Track 2
Greek and Iberian Electricity Market

GrEnFIn

Greening Energy Market and Finance

Project website: http://grenfin.eu

With the support of the Erasmus+ Programme of the European Union

Agenda

1 Introduction

2 Descriptive statistics and preliminary analysis

3 Modelling of electricity prices

4 VaR simulation

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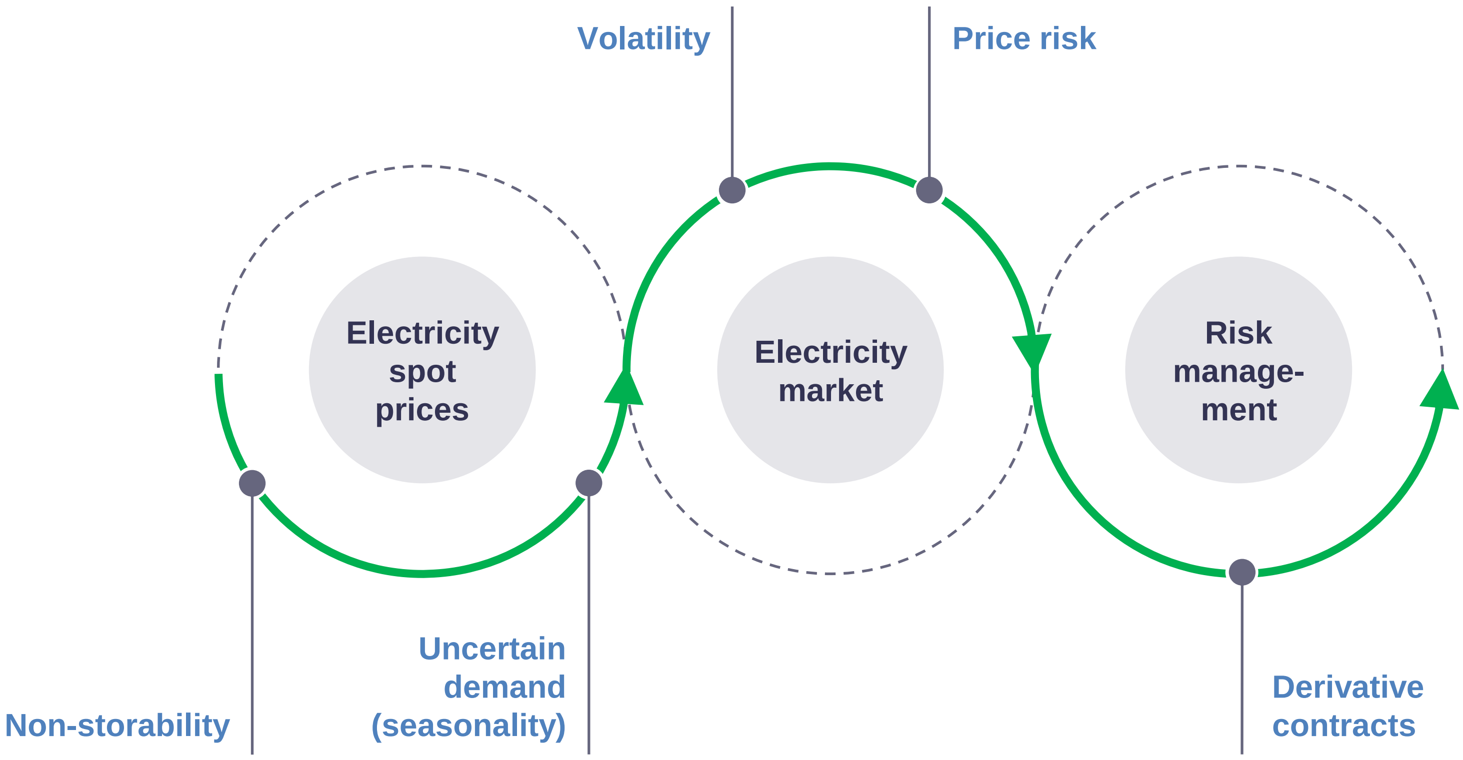
1 Introduction



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2 Descriptive statistics and preliminary analysis

Hellenic Energy Exchange (HEnEX) operates on the **Day-Ahead Market (DAM)** and the **Intraday Market**. DAM is to buy and sell trades of electricity with an obligation of **physical delivery** on the **next Delivery Day**.

To be able to investigate our dataset, it is necessary to understand that this market has **a Market Time Unit of 1 hour** and the **physical delivery** must be within the Bidding Zones of the Hellenic transmission System Operator (HTSO).

DAM allows for efficient sell and buy scheduling using the following order types: 1) **Hourly Hybrid Orders**; 2) **Block Orders**; 3) **Linked Block Orders**; 4) **Exclusive Group of Block Orders**.

Focus on the dataset and obtain some important statistical parameters which can help us interpret the data.

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2 Descriptive statistics and preliminary analysis

Operador del Mercado Ibérico de Energía (OMIE) operates on the **Day-Ahead Market (DAM).**

OMIE for both, **Spain and Portugal**

Market Time Unit: **1 hour**

Complex system operator in place:
“Managing the system's technical limitations and ensure that the market results can be technically accommodated on the transportation network”

Focus on the dataset and obtain some important statistical parameters which can help us interpret the data.

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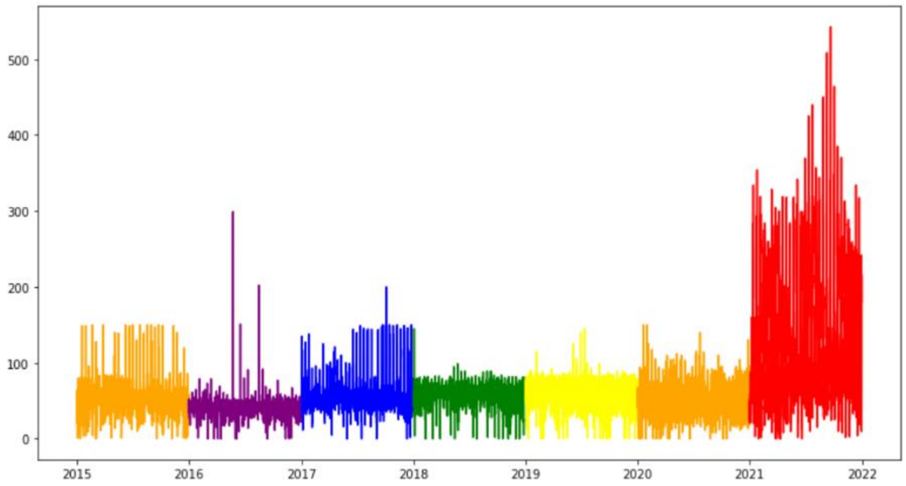
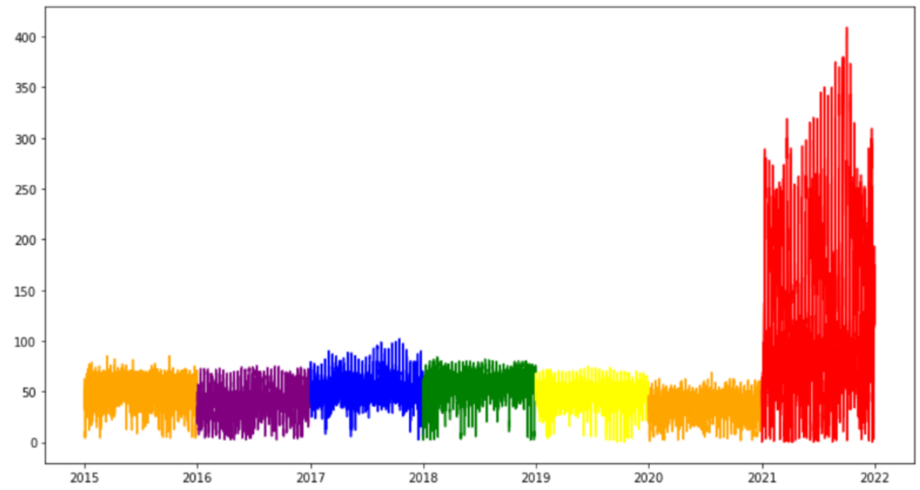
2 Descriptive statistics and preliminary analysis

Day-ahead Market Prices - 2015 - 2021



Greece



Iberia

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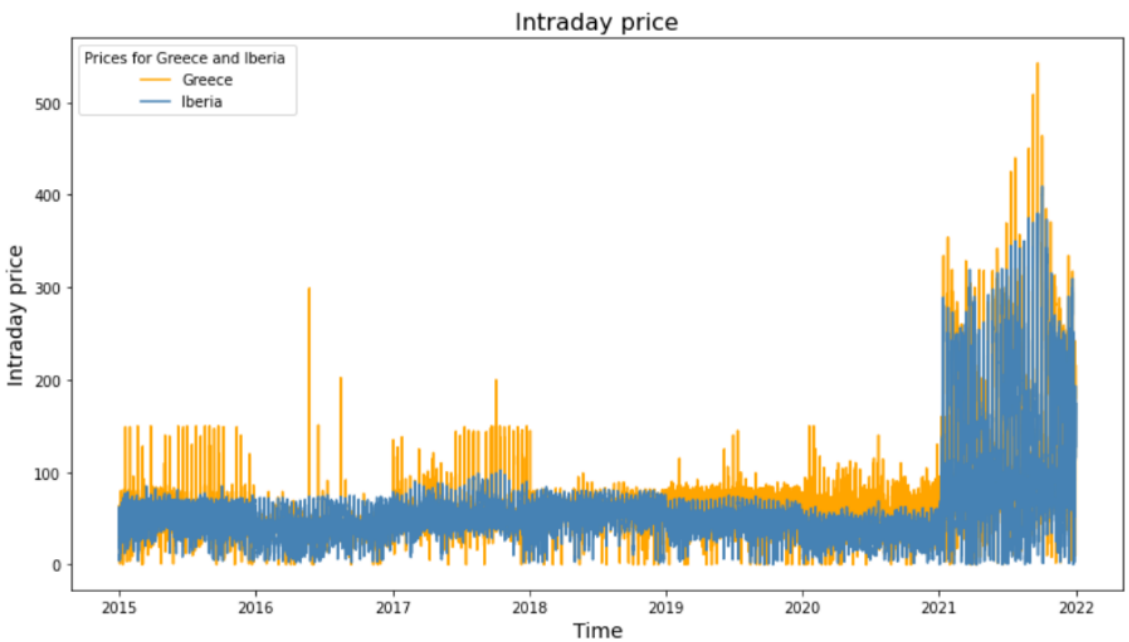
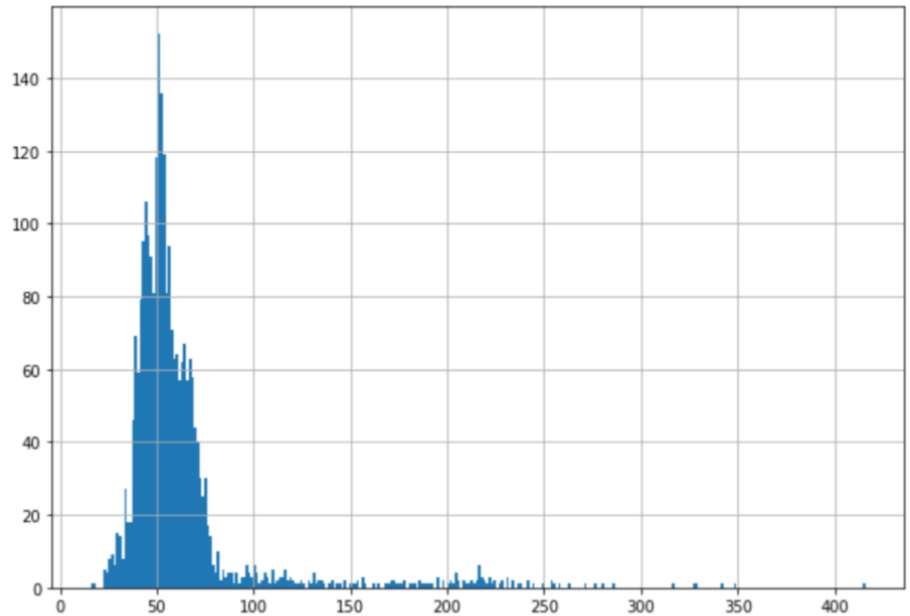
2 Descriptive statistics and preliminary analysis



Compared to Iberia, the Greek electricity prices show a higher volatility across all the timespan considered. This is due to the different structure of production of energy. In particular in Greece the main sources of energy production are gas, renewables and imports from the Baltic nations around it. In Greece there is at the moment only 1 plant for LNG gas near Athens, with only 1 floating storage.

2 Descriptive statistics and preliminary analysis

Histogram of prices - 2015 - 2021



Greece

Shapiro Test
Statistics=0.564, p=0.000
Sample does not look Gaussian (reject H0)

Normality Test
Statistics=2122.375, p=0.000
Sample does not look Gaussian (reject H0)

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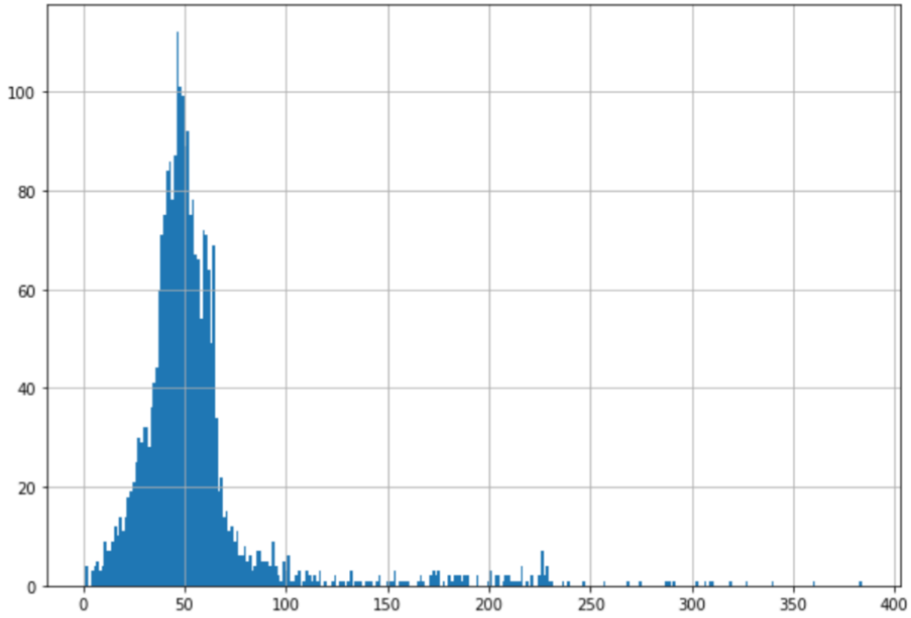
2 Descriptive statistics and preliminary analysis

Histogram of prices - 2015 - 2021



Iberia

Shapiro Test
Statistics=0.613, p=0.000
Sample does not look Gaussian (reject H0)

Normality Test
Statistics=2051.227, p=0.000
Sample does not look Gaussian (reject H0)

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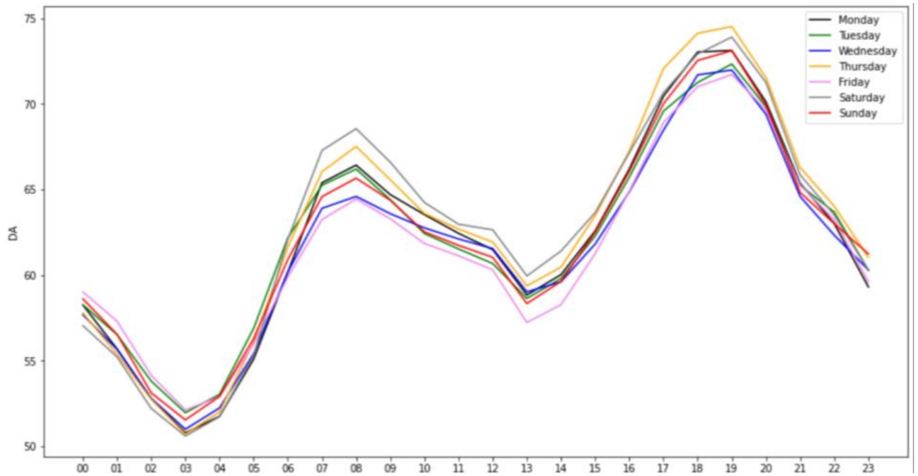
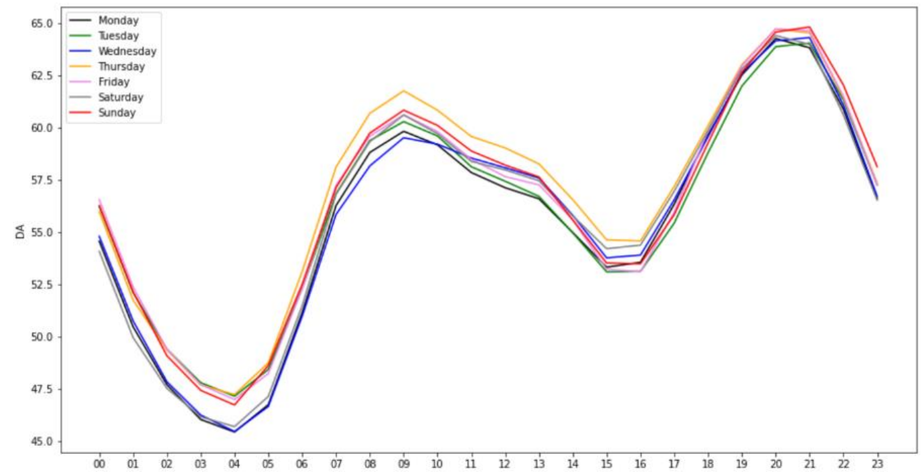
2 Descriptive statistics and preliminary analysis

Time series decomposition - Weekly



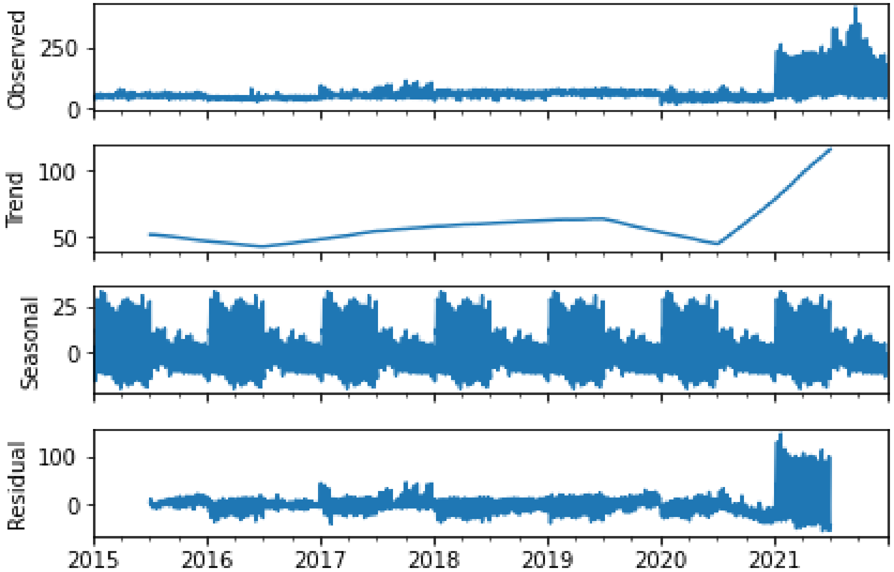
Greece



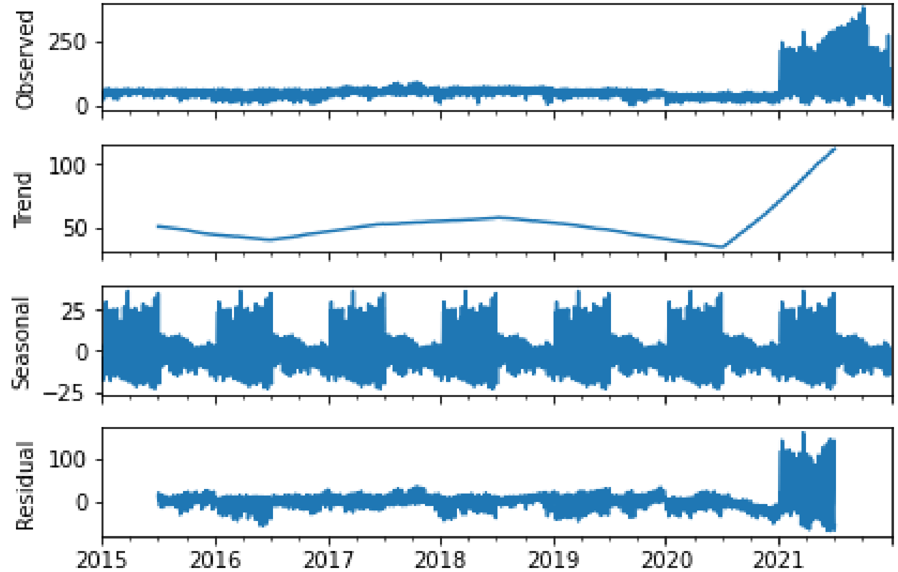
Iberia

2 Descriptive statistics and preliminary analysis

Time series decomposition - Daily



Greece



Iberia

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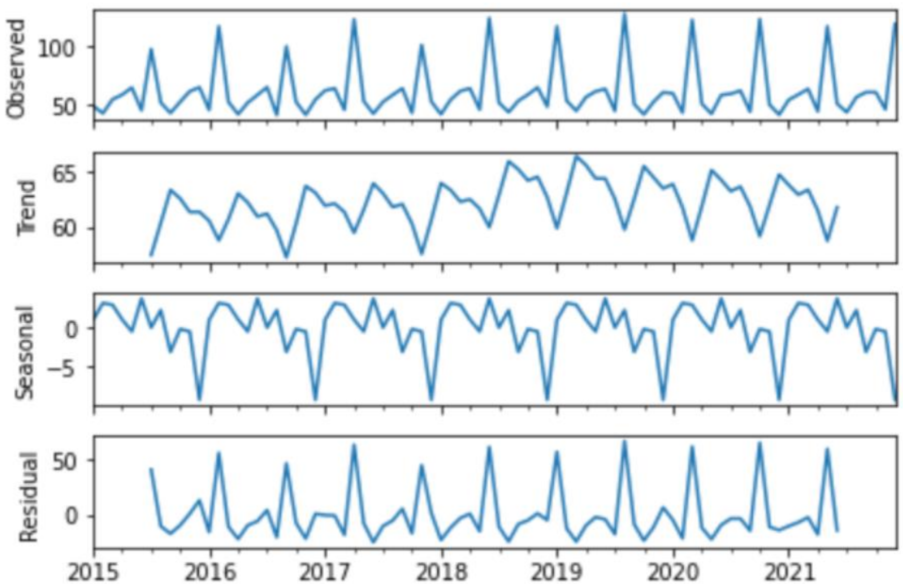
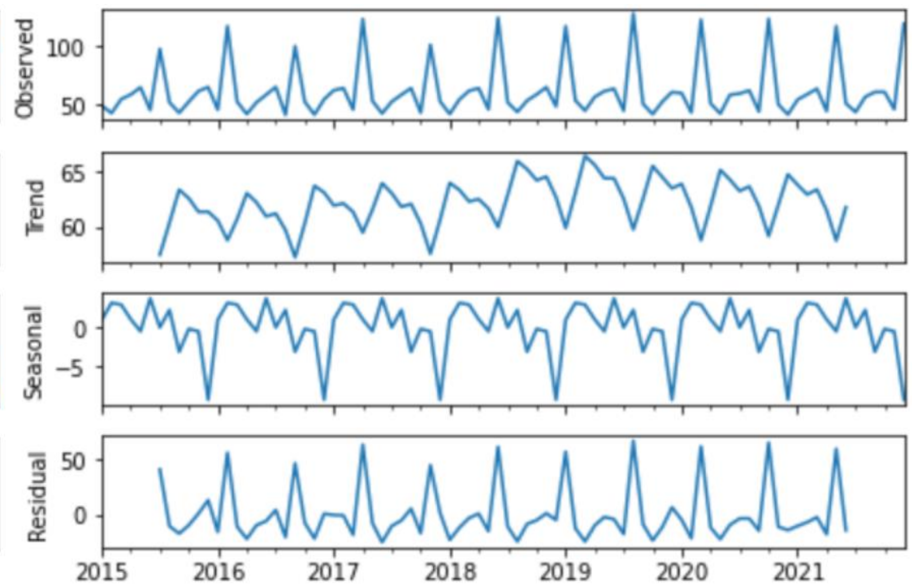
2 Descriptive statistics and preliminary analysis

Time series decomposition - Monthly



Greece



Iberia

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2 Descriptive statistics and preliminary analysis

Greece	**Iberia**
ADF Test not stationary p-value = 0.9447	**ADF Test** not stationary p-value = 0.9256
First Difference Test: stationary p-value = 0.0000	**First Difference Test:** stationary p-value = 0.0000

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Modelling of electricity prices - Greece

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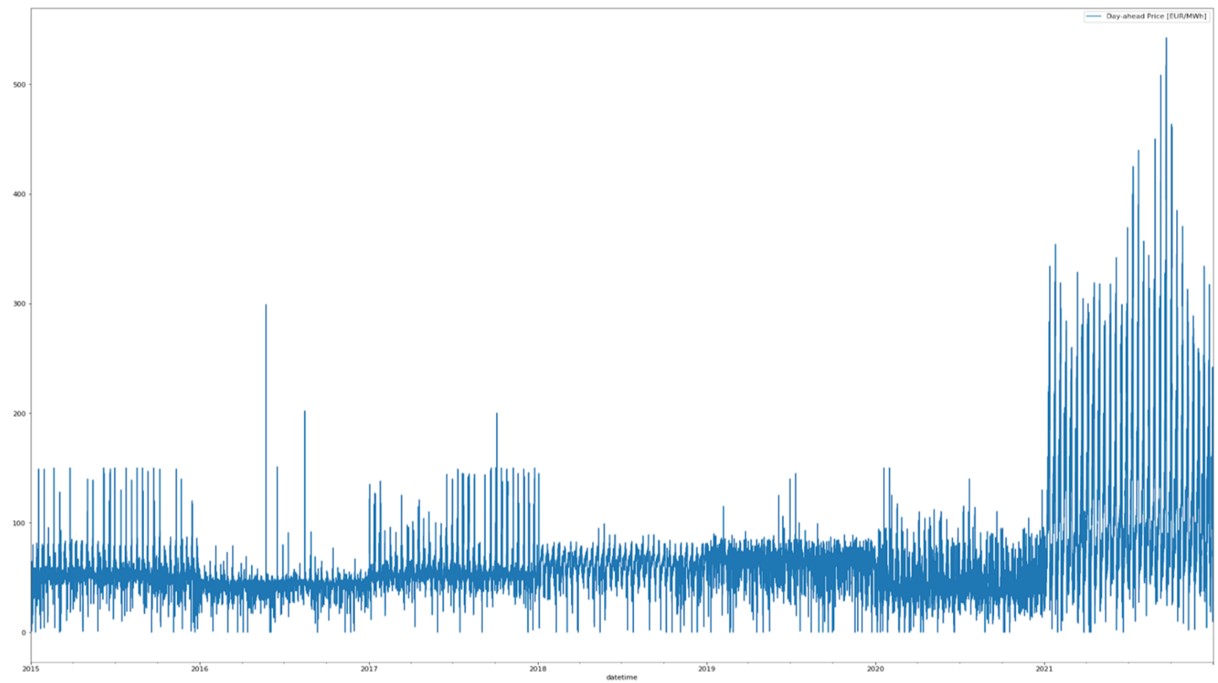
3 Modelling of electricity prices

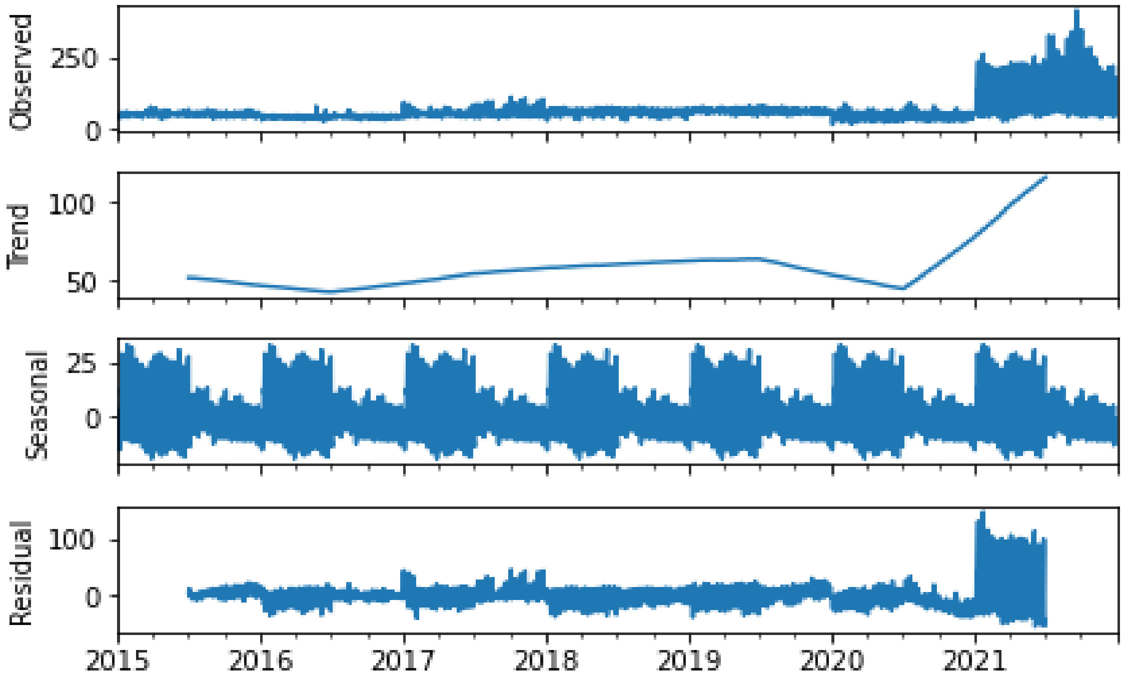
Day-ahead Market Prices - Greece - 2015 - 2021



Note that it is **not clear** if it is stationary or non-stationary

3 Modelling of electricity prices

Time series decomposition – Greece – Daily



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3 Modelling of electricity prices

Since our prices have a high volatility and exhibit price spikes, we need to perform the ADF stationarity test to show if the series are stationary.

```
 > Is the daily prices stationary ?
H0: time series is not stationary
Test statistic = -0.145
P-value = 0.945
Critical values :
        1%: -3.432938355012086 - The "daily prices" is not stationary with 99% confidence
        5%: -2.8626835272597217 - The "daily prices" is not stationary with 95% confidence
        10%: -2.567378742868999 - The "daily prices" is not stationary with 90% confidence
```

Daily data itself is not stationary. This suggests that at least one level of differencing is required. Now we check if the differenced series are stationary.

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3 Modelling of electricity prices

- d = 1 => constant average trend, but in our data, sudden mega trend 2021…?

- Let’s try with d=1 first and then see

```
 > Is the daily prices differenced stationary ?
H0: time series is not stationary
Test statistic = -11.835
P-value = 0.000
Critical values :
        1%: -3.432939379929173 - The "daily prices differenced" is  stationary with 99% confidence
        5%: -2.862683979868293 - The "daily prices differenced" is  stationary with 95% confidence
        10%: -2.5673789838429837 - The "daily prices differenced" is  stationary with 90% confidence
```

The differenced time series is stationary. The d parameter in our ARIMA model should be a value of 1.

3 Modelling of electricity prices

We can apply the seasonal ARIMA model. (S-ARIMA)
=> ARIMA with seasonality

- A seasonal ARIMA (SARIMA) model is denoted by ARIMA$(p, d, q)(P, D, Q)_m$:
  - m is the seasonality period;
  - (P, D, Q) are the equivalent of (p, d, q) in the seasonality term.

The next step is to select the lag values for the **Autoregression (AR)** and **Moving Average (MA) parameters**, p and q respectively.

We can do this by reviewing **Autocorrelation Function (ACF)** and **Partial Autocorrelation Function (PACF)** plots of the differentiated data.

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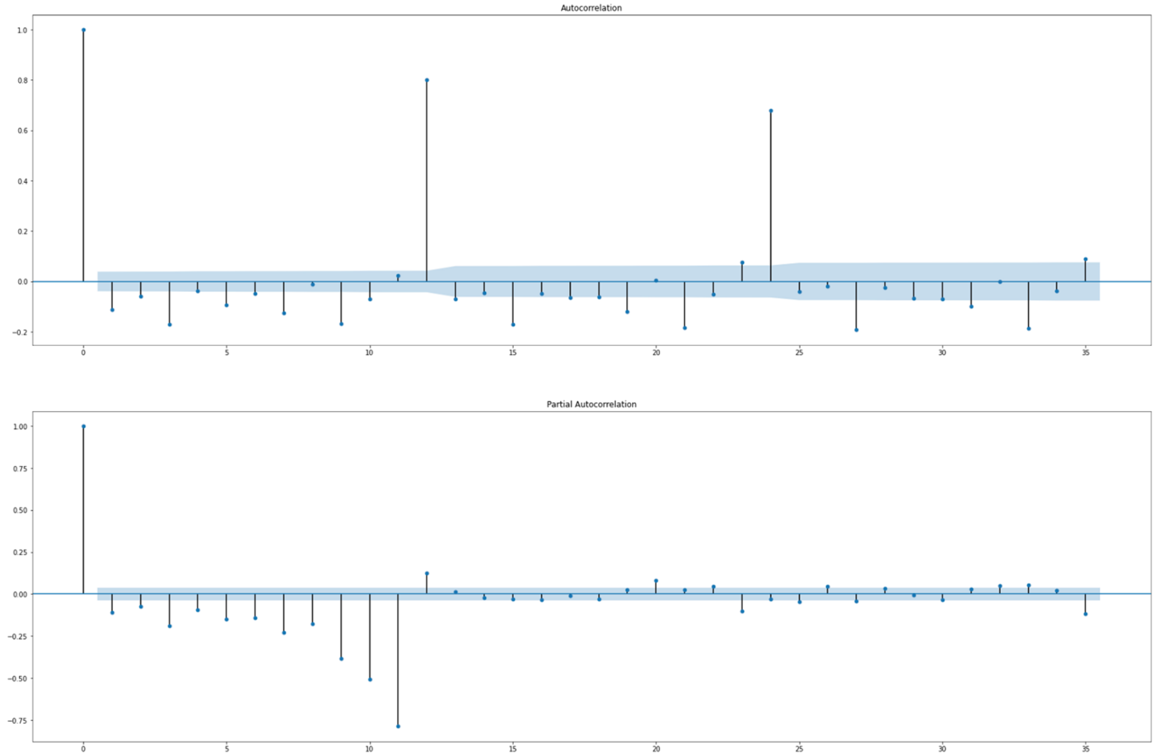
3 Modelling of electricity prices

Autocorrelation function and Partial Autocorrelation Function - Greece - Daily difference

ACF, PACF of (d=1)



3 Modelling of electricity prices

Based on the ACF, we choose m = 12 (seasonality period is 12)

What about the other parameter?
=> we use auto.arima function.
=> we choose parameter if they have lowest BIC, AIC

Autocorrelation function and Partial Autocorrelation Function - Greece - Daily difference

Model	AIC	BIC
ARIMA(2,1,1)(1,0,2,12)	20098.382	20139.305
ARIMA(2,1,1)(0,0,2,12)	21144.786	21179.864
ARIMA(2,1,1)(0,0,1,12)	21783.528	21812.759

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SARIMA - Performance analysis

```
                                     SARIMAX Results
==========================================================================================
Dep. Variable:                                  y   No. Observations:                 2557
Model:             SARIMAX(2, 1, 1)x(1, 0, [1, 2], 12)   Log Likelihood          -10042.191
Date:                            Wed, 22 Jun 2022   AIC                          20098.382
Time:                                    12:36:58   BIC                          20139.305
Sample:                                         0   HQIC                         20113.222
                                           - 2557
Covariance Type:                              opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.1939      0.009     22.715      0.000       0.177       0.211
ar.L2          0.0858      0.009      9.222      0.000       0.068       0.104
ma.L1         -0.9895      0.002   -409.701      0.000      -0.994      -0.985
ar.S.L12       0.9388      0.003    282.330      0.000       0.932       0.945
ma.S.L12      -0.1335      0.011    -12.295      0.000      -0.155      -0.112
ma.S.L24      -0.1539      0.008    -20.418      0.000      -0.169      -0.139
sigma2       150.2430      1.167    128.723      0.000     147.955     152.531
===================================================================================
Ljung-Box (L1) (Q):                   0.01   Jarque-Bera (JB):            182590.46
Prob(Q):                              0.94   Prob(JB):                         0.00
Heteroskedasticity (H):              11.80   Skew:                             0.58
Prob(H) (two-sided):                  0.00   Kurtosis:                        44.39
===================================================================================
```

3 Modelling of electricity prices

SARIMA - Performance analysis

- The **root-mean-square error** (**RMSE**) is a frequently used measure of the differences between values (sample or population values) predicted by a model or an estimator and the values observed.
- **R-squared (R^2)** is a statistical measure that represents the proportion of the variance for a dependent variable that's explained by an independent variable or variables in a regression model.
- The **mean absolute percentage error** (**MAPE**) : a measure of prediction accuracy of a forecasting method tp expresses the accuracy as a ratio.

RMSE	20.23
R^2	0.944
MAPE	0.397

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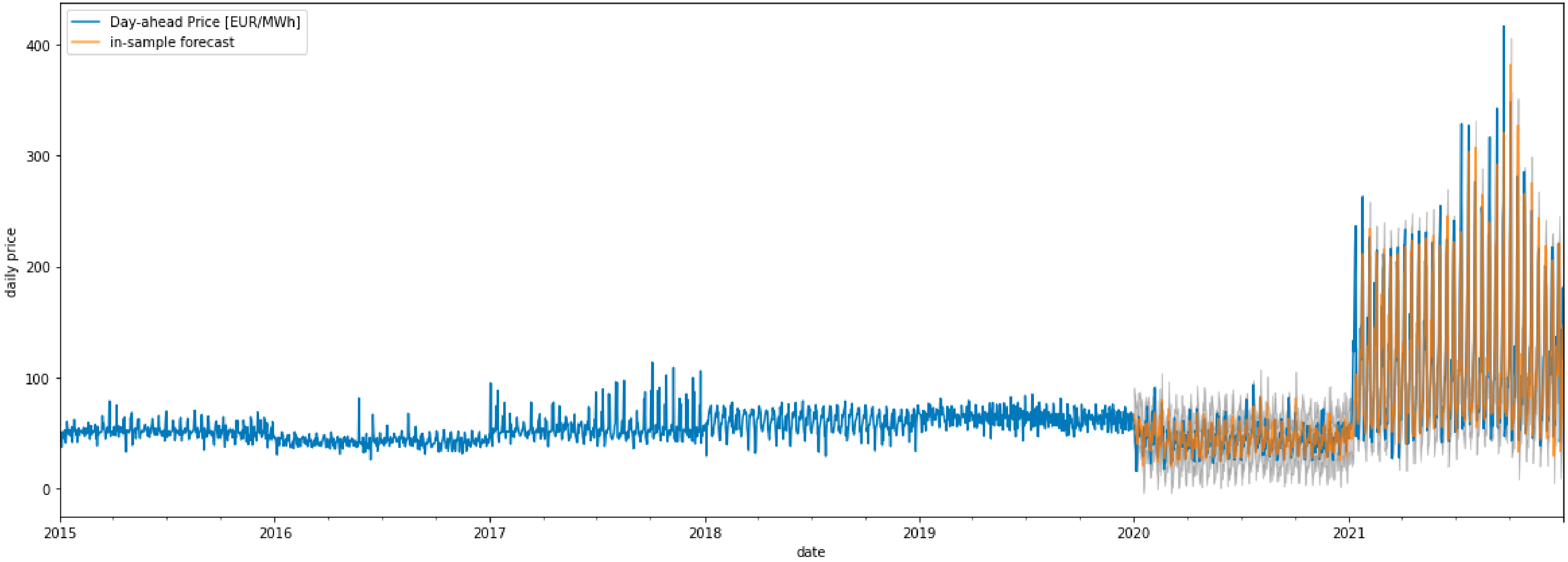
Forecast price (In-sample)

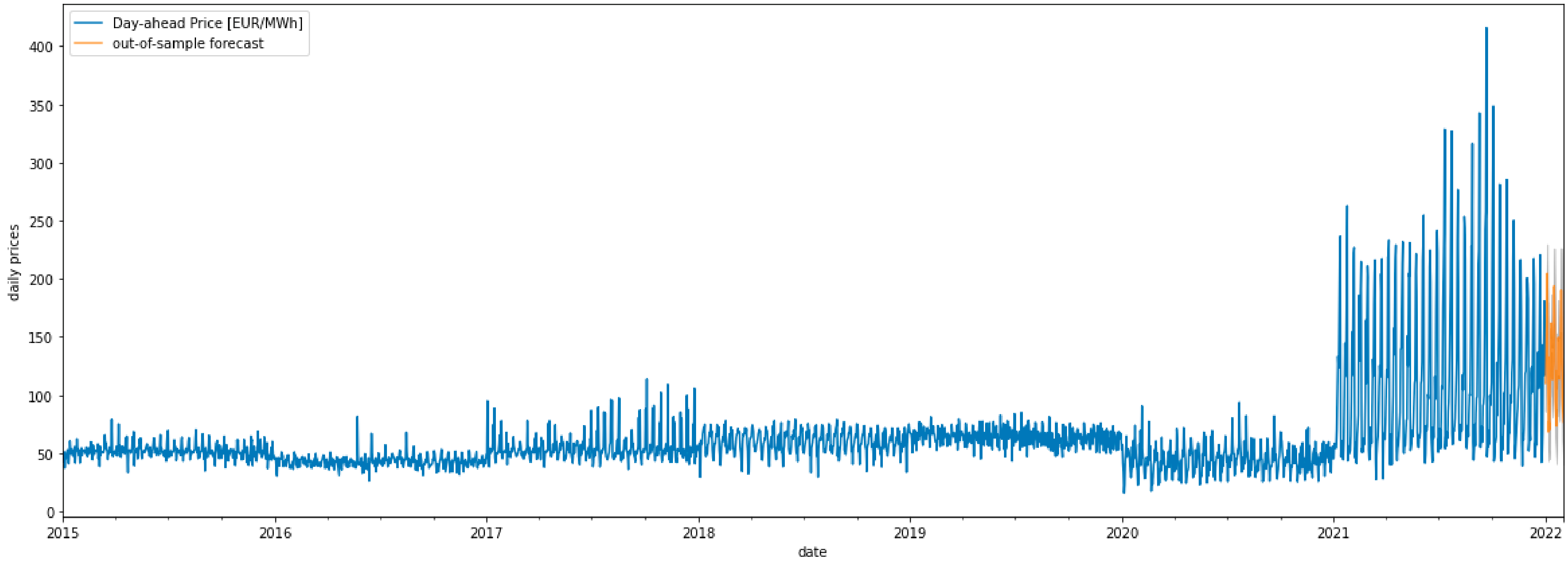
Observed daily price difference vs Forecasted daily price difference - Greece



3 Modelling of electricity prices

Forecast price (Out-sample)

Forecast daily price difference for January 2022 - Greece



Modelling of electricity prices – Iberia

3 Modelling of electricity prices

Time series decomposition – Iberia – Daily

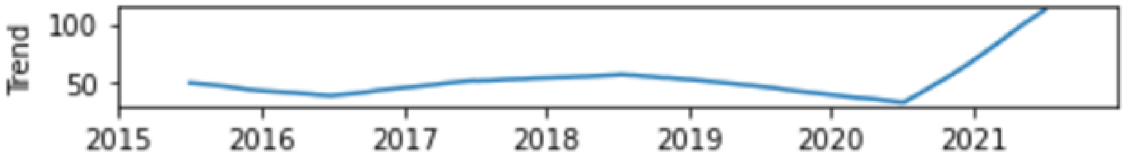
$$Y_t - S_t = T_t + E_t$$

3 Modelling of electricity prices

Model Selection Parameters

Trending

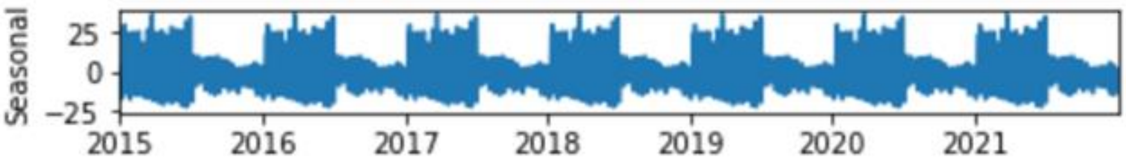
- The data displays trends in the periods mentioned above which fluctuates.
- However, it can be clearly seen in the monthly plots that there is an overall increasing trend over the time period.
- Therefore a moving average process is required to estimate the trending component.



3 Modelling of electricity prices

Seasonality

- Data exhibits seasonality as seen in the plots whereby there is a constant and predictable pattern seen throughout.
- Evidenced by the constant view of the data at a daily and monthly frequency.



3 Modelling of electricity prices

Stationarity

- The time series exhibits characteristics of a non-stationary time series ie trending(follows a trend at certain periods) and seasonality(spikes during days).
- Detrending is required to remove the trending and seasonality components and the resultant residuals will be stationary.
- To detrend the time series an autoregressive process is required whereby the time series is regressed against a lagged version of itself.
- Stationary series which are stationary exhibit constant mean and variance.

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Testing

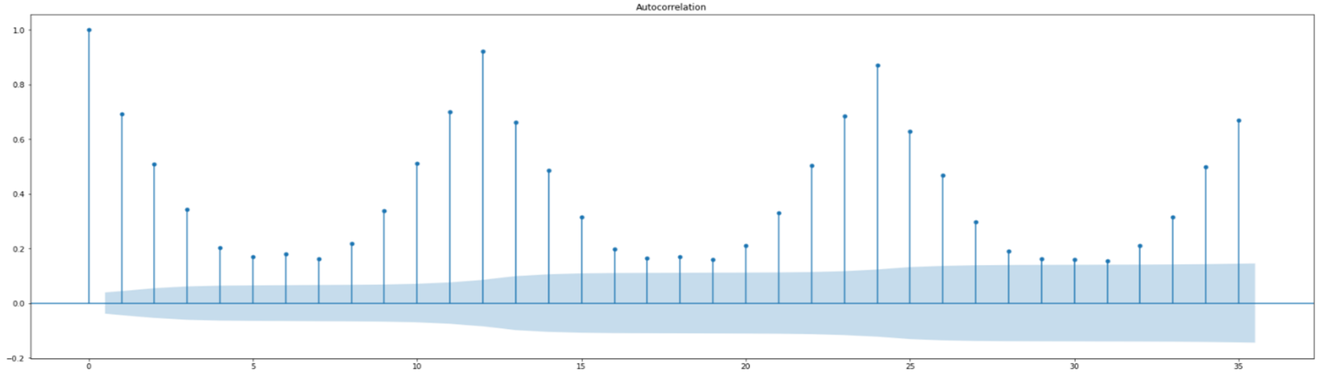
- Augmented dickey-fuller test upon the differenced time series

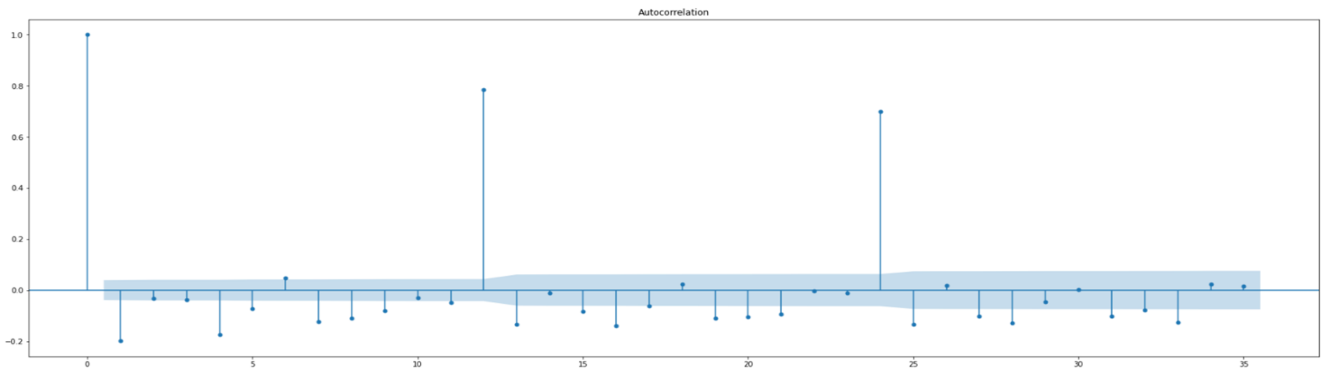
```
In [30]: ADF_test(germany_daily.diff(), 'daily prices differenced')

 > Is the daily prices differenced stationary ?
H0: time series is not stationary
Test statistic = -11.977
P-value = 0.000
Critical values :
        1%: -3.4329373309060354 - The "daily prices differenced" is  stationary with 99% confidence
        5%: -2.862683075009153 - The "daily prices differenced" is  stationary with 95% confidence
        10%: -2.5673785020856443 - The "daily prices differenced" is  stationary with 90% confidence
```

- Significant at 1% level

3 Modelling of electricity prices

Autocorrelation





ACF of differenced series vs raw

=> Impact of seasonality is evident in second plot (diff time series), hence m=12

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3 Modelling of electricity prices

Choice of model

- Due to seasonality, only SARIMA is an appropriate choice of model .
- Based on AIC selection criteria using m=12.

```
 ARIMA(5,1,1)(0,0,0)[0]
 ARIMA(5,1,3)(0,0,0)[0]

Best model:  ARIMA(6,1,2)(0,0,0)[0]
Total fit time: 63.799 seconds
23414.834421711173
```

```
 ARIMA(3,1,0)(2,0,2)[12]
 ARIMA(3,1,2)(2,0,2)[12]

Best model:  ARIMA(2,1,1)(2,0,2)[12]
Total fit time: 1013.105 seconds
20366.000940207774
```

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3 Modelling of electricity prices

Performance analysis

```
In [97]: arma_rmse = np.sqrt(mean_squared_error(germany_daily.loc[germany_daily.index>='2020-01-01']["price"].values, pred.predicted_mean)
         print("RMSE: ",arma_rmse)

RMSE:  21.037911334697878

In [98]: arma_mape = mean_absolute_percentage_error(germany_daily.loc[germany_daily.index>='2020-01-01']["price"].values, pred.predicted_m
         print("MAPE: ",arma_mape)

MAPE:  0.43979362952512685

In [101]: arma_r2 = r2_score(germany_daily.loc[germany_daily.index>='2020-01-01']["price"].values, pred.predicted_mean)
          print("r2: ",arma_r2)

r2:  0.8942303775570486
```

RMSE - Difference in values between predicted and observed data
MAPE - Measure of a prediction accuracy
R2 - Goodness of fit of model

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4 VaR simulation

On 31.12.2021 we bought a forward contract to buy a 1 MWh of electricity for a forward price of 150 EUR/MWh on 01.02.2022 (one month maturity) on Iberian and Greece market. Simulating the price paths with **Monte Carlo approach**, which is the **VaR value**? Which is **the distribution of profit and loss function**?

Electricity forward contracts represent the obligation to buy or sell a fixed amount of electricity at a prespecified contract price, known as the forward price, at certain time in the future.

Monte Carlo simulation is a broad class of computational algorithms that rely majorly on repeated random sampling to obtain numerical results.

VaR expresses the maximum loss of the portfolio value in a set time period with a given confidence level.

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VaR simulation- Iberia

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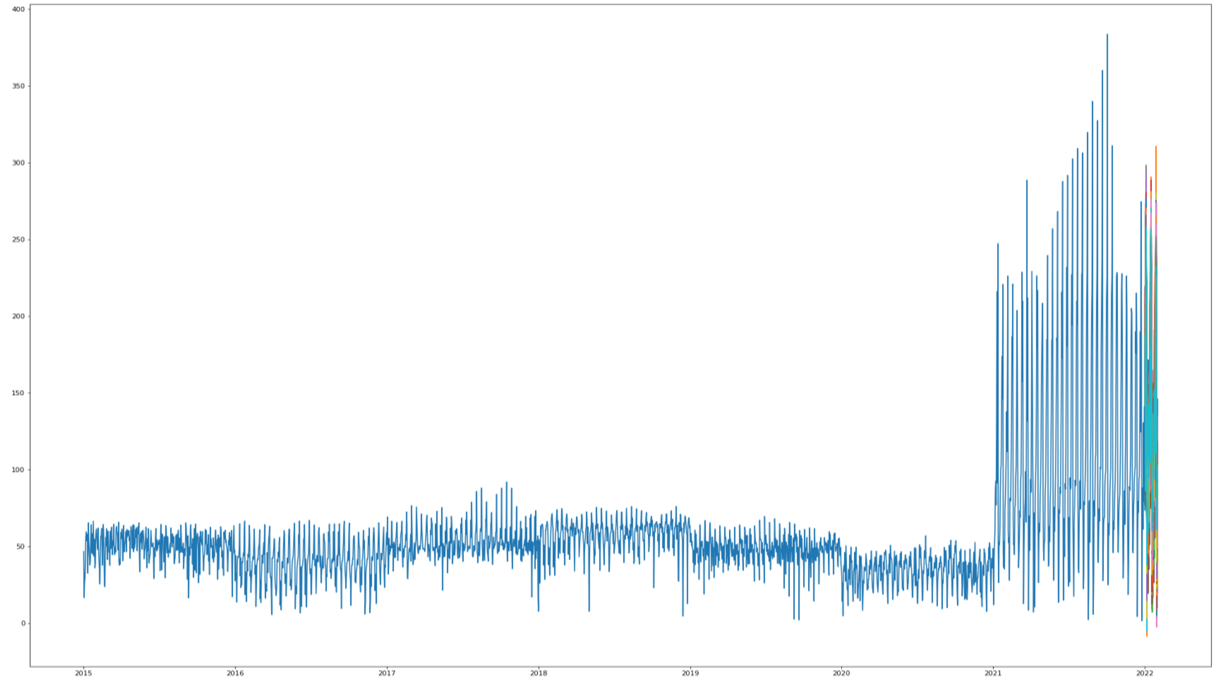
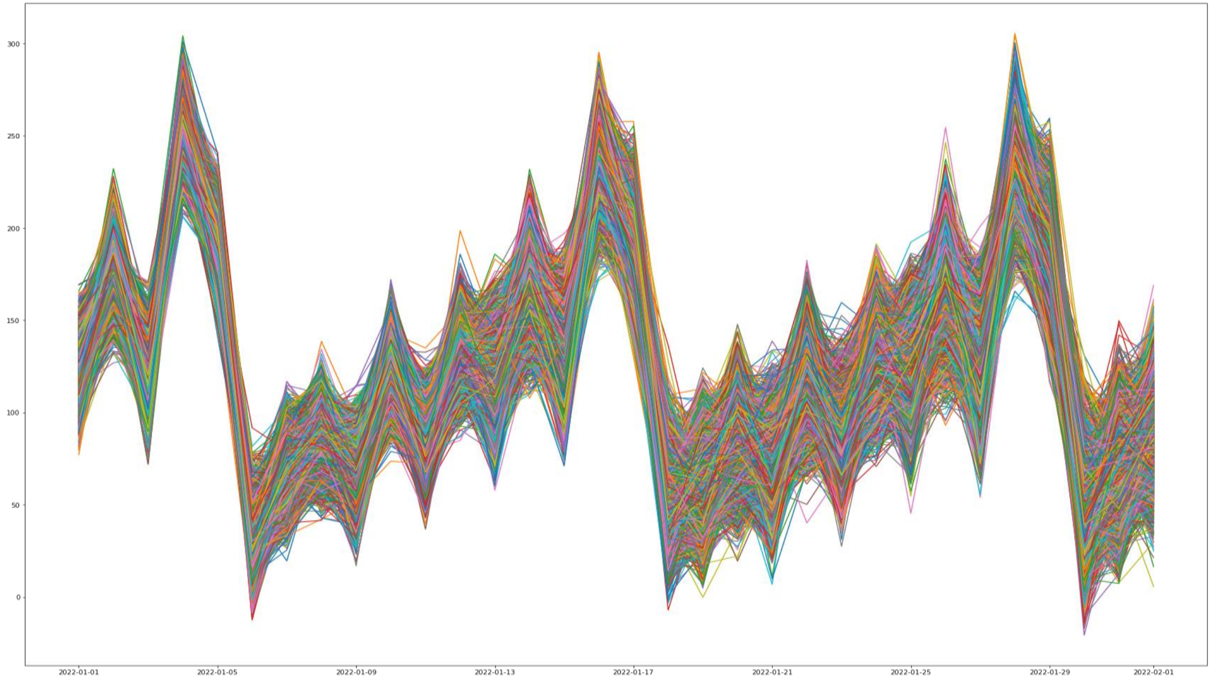
4 VaR simulation

Forecast daily prices with **1.000** scenarios for January 2022 - Iberia



4 VaR simulation

Forecast daily prices with **10.000** scenarios for January 2022 - Iberia



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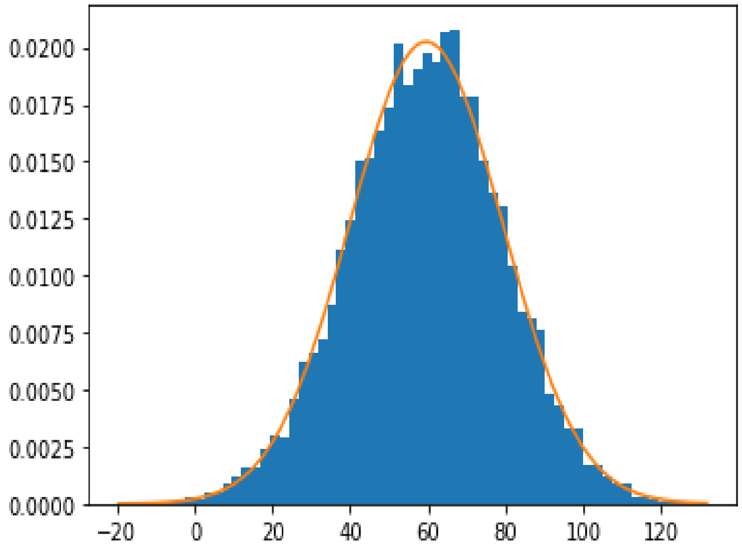
4 VaR simulation

With the **10.000** simulated price we obtain the following results:

- We have that **90% one-month VaR** is **84.6 EUR**;
- We have that **95% one-month VaR** is **91.4 EUR**;
- We have that **99% one-month VaR** is **105.0 EUR**.

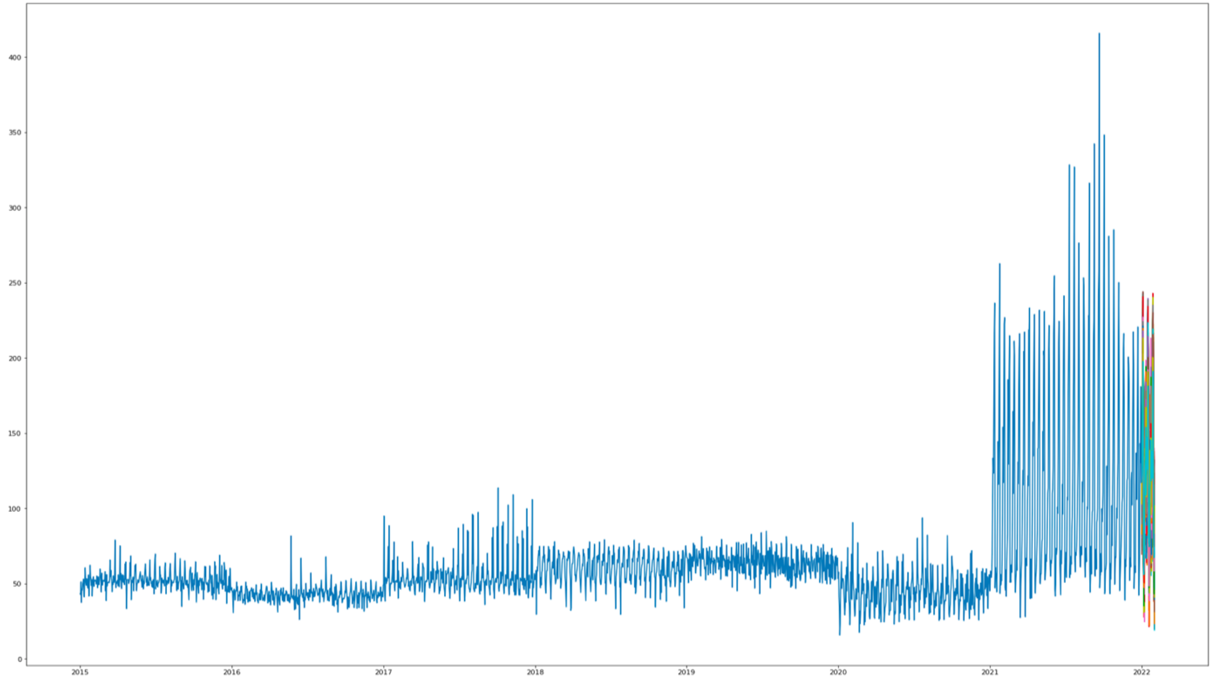


Distribution function of P&L – Iberia

VaR simulation- Greece

4 VaR simulation

Forecast daily prices with **1.000** scenarios for January 2022 - Greece



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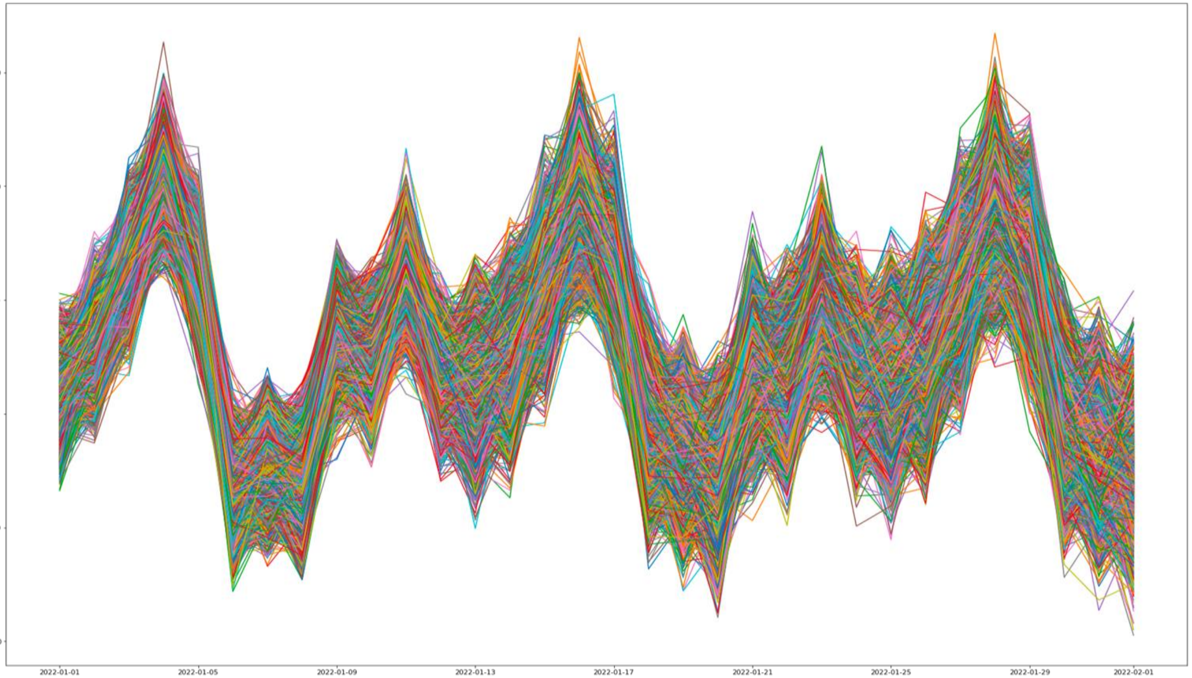
4 VaR simulation

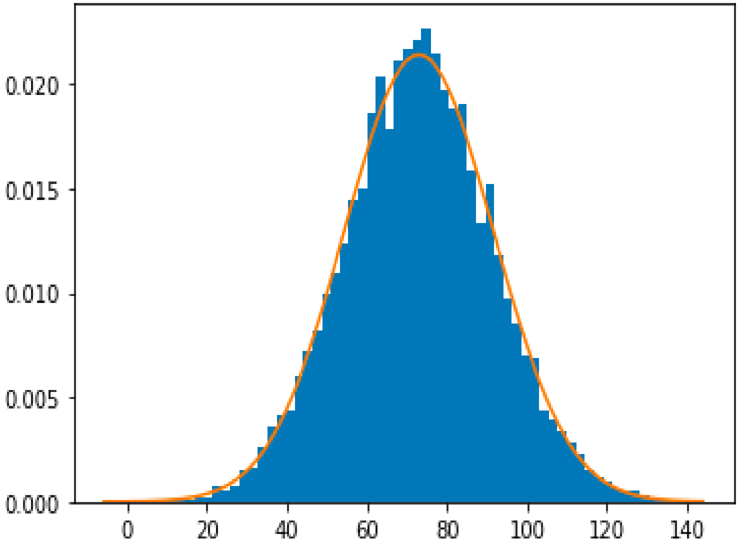
Forecast daily prices with **10.000** scenarios for January 2022 - Greece



4 VaR simulation

With the 10.000 simulated price we obtain the following results:

- We have that **90% one-month VaR** is **96.6 EUR**;
- We have that 95% **one-month VaR** is **103.5 EUR**;
- We have that 99% **one-month VaR** is **117.11 EUR**.



Distribution function of P&L – Iberia

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4 VaR simulation

Comparison

Greek market seems to be more volatile than Iberian market

➔ **we would expect a higher portfolio-VaR in Greece**

Results confirm this expectation. VaR in Greek market is:

- **14.2% higher** at **90%** confidence level
- **13.3% higher** at **95%** confidence level
- **11.5% higher** at **99%** confidence level

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