# Energy Consumption Forecast towards Net Zero Transition

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# Methodology

Background
Business Understanding
Data Understanding
Data Preprocessing
Exploratory Data Analysis
Modeling
Evaluation
Forecast
Follow-up Action
Conclusion and Recommendation

# Background

## We're in the midst of an energy transition that continues to evolve.

**Net Zero 2050**

Net Zero 2050 is an ambitious scenario that limits global warming to 1.5 °C through stringent climate policies and innovation, reaching net-zero $CO_2$ emissions around 2050.

+1.5 °C ⟷ +3 °C

**Renewable Energy show accelerated growth**

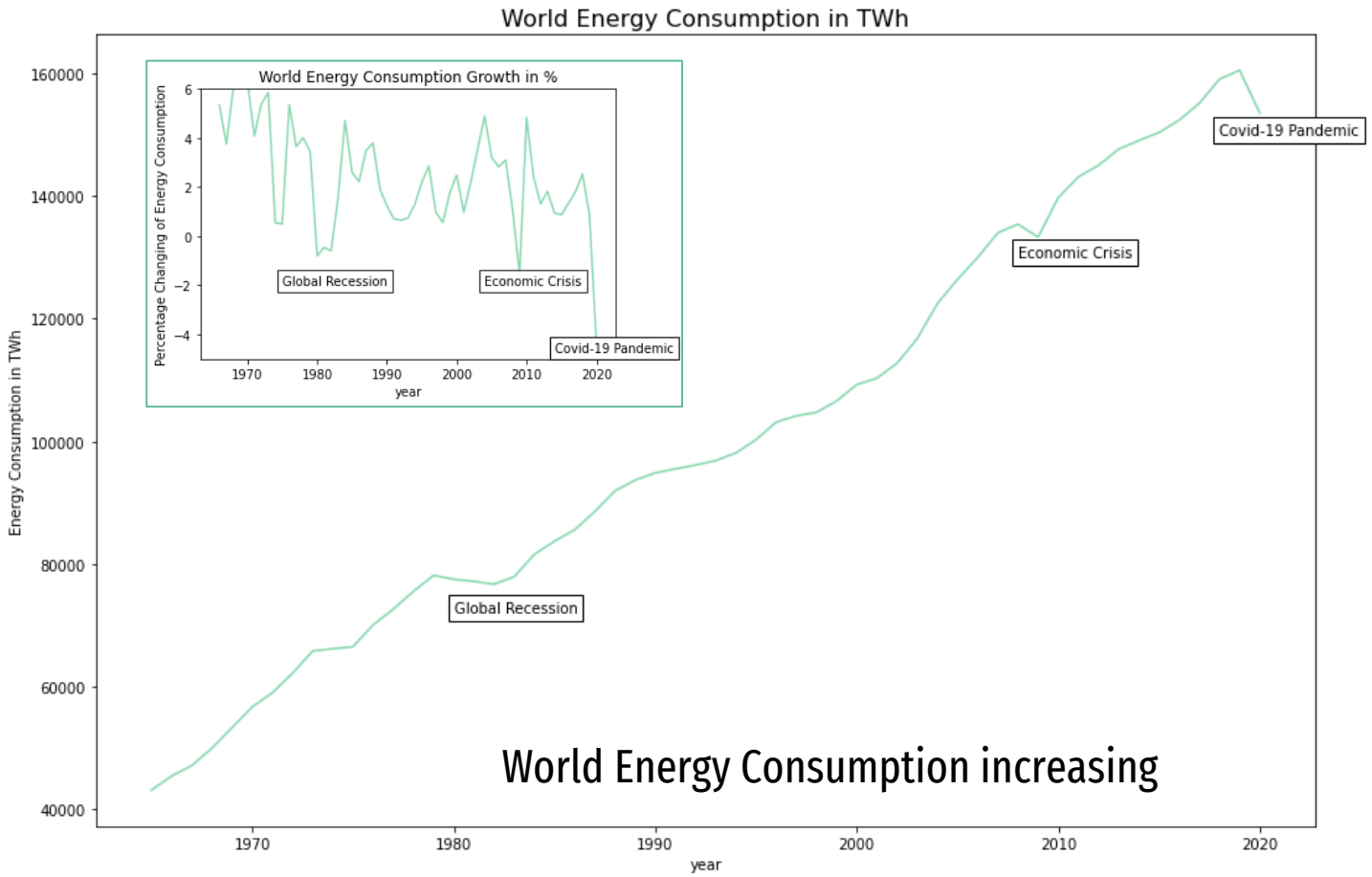
32% 2035

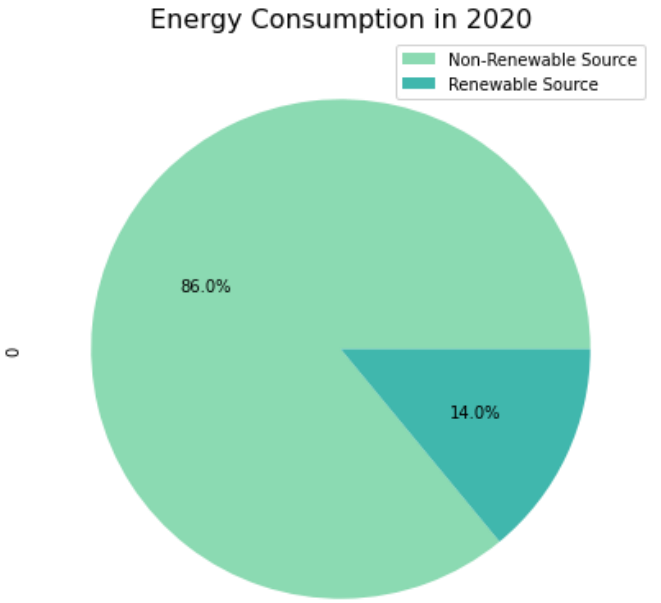
50% 2050

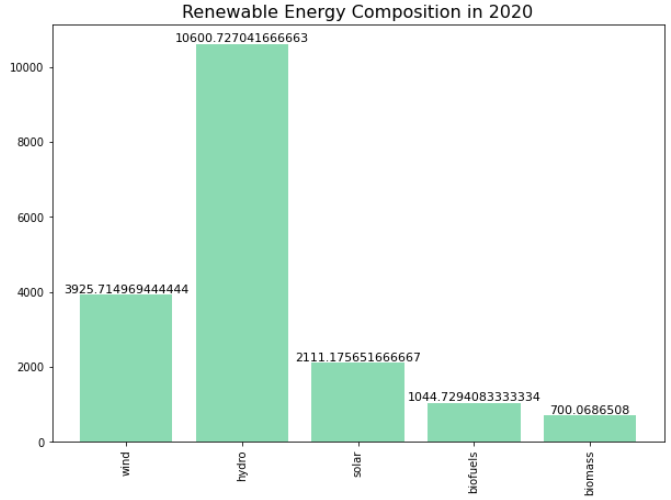
This analysis mainly provides insights into the longer-term trends that will continue to be essential in shaping future energy systems.

# Background

## Current Condition of Energy Consumption



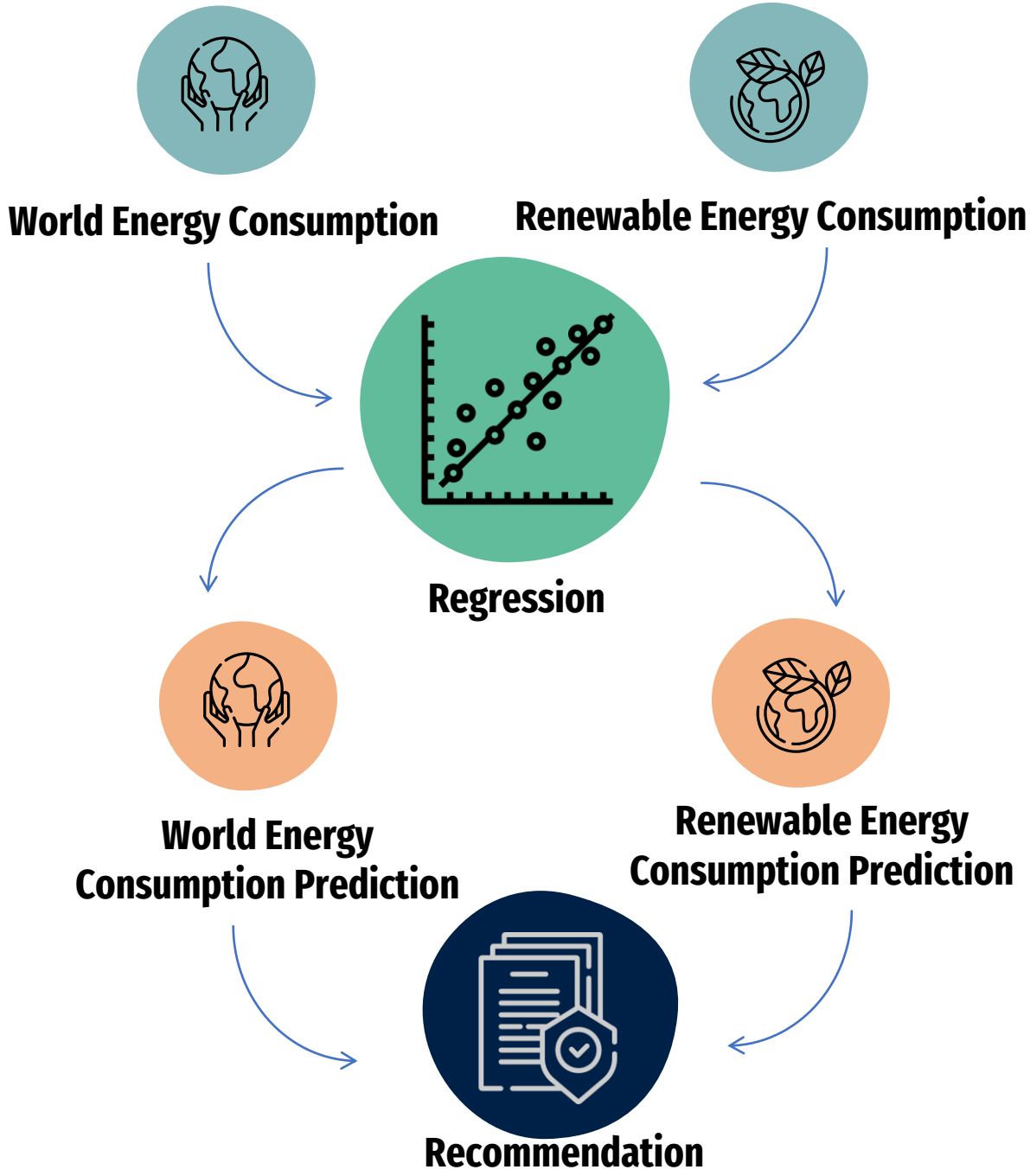



# Objective

Will the Energy Mix of renewable energy reach

32% in 2035 and 50% in 2050 ?

Getting insights into how have energy consumption changed.
Getting insights into how have renewable energy generation changed.



# About Data

Our World in Data

OXFORD MARTIN SCHOOL

UNIVERSITY OF OXFORD

GC DL

Dataset can be found on
https://ourworldindata.org/grapher/primary-sub-energy-source

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 5003 entries, 0 to 5002
Data columns (total 12 columns):
 #   Column                                Non-Null Count  Dtype
---  ------                                --------------  -----
 0   Entity                                5003 non-null   object
 1   Code                                  4219 non-null   object
 2   Year                                  5003 non-null   int64
 3   Wind Consumption - TWh                5003 non-null   float64
 4   Hydro Consumption - TWh               5003 non-null   float64
 5   Solar Consumption - TWh               5003 non-null   float64
 6   Nuclear Consumption - TWh             5003 non-null   float64
 7   Biofuels Consumption - TWh - Total    1085 non-null   float64
 8   Geo Biomass Other - TWh               5003 non-null   float64
 9   Coal Consumption - TWh                5003 non-null   float64
 10  Oil Consumption - TWh                 5003 non-null   float64
 11  Gas Consumption - TWh                 5003 non-null   float64
dtypes: float64(9), int64(1), object(2)
memory usage: 469.2+ KB
```

**Network of Central Banks and Supervisors for Greening the Financial System (NGFS).

This dataset outline the number of terawatt-hours (TWh) of energy consumed from 1965-2020 through various sources of energy.

Energy consumption by source datasets provides context about the quantity of energy required, how that is changing over time, and how we are doing in terms of transitioning from non-renewable to renewable energy use.

# Data Preprocessing

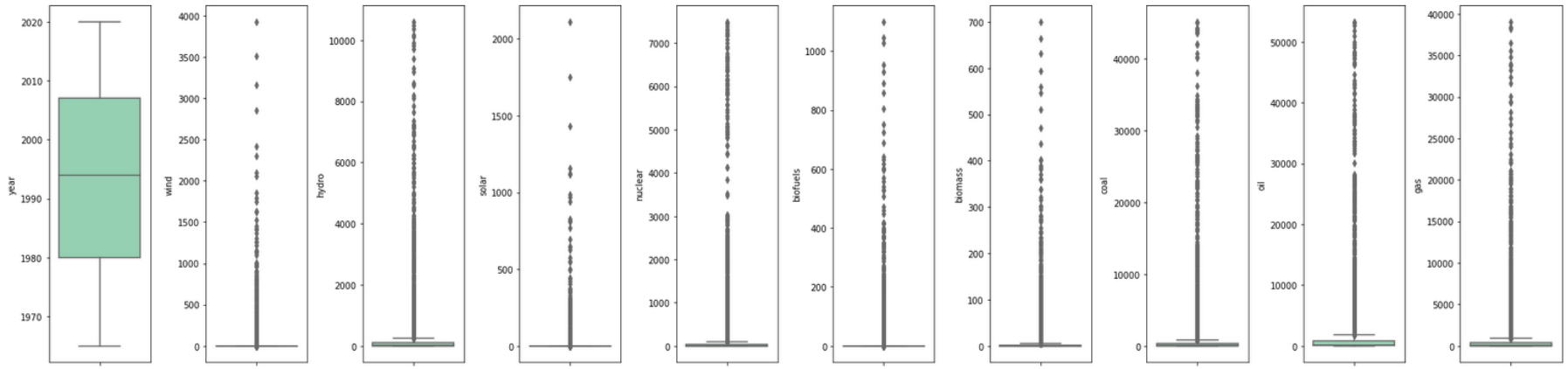
```
# missing values check
energy.isna().sum()
```

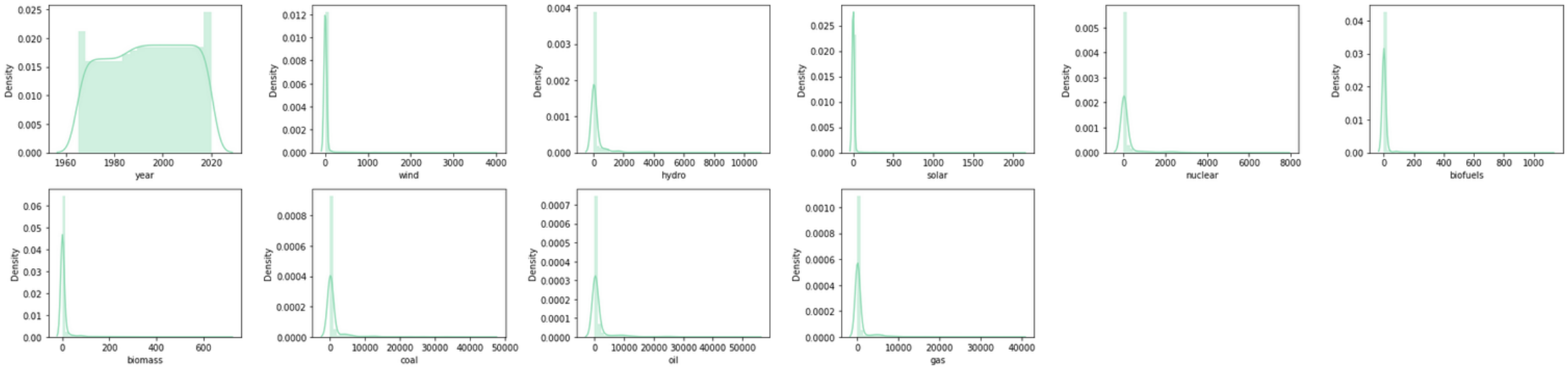
```
entity          0
code          784
year            0
wind            0
hydro           0
solar           0
nuclear         0
biofuels     3918
biomass         0
coal            0
oil             0
gas             0
```

Drop

Fill with 0 (Zero)

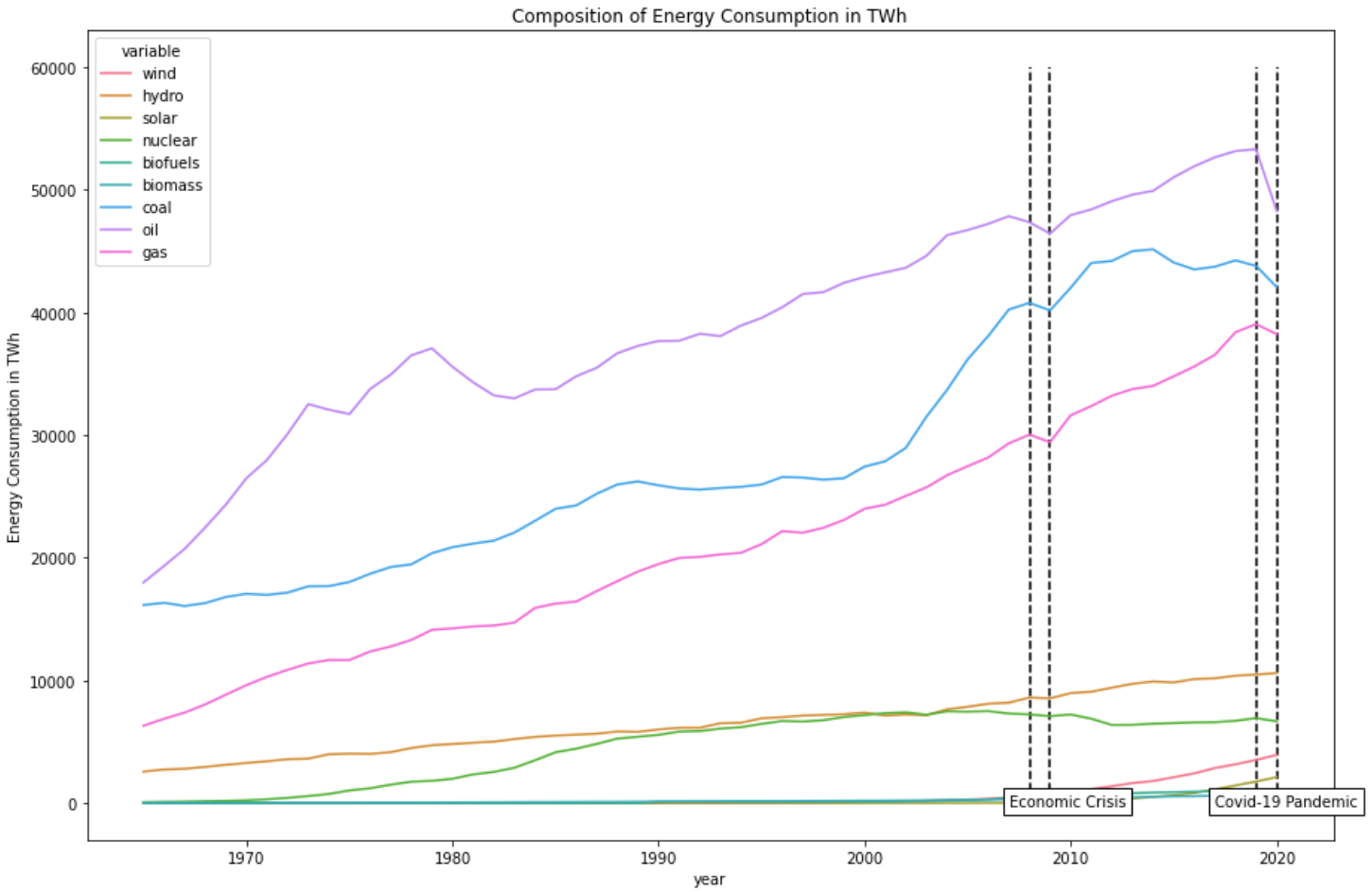
No duplicated row found.



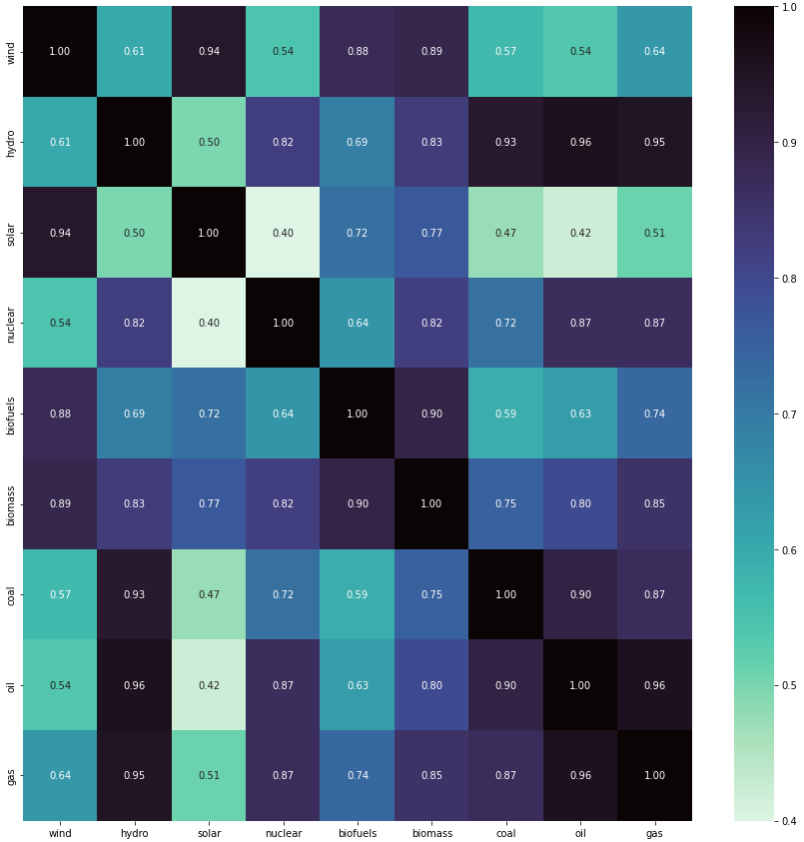



# Exploratory Data Analysis

## Total Energy Consumption



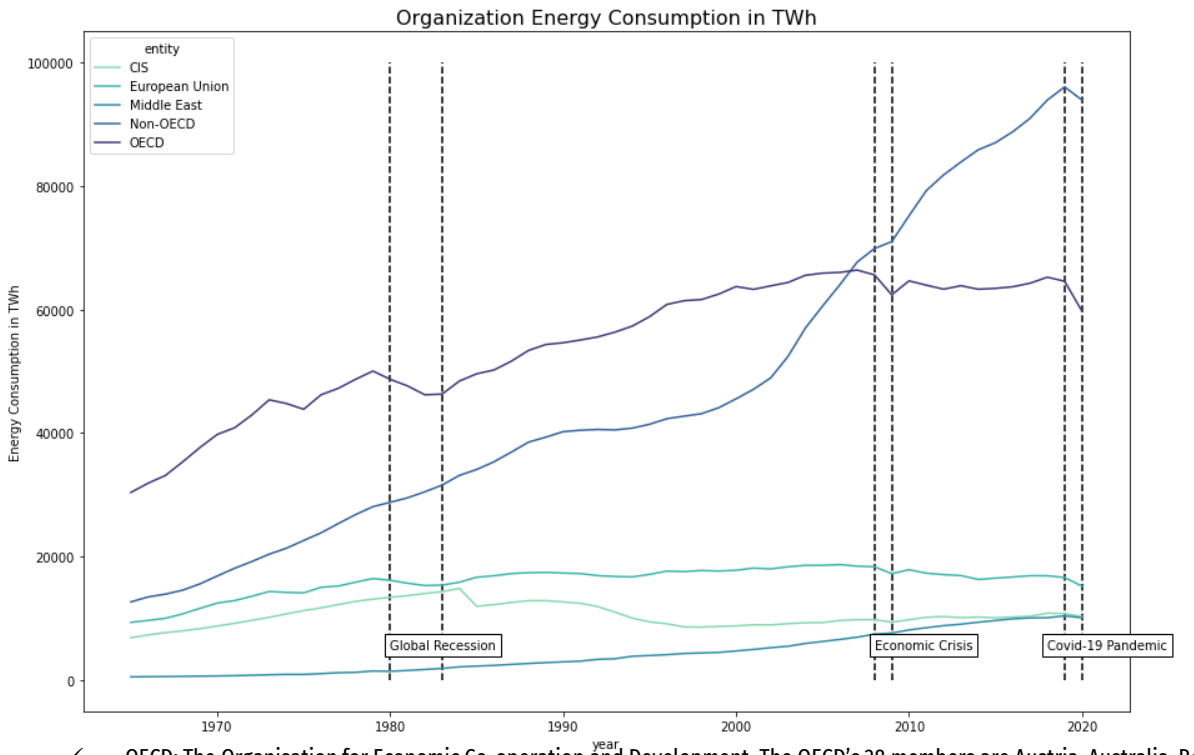

The Majority of energy consumption is coal, oil, and gas.
Renewable energy sources do not affect by the economic condition.

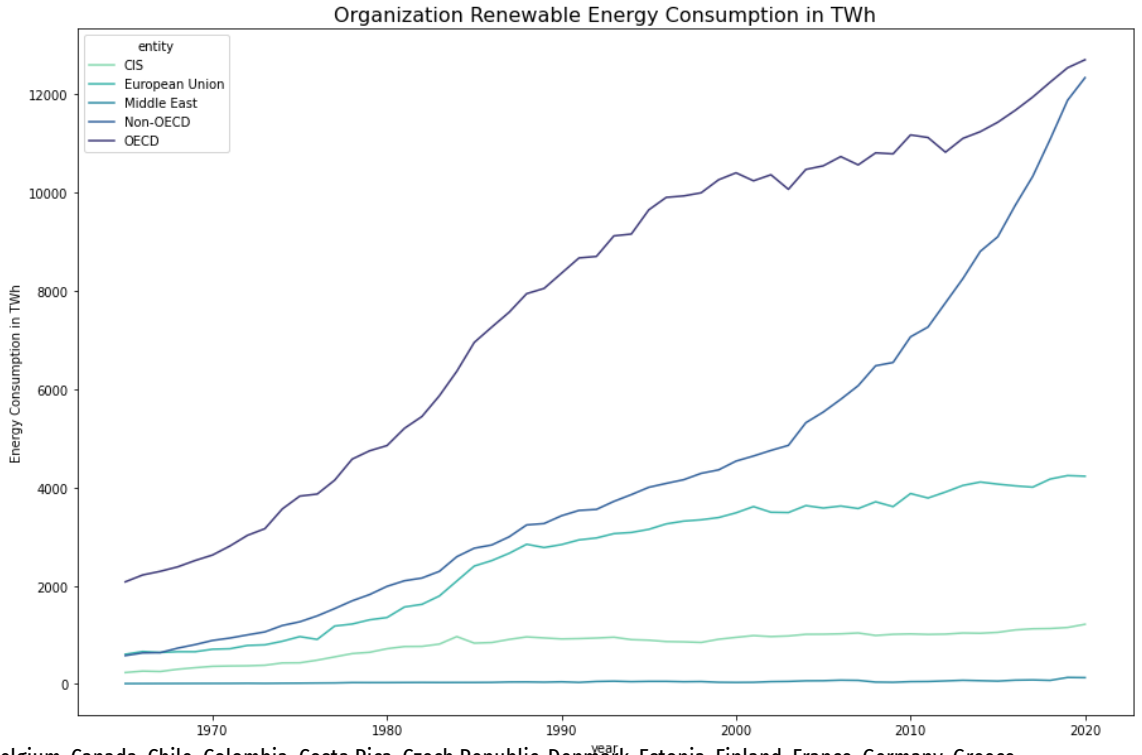



Observation:
1. Wind energy is highly correlated with solar, biofuels, and biomass
2. Hydro is highly correlated with gas, oil, coal, nuclear.
3. Solar energy is highly correlated with wind.
4. Nuclear is highly correlated with gas, oil, biomass, and wind.
5. Biofuel is highly correlated with biomass and wind.
6. Biomass is highly correlated with gas, oil, biofuels, nuclear, and wind.
7. Coal is highly correlated with gas, oil, and hydro.
8. Oil is highly correlated with gas, coal, biomass, nuclear, and hydro.
9. Gas is highly correlated with oil, coal, biomass, biofuels, nuclear, and hydro.

# Exploratory Data Analysis

## Organization Energy Consumption



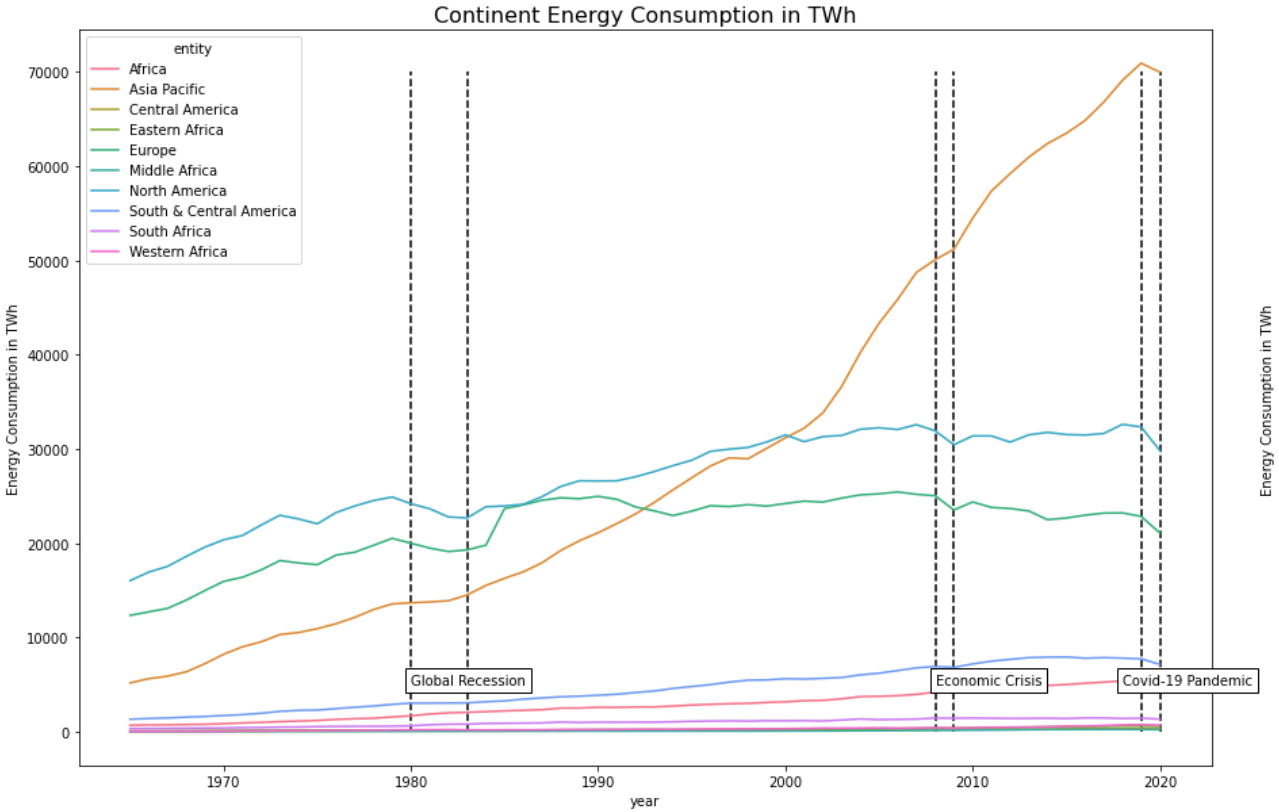



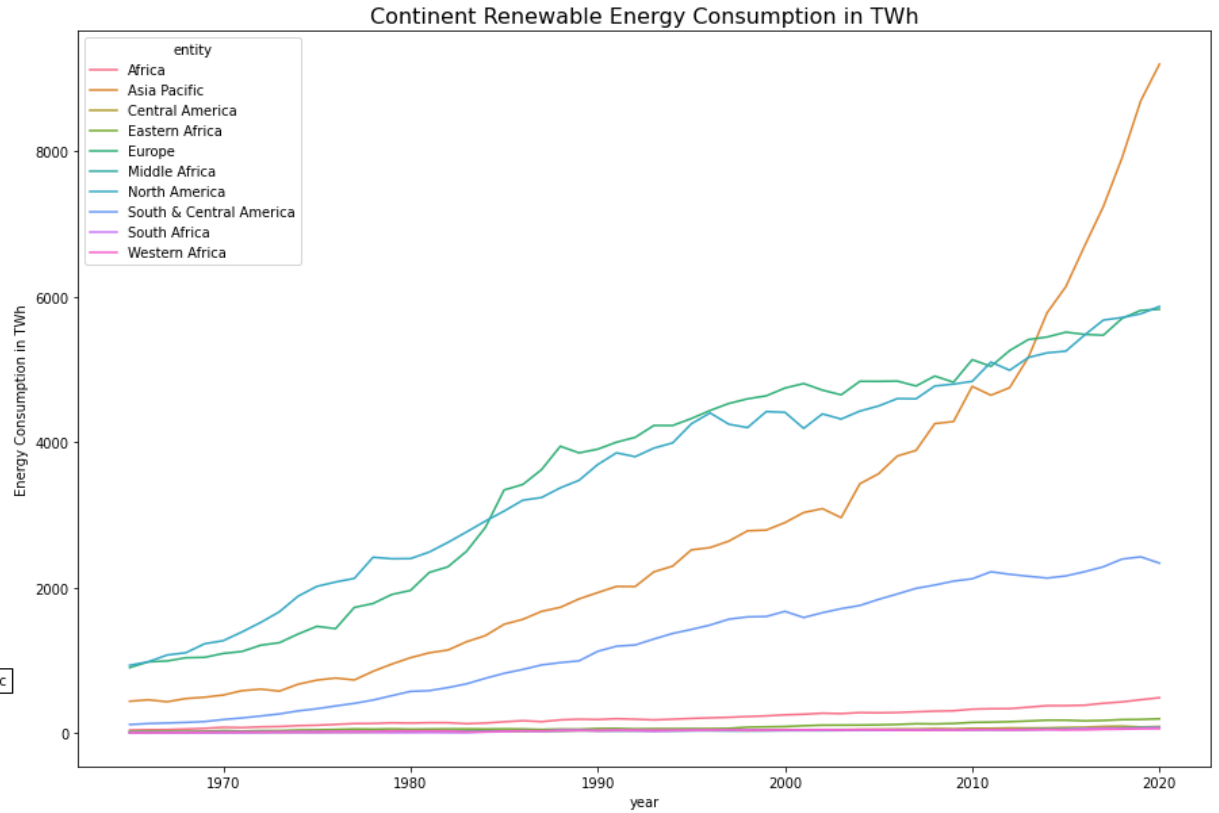

- ✓ OECD: The Organisation for Economic Co-operation and Development. The OECD's 38 members are Austria, Australia, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.
- ✓ CIS: Commonwealth of Independent States (CIS) Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan

The majority of energy use was by OECD countries (countries in Europe and the US) but since 2008 the value has been followed by Non-OECD with the development of industry and shifting manufacturing in Non-OECD countries, especially Asia Pacific. Meanwhile, the use of renewable energy is still being led by OECD countries if seen because a lot of research is being carried out in that country.

# Exploratory Data Analysis

## Continent Energy Consumption

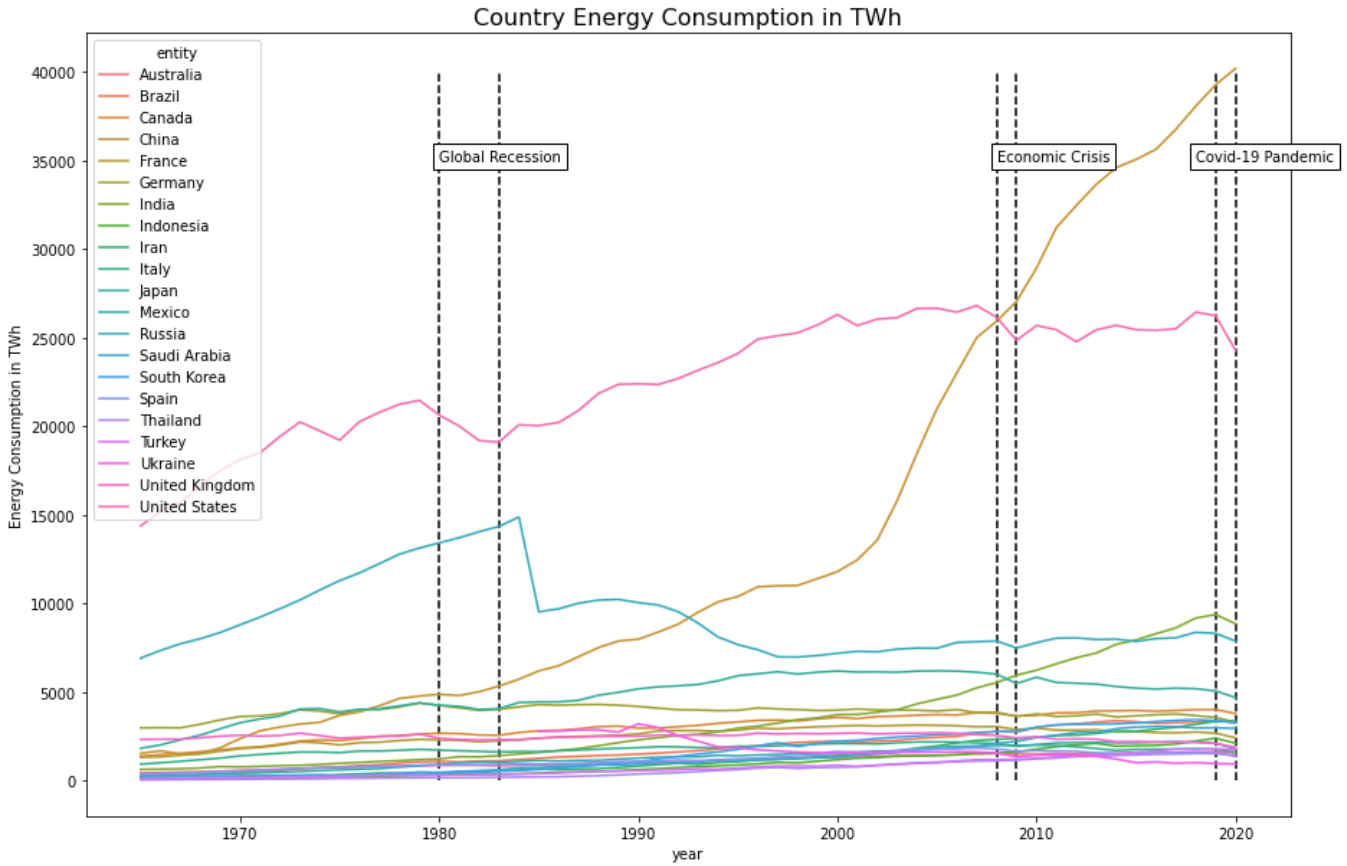



As for the energy consumption of each continent, the highest in the Asia Pacific, this is due to the shifting of the manufacturing area to Asia. Meanwhile, renewable energy is also the most abundant in the Asia Pacific because there is significant growth in China and many other countries in the Asia Pacific that have ambitious projects and energy councils.

# Exploratory Data Analysis

## Country Total Energy Consumption

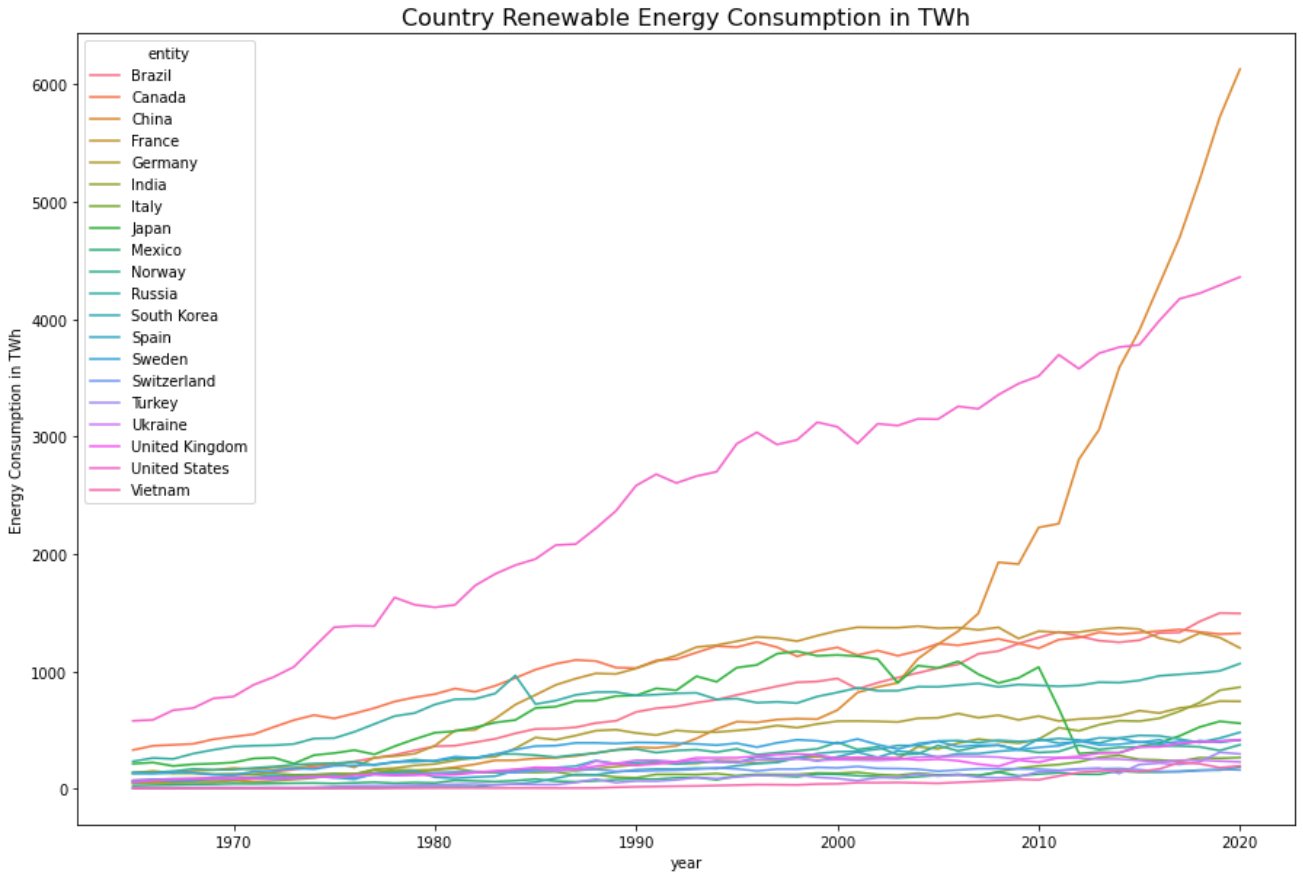



| Rank | entity | energy_total |
|---|---|---|
| 0 | World | 153593.345591 |
| 1 | China | 40205.612739 |
| 2 | United States | 24274.675985 |
| 3 | India | 8837.288286 |
| 4 | Russia | 7862.609703 |
| 5 | Japan | 4674.827030 |
| 6 | Canada | 3770.207007 |
| 7 | Iran | 3341.653124 |
| 8 | Germany | 3289.622781 |
| 9 | Brazil | 3254.323685 |
| 10 | South Korea | 3248.875830 |
| 11 | Saudi Arabia | 2933.478211 |
| 12 | France | 2402.240415 |
| 13 | Indonesia | 2097.218126 |
| 14 | United Kingdom | 1857.330738 |
| 15 | Mexico | 1787.707571 |
| 16 | Turkey | 1725.107006 |
| 17 | Italy | 1590.959188 |
| 18 | Australia | 1541.826678 |
| 19 | Thailand | 1401.757539 |
| 20 | Spain | 1371.654702 |

The country with the highest energy consumption is in China and followed by the US. The US rate is fixed because industrialization is already saturated. When viewed from the rank of 20 countries, it can be seen that 18 countries with the highest energy consumption are G20 countries, so energy consumption is influenced by GDP.

# Exploratory Data Analysis

## Renewable Energy Consumption



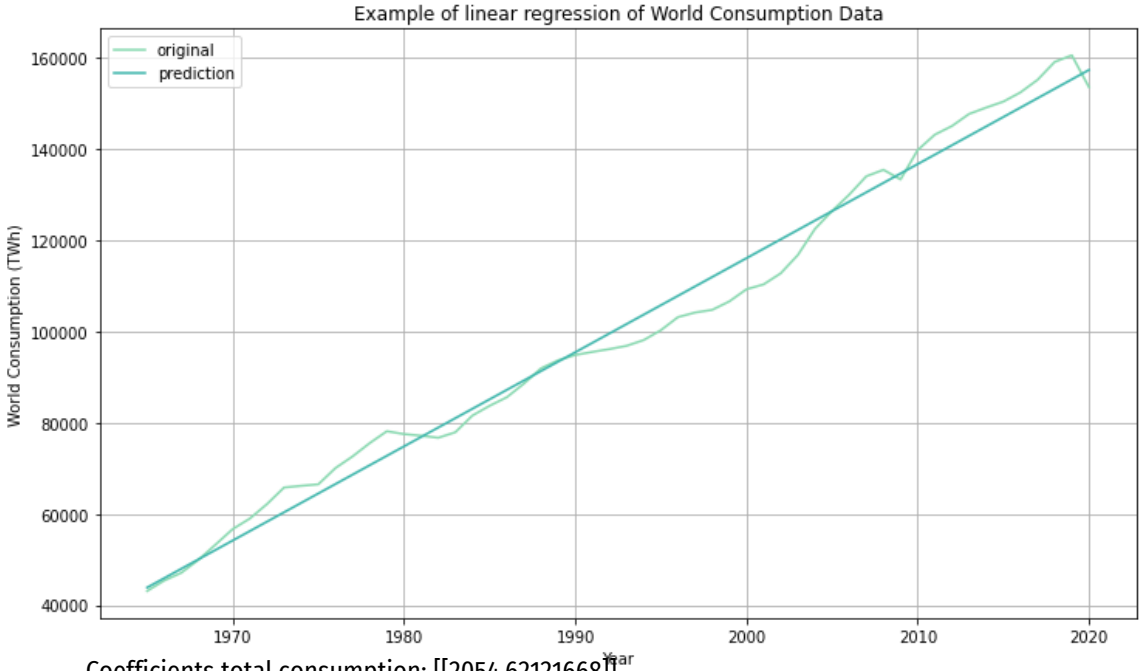

| Rank | entity | renewable_total |
|---|---|---|
| 0 | World | 25043.893091 |
| 1 | China | 6130.451370 |
| 2 | United States | 4359.180480 |
| 3 | Brazil | 1492.653525 |
| 4 | Canada | 1322.788200 |
| 5 | France | 1197.974574 |
| 6 | Russia | 1064.712358 |
| 7 | India | 864.077589 |
| 8 | Germany | 742.805675 |
| 9 | Japan | 556.049624 |
| 10 | South Korea | 478.807054 |
| 11 | United Kingdom | 415.841831 |
| 12 | Spain | 414.613605 |
| 13 | Sweden | 412.050931 |
| 14 | Norway | 372.789358 |
| 15 | Turkey | 294.636075 |
| 16 | Italy | 264.279221 |
| 17 | Ukraine | 226.920137 |
| 18 | Vietnam | 193.468097 |
| 19 | Mexico | 182.094024 |
| 20 | Switzerland | 158.546115 |

As for renewable energy, the highest is in China and followed by the United States. The amount of renewable energy is influenced by state policy and R&D, as well as global pressure.

# Modeling

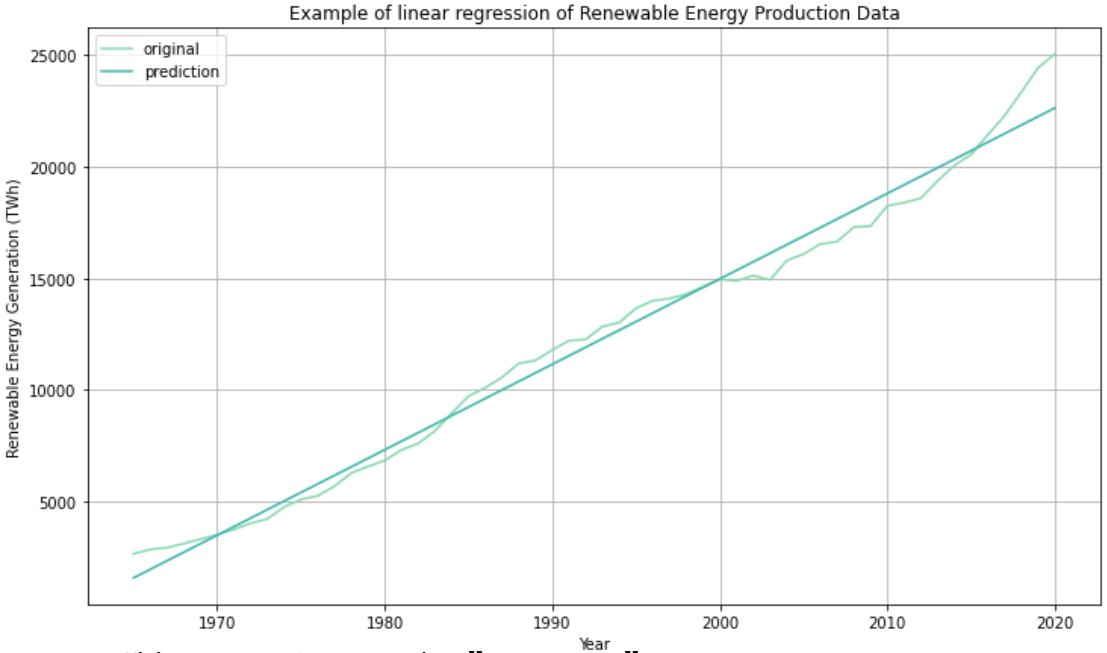
## Simple Linear Regression

### Baseline Model




Coefficients total consumption: [[2054.62121668]]
Intercept total consumption: -3993548.2297531567
Residual sum of squares: 2741072224.02
Variance score: 0.99

MAE: 4040.9212110047374
MAPE: 0.038681099829852 34
RMSE: 4501.132771395035

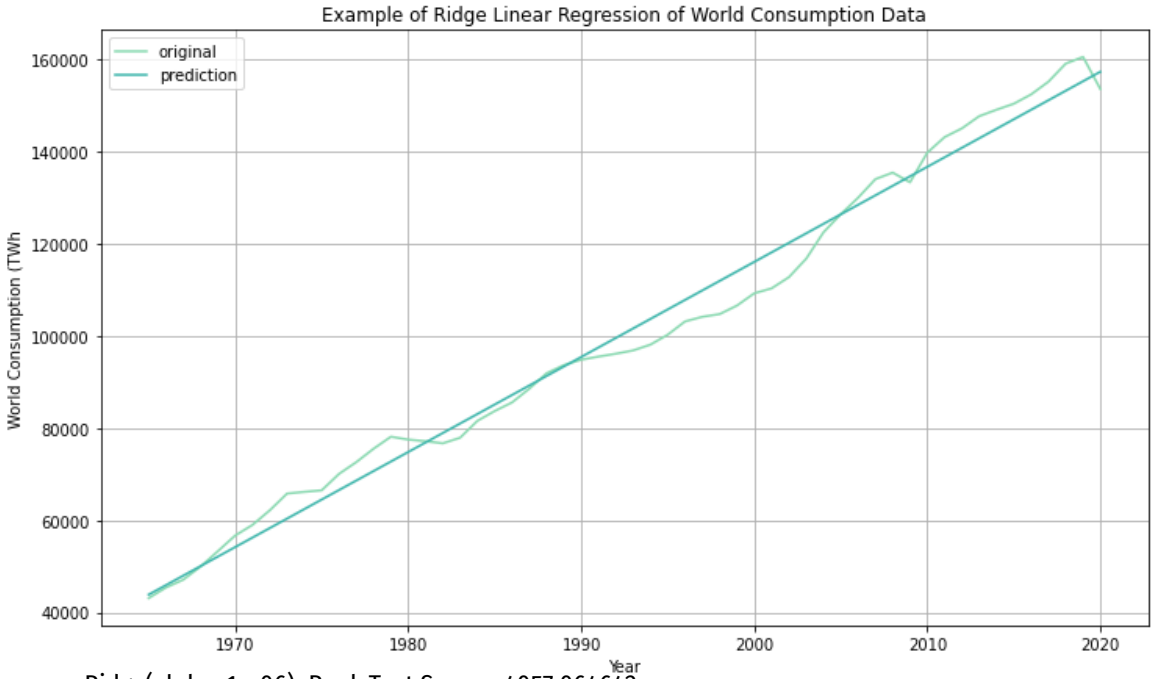



Coefficients renewable generation: [[370.80997815]]
Intercept renewable generation: -726820.4748541047
Residual sum of squares:117594821.66
Variance score: 0.99

MAE: 972.6329378142814
MAPE: 0.08567532132870648
RMSE: 1318.5432554145223

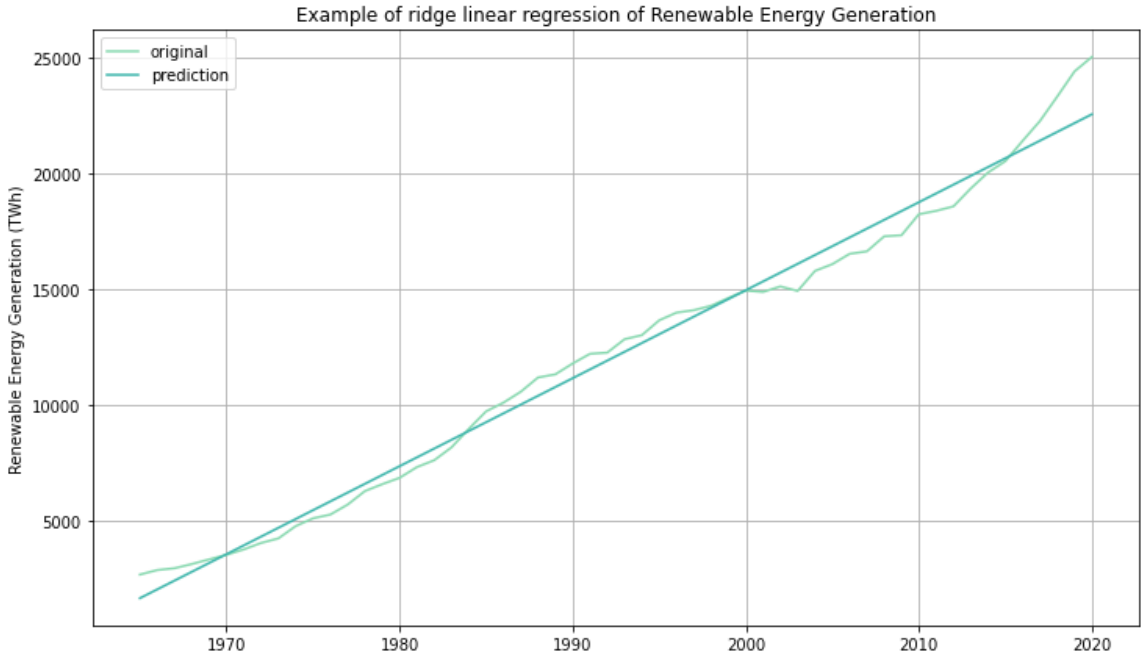
# Modeling

## Ridge Regression




Ridge(alpha=1e-06), Rank Test Score: -4057.064642
Coefficients world consumption : [[2054.62121647]]
Intercept world consumption: [-3993548.22933293]

MAE: 4040.921211327712
MAPE: 0.03868109983041363
RMSE: 4501.1327717306785

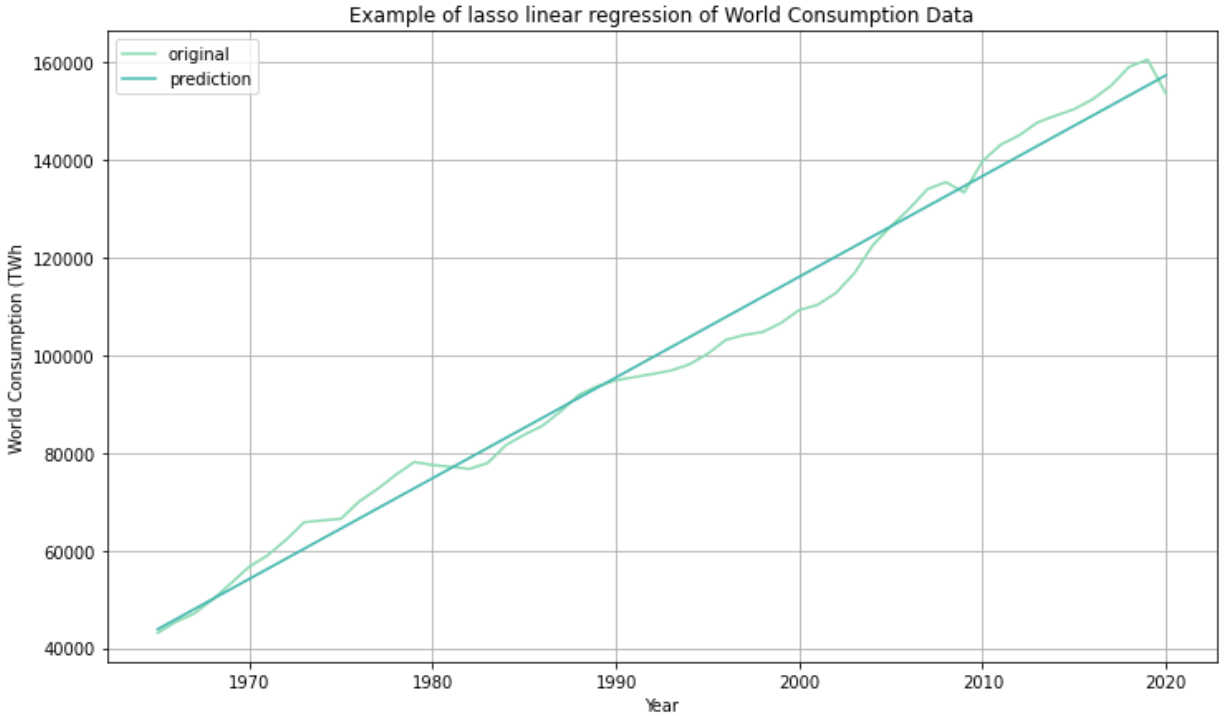



Ridge(alpha=20), Rank Test Score: -564.169196
Coefficients renewable generation : [[370.04985967]]
Coefficients renewable generation: [-725306.76801097]

MAE: 979.5488642505542
MAPE: 0.08601418509642077
RMSE: 1327.4182736359692

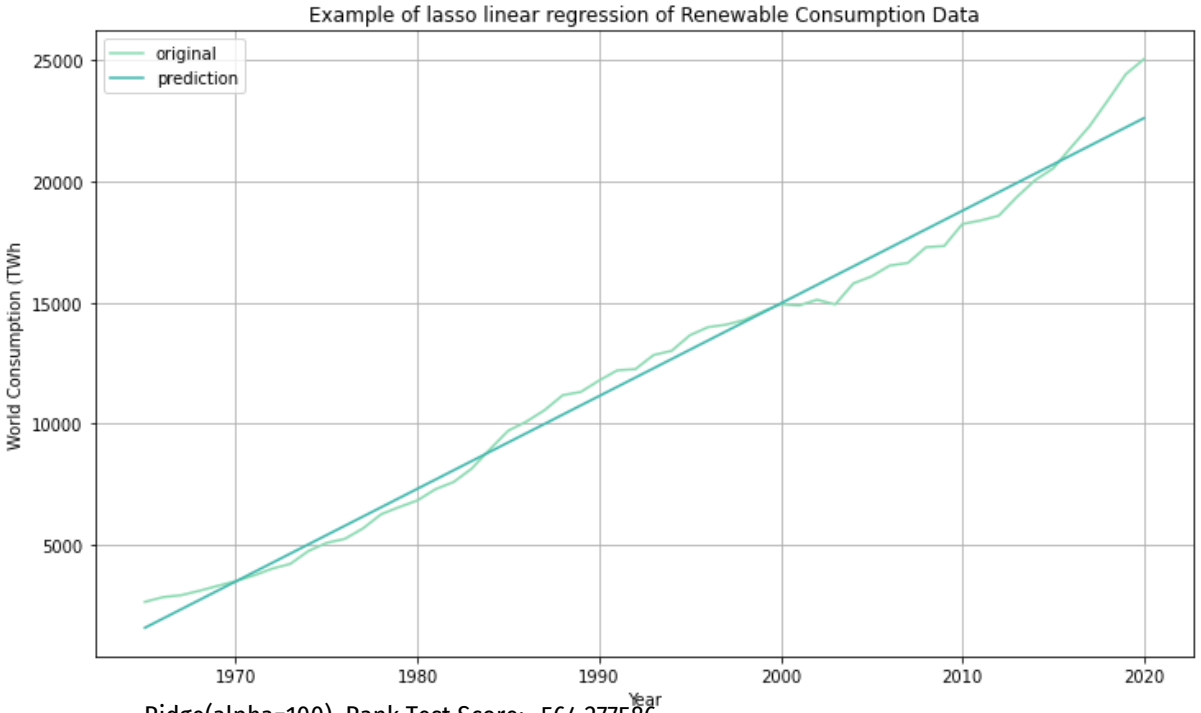
# Modeling

## Lasso Regression




Ridge(alpha=1e-06), Rank Test Score: -4057.064642
Coefficients world consumption : [2054.62121667]
Intercept world consumption: [-3993548.22974416]

MAE: 4040.9212110116446
MAPE: 0.03868109829864764
RMSE: 4501.132771402146



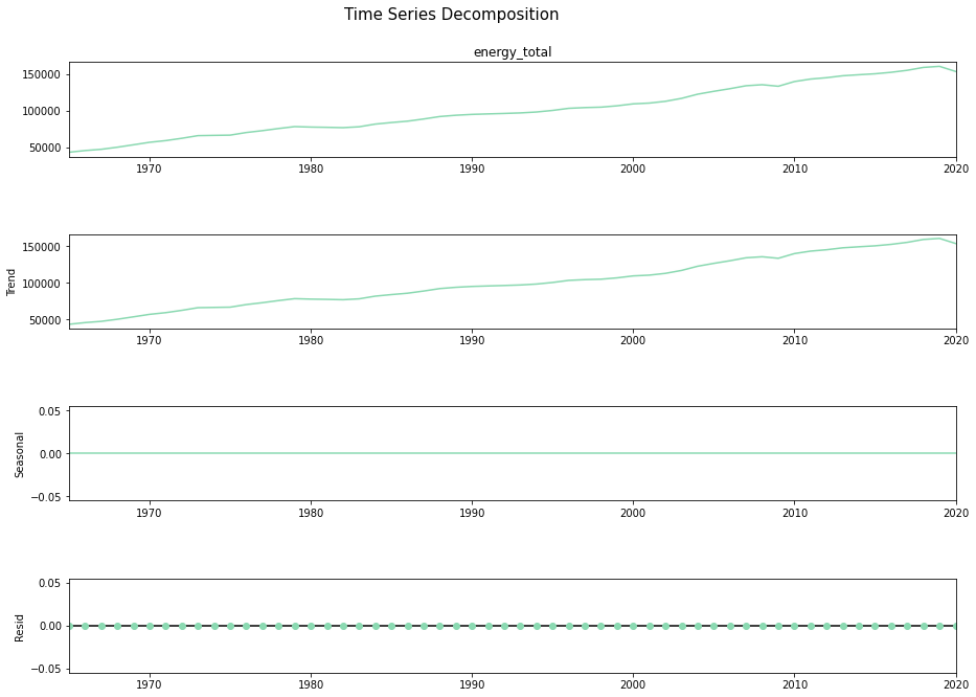

Ridge(alpha=100), Rank Test Score: -564.277586
Coefficients renewable generation : [[370.04985967]]
Coefficients renewable generation: [-725306.76801097]

MAE: 976.7445562252132
MAPE: 0.08601418509642077
RMSE: 1327.4182736359692

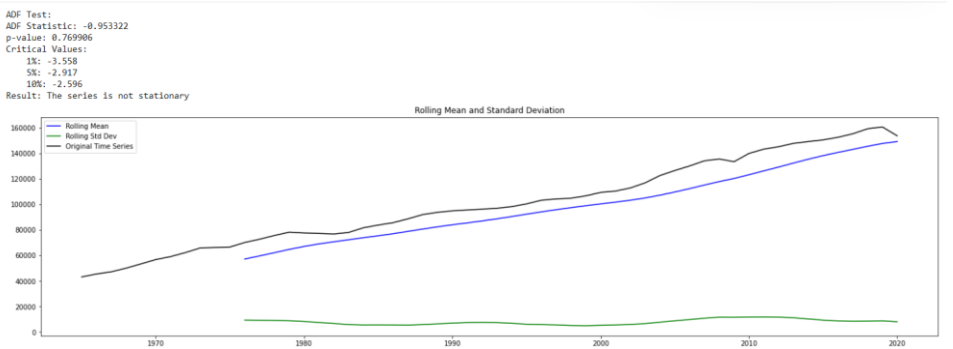
# Modeling

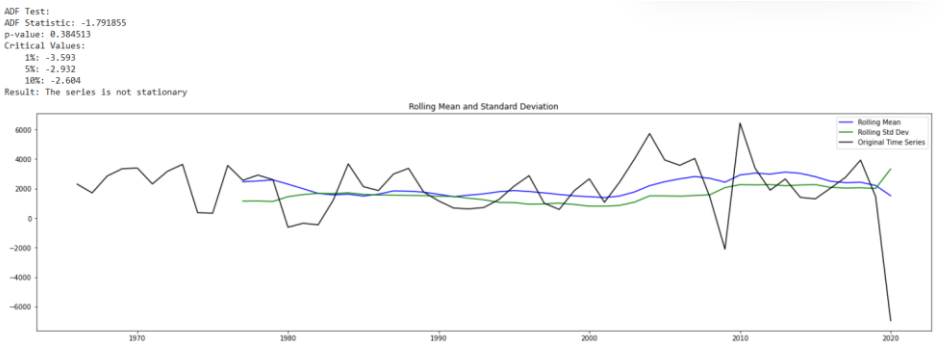
## Time Series

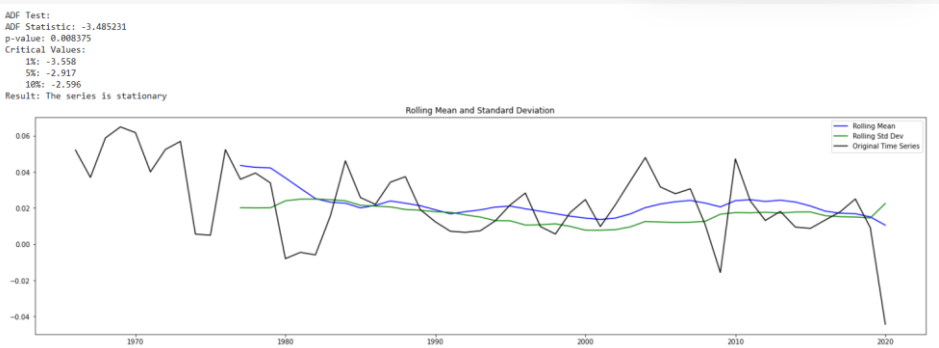
## World Energy Consumption



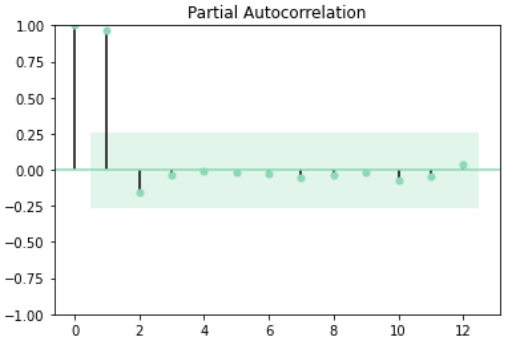

Data has trend and no seasonality

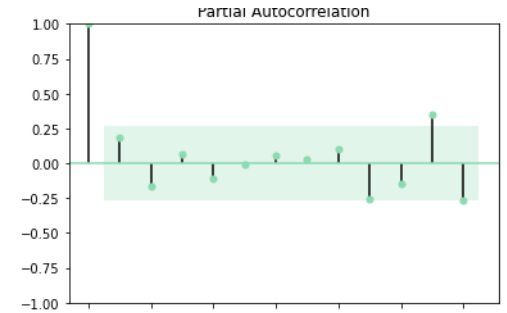


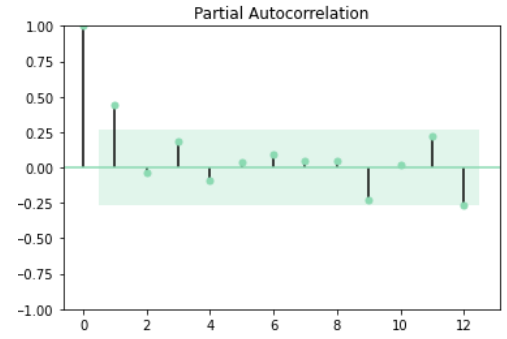




Data is stationary



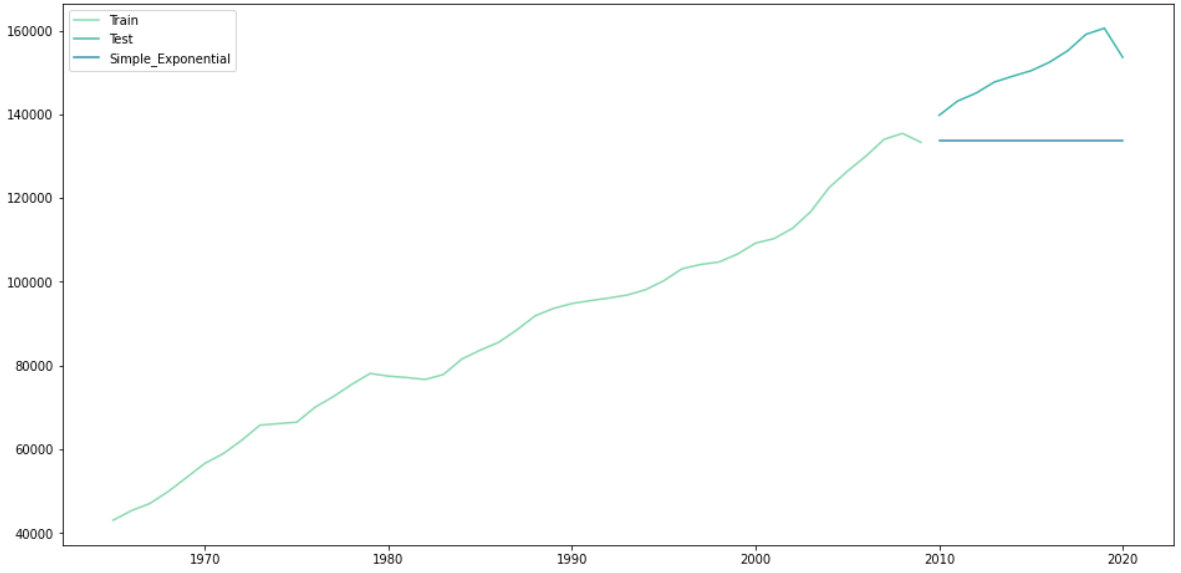



# Modeling

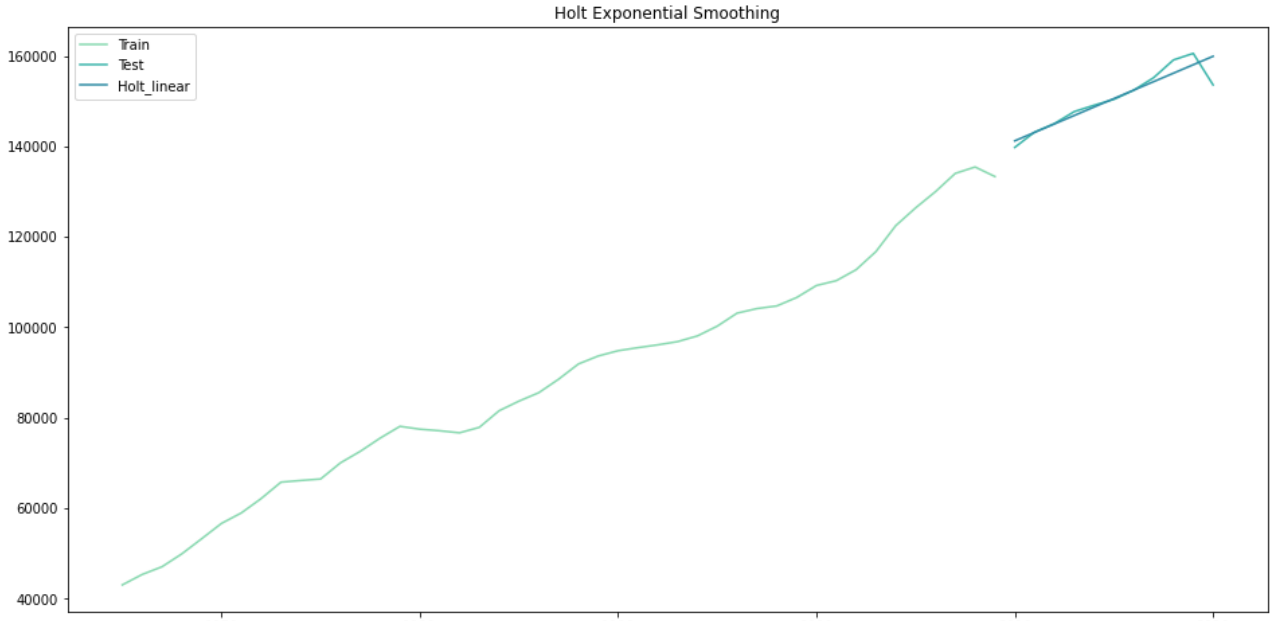
## Time Series – Simple Exponential Smoothing & Holt Exponential Smoothing

### World Energy Consumption




Simple Exponential Smoothing Level :- 0.75

MAE: 16853.851587644545
MAPE: 0.11045592786770939
RMSE: 17948.114379130744




Holt's Exponential Smoothing RMS : 2307.102 & Smoothing Level :- 0.3 & Smoothing Slope :- 0.85

MAE: 1423.591457612474
MAPE: 0.009258938683930953
RMSE: 2307.102195531802

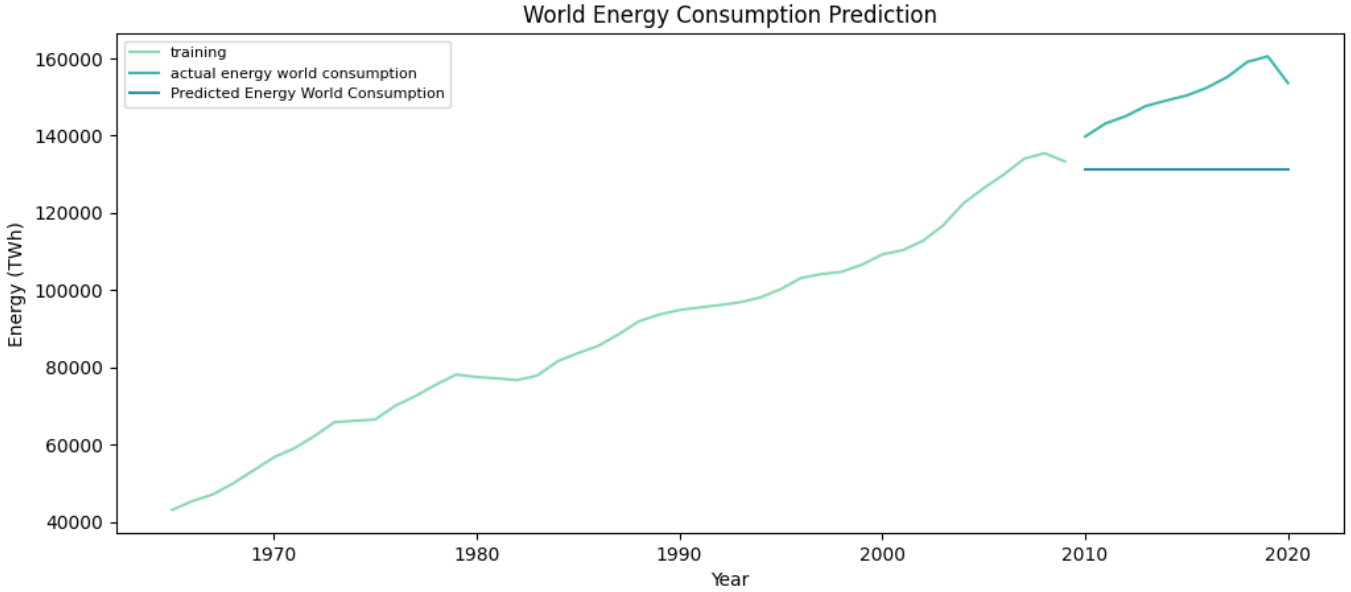
# Modeling

## ARIMA

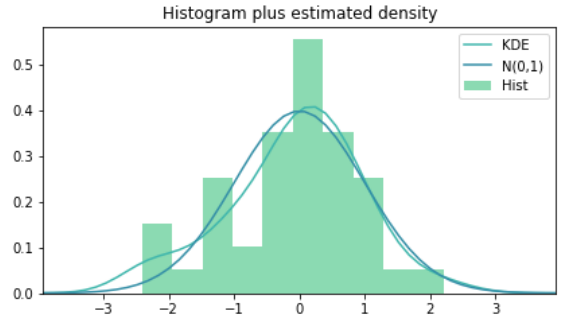
## World Energy Consumption

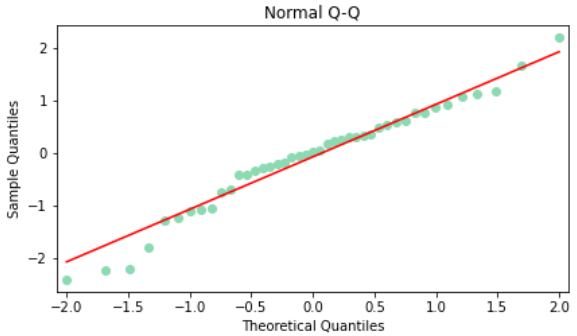
```
Best model:  ARIMA(0,2,0)(0,0,0)[0]
Total fit time: 0.179 seconds
                               SARIMAX Results
==============================================================================
Dep. Variable:                      y   No. Observations:                   45
Model:               SARIMAX(0, 2, 0)   Log Likelihood                -374.651
Date:                Thu, 19 May 2022   AIC                            751.303
Time:                        10:53:59   BIC                            753.064
Sample:                             0   HQIC                           751.952
                                  - 45
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
sigma2      2.16e+06   4.41e+05      4.903      0.000     1.3e+06    3.02e+06
===================================================================================
Ljung-Box (L1) (Q):                   0.06   Jarque-Bera (JB):                 1.25
Prob(Q):                              0.80   Prob(JB):                         0.53
Heteroskedasticity (H):               1.06   Skew:                            -0.41
Prob(H) (two-sided):                  0.91   Kurtosis:                         3.11
===================================================================================
```

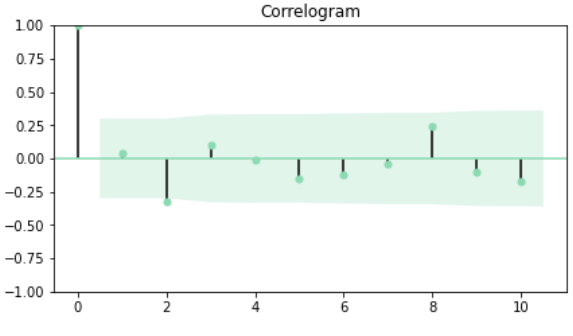
MAE: 132815.78191329486
MAPE: 0.8820595430524025
RMSE: 132959.07047534556







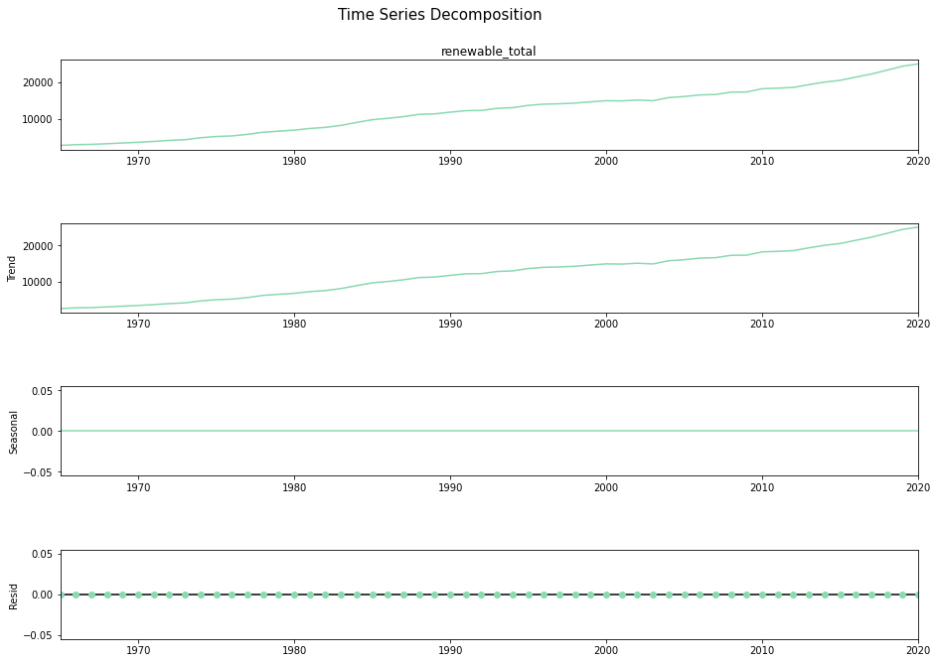



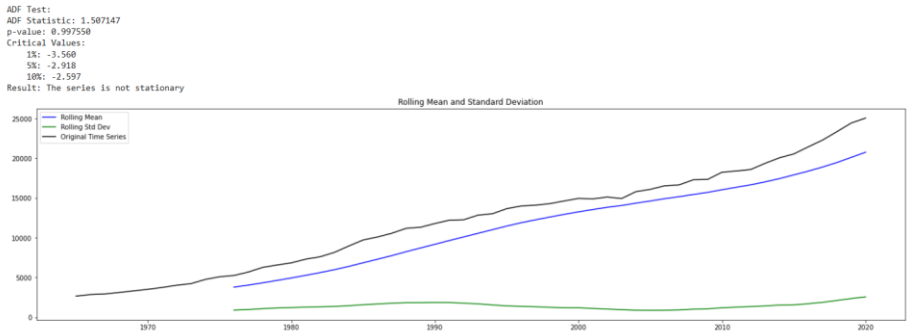
# Modeling

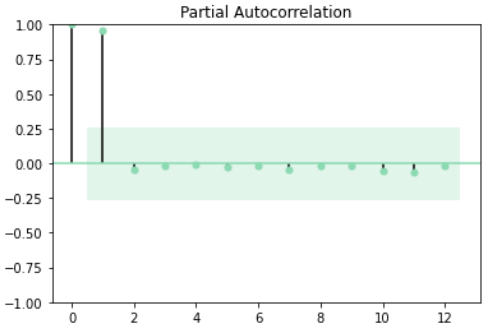
## Time Series

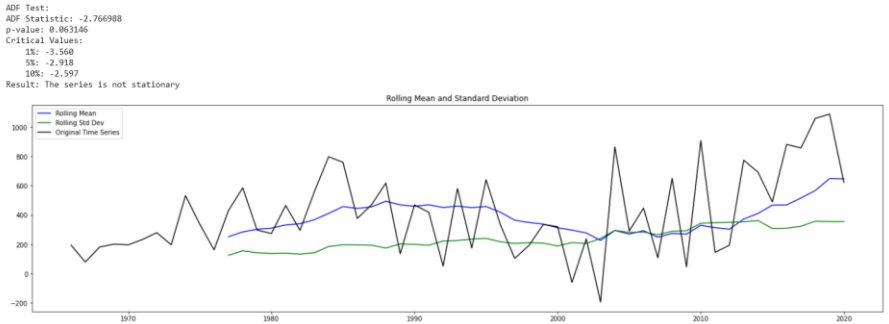
## Renewable Energy Consumption

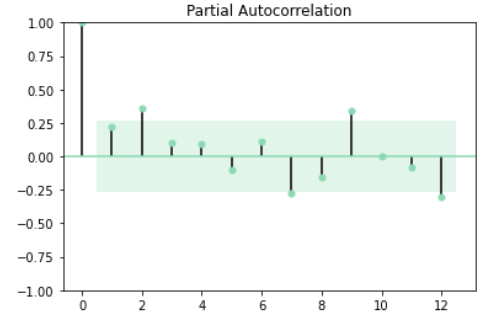


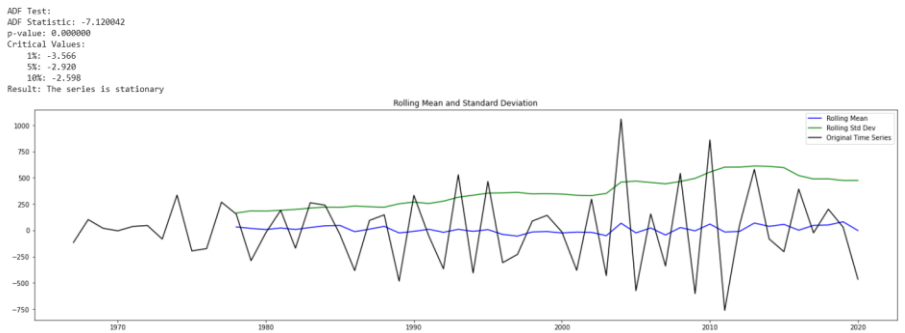

Data has trend and no seasonality

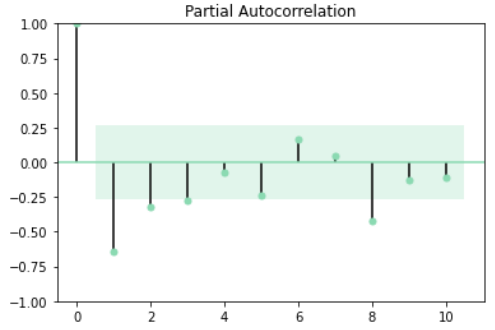


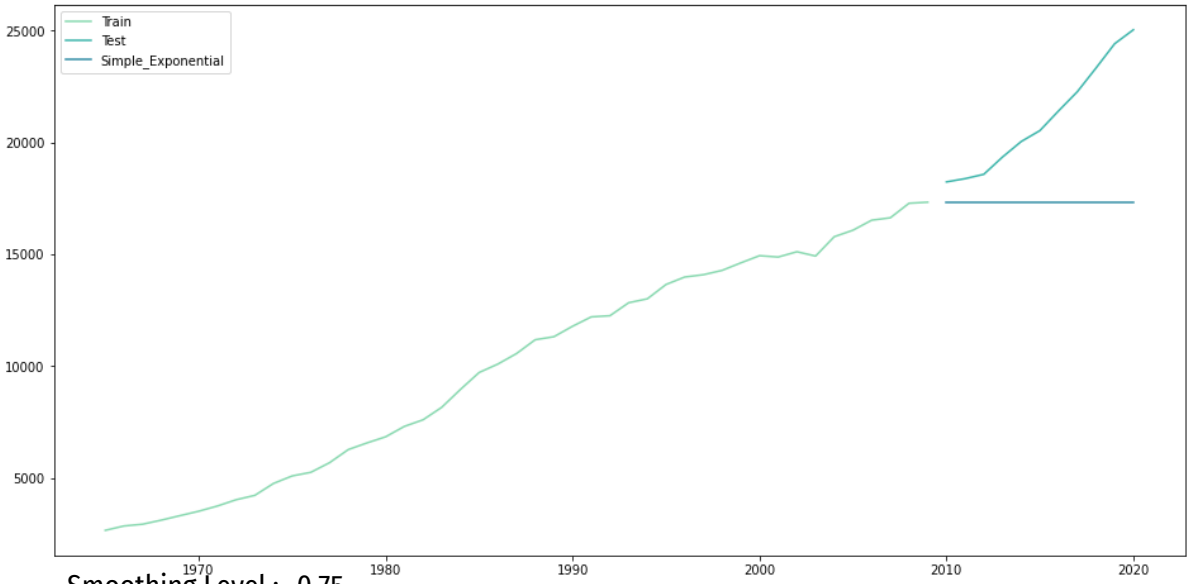




Data is stationary

# Modeling

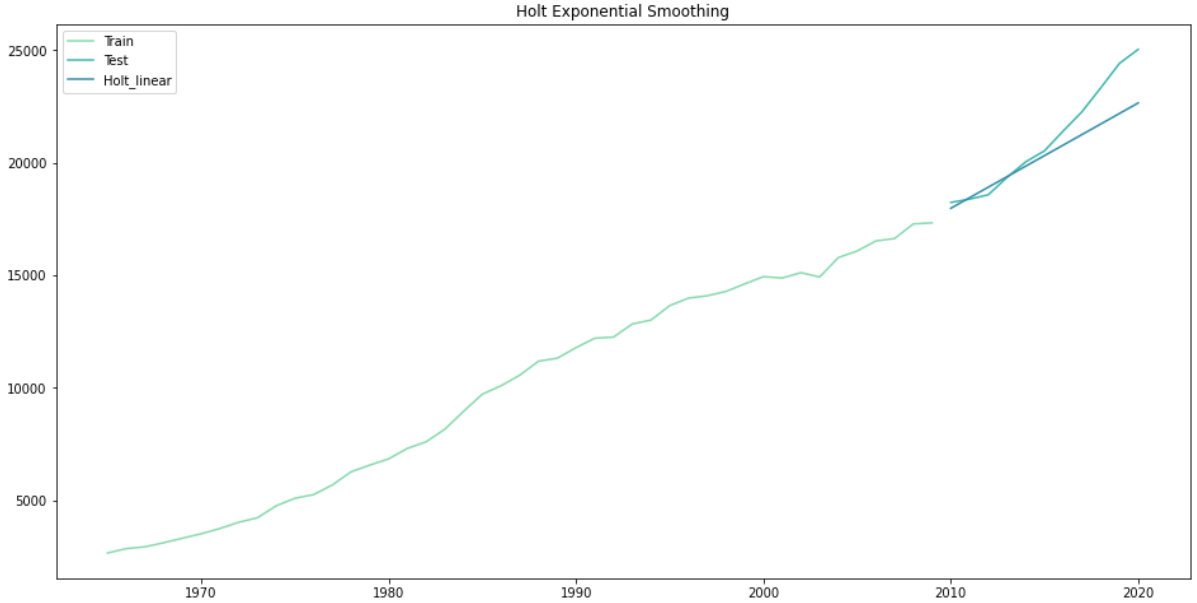
## Time Series – Simple Exponential Smoothing & Holt Exponential Smoothing

### Renewable Energy Consumption




Smoothing Level :- 0.75

MAE: 16853.851587644545
MAPE: 0.11045592786770939
RMSE: 17948.114379130744




Holt's Exponential Smoothing Smoothing Slope :- 1.0

MAE: 814.1174943085418
MAPE: 0.03522427607653008
RMSE: 1164.0991406934272

# Modeling

## ARIMA

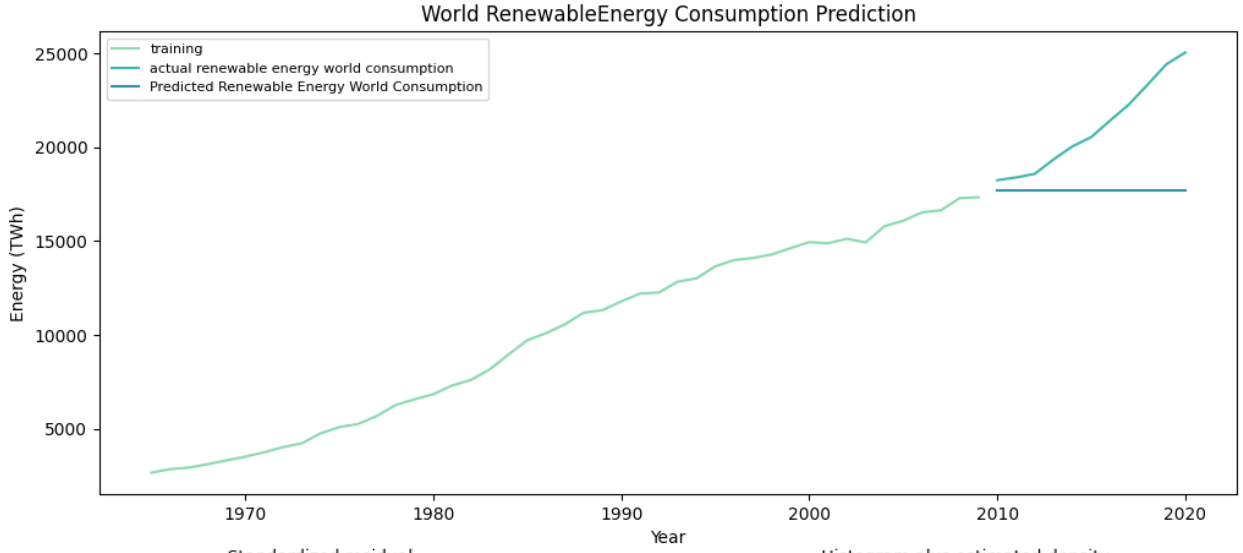
## Renewable Energy

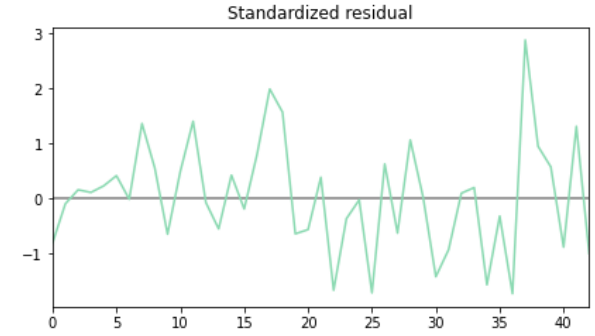
```
Best model:  ARIMA(1,2,1)(0,0,0)[0]
Total fit time: 1.783 seconds
                               SARIMAX Results
==============================================================================
Dep. Variable:                      y   No. Observations:                   45
Model:               SARIMAX(1, 2, 1)   Log Likelihood                -294.771
Date:                Thu, 19 May 2022   AIC                            595.543
Time:                        11:11:23   BIC                            600.826
Sample:                             0   HQIC                           597.491
                                  - 45
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1         -0.3100      0.212     -1.466      0.143      -0.725       0.105
ma.L1         -0.7087      0.141     -5.010      0.000      -0.986      -0.431
sigma2      5.082e+04   1.11e+04      4.564      0.000     2.9e+04    7.26e+04
===================================================================================
Ljung-Box (L1) (Q):                   0.01   Jarque-Bera (JB):                 0.97
Prob(Q):                              0.91   Prob(JB):                         0.61
Heteroskedasticity (H):               3.56   Skew:                             0.36
Prob(H) (two-sided):                  0.02   Kurtosis:                         3.19
===================================================================================
```

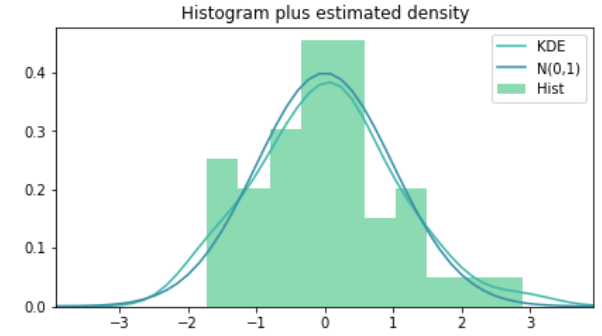
MAE: 132815.78191329486

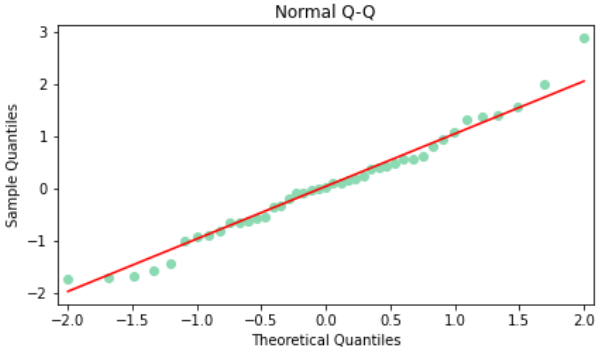
MAPE: 0.8820595430524025

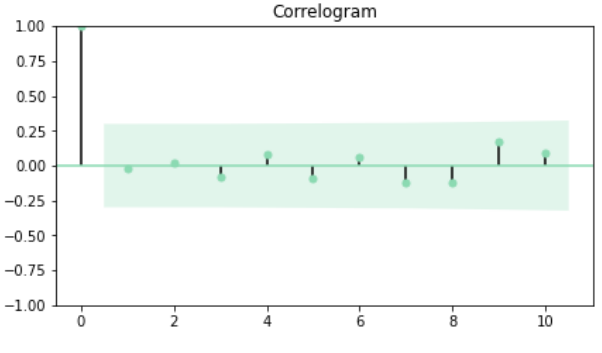
RMSE: 132959.07047534556



# Evaluation

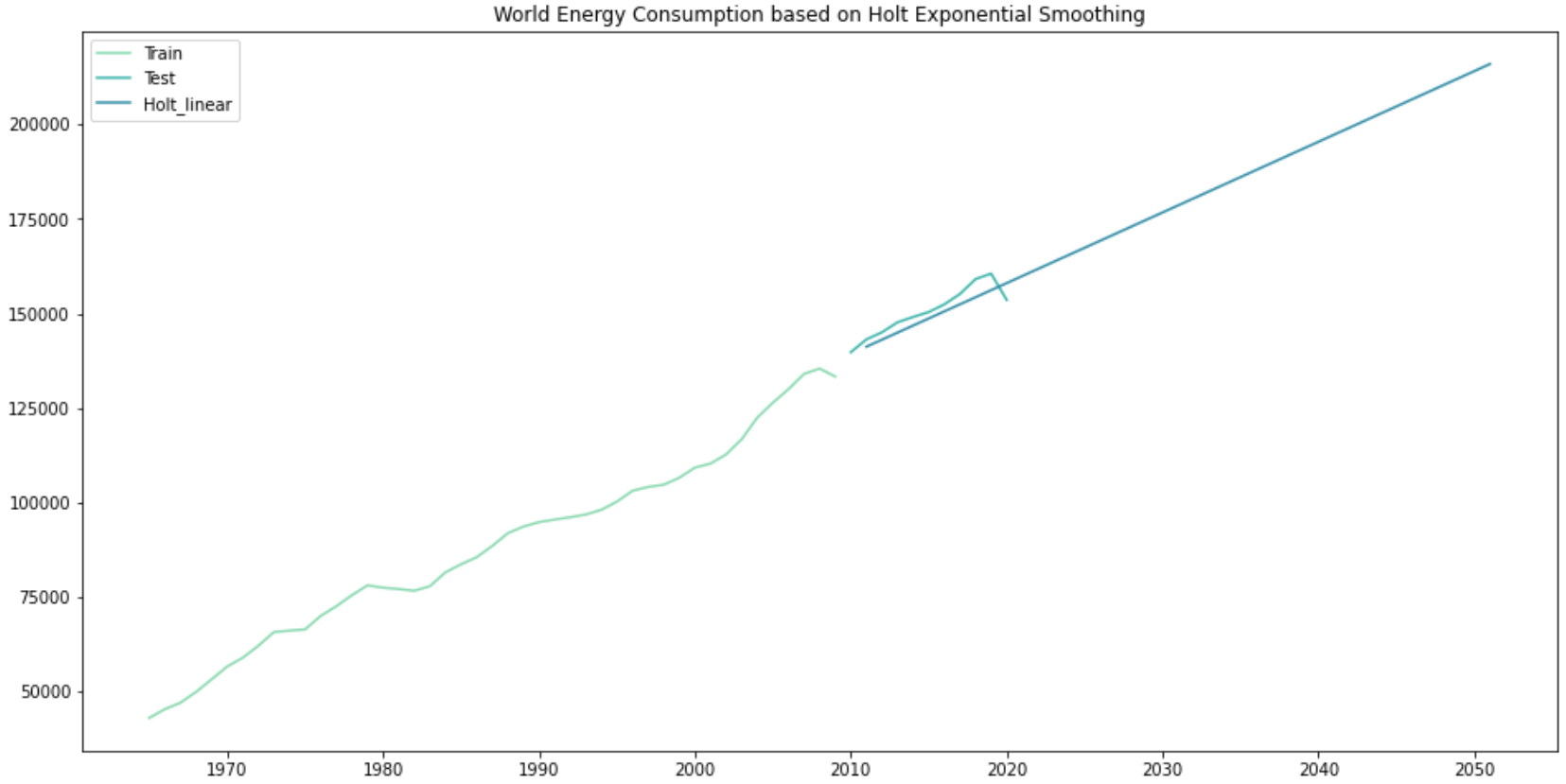
## World Energy Consumption

| | Simple Regression | Ridge Regression | Lasso Regression | Exponential Smoothing | Holt Exponential Smoothing | ARIMA |
|---|---|---|---|---|---|---|
| MAE | 4040.92 | 4040.92 | 4040.92 | 16853.85 | 423.59 | 132815.78 |
| MAPE | 0.04 | 0.04 | 0.04 | 0.11 | 0.01 | 0.88 |
| RMSE | 4501.13 | 4501.13 | 4501.13 | 17948.11 | 2307.10 | 132959.07 |

## Renewable Energy Consumption

| | Simple Regression | Ridge Regression | Lasso Regression | Exponential Smoothing | Holt Exponential Smoothing | ARIMA |
|---|---|---|---|---|---|---|
| MAE | 972.63 | 979.54 | 979.74 | 16853.85 | 814.11 | 132815.78 |
| MAPE | 0.08 | 0.09 | 0.09 | 0.11 | 0.03 | 0.88 |
| RMSE | 1318.54 | 1327.41 | 1327.42 | 17948.11 | 1164.10 | 132959.07 |

# Prediction World Energy Consumption

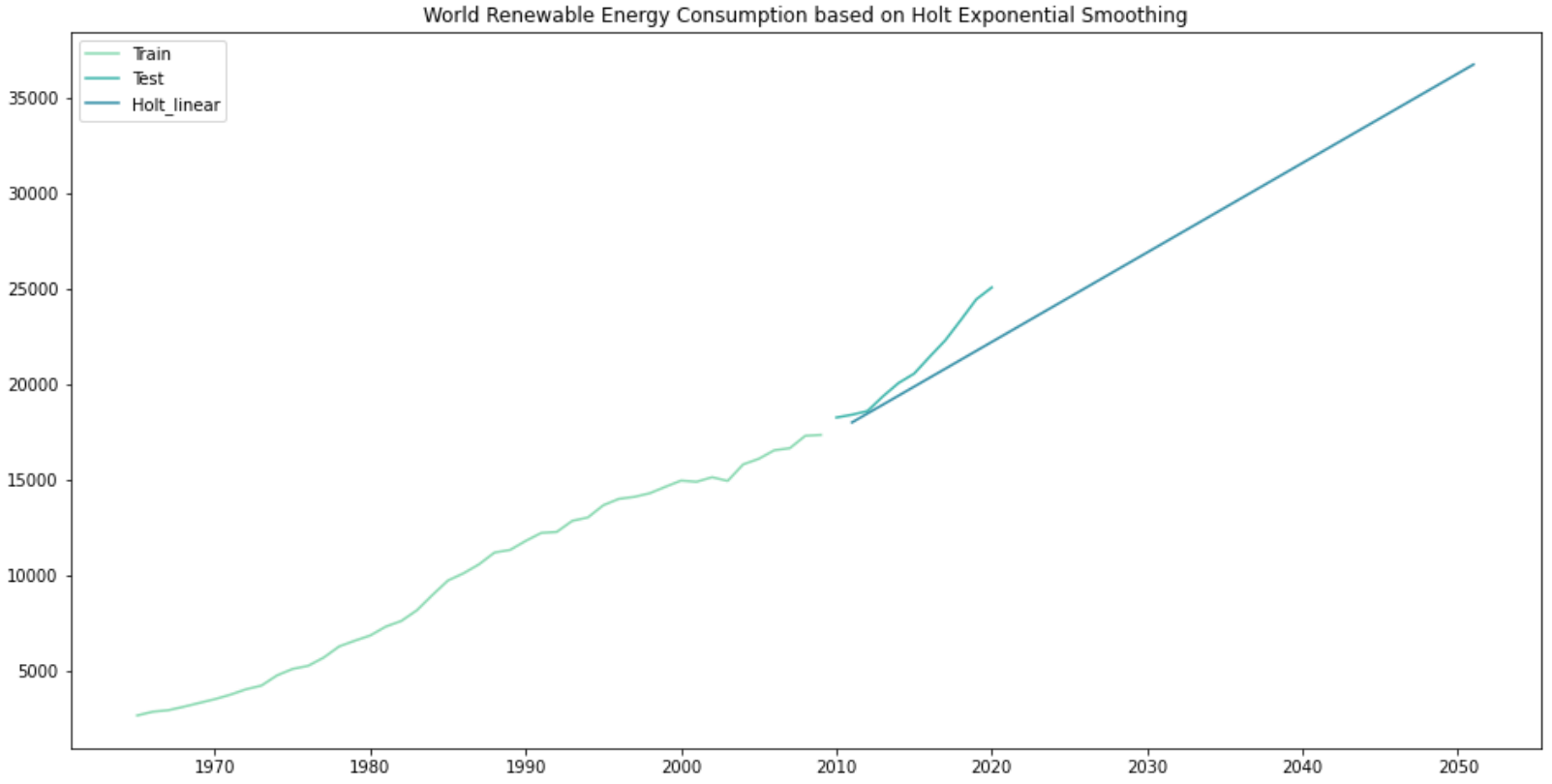



| year | energy_total_prediction | | |
|---|---|---|---|
| 2021-01-01 | 159909.476902 | 2036-01-01 | 187943.359771 |
| 2022-01-01 | 161778.402427 | 2037-01-01 | 189812.285295 |
| 2023-01-01 | 163647.327951 | 2038-01-01 | 191681.210820 |
| 2024-01-01 | 165516.253476 | 2039-01-01 | 193550.136344 |
| 2025-01-01 | 167385.179000 | 2040-01-01 | 195419.061869 |
| 2026-01-01 | 169254.104525 | 2041-01-01 | 197287.987393 |
| 2027-01-01 | 171123.030050 | 2042-01-01 | 199156.912918 |
| 2028-01-01 | 172991.955574 | 2043-01-01 | 201025.838442 |
| 2029-01-01 | 174860.881099 | 2044-01-01 | 202894.763967 |
| 2030-01-01 | 176729.806623 | 2045-01-01 | 204763.689492 |
| 2031-01-01 | 178598.732148 | 2046-01-01 | 206632.615016 |
| 2032-01-01 | 180467.657672 | 2047-01-01 | 208501.540541 |
| 2033-01-01 | 182336.583197 | 2048-01-01 | 210370.466065 |
| 2034-01-01 | 184205.508721 | 2049-01-01 | 212239.391590 |
| 2035-01-01 | 186074.434246 | 2050-01-01 | 214108.317114 |
| | | 2051-01-01 | 215977.242639 |

**186074.43TWh**
**2035**

**214108.32TWh**
**2050**

# Prediction Renewable Energy Consumption

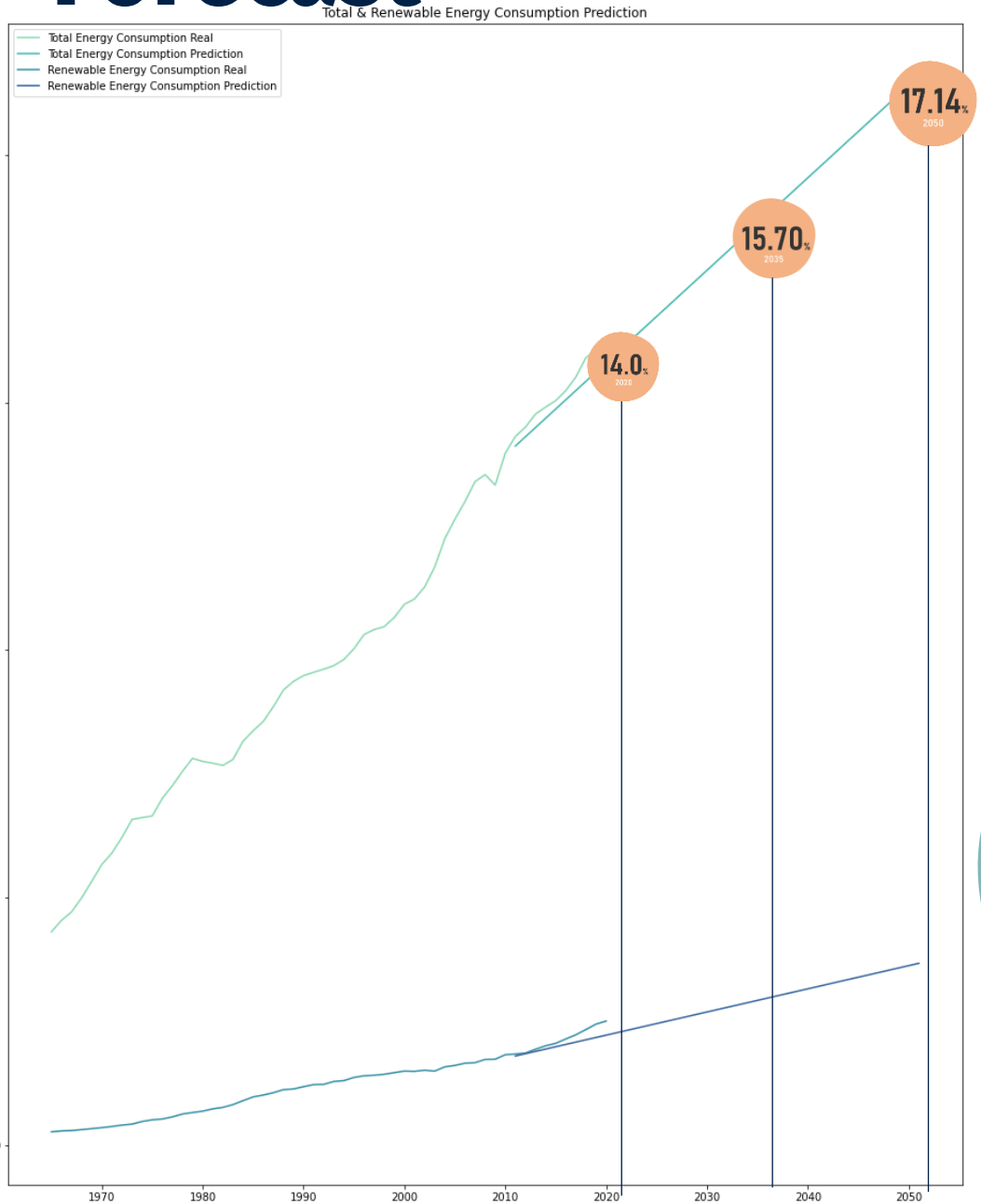



| year | renewable_prediction |
|---|---|
| 2021-01-01 | 22662.200925 |
| 2022-01-01 | 23130.361094 |
| 2023-01-01 | 23598.521263 |
| 2024-01-01 | 24066.681432 |
| 2025-01-01 | 24534.841601 |
| 2026-01-01 | 25003.001770 |
| 2027-01-01 | 25471.161938 |
| 2028-01-01 | 25939.322107 |
| 2029-01-01 | 26407.482276 |
| 2030-01-01 | 26875.642445 |
| 2031-01-01 | 27343.802614 |
| 2032-01-01 | 27811.962783 |
| 2033-01-01 | 28280.122952 |
| 2034-01-01 | 28748.283120 |
| 2035-01-01 | 29216.443289 |
| 2036-01-01 | 29684.603458 |
| 2037-01-01 | 30152.763627 |
| 2038-01-01 | 30620.923796 |
| 2039-01-01 | 31089.083965 |
| 2040-01-01 | 31557.244134 |
| 2041-01-01 | 32025.404302 |
| 2042-01-01 | 32493.564471 |
| 2043-01-01 | 32961.724640 |
| 2044-01-01 | 33429.884809 |
| 2045-01-01 | 33898.044978 |
| 2046-01-01 | 34366.205147 |
| 2047-01-01 | 34834.365316 |
| 2048-01-01 | 35302.525485 |
| 2049-01-01 | 35770.685653 |
| 2050-01-01 | 36238.845822 |
| 2051-01-01 | 36707.005991 |

**29216.44TWh**
**2035**

**36707.32TWh**
**2050**

# Forecast




**2035**

186074.43TWh

29216.44TWh

**2050**

214108.32TWh

36707.32TWh

15.70%

2035

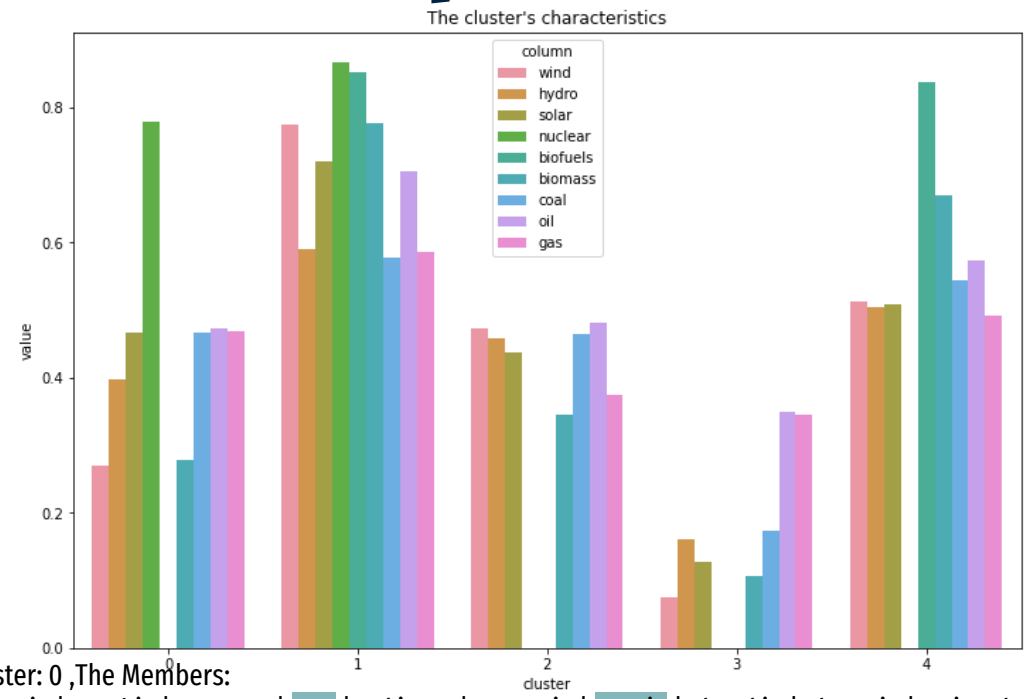
17.14%

2050

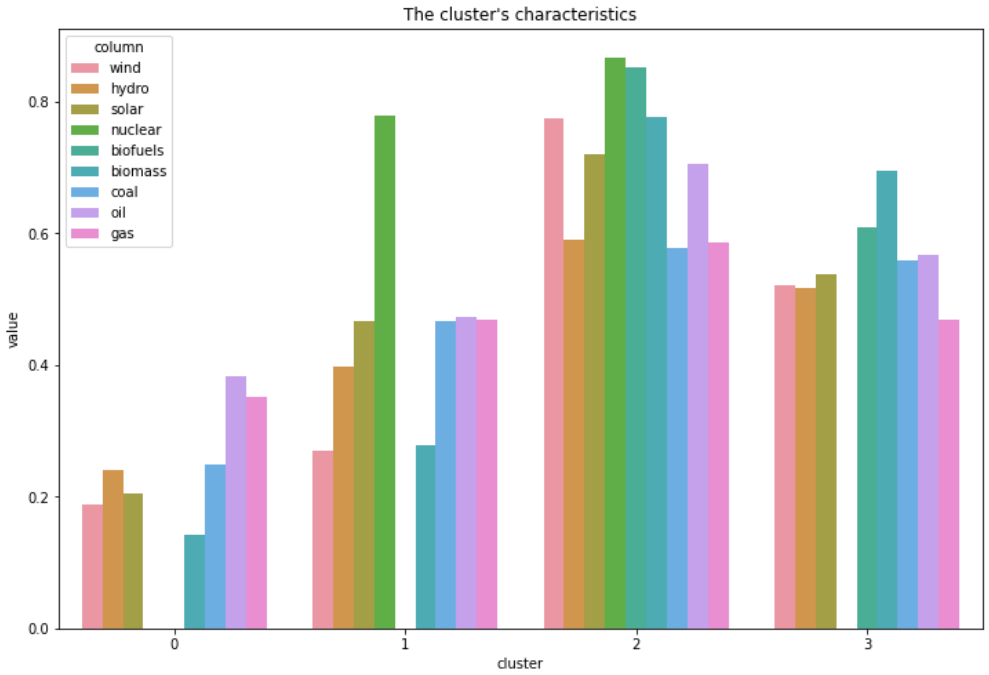
Reduce Consumption with energy efficiency

Increase renewable energy mix

# Follow-up Action




Cluster: 0 ,The Members:
Bulgaria | Czechia | Hungary | Iran | Pakistan | Romania | Russia | Slovakia | Slovenia | Switzerland | Taiwan | Ukraine | United Arab Emirates Total Members: 13
Cluster: 1 The Members:
Argentina | Belgium | Brazil | Canada | China | Finland | France | Germany | India | Japan | Mexico | Netherlands | South Korea | Spain | Sweden | United Kingdom | United States Total Members: 17
Cluster: 2 The Members:
Chile | Denmark | Egypt | Greece | Ireland | Kazakhstan | Malaysia | Morocco | New Zealand | Norway | Peru | Philippines | Turkey | Vietnam Total Members: 14
Cluster: 3 The Members:
Algeria | Azerbaijan | Bangladesh | Belarus | Croatia | Cyprus | Ecuador | Estonia | Hong Kong | Iceland | Iraq | Israel | Kuwait | Latvia | Lithuania | Luxembourg | North Macedonia | Oman | Qatar | Saudi Arabia | Singapore | Sri Lanka | Trinidad and Tobago | Turkmenistan | Uzbekistan | Venezuela Total Members: 26
Cluster: 4
The Members: Australia | Austria | Colombia | Indonesia | Italy | Poland | Portugal | Thailand Total Members: 8




Cluster: 0 The Members:
Algeria | Azerbaijan | Bangladesh | Belarus | Croatia | Cyprus | Denmark | Ecuador | Egypt | Estonia | Greece | Hong Kong | Iceland | Iraq | Ireland | Israel | Kazakhstan | Kuwait | Latvia | Lithuania | Luxembourg | Malaysia | Morocco | New Zealand | North Macedonia | Norway | Oman | Peru | Qatar | Saudi Arabia | Singapore | Sri Lanka | Trinidad and Tobago | Turkmenistan | Uzbekistan | Venezuela | Vietnam Total Members: 37
Cluster: 1 The Members:
Bulgaria | Czechia | Hungary | Iran | Pakistan | Romania | Russia | Slovakia | Slovenia | Switzerland | Taiwan | Ukraine | United Arab Emirates Total Members: 13
Cluster: 2 The Members:
Argentina | Belgium | Brazil | Canada | China | Finland | France | Germany | India | Japan | Mexico | Netherlands | South Korea | Spain | Sweden | United Kingdom | United States Total Members: 17
Cluster: 3 The Members:
Australia | Austria | Chile | Colombia | Indonesia | Italy | Philippines | Poland | Portugal | Thailand | Turkey Total Members: 11

# Follow-up Action

## Agricultural and Service Based Country:

Algeria | Azerbaijan | Bangladesh | Belarus | Croatia | Cyprus | Denmark | Ecuador | Egypt | Estonia | Greece | Hong Kong | Iceland | Iraq | Ireland | Israel | Kazakhstan | Kuwait | Latvia | Lithuania | Luxembourg | Malaysia | Morocco | New Zealand | North Macedonia | Norway | Oman | Peru | Qatar | Saudi Arabia | Singapore | Sri Lanka | Trinidad and Tobago | Turkmenistan | Uzbekistan | Venezuela | Vietnam Total Members: 37

## Fossil Fuel Producer

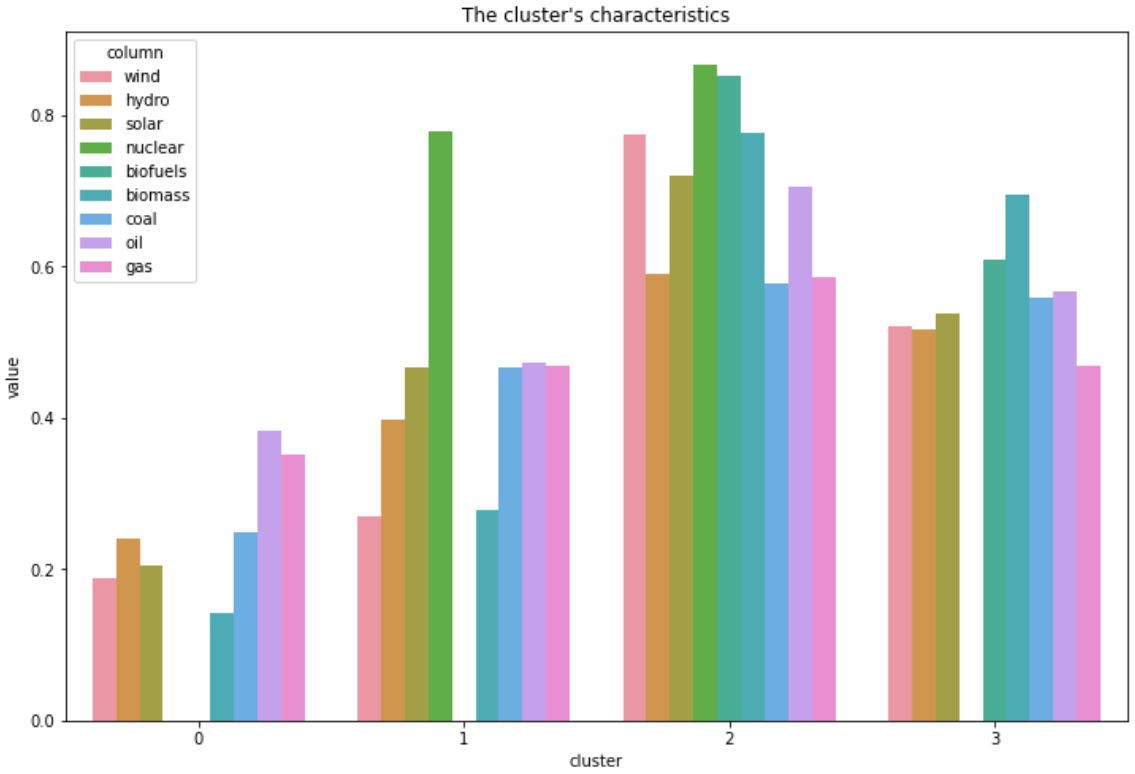
Bulgaria | Czechia | Hungary | Iran | Pakistan | Romania | Russia | Slovakia | Slovenia | Switzerland | Taiwan | Ukraine | United Arab Emirates Total Members: 13

## Emission Intensive Producer

Argentina | Belgium | Brazil | Canada | China | Finland | France | Germany | India | Japan | Mexico | Netherlands | South Korea | Spain | Sweden | United Kingdom | United States Total Members: 17

## Emerging Energy Consumer Country

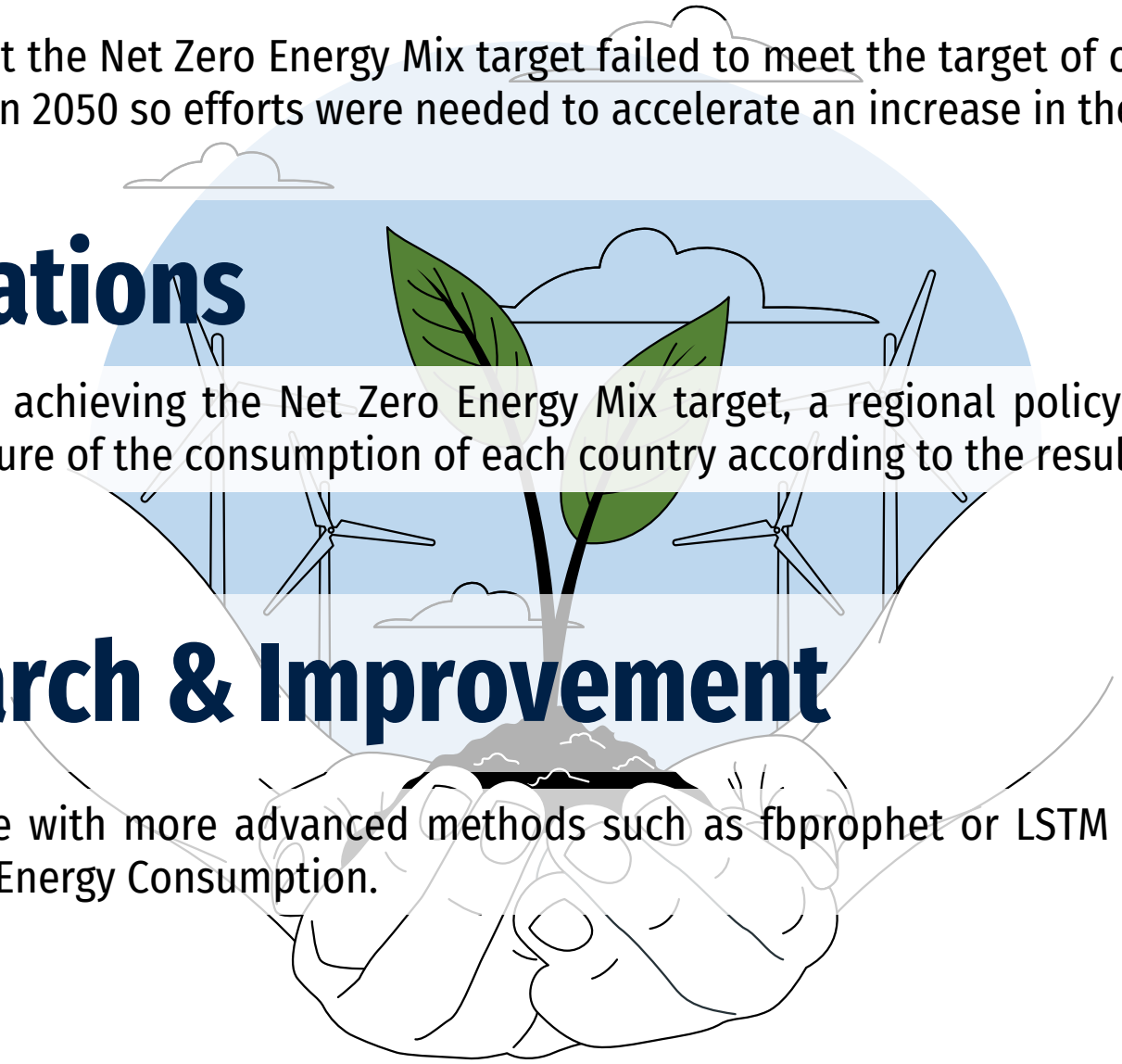
Australia | Austria | Chile | Colombia | Indonesia | Italy | Philippines | Poland | Portugal | Thailand | Turkey Total Members: 11




| Cluster Country | Priority | Reluctancy | Rank Renewable Energy Source | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Wind | Hydro | Solar | Nuclear | Biofuel | Biomass |
| Agricultural and Service | 4 | 4 | 3 | 1 | 2 | 6 | 5 | 4 |
| Fossil Fuel Producer | 2 | 1 | 5 | 3 | 2 | 1 | 6 | 4 |
| Emission Intensive Producer | 1 | 2 | 3 | 6 | 5 | 1 | 2 | 4 |
| Emerging Energy Consumer Country | 3 | 3 | 4 | 5 | 3 | 6 | 1 | 2 |

# Conclusion

The forecast results show that the Net Zero Energy Mix target failed to meet the target of only 15.70% from 35% in 2035 and only 17.14% of 50% in 2050 so efforts were needed to accelerate an increase in the increase in renewable energy.



# Recommendations

To accelerate the process of achieving the Net Zero Energy Mix target, a regional policy variation and effort is required according to the nature of the consumption of each country according to the results of the clustering.

# Future Research & Improvement

Forecasting needs to be done with more advanced methods such as fbprophet or LSTM to forecast Total Energy Consumption and Renewable Energy Consumption.

# THANK YOU

## Maulani Candra