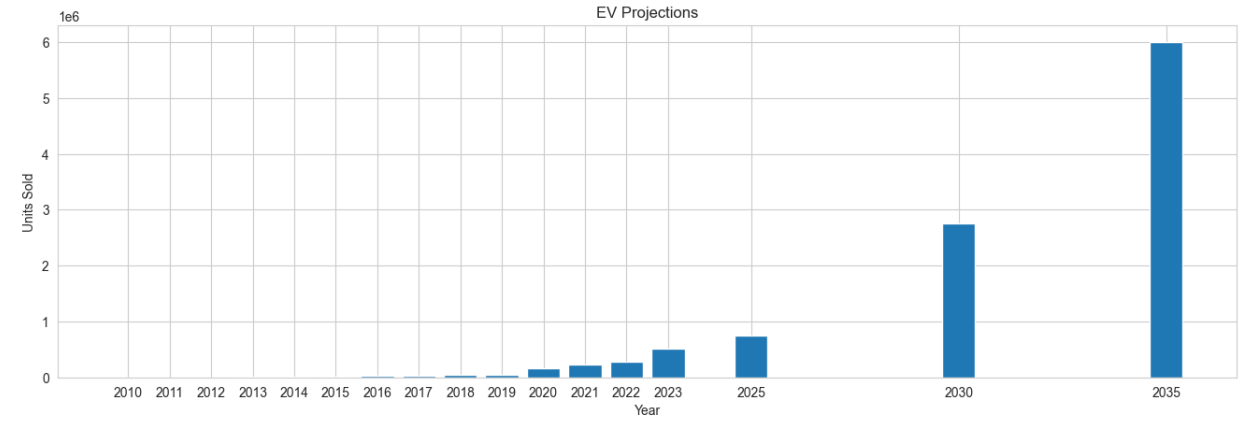
Takeaway: The market is consolidating towards BEVs as the primary technology.

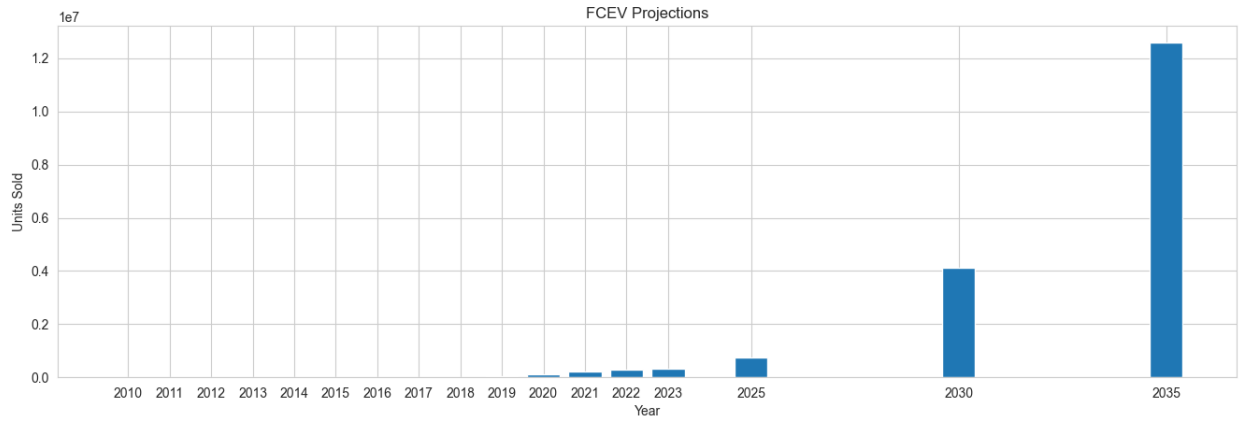
```
#Vehicle powertrain over years
plotdata=vpoy.reset_index().pivot(index='year',values='value',columns=
```

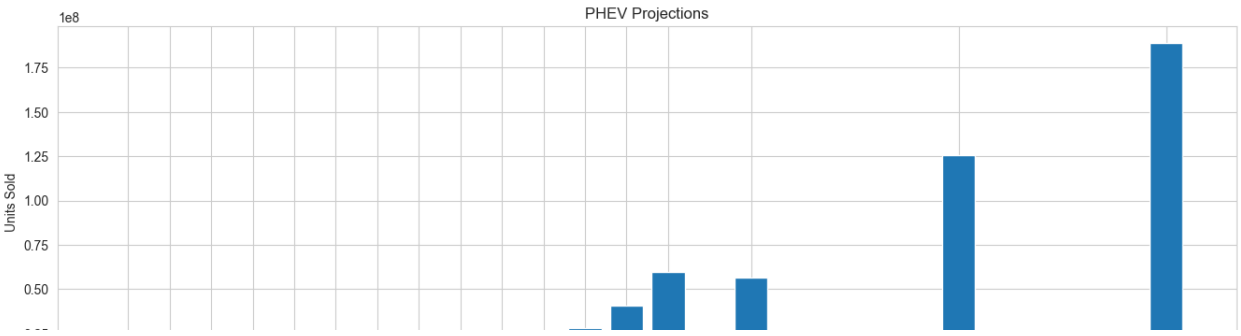
```
'powertrain')
powertrains=vpoy['powertrain'].unique()
fig,axes=plt.subplots(nrows=len(powertrains), figsize=(14,
5*len(powertrains)))
fig.suptitle('Vehicle powertrain growth over years', fontsize=20)
for index, powertrains in enumerate(powertrains):
    ax=axes[index]
    ax.bar(plotdata.index, plotdata[powertrains])
    ax.set_xlabel('Year')
    ax.set_ylabel('Units Sold')
    ax.set_xticks(plotdata.index)
    ax.set_title(f'{powertrains} Projections')
plt.tight_layout(pad=3)
```

Vehicle powertrain growth over years









BEVs show exponential growth post-2015.

PHEVs peaked around 2018–2020 but show slower growth.

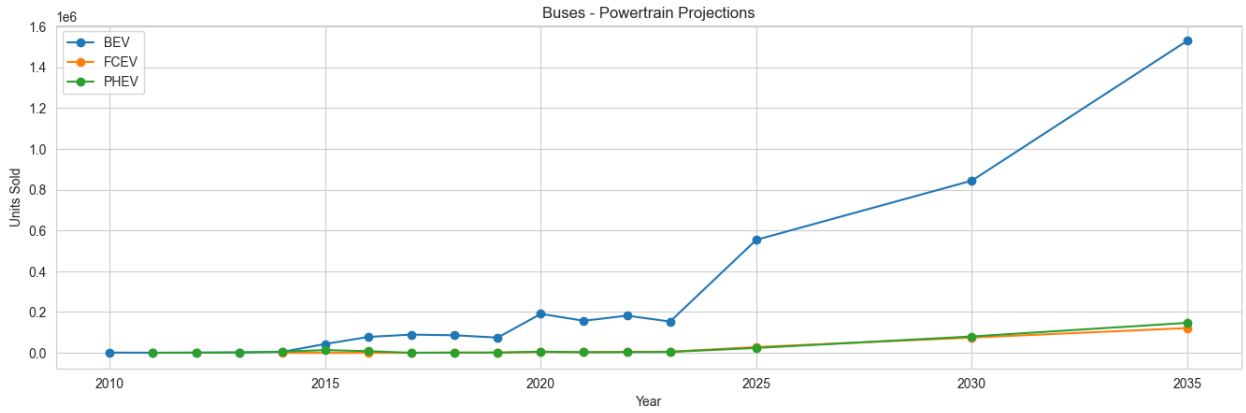
FCEVs adoption is flat, with limited scaling.

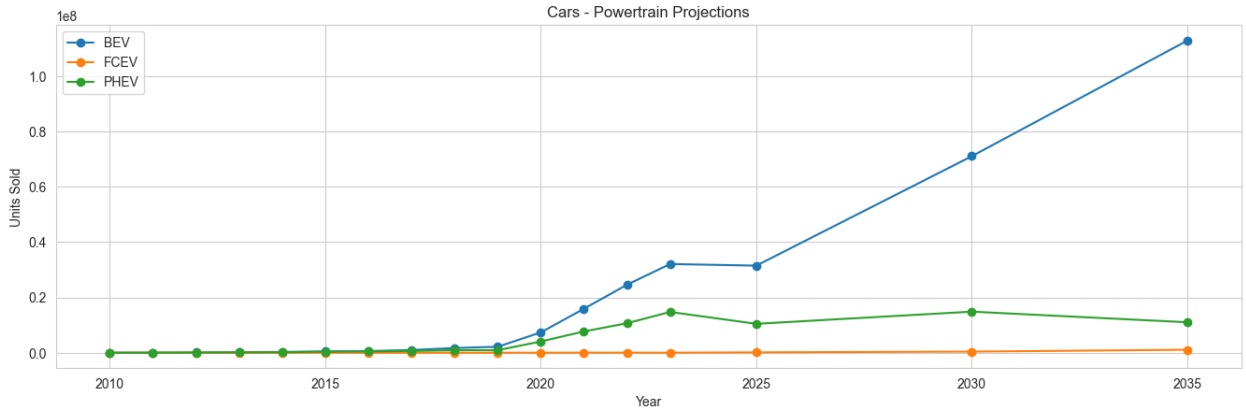
Takeaway: Policy + technology trends favor BEVs long-term, while PHEVs may serve as a transitional technology.

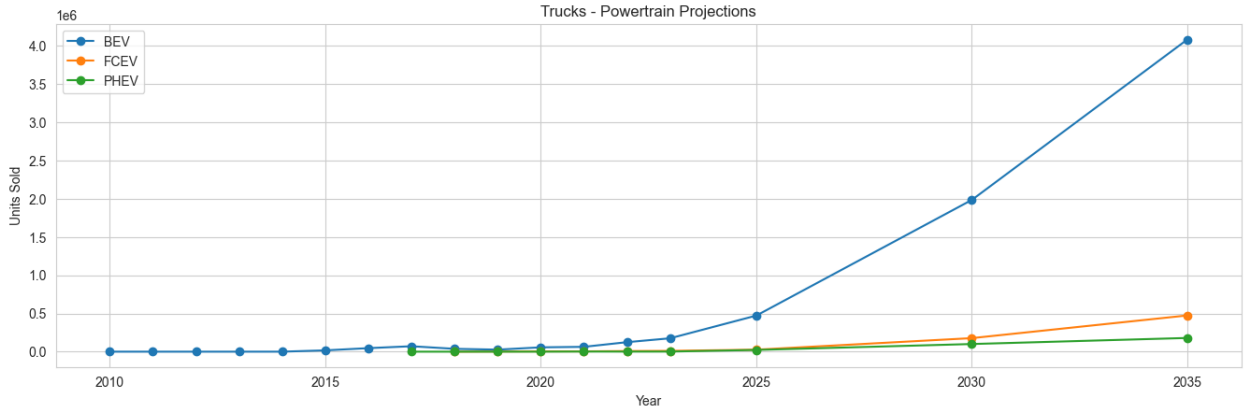
```
#Projection-STEPS of EVs

modes = POE['mode'].unique()

fig, axes = plt.subplots(nrows=len(modes), figsize=(14, 5 *
len(modes)))
fig.suptitle('Projection-STEPS of EVs', fontsize=20)
if len(modes) == 1:
    axes = [axes]
print(axes)
for ax,mode in zip(axes,modes):
    mode_data = POE[POE['mode'] == mode]

    for powertrain in mode_data['powertrain'].unique():
        pt_data = mode_data[mode_data['powertrain'] == powertrain]
        ax.plot(pt_data['year'], pt_data['value'], marker='o',
label=powertrain)

    ax.set_title(f'{mode} - Powertrain Projections')
    ax.set_xlabel('Year')
    ax.set_ylabel('Units Sold')
    ax.legend()
    ax.grid(True)

plt.tight_layout(pad=3)
```

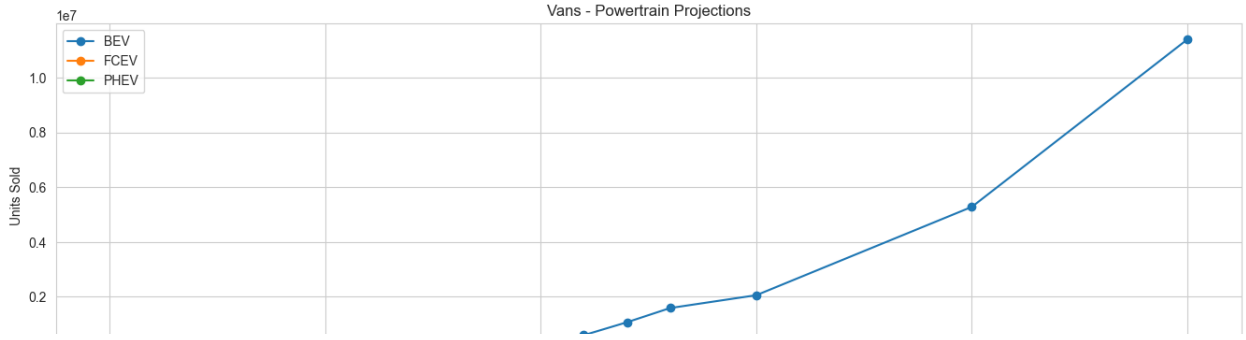
```
[<Axes: > <Axes: > <Axes: > <Axes: >]
```

Projection-STEPS of EVs



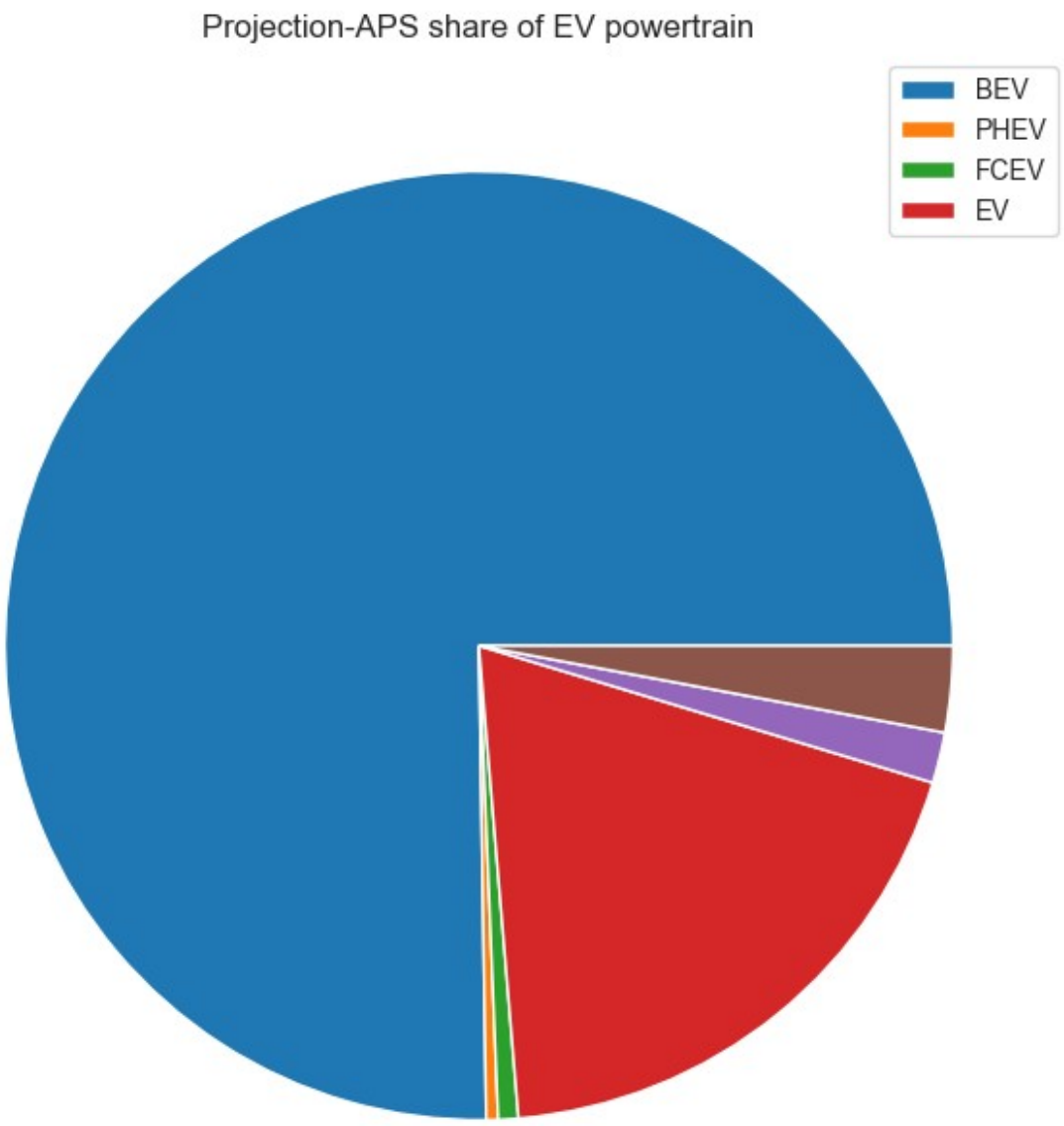






```
# Share of projection-APS of EVs
plotdata=SPOE['value'].plot(kind='pie', labels=None, figsize=(12,8))
plt.ylabel(None)
plt.title('Projection-APS share of EV powertrain')
labels=['BEV', 'PHEV', 'FCEV', 'EV']
plt.legend(loc='best', labels=labels)
```

```
<matplotlib.legend.Legend at 0x1555bc79210>
```



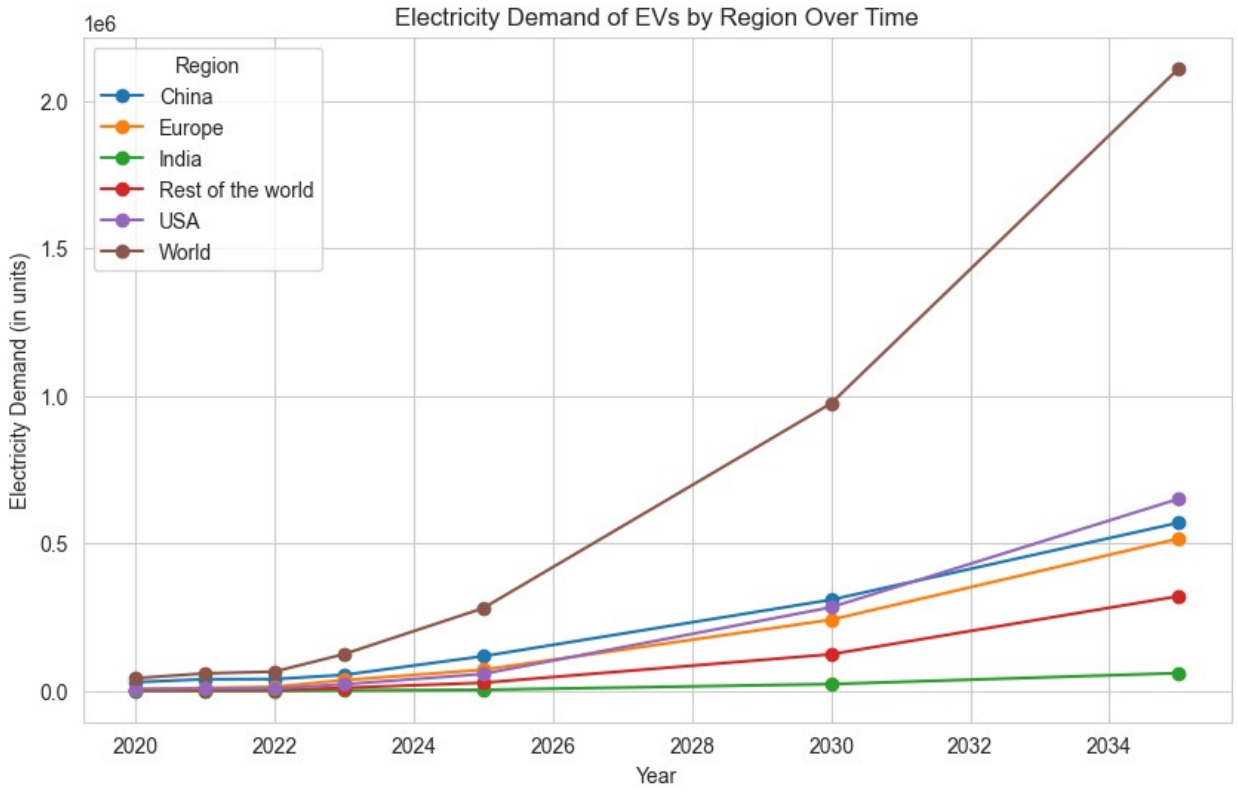
Under Stated Policies (STEPS), BEV sales are projected to quadruple by 2030.

PHEVs will remain relevant but with slower growth.

EV adoption is expected to become mainstream across most regions.

Takeaway: Even conservative projections show strong EV adoption momentum.

```
#Projection of Global Electricity demand of EVs
regions=POED['region'].unique()
plotdata=POED.reset_index().pivot(index='year',values='value',columns=
'region')
plt.figure(figsize=(10, 6))
for region in plotdata.columns:
    plt.plot(plotdata.index, plotdata[region], label=region,
marker='o')

plt.title('Electricity Demand of EVs by Region Over Time')
plt.xlabel('Year')
plt.ylabel('Electricity Demand (in units)')
plt.legend(title="Region")
plt.grid(True)
plt.show()
```



EV electricity demand will grow significantly post-2025.

By 2030, electricity demand for EVs could exceed 1000 TWh globally.

China, Europe, and the US will account for the majority of demand.

Takeaway: EV adoption has direct implications for energy infrastructure and grid capacity.

KPIs

```
# Global EV sales in 2011 and 2023
ev_sales = df[(df['parameter'] == 'EV sales') & (df['unit'] ==
'Vehicles')]

global_sales = ev_sales.groupby('year')['value'].sum()

sales_2011 = global_sales.loc[2011] if 2011 in global_sales.index else
np.nan
sales_2023 = global_sales.loc[2023] if 2023 in global_sales.index else
np.nan

print(f"Global EV sales in 2011: {sales_2011:,.0f} vehicles")
print(f"Global EV sales in 2023: {sales_2023:,.0f} vehicles (latest)")
```

```
Global EV sales in 2011: 130,608 vehicles
Global EV sales in 2023: 92,012,445 vehicles (latest)
```

```
# CAGR (Compound Annual Growth Rate) 2011–2023
years = 12 #(2023-2011 = 12 years)
if not np.isnan(sales_2011) and sales_2011 > 0:
    cagr = ((sales_2023 / sales_2011) ** (1/years) - 1) * 100
else:
    cagr = np.nan

print(f"CAGR (2011–2023): {cagr:.2f}%")
```

```
CAGR (2011–2023): 72.71%
```

```
# Market share by region in 2023
sales_2023_region = ev_sales[ev_sales['year'] ==
2023].groupby('region')['value'].sum()
total_2023_sales = sales_2023_region.sum()
region_share = (sales_2023_region / total_2023_sales *
100).sort_values(ascending=False)

print("\nRegional market share in 2023 (%):")
print(region_share.head(10))
```

```
Regional market share in 2023 (%):
region
World                46.903416
China                27.438593
Europe               11.323485
USA                   4.544222
EU27                  2.800485
Rest of the world     2.241259
Germany               0.792032
France                0.548288
United Kingdom        0.516102
```

```
India                  0.276882
Name: value, dtype: float64
```

```
# BEV share of global EV stock in 2023
ev_stock = df[(df['parameter'] == 'EV stock') & (df['unit'] ==
'Vehicles')]
bev_stock_2023 = ev_stock[(ev_stock['year'] == 2023) &
(ev_stock['powertrain'] == 'BEV')]['value'].sum()
total_stock_2023 = ev_stock[ev_stock['year'] == 2023]['value'].sum()

bev_share = (bev_stock_2023 / total_stock_2023 * 100) if
total_stock_2023 > 0 else np.nan
print(f"\nBEV share of global EV stock in 2023: {bev_share:.2f}%")
```

```
BEV share of global EV stock in 2023: 70.32%
```

```
# Projected global EV sales in 2030 (STEPS scenario)
proj_sales = df[
    (df['category'] == 'Projection-STEPS') &
    (df['parameter'] == 'EV sales') &
    (df['unit'] == 'Vehicles')
]
sales_2030 = proj_sales.groupby('year')['value'].sum().get(2030,
np.nan)

print(f"\nProjected global EV sales in 2030 (STEPS): {sales_2030:,.0f}
vehicles")
```

```
Projected global EV sales in 2030 (STEPS): 89,978,960 vehicles
```

```
# Combined KPI summary table
kpi_summary = {
    "Global EV sales in 2011": f"{sales_2011:,.0f}",
    "Global EV sales in 2023": f"{sales_2023:,.0f}",
    "CAGR (2011–2023)": f"{cagr:.2f}%",
    "China Market Share (2023)": f"{region_share.get('China',
np.nan):.2f}%",
    "BEV share of global EV stock (2023)": f"{bev_share:.2f}%",
    "Projected global EV sales in 2030 (STEPS)": f"{sales_2030:,.0f}"
}

kpi_df = pd.DataFrame.from_dict(kpi_summary, orient='index',
columns=['Value'])
kpi_df
```

	Value
Global EV sales in 2011	130,608
Global EV sales in 2023	92,012,445
CAGR (2011–2023)	72.71%

```
China Market Share (2023)                      27.44%
BEV share of global EV stock (2023)            70.32%
Projected global EV sales in 2030 (STEPS)  89,978,960
```