Monthly Electricity Production in GWh [2010-2022]

July 2, 2025

[108]:
```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

[109]:
```
df = pd.read_csv('../data/data.csv')
print(df.head())
print(df.info())
```

```
     COUNTRY CODE_TIME          TIME  YEAR  MONTH MONTH_NAME  \
0  Australia   JAN2010  January 2010  2010      1    January
1  Australia   JAN2010  January 2010  2010      1    January
2  Australia   JAN2010  January 2010  2010      1    January
3  Australia   JAN2010  January 2010  2010      1    January
4  Australia   JAN2010  January 2010  2010      1    January

                    PRODUCT      VALUE  DISPLAY_ORDER  yearToDate  \
0                     Hydro    990.728              1   16471.891
1                      Wind    409.469              2    4940.909
2                     Solar     49.216              3     908.238
3               Geothermal      0.083              4       0.996
4  Total combustible fuels  19289.730              7  214302.969

   previousYearToDate     share
0                 NaN  0.047771
1                 NaN  0.019744
2                 NaN  0.002373
3                 NaN  0.000004
4                 NaN  0.930108
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 181915 entries, 0 to 181914
Data columns (total 12 columns):
 #   Column              Non-Null Count   Dtype
---  ------              --------------   -----
 0   COUNTRY             181915 non-null  object
 1   CODE_TIME           181915 non-null  object
 2   TIME                181915 non-null  object
 3   YEAR                181915 non-null  int64
 4   MONTH               181915 non-null  int64
```

```
 5   MONTH_NAME          181915 non-null  object
 6   PRODUCT             181915 non-null  object
 7   VALUE               181915 non-null  float64
 8   DISPLAY_ORDER       181915 non-null  int64
 9   yearToDate          181915 non-null  float64
 10  previousYearToDate  164810 non-null  float64
 11  share               181915 non-null  float64
dtypes: float64(4), int64(3), object(5)
memory usage: 16.7+ MB
None
```

[110]:
```
# Missing values are checked for each column
print("Missing values:\n", df.isna().sum())
```

```
Missing values:
 COUNTRY                 0
CODE_TIME                0
TIME                     0
YEAR                     0
MONTH                    0
MONTH_NAME               0
PRODUCT                  0
VALUE                    0
DISPLAY_ORDER            0
yearToDate               0
previousYearToDate    17105
share                    0
dtype: int64
```

[111]:
```
# Create continent mapping
continent_map = {
    # Europe
    'Finland': 'Europe', 'Denmark': 'Europe', 'Iceland': 'Europe', 'Sweden':␣
↪'Europe',
    'Netherlands': 'Europe', 'Norway': 'Europe', 'Luxembourg': 'Europe',␣
↪'Switzerland': 'Europe',
    'Austria': 'Europe', 'Belgium': 'Europe', 'Ireland': 'Europe', 'Czechia':␣
↪'Europe',
    'Lithuania': 'Europe', 'United Kingdom': 'Europe', 'Slovenia': 'Europe',␣
↪'France': 'Europe',
    'Kosovo': 'Europe', 'Romania': 'Europe', 'Estonia': 'Europe', 'Poland':␣
↪'Europe',
    'Spain': 'Europe', 'Serbia': 'Europe', 'Malta': 'Europe', 'Italy': 'Europe',
    'Slovakia': 'Europe', 'Latvia': 'Europe', 'Cyprus': 'Europe', 'Portugal':␣
↪'Europe',
    'Hungary': 'Europe', 'Croatia': 'Europe', 'Greece': 'Europe', 'Bosnia and␣
↪Herzegovina': 'Europe',
```

```
    'Moldova': 'Europe', 'Montenegro': 'Europe', 'Bulgaria': 'Europe', 'North␣
↪Macedonia': 'Europe',
    'Albania': 'Europe', 'Ukraine': 'Europe',

    # Middle East
    'Kuwait': 'Middle East', 'Saudi Arabia': 'Middle East',
    'United Arab Emirates': 'Middle East', 'Bahrain': 'Middle East', 'Iraq':␣
↪'Middle East',
    'Iran': 'Middle East', 'State of Palestine': 'Middle East', 'Jordan':␣
↪'Middle East',
    'Yemen': 'Middle East', 'Lebanon': 'Middle East',

    # Asia
    'Singapore': 'Asia', 'Taiwan Province of China': 'Asia', 'Uzbekistan':␣
↪'Asia',
    'Kazakhstan': 'Asia', 'Japan': 'Asia', 'South Korea': 'Asia', 'Philippines':␣
↪'Asia',
    'Vietnam': 'Asia', 'Thailand': 'Asia', 'Malaysia': 'Asia', 'China': 'Asia',
    'Kyrgyzstan': 'Asia', 'Mongolia': 'Asia', 'Armenia': 'Asia', 'Georgia':␣
↪'Asia',
    'Nepal': 'Asia', 'Laos': 'Asia', 'Azerbaijan': 'Asia', 'Pakistan': 'Asia',
    'Myanmar': 'Asia', 'Cambodia': 'Asia', 'India': 'Asia', 'Sri Lanka': 'Asia',
    'Bangladesh': 'Asia', 'Hong Kong S.A.R. of China': 'Asia', 'Tajikistan':␣
↪'Asia',
    'Indonesia': 'Asia',

    # Latin America
    'Costa Rica': 'Latin America', 'Mexico': 'Latin America', 'Uruguay': 'Latin␣
↪America',
    'El Salvador': 'Latin America', 'Chile': 'Latin America', 'Panama': 'Latin␣
↪America',
    'Guatemala': 'Latin America', 'Nicaragua': 'Latin America', 'Brazil': 'Latin␣
↪America',
    'Argentina': 'Latin America', 'Paraguay': 'Latin America', 'Honduras':␣
↪'Latin America',
    'Jamaica': 'Latin America', 'Peru': 'Latin America', 'Dominican Republic':␣
↪'Latin America',
    'Bolivia': 'Latin America', 'Ecuador': 'Latin America', 'Colombia': 'Latin␣
↪America',
    'Venezuela': 'Latin America',

    # Africa
    'Libya': 'Africa', 'Mauritius': 'Africa', 'South Africa': 'Africa',
    'Algeria': 'Africa', 'Congo (Brazzaville)': 'Africa', 'Mozambique': 'Africa',
    'Gabon': 'Africa', 'Ivory Coast': 'Africa', 'Guinea': 'Africa', 'Nigeria':␣
↪'Africa',
```

```
    'Cameroon': 'Africa', 'Namibia': 'Africa', 'Morocco': 'Africa', 'Niger':␣
↪'Africa',
    'Burkina Faso': 'Africa', 'Mauritania': 'Africa', 'Gambia': 'Africa', 'Chad':
↪ 'Africa',
    'Kenya': 'Africa', 'Tunisia': 'Africa', 'Benin': 'Africa', 'Uganda':␣
↪'Africa',
    'Ghana': 'Africa', 'Liberia': 'Africa', 'Mali': 'Africa', 'Madagascar':␣
↪'Africa',
    'Togo': 'Africa', 'Ethiopia': 'Africa', 'Tanzania': 'Africa', 'Comoros':␣
↪'Africa',
    'Zambia': 'Africa', 'Eswatini': 'Africa', 'Malawi': 'Africa', 'Botswana':␣
↪'Africa',
    'Zimbabwe': 'Africa', 'Congo (Kinshasa)': 'Africa', 'Sierra Leone': 'Africa',
    'Lesotho': 'Africa', 'Senegal': 'Africa', 'Egypt': 'Africa',

    # Oceania
    'Australia': 'Oceania', 'New Zealand': 'Oceania',

    # Mixed region
    'Russia': 'Europe/Asia', 'Turkiye': 'Europe/Asia'
}

# Apply mapping and handle missing continents
df["CONTINENT"] = df["COUNTRY"].map(continent_map).fillna("Unknown")
```

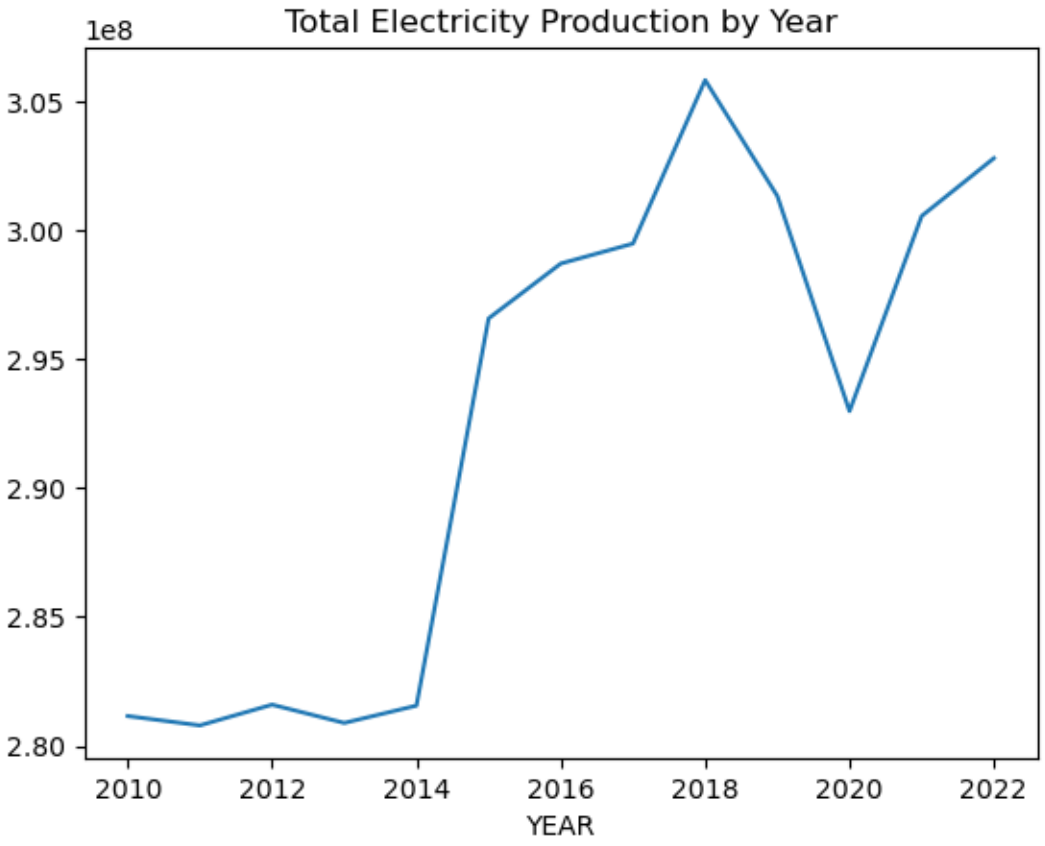
[112]:
```
#Total production by country

country_total = df.groupby("COUNTRY")["VALUE"].sum().sort_values(ascending=False)
print(country_total)
```

```
COUNTRY
OECD Total              9.242596e+08
IEA Total               9.096110e+08
OECD Americas           4.527393e+08
United States           3.624349e+08
OECD Europe             3.056325e+08
OECD Asia Oceania       1.658877e+08
Japan                   9.367340e+07
India                   7.716980e+07
Germany                 5.233599e+07
Canada                  5.125470e+07
Korea                   4.683166e+07
France                  4.332543e+07
Brazil                  2.909683e+07
United Kingdom          2.907350e+07
Mexico                  2.797201e+07
Italy                   2.604113e+07
```

```
Spain                  2.335283e+07
Republic of Turkiye    2.305181e+07
Australia              2.182063e+07
Poland                 1.411084e+07
Sweden                 1.297384e+07
Norway                 1.139089e+07
Netherlands            1.059264e+07
Belgium                7.404547e+06
Argentina              7.291167e+06
Czech Republic         7.112194e+06
Chile                  6.494507e+06
Finland                6.373295e+06
Austria                6.162604e+06
Switzerland            6.091422e+06
Portugal               4.691351e+06
Greece                 4.647115e+06
Colombia               4.429160e+06
New Zealand            3.562025e+06
Hungary                3.126454e+06
Denmark                3.103078e+06
Romania                2.870030e+06
Ireland                2.595994e+06
Slovak Republic        2.461672e+06
Bulgaria               2.176951e+06
Serbia                 1.875004e+06
Iceland                1.499897e+06
Slovenia               1.461820e+06
Estonia                9.715635e+05
Croatia                8.133567e+05
Lithuania              6.531533e+05
Latvia                 6.092211e+05
Luxembourg             4.182565e+05
North Macedonia        3.012701e+05
Cyprus                 2.861298e+05
Costa Rica             1.540189e+05
Malta                  1.043743e+05
Name: VALUE, dtype: float64
```

[113]:
```
#Total electricity production by year

yearly_total = df.groupby("YEAR")["VALUE"].sum()
yearly_total.plot(kind="line", title="Total Electricity Production by Year")
```

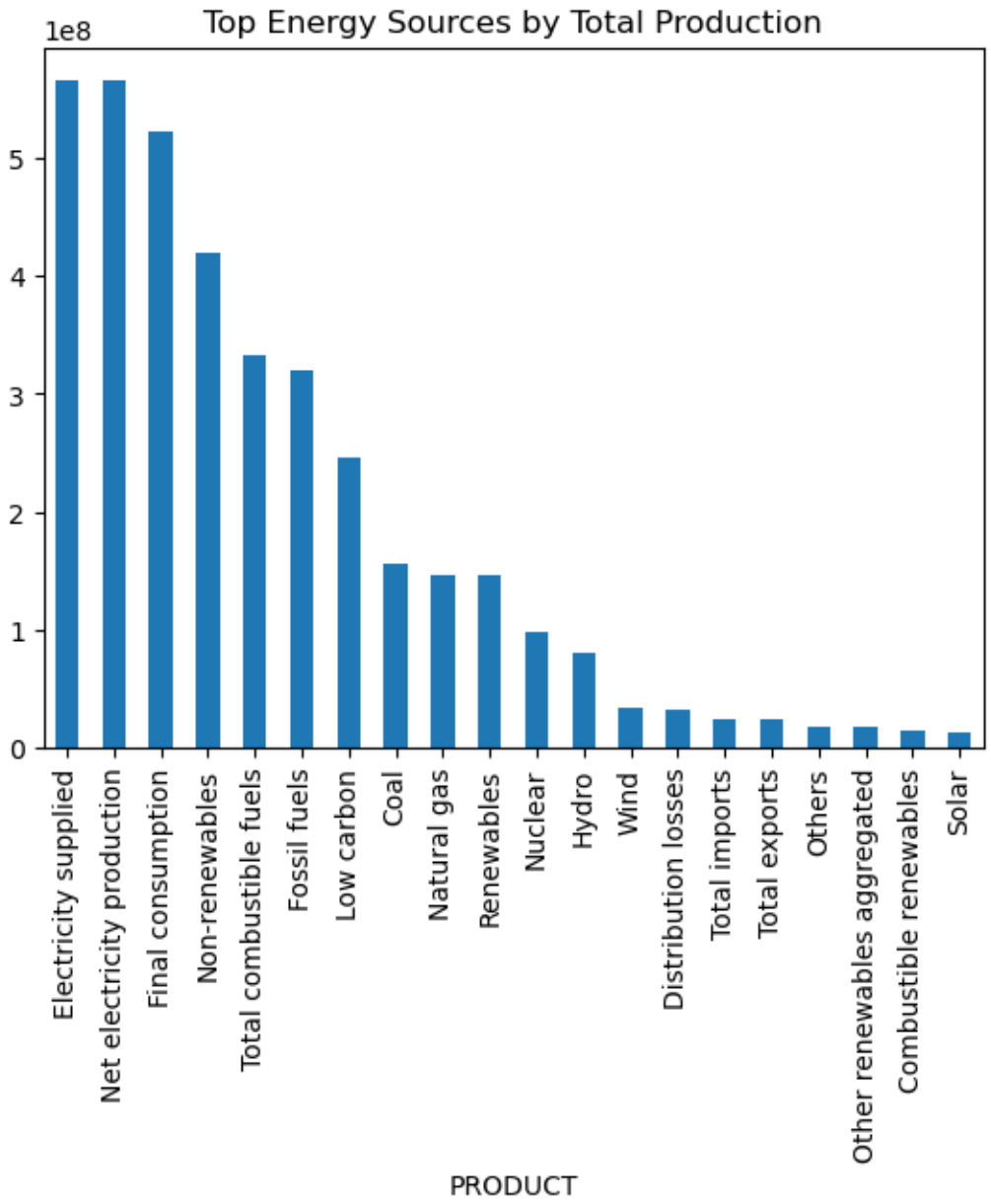
[113]: <Axes: title={'center': 'Total Electricity Production by Year'}, xlabel='YEAR'>



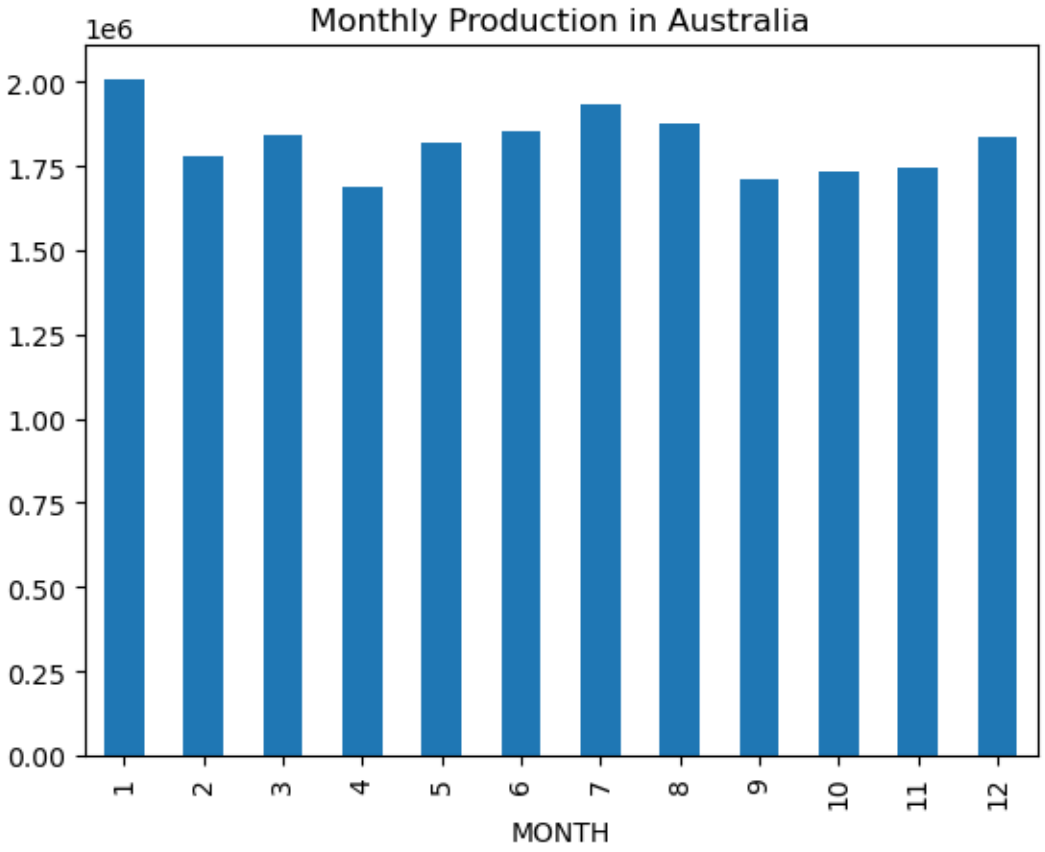
[114]:
```
# Top 20 most productive energy sources
source_total = df.groupby("PRODUCT")["VALUE"].sum().sort_values(ascending=False)
print(source_total.head(20))
source_total.head(20).plot(kind="bar", title="Top Energy Sources by Total␣
↪Production")
```

```
PRODUCT
Electricity supplied           5.652626e+08
Net electricity production     5.648743e+08
Final consumption              5.226701e+08
Non-renewables                 4.186862e+08
Total combustible fuels        3.329794e+08
Fossil fuels                   3.199421e+08
Low carbon                     2.468221e+08
Coal                           1.553674e+08
Natural gas                    1.469984e+08
Renewables                     1.461857e+08
Nuclear                        9.874406e+07
Hydro                          8.108343e+07
Wind                           3.415691e+07
Distribution losses            3.310850e+07
Total imports                  2.515404e+07
Total exports                  2.476580e+07
Others                         1.757629e+07
Other renewables aggregated    1.731865e+07
Combustible renewables         1.492679e+07
Solar                          1.362672e+07
Name: VALUE, dtype: float64
```

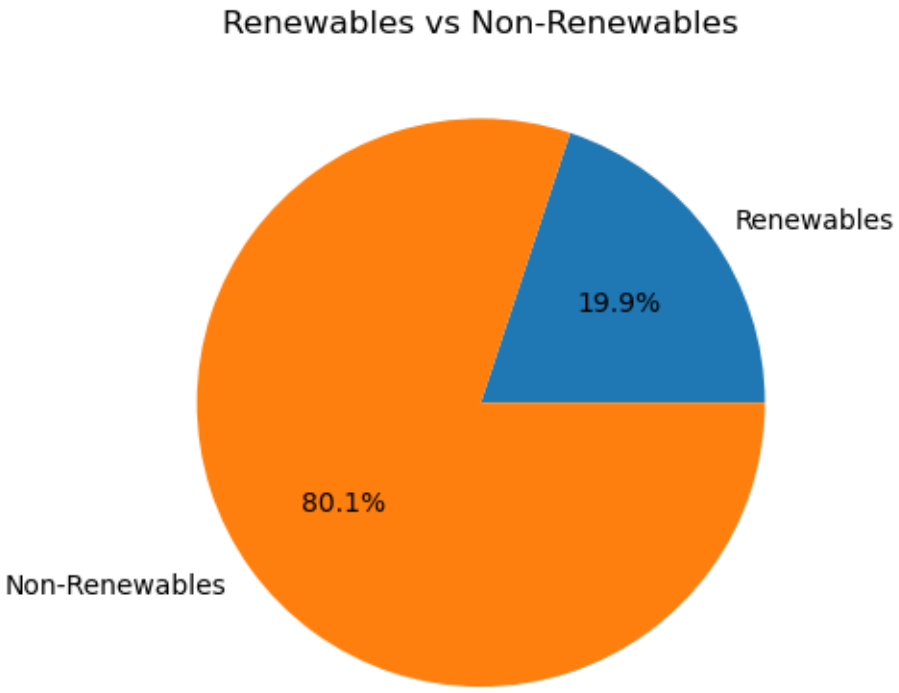
[114]:
```
<Axes: title={'center': 'Top Energy Sources by Total Production'},
xlabel='PRODUCT'>
```


Top Energy Sources by Total Production
1e8
5
4
3
2
1
0
Electricity supplied
Net electricity production
Final consumption
Non-renewables
Total combustible fuels
Fossil fuels
Low carbon
Coal
Natural gas
Renewables
Nuclear
Hydro
Wind
Distribution losses
Total imports
Total exports
Others
Other renewables aggregated
Combustible renewables
Solar
PRODUCT

[115]:
```
# Monthly production trend for a specific country (Australia)
aus_df = df[df["COUNTRY"] == "Australia"]
aus_df.groupby("MONTH")["VALUE"].sum().plot(kind="bar", title="Monthly␣
 ↪Production in Australia")
plt.show()
```

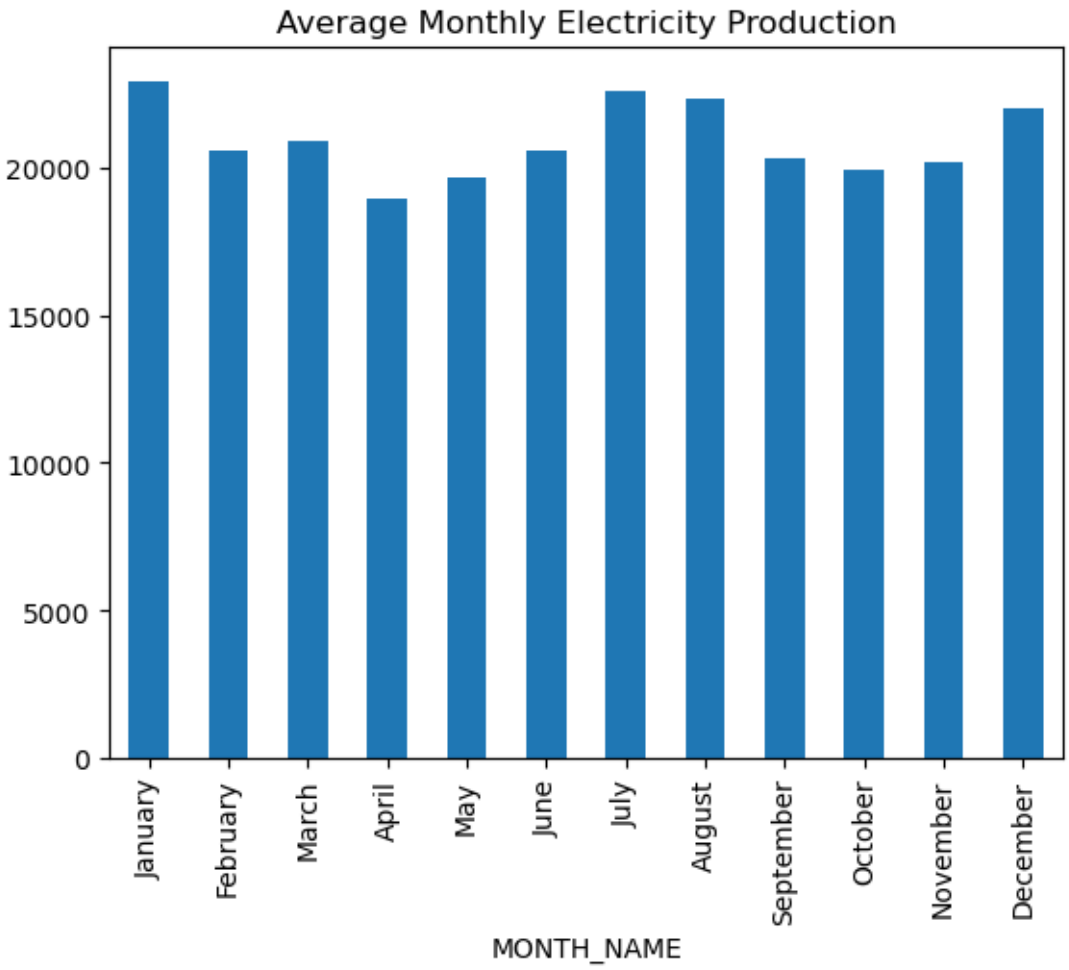


[158]:
```
#Comparison of electricity production from renewable vs non-renewable sources
renewables = df[df["PRODUCT"].str.contains("Hydro|Wind|Solar|Other␣
↪renewables|Combustible renewables", case=False)]["VALUE"].sum()
non_renewables = df[df["PRODUCT"].str.contains("Coal|Natural gas|Oil|Total␣
↪combustible fuels", case=False)]["VALUE"].sum()
plt.pie([renewables, non_renewables], labels=["Renewables", "Non-Renewables"],␣
↪autopct="%1.1f%%")
plt.title("Renewables vs Non-Renewables")
plt.show()
```



[117]:
```
#Average Monthly Electricity Production
monthly_avg = df.groupby("MONTH_NAME")["VALUE"].mean().reindex([
    "January", "February", "March", "April", "May", "June",
    "July", "August", "September", "October", "November", "December"
])
monthly_avg.plot(kind="bar", title="Average Monthly Electricity Production")
```

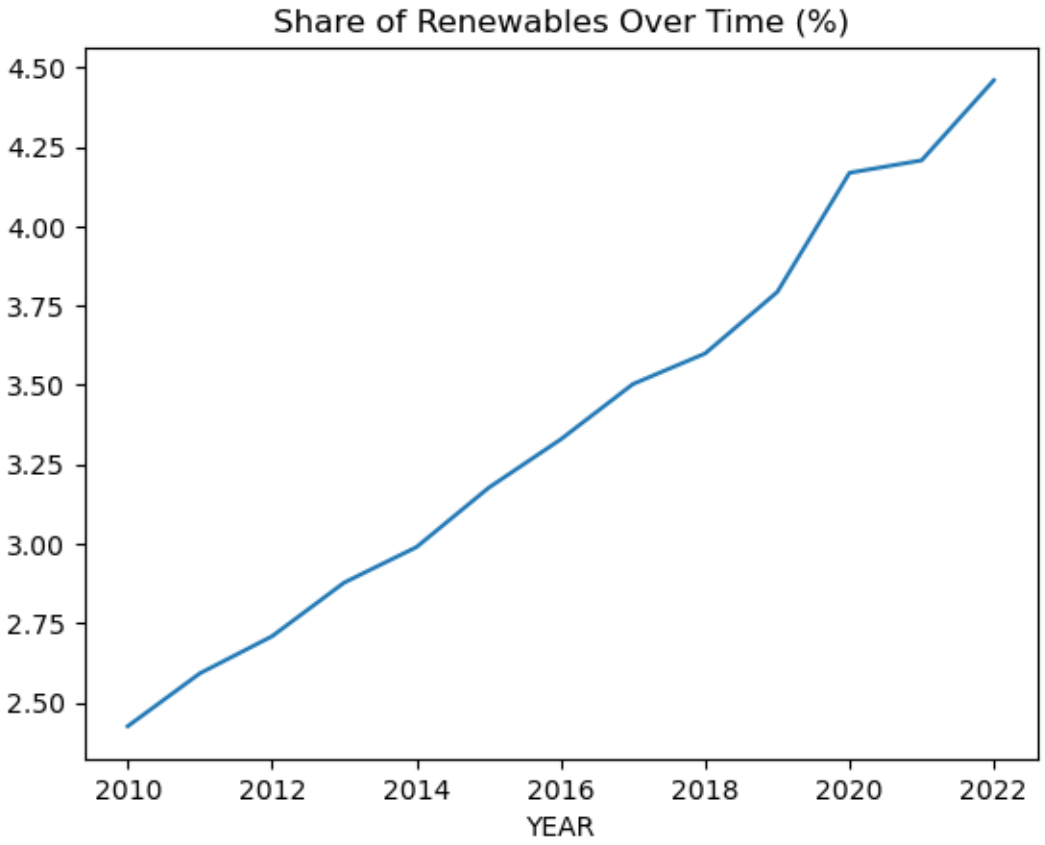
[117]:
```
<Axes: title={'center': 'Average Monthly Electricity Production'},
xlabel='MONTH_NAME'>
```



[118]:
```
#Share of Renewables Over Time (%)
renew_yearly = df[df["PRODUCT"].str.contains("Hydro|Wind|Solar", case=False)].
 ↪groupby("YEAR")["VALUE"].sum()
total_yearly = df.groupby("YEAR")["VALUE"].sum()
```

```
share_renew = (renew_yearly / total_yearly) * 100
share_renew.plot(kind="line", title="Share of Renewables Over Time (%)")
```

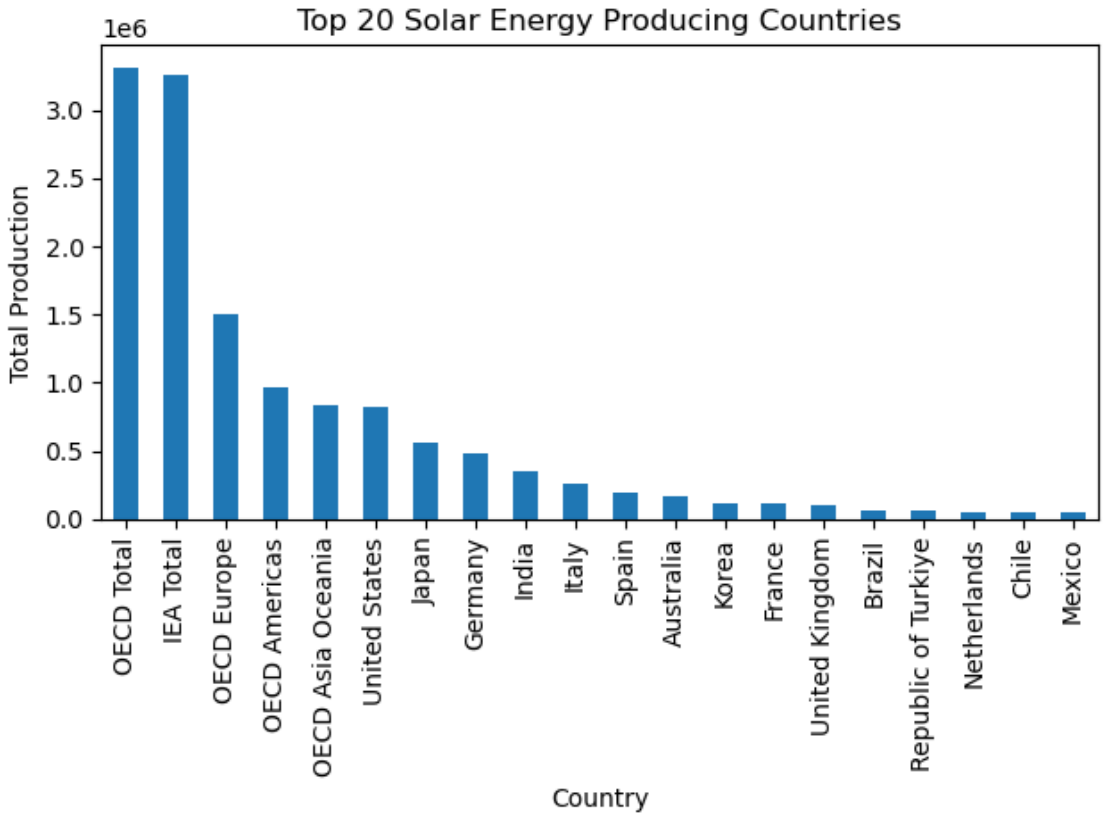
[118]: <Axes: title={'center': 'Share of Renewables Over Time (%)'}, xlabel='YEAR'>



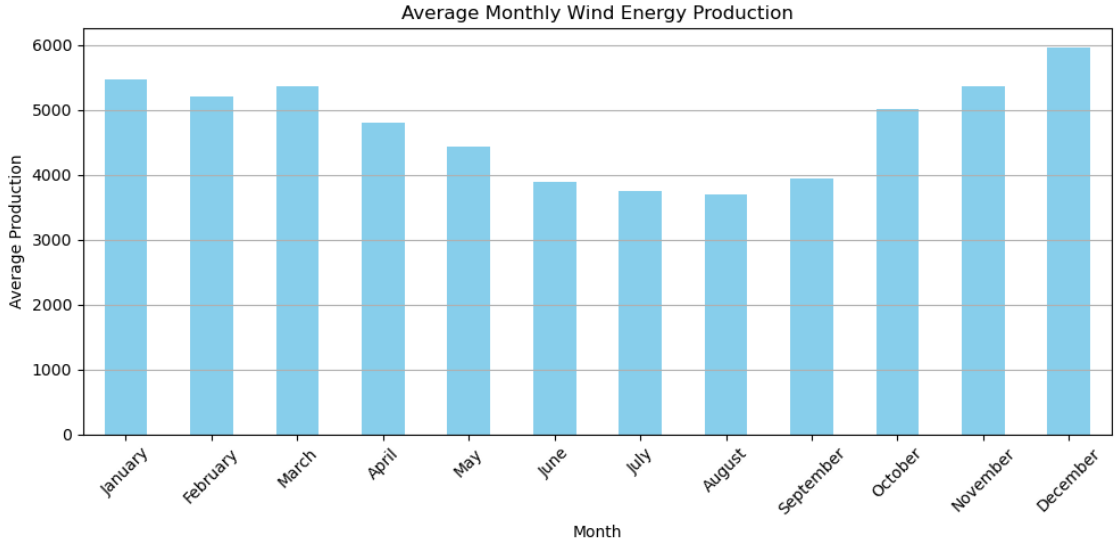
[119]:
```
#Top countries in solar energy production
solar_production = df[df["PRODUCT"].str.contains("Solar", case=False)].
 ↪groupby("COUNTRY")["VALUE"].sum().sort_values(ascending=False)
print(solar_production.head(20))

solar_production.head(20).plot(kind="bar", title="Top 20 Solar Energy Producing␣
 ↪Countries")
plt.ylabel("Total Production")
plt.xlabel("Country")
plt.tight_layout()
plt.show()
```

```
COUNTRY
OECD Total              3.308954e+06
```

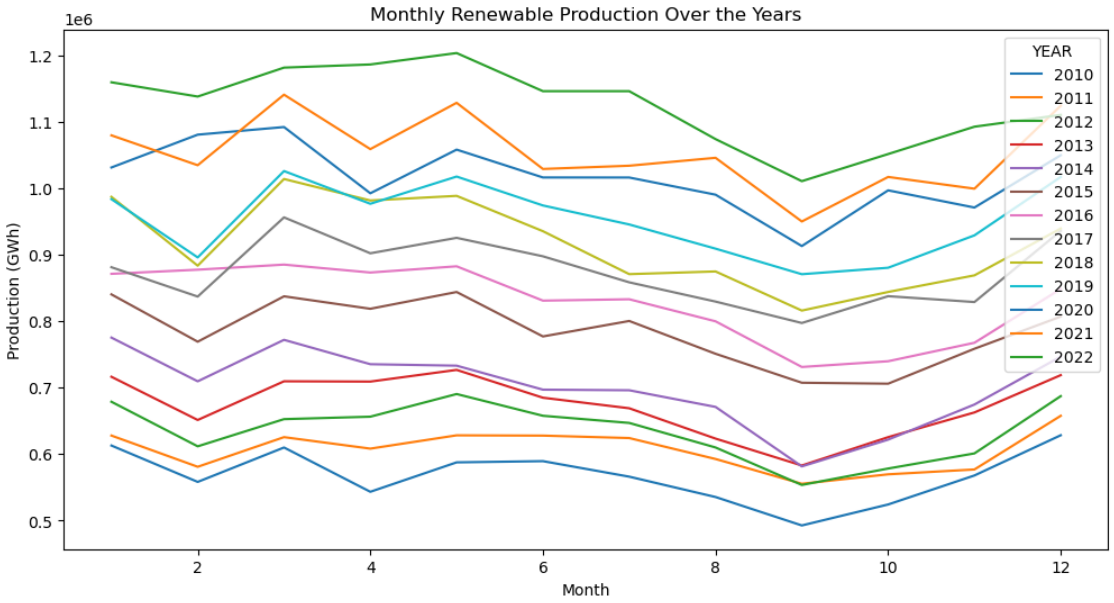
```
IEA Total              3.252181e+06
OECD Europe            1.506510e+06
OECD Americas          9.657639e+05
OECD Asia Oceania      8.366802e+05
United States          8.259103e+05
Japan                  5.543602e+05
Germany                4.846032e+05
India                  3.467374e+05
Italy                  2.639054e+05
Spain                  1.995112e+05
Australia              1.632382e+05
Korea                  1.180891e+05
France                 1.164645e+05
United Kingdom         1.023523e+05
Brazil                 6.256879e+04
Republic of Turkiye    5.997132e+04
Netherlands            5.414579e+04
Chile                  5.202431e+04
Mexico                 4.771209e+04
Name: VALUE, dtype: float64
```



[120]:
```
#Average Monthly Wind Energy Production

wind_df = df[df["PRODUCT"] == "Wind"]

monthly_avg_wind = (
    wind_df.groupby("MONTH_NAME")["VALUE"] .mean().reindex([
        "January", "February", "March", "April", "May", "June",
        "July", "August", "September", "October", "November", "December"  ]))
monthly_avg_wind.plot(kind="bar", figsize=(10, 5), color="skyblue",␣
 ↪title="Average Monthly Wind Energy Production")
plt.xlabel("Month")
plt.ylabel("Average Production")
plt.xticks(rotation=45)
plt.tight_layout()
plt.grid(axis="y")
plt.show()
```



[121]:
```
#Monthly Renewable Production Over the Years
renew_df = df[df["PRODUCT"].str.contains("Hydro|Solar|Wind", case=False)]
monthly_trend = renew_df.groupby(["YEAR", "MONTH"])["VALUE"].sum().unstack().T
monthly_trend.plot(figsize=(12, 6), title="Monthly Renewable Production Over the␣
↪Years")
plt.xlabel("Month")
plt.ylabel("Production (GWh)")
plt.show()
```

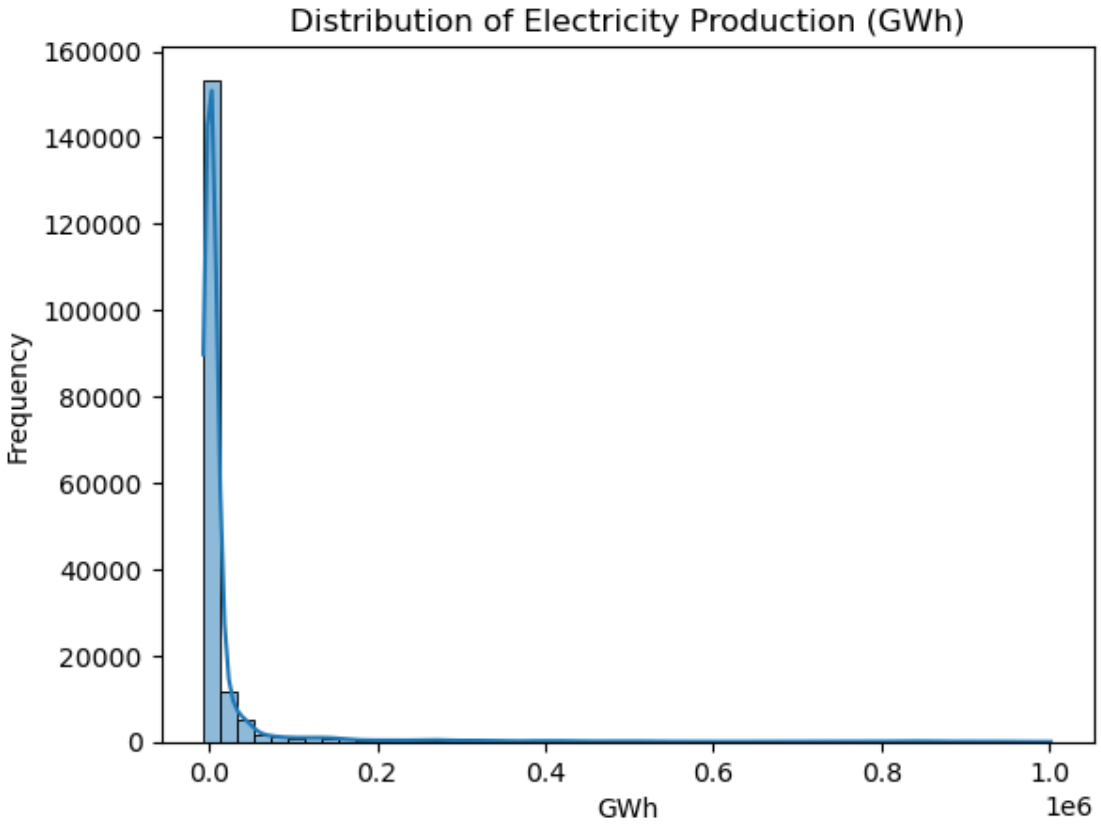


[122]:
```
top_sources = df.groupby(["COUNTRY", "PRODUCT"])["VALUE"].sum()
top_sources = top_sources.groupby(level=0, group_keys=False).nlargest(10)
print(top_sources)
```

```
COUNTRY        PRODUCT
Argentina      Electricity supplied          1.117895e+06
               Net electricity production    1.115406e+06
               Final consumption             8.341122e+05
               Non-renewables                8.262345e+05
               Total combustible fuels       7.777827e+05
                                                   ...
United States  Fossil fuels                   3.482059e+07
               Low carbon                    1.916159e+07
               Coal                          1.716032e+07
               Natural gas                   1.700318e+07
               Nuclear                       1.031649e+07
```

```
Name: VALUE, Length: 520, dtype: float64
```

[123]:
```
#Distribution of energy production values using a histogram
sns.histplot(df["VALUE"], bins=50, kde=True)
plt.title("Distribution of Electricity Production (GWh)")
plt.xlabel("GWh")
plt.ylabel("Frequency")
plt.show()
```

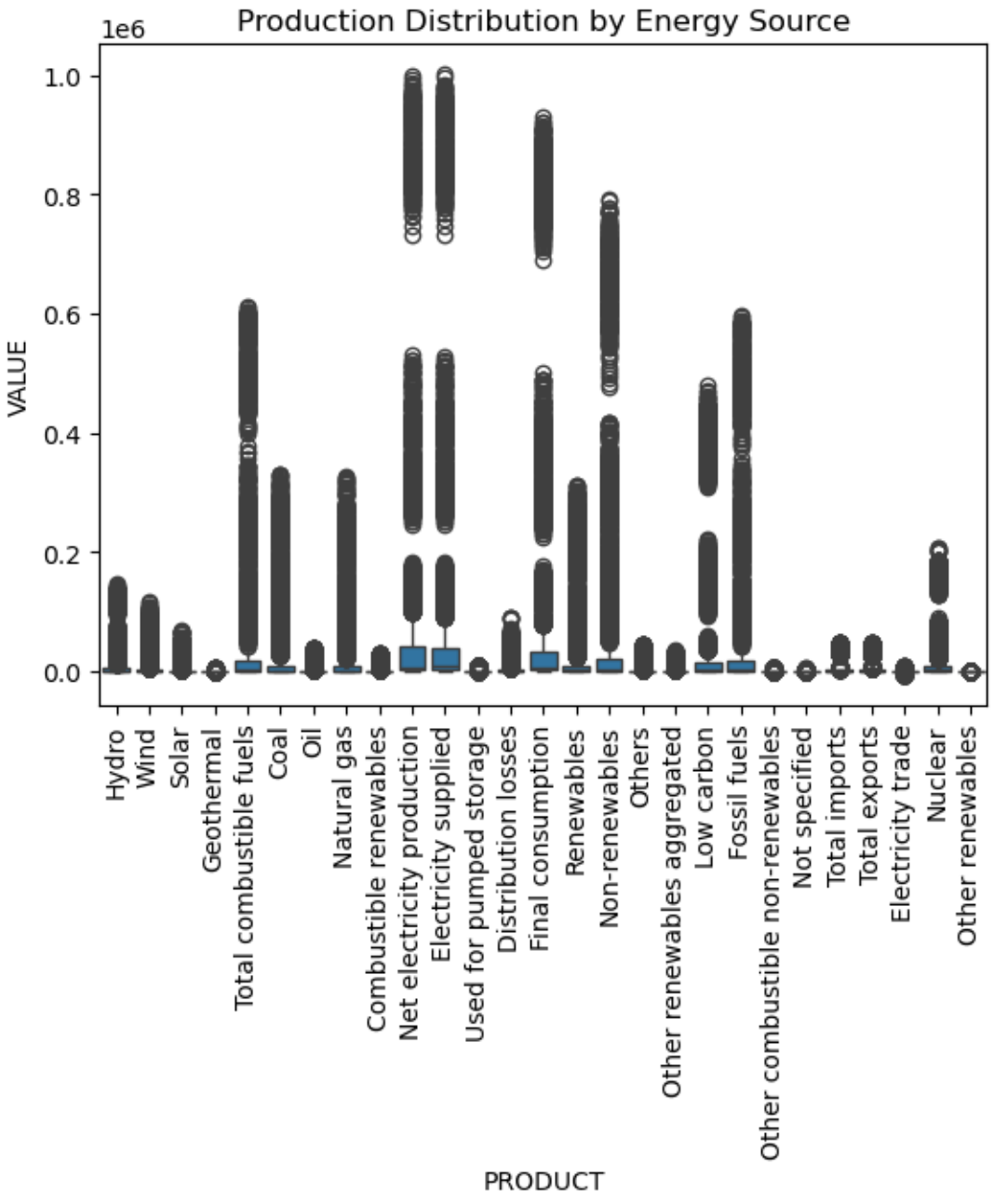


[124]:
```
#Detecting outliers in energy production values
mean_val = df["VALUE"].mean()
std_val = df["VALUE"].std()
df["Z_SCORE"] = (df["VALUE"] - mean_val) / std_val
outliers = df[abs(df["Z_SCORE"]) > 3]
print(outliers[["COUNTRY", "PRODUCT", "VALUE", "TIME"]])
```

```
             COUNTRY                      PRODUCT          VALUE  \
311         IEA Total    Total combustible fuels  587612.881000
312         IEA Total                      Coal  329335.711000
318         IEA Total  Net electricity production  943609.626000
321         IEA Total       Electricity supplied  946083.601000
```

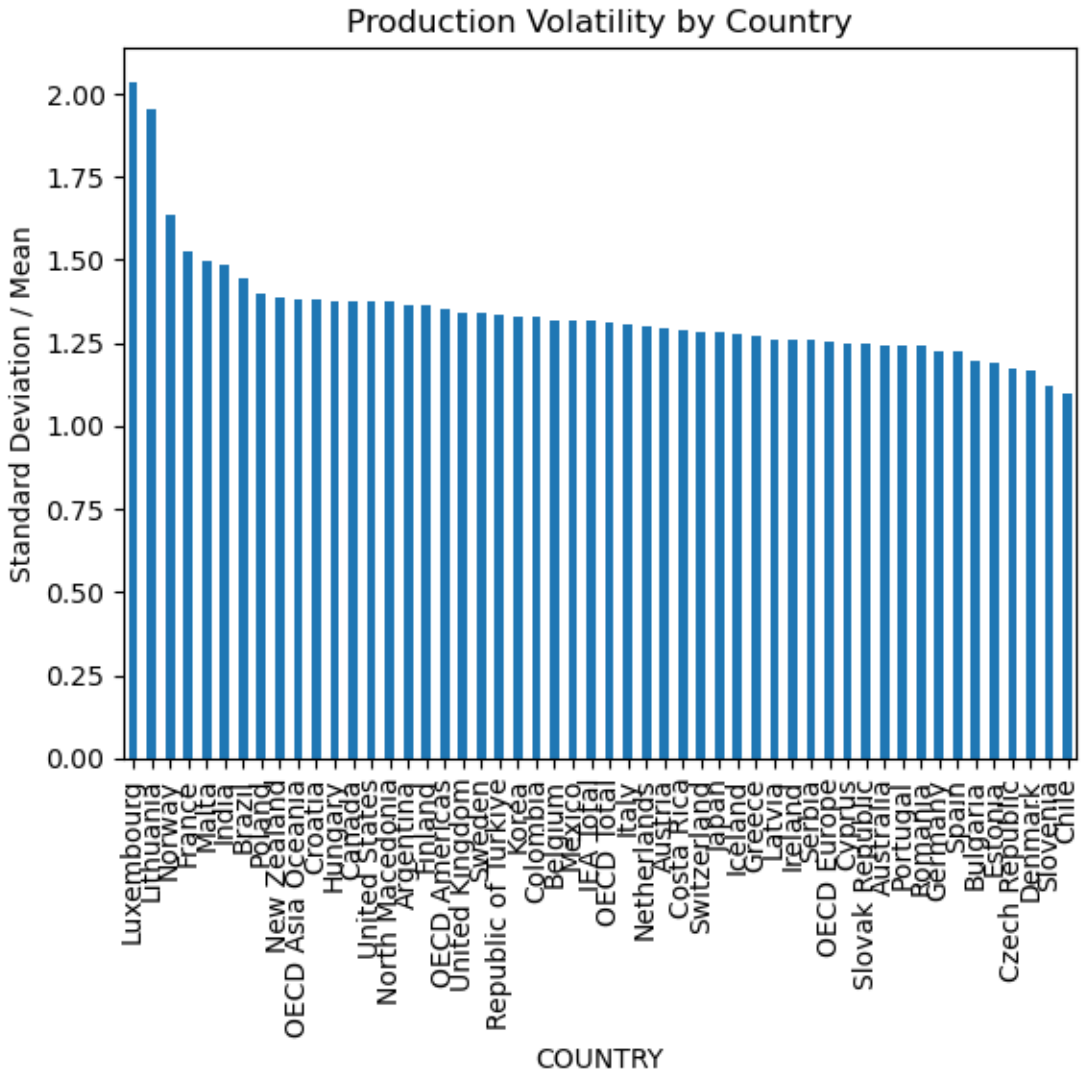
```
324         IEA Total           Final consumption  877213.615000
...               ...                         ...            ...
181637     OECD Total                Fossil fuels  489939.125106
181901  United States  Net electricity production  369604.059764
181904  United States        Electricity supplied  372975.265154
181907  United States           Final consumption  343222.453509
181910  United States              Non-renewables  292417.548132

                TIME
311      January 2010
312      January 2010
318      January 2010
321      January 2010
324      January 2010
...               ...
181637  December 2022
181901  December 2022
181904  December 2022
181907  December 2022
181910  December 2022

[3810 rows x 4 columns]
```

[125]:
```
sns.boxplot(x="PRODUCT", y="VALUE", data=df)
plt.xticks(rotation=90)
plt.title("Production Distribution by Energy Source")
plt.show()
```



[126]:
```
volatility = df.groupby("COUNTRY")["VALUE"].std() / df.
↪groupby("COUNTRY")["VALUE"].mean()
```

```
volatility.sort_values(ascending=False).plot(kind="bar", title="Production␣
 ↪Volatility by Country")
plt.ylabel("Standard Deviation / Mean")
plt.show()
```



[127]:
```
#Years with lowest production
min_years = df.groupby("YEAR")["VALUE"].sum().sort_values().head(5)
print("Years with lowest production:")
print(min_years)
```

```
Years with lowest production:
YEAR
2011    2.807929e+08
2013    2.808882e+08
2010    2.811565e+08
2014    2.815608e+08
2012    2.815982e+08
Name: VALUE, dtype: float64
```

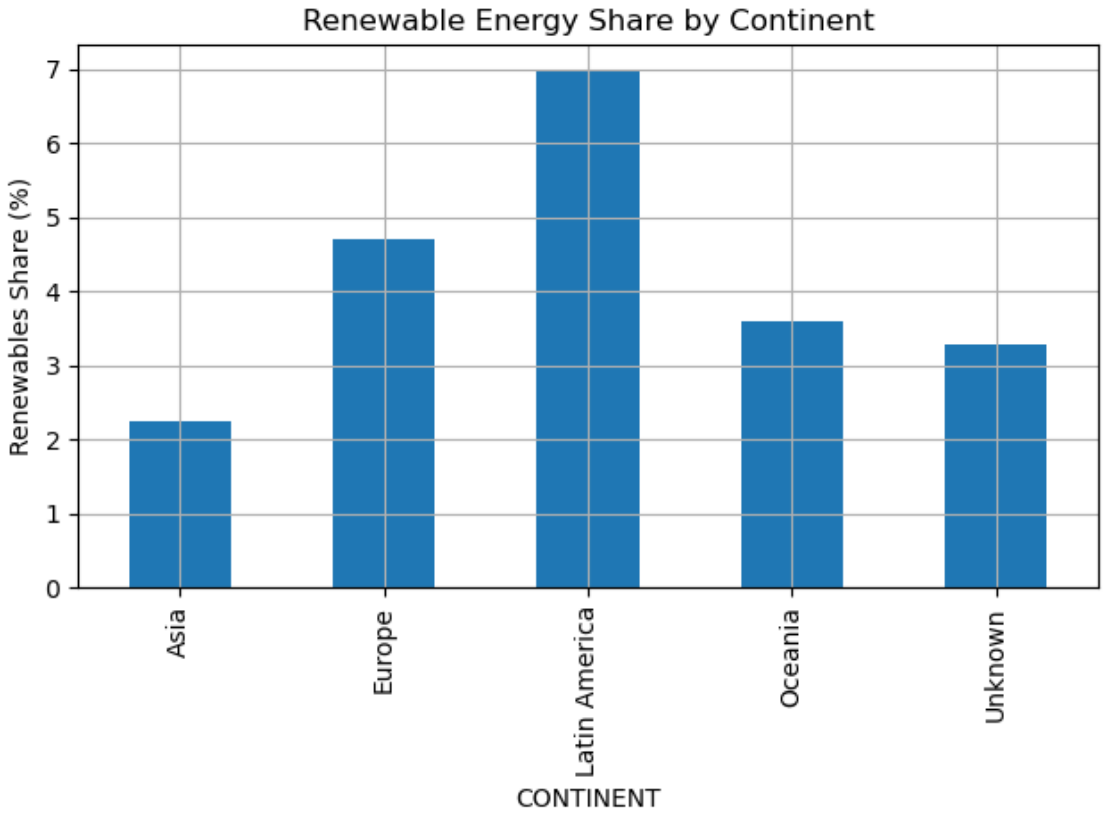
[128]:
```
# Calculate renewable production by continent
renew_cont = df[df["PRODUCT"].str.contains("Hydro|Wind|Solar", case=False)].
 ↪groupby("CONTINENT")["VALUE"].sum()
print("Renewable Production by Continent (GWh):")
print(renew_cont)
```

```
Renewable Production by Continent (GWh):
CONTINENT
Asia             3.827335e+06
Europe           1.076388e+07
Latin America    5.258212e+06
Oceania          9.155263e+05
Unknown          1.081021e+08
Name: VALUE, dtype: float64
```

[129]:
```
total_cont = df.groupby("CONTINENT")["VALUE"].sum()
renew_share_cont = (renew_cont / total_cont) * 100
print("Renewable Share by Continent (%):")
print(renew_share_cont)

renew_share_cont.plot(kind="bar", title="Renewable Energy Share by Continent")
plt.ylabel("Renewables Share (%)")
plt.grid(True)
plt.tight_layout()
plt.show()
```

```
Renewable Share by Continent (%):
CONTINENT
Asia             2.240262
Europe           4.698373
Latin America    6.970271
Oceania          3.606898
```

```
Unknown           3.272239
Name: VALUE, dtype: float64
```



[162]:
```
#Production Volatility by Continent
volatility_cont = df.groupby("CONTINENT")["VALUE"].std() / df.
 ↪groupby("CONTINENT")["VALUE"].mean()
volatility_cont.plot(kind="bar", title="Production Volatility by Continent")
plt.ylabel("Standard Deviation / Mean")
plt.show()
```