Hydro power plant constraints forecast

1 Module #2: Exploratory data analysis

1.1 Import libraries

Entrée [2]:

```
import math
import pandas as pd
import numpy as np
import array as arr
from pandas import ExcelWriter
from pandas import ExcelFile
import re
import matplotlib.pyplot as plt
import seaborn as sns
import statistics
```

executed in 3.37s, finished 19:41:43 2019-09-15

1.2 Read source file into data frame and display columns

Entrée [3]:

```
dateparse = lambda x: pd.datetime.strptime(x, '%Y-%m-%d')

df = pd.read_csv("clean_dataframe.csv", parse_dates=['Date'], date_parser=dateparse, index_
# rename date column
df.rename(columns={ df.columns[0]: "Date"}, inplace=True)
# rename "Variante Prio" into "Max prod"
df.rename(columns={ df.columns[14]: "Max prod"}, inplace=True)

df.index = df["Date"]
df.info()
```

executed in 83ms, finished 19:41:44 2019-09-15

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 1917 entries, 2014-04-01 to 2019-06-30
Data columns (total 23 columns):
Date                         1917 non-null datetime64[ns]
Min prod                     1917 non-null float64
Inflow lake 1 [m3]           1917 non-null float64
Inflow lake 2 [m3]           1917 non-null float64
Inflow lake 3 [m3]           1917 non-null float64
Inflow lake 4 [m3]           1917 non-null float64
Vol lake 1 [%]               1917 non-null float64
Max lake 1 [1000m3]          1917 non-null float64
Availability plant 1 [%]     1917 non-null float64
Availability plant 2 [%]     1917 non-null float64
Availability plant 3 [%]     1917 non-null float64
Availability plant 4 [%]     1917 non-null float64
SDL [MWh]                    1917 non-null float64
Weekend                      1917 non-null bool
Max prod                     1917 non-null float64
PrioH1                       1917 non-null float64
PrioP1                       1917 non-null float64
PrioH2                       1917 non-null float64
PrioP2                       1917 non-null float64
PrioH3                       1917 non-null float64
PrioP3                       1917 non-null float64
PrioH4                       1917 non-null float64
PrioP4                       1917 non-null float64
dtypes: bool(1), datetime64[ns](1), float64(21)
memory usage: 346.3 KB
```

Entrée [4]:

```
# Read baseline for benchmark data as well
df_benchmark = pd.read_csv("baseline_dataframe.csv", parse_dates=['Date'], date_parser=date
# Force index to be date (as provided in the first column)
df_benchmark.index = df_benchmark['Date']
df_benchmark.info()
```

executed in 45ms, finished 19:41:46 2019-09-15

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 1918 entries, 2014-04-01 to 2019-07-01
Data columns (total 10 columns):
Date             1918 non-null datetime64[ns]
P1 [MW]          1918 non-null float64
P2 [MW]          1918 non-null float64
P3 [MW]          1918 non-null float64
P4 [MW]          1918 non-null int64
H1 [#]           1918 non-null int64
H2 [#]           1918 non-null int64
H3 [#]           1918 non-null int64
Min Prod [MWh]   1918 non-null float64
MaxEnergy        1918 non-null float64
dtypes: datetime64[ns](1), float64(5), int64(4)
memory usage: 164.8 KB
```

1.2.1 Check first few lines of imported file

Entrée [5]:

```
df.head()
```

executed in 28ms, finished 19:41:50 2019-09-15

Out[5]:

Date	Date	Min prod	Inflow lake 1 [m3]	Inflow lake 2 [m3]	Inflow lake 3 [m3]	Inflow lake 4 [m3]	Vol lake 1 [%]	Max lake 1 [1000m3]	Availability plant 1 [%]	Availability plant 2 [%]	.
2014-04-01	2014-04-01	0.0	31.0	4.0	129.0	107.0	0.16467	30000.0	1.0	1.0	.
2014-04-02	2014-04-02	150.0	0.0	-14.0	148.0	116.0	0.15557	30000.0	1.0	1.0	.
2014-04-03	2014-04-03	150.0	10.0	6.0	132.0	118.0	0.14765	30000.0	1.0	1.0	.
2014-04-04	2014-04-04	150.0	19.0	6.0	150.0	118.0	0.13716	30000.0	1.0	1.0	.
2014-04-05	2014-04-05	180.0	41.0	15.0	148.0	124.0	0.13091	30000.0	1.0	1.0	.

5 rows × 23 columns

1.3 Visual data analysis

1.3.1 Timeseries plots

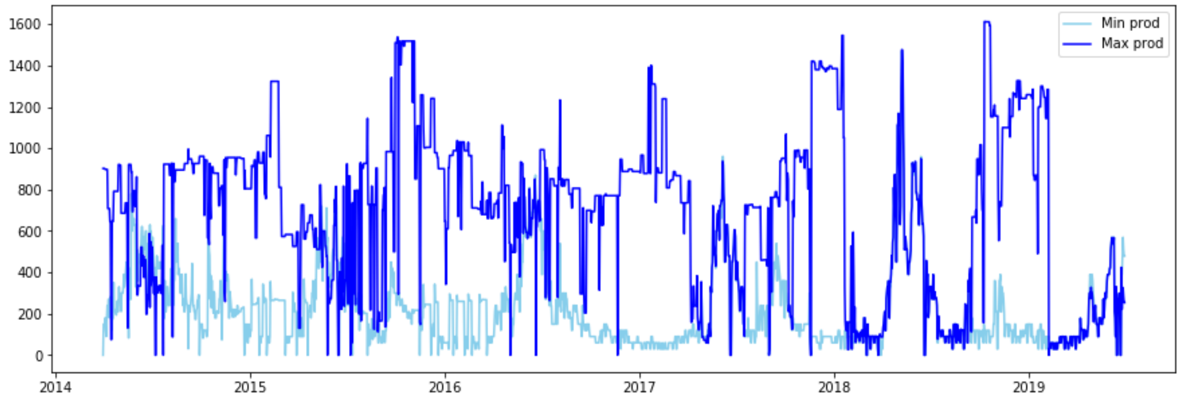
Entrée [7]:

```
from pandas.plotting import register_matplotlib_converters
register_matplotlib_converters()

# Plot daily target features time series: min and max production
fig_size = plt.rcParams["figure.figsize"]
fig_size[0] = 15
fig_size[1] = 5
plt.rcParams["figure.figsize"] = fig_size
plt.plot('Min prod', data=df, color='skyblue')
plt.plot('Max prod', data=df, color='blue')
plt.legend()
```

executed in 225ms, finished 19:42:02 2019-09-15

Out[7]:

<matplotlib.legend.Legend at 0x19b9a771e80>



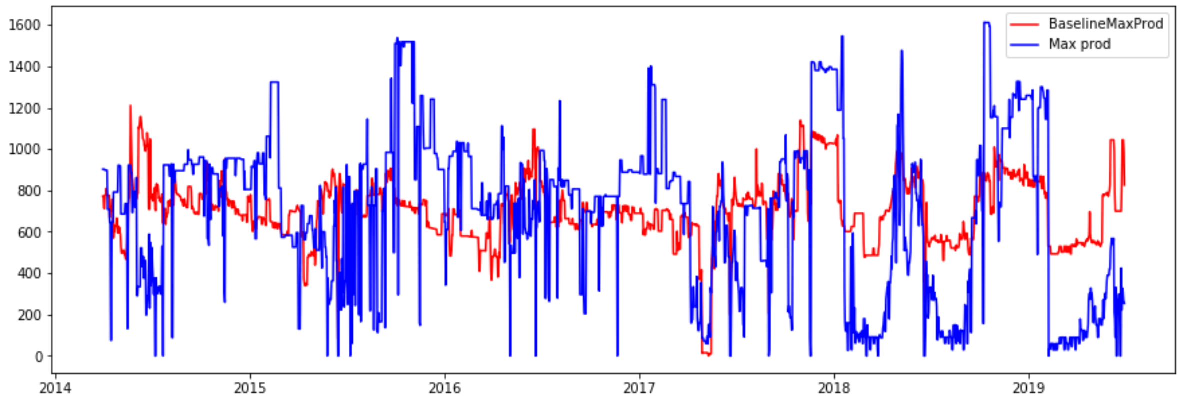
Entrée [8]:

```
#Plot maximum along with baseline
# Plot minimum production baseline as well
df["BaselineMaxProd"] = df_benchmark["MaxEnergy"]
plt.plot('BaselineMaxProd', data=df, color='red')
plt.plot('Max prod', data=df, color='blue')
plt.legend()
```

executed in 223ms, finished 19:42:43 2019-09-15

Out[8]:

<matplotlib.legend.Legend at 0x19b9aa57b70>



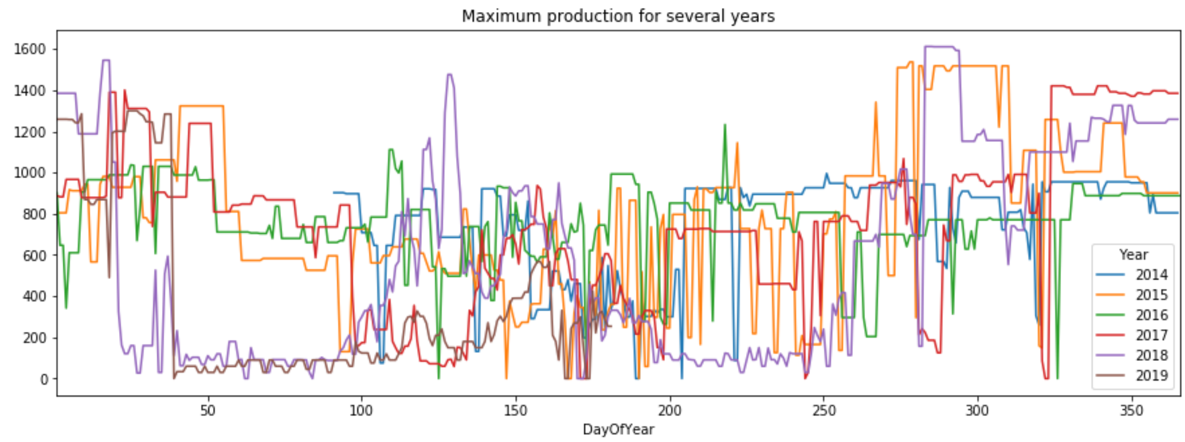
Entrée [9]:

```
# all value plotted on one year
VariantPrio = pd.DataFrame(df.loc[:, ['Date','Max prod']])
VariantPrio.index = VariantPrio['Date']

# Add the year and day of years features, then pivot to have one column of data per year (r
VariantPrio["Year"] = VariantPrio.index.year
VariantPrio["DayOfYear"] = VariantPrio.index.dayofyear

YearVariantPrio = VariantPrio.pivot(index='DayOfYear', columns='Year', values='Max prod')

YearVariantPrio.plot(title="Maximum production for several years")
```

executed in 303ms, finished 19:42:48 2019-09-15

Out[9]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x19b9ad2f198>
```



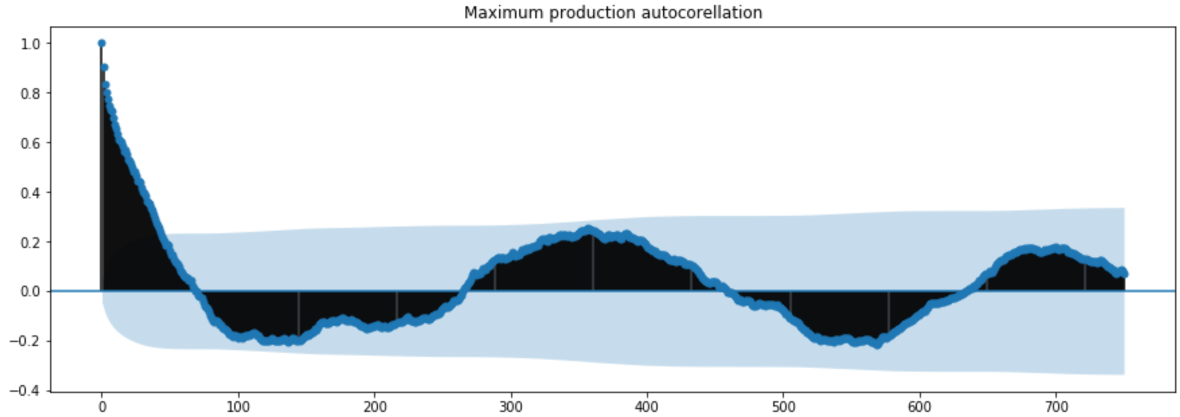
1.3.2 Autocorellation function plot (ACF)

Confidence intervals are drawn as a cone. By default, this is set to a 95% confidence interval, suggesting that correlation values outside of this code are very likely a correlation and not a statistical fluke.

Entrée [10]:

```
# plot correlogram
from pandas import Series
from matplotlib import pyplot
from statsmodels.graphics.tsaplots import plot_acf
plot_acf(df['Max prod'], lags=750, title ="Maximum production autocorellation")
pyplot.show()
```

executed in 530ms, finished 19:43:17 2019-09-15



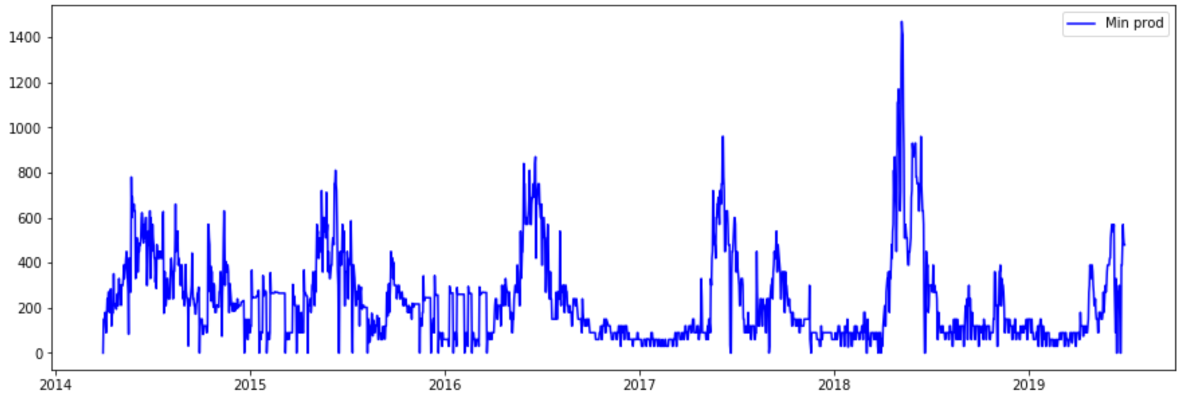
Entrée [11]:

```
# Plot minimum production
plt.plot('Min prod', data=df, color='blue')
plt.legend()
```

executed in 185ms, finished 19:43:18 2019-09-15

Out[11]:

```
<matplotlib.legend.Legend at 0x19b9aa4cd30>
```



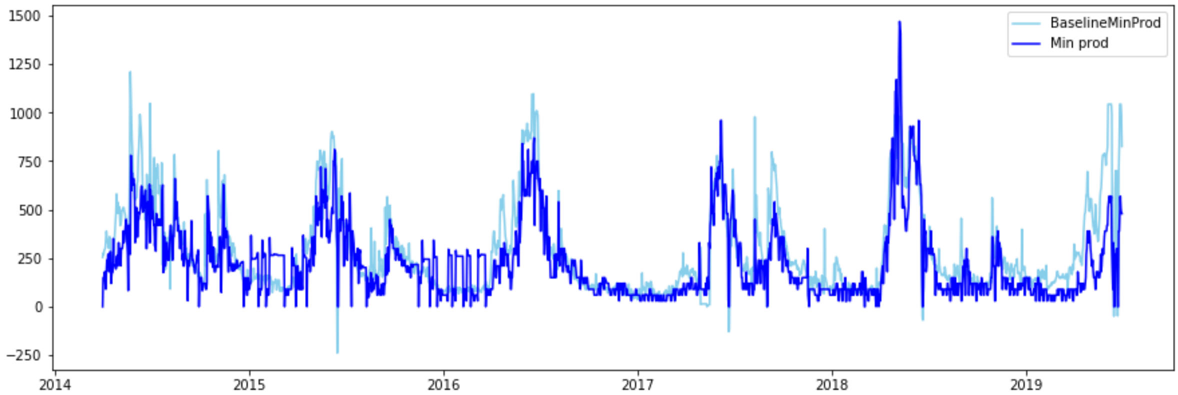
Entrée [12]:

```
# Plot minimum production baseline as well
df["BaselineMinProd"] = df_benchmark["Min Prod [MWh]"]
plt.plot('BaselineMinProd', data=df, color='skyblue')
plt.plot('Min prod', data=df, color='blue')
plt.legend()
```

executed in 218ms, finished 19:43:19 2019-09-15

Out[12]:

```
<matplotlib.legend.Legend at 0x19b9b4e6898>
```

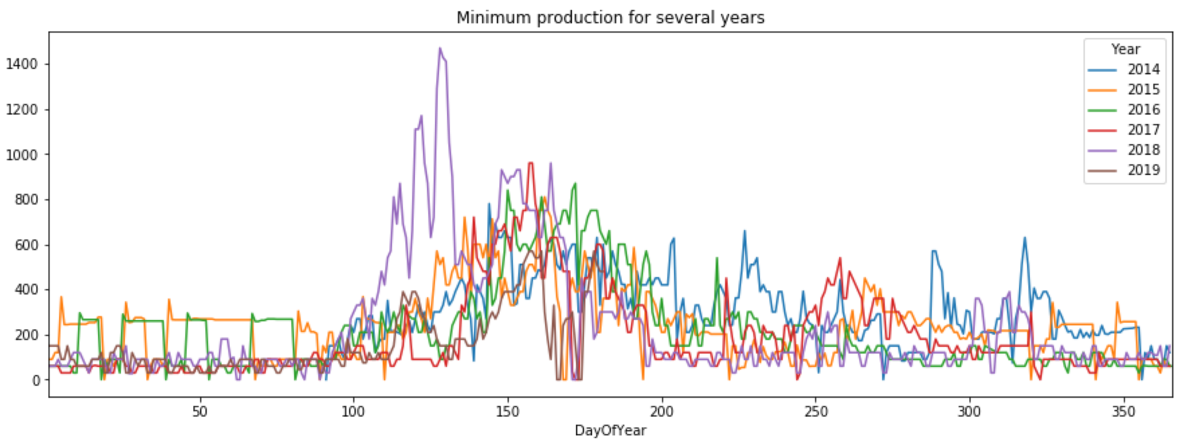


Entrée [43]:

```
# all value plotted on one year
MindProd = pd.DataFrame(df.loc[:, ['Date','Min prod']])
MindProd.index = MindProd['Date']

# Add the year and day of years features, then pivot to have one column of data per year (r
MindProd["Year"] = MindProd.index.year
MindProd["DayOfYear"] = MindProd.index.dayofyear

YearMindProd = MindProd.pivot(index='DayOfYear', columns='Year', values='Min prod')

YearMindProd.plot(title="Minimum production for several years")
```

Out[43]:

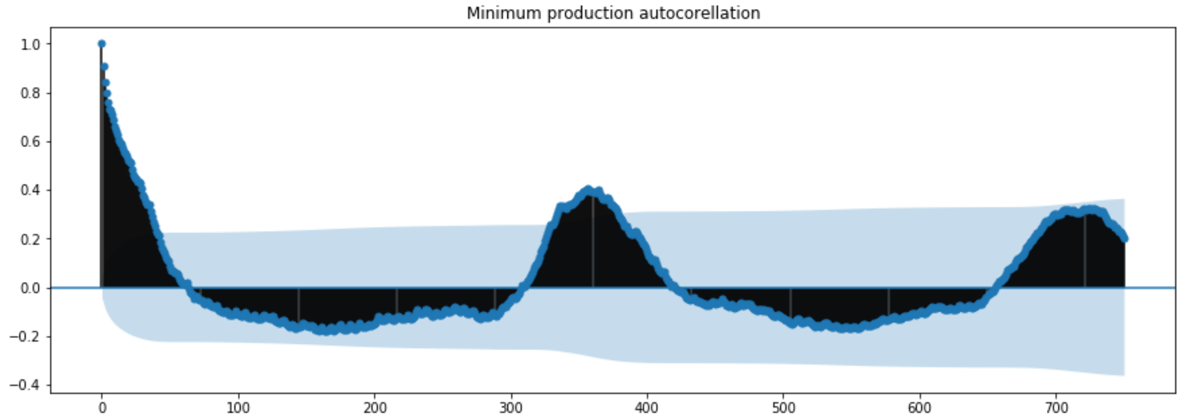
```
<matplotlib.axes._subplots.AxesSubplot at 0x19a0801eba8>
```



Entrée [13]:

```
# plot correlogram
from pandas import Series
from matplotlib import pyplot
from statsmodels.graphics.tsaplots import plot_acf
plot_acf(df['Min prod'], lags=750, title ="Minimum production autocorellation")
pyplot.show()
```

executed in 234ms, finished 19:45:14 2019-09-15



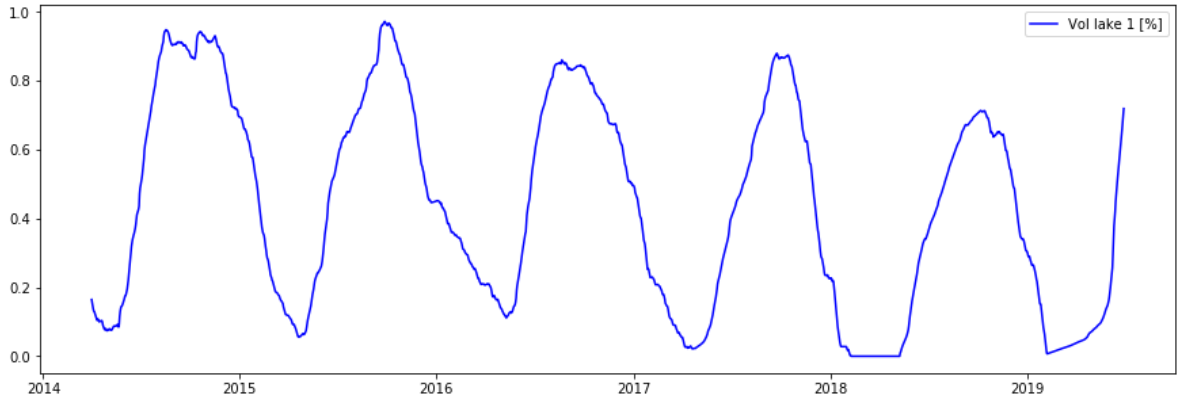
Entrée [14]:

```
plt.plot('Vol lake 1 [%]', data=df, color='blue')
plt.legend()
```

executed in 180ms, finished 19:45:15 2019-09-15

Out[14]:

```
<matplotlib.legend.Legend at 0x19b9b4daf60>
```



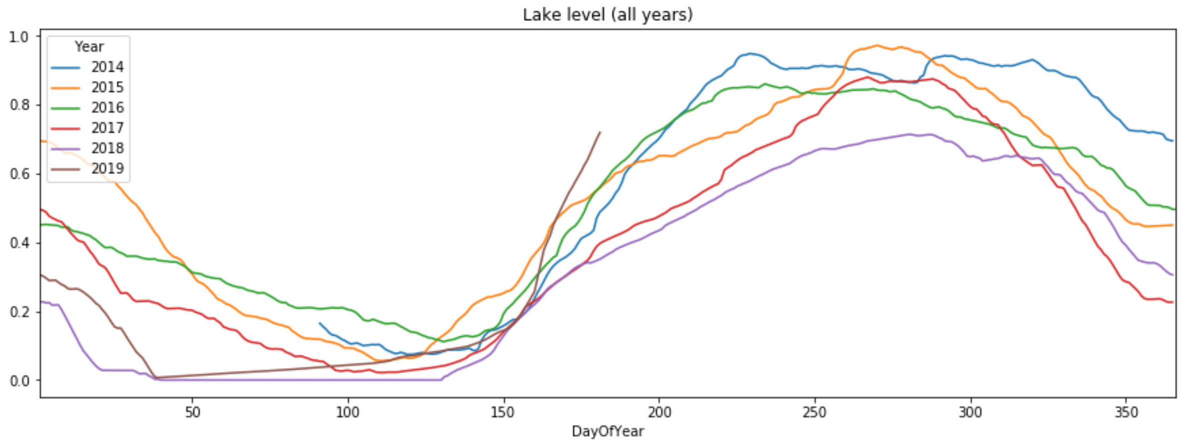
Entrée [15]:

```
# all value plotted on one year
Lakelevel = pd.DataFrame(df.loc[:, ['Date','Vol lake 1 [%]']])
Lakelevel.index = Lakelevel['Date']

# Add the year and day of years features, then pivot to have one column of data per year (r
Lakelevel["Year"] = Lakelevel.index.year
Lakelevel["DayOfYear"] = Lakelevel.index.dayofyear

YearLakelevel = Lakelevel.pivot(index='DayOfYear', columns='Year', values='Vol lake 1 [%]')

YearLakelevel.plot(title="Lake level (all years)")
```

executed in 257ms, finished 19:45:16 2019-09-15

Out[15]:

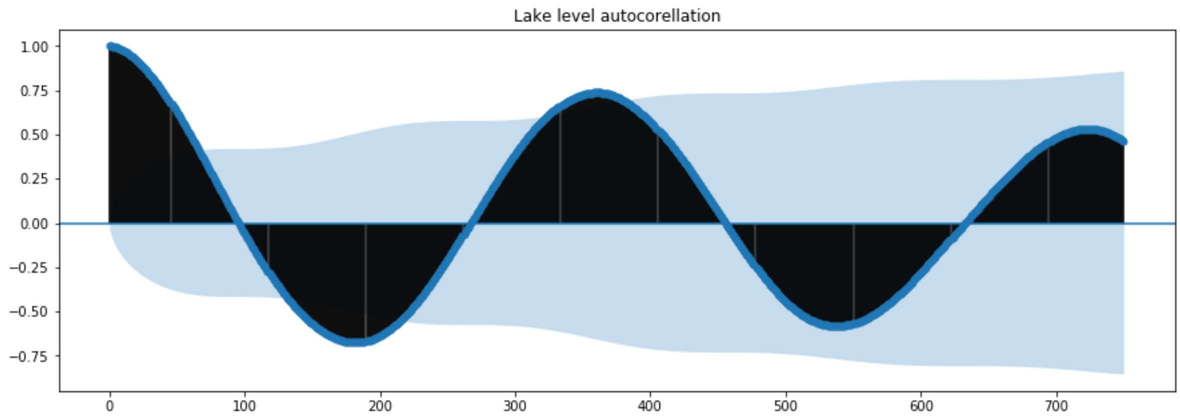
```
<matplotlib.axes._subplots.AxesSubplot at 0x19b9c55f8d0>
```



Entrée [16]:

```
# plot correlogram
from pandas import Series
from matplotlib import pyplot
from statsmodels.graphics.tsaplots import plot_acf
plot_acf(df['Vol lake 1 [%]'], lags=750, title ="Lake level autocorellation")
pyplot.show()
```

executed in 202ms, finished 19:45:17 2019-09-15



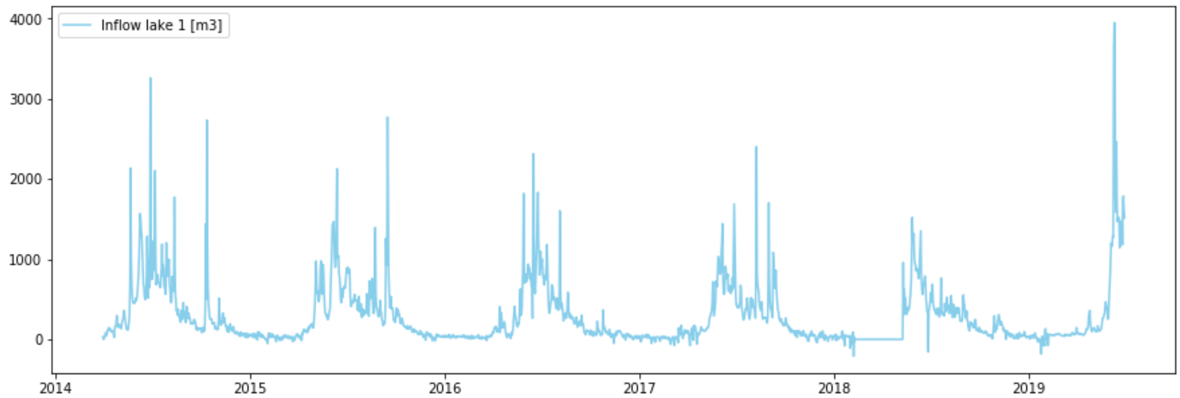
Entrée [17]:

```
plt.plot('Inflow lake 1 [m3]', data=df, color='skyblue')
plt.legend()
```

executed in 175ms, finished 19:45:18 2019-09-15

Out[17]:

<matplotlib.legend.Legend at 0x19b9ca7c2b0>



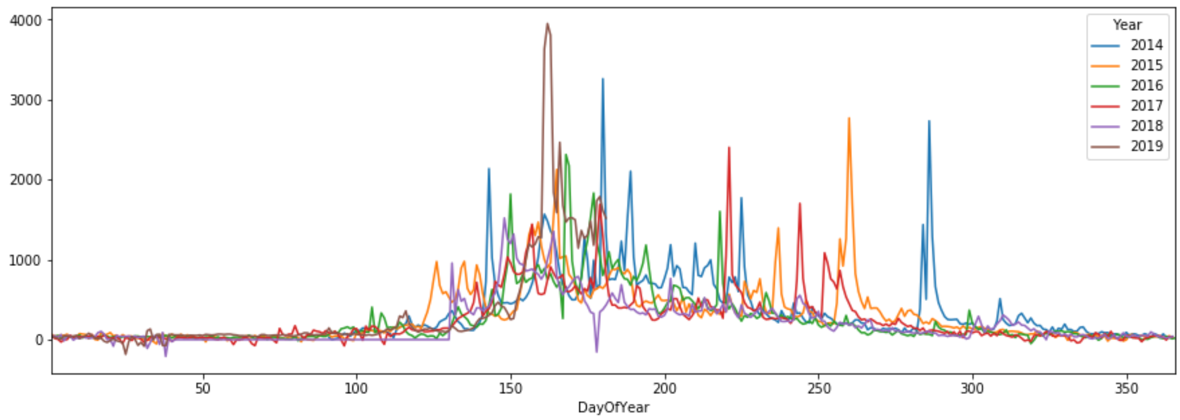
Entrée [18]:

```
# all value plotted on one year
Inflows = pd.DataFrame(df.loc[:, ['Date','Inflow lake 1 [m3]']])
Inflows.index = Inflows['Date']

# Add the year and day of years features, then pivot to have one column of data per year (r
Inflows["Year"] = Inflows.index.year
Inflows["DayOfYear"] = Inflows.index.dayofyear

YearInflows = Inflows.pivot(index='DayOfYear', columns='Year', values='Inflow lake 1 [m3]')

YearInflows.plot()
```

executed in 268ms, finished 19:45:18 2019-09-15

Out[18]:

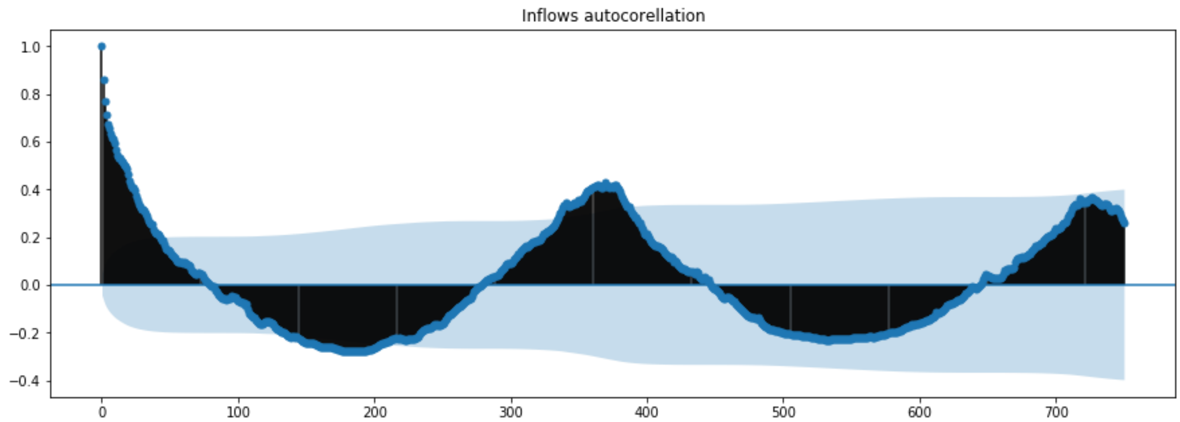
<matplotlib.axes._subplots.AxesSubplot at 0x19b9cb94668>



Entrée [19]:

```
# plot correlogram
from pandas import Series
from matplotlib import pyplot
from statsmodels.graphics.tsaplots import plot_acf
plot_acf(df['Inflow lake 1 [m3]'], lags=750, title ="Inflows autocorellation")
pyplot.show()
```

executed in 187ms, finished 19:45:19 2019-09-15



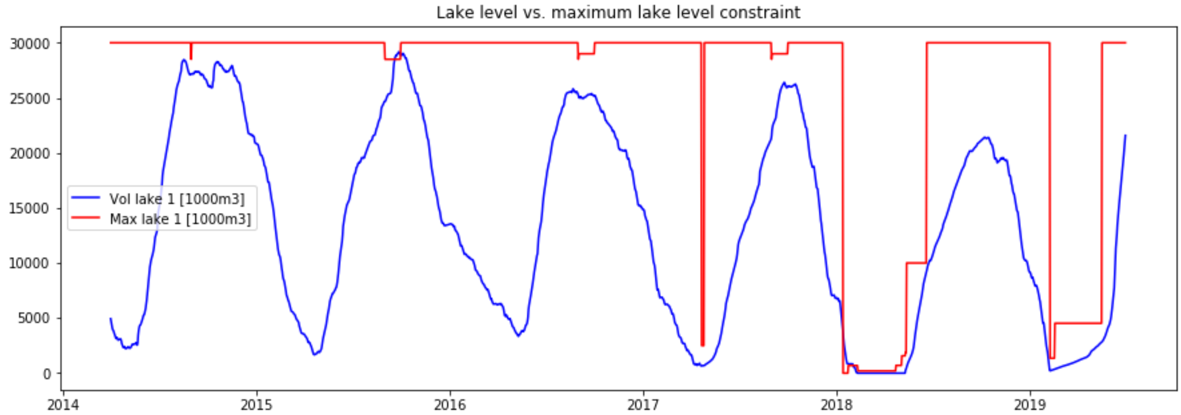
Entrée [20]:

```
df['Vol lake 1 [1000m3]'] = df['Vol lake 1 [%]'] * 30000
plt.plot('Vol lake 1 [1000m3]', data=df, color='blue' )
plt.plot('Max lake 1 [1000m3]', data=df, color='red' )

plt.title(label = "Lake level vs. maximum lake level constraint")
plt.legend()
```

executed in 264ms, finished 19:45:21 2019-09-15

Out[20]:

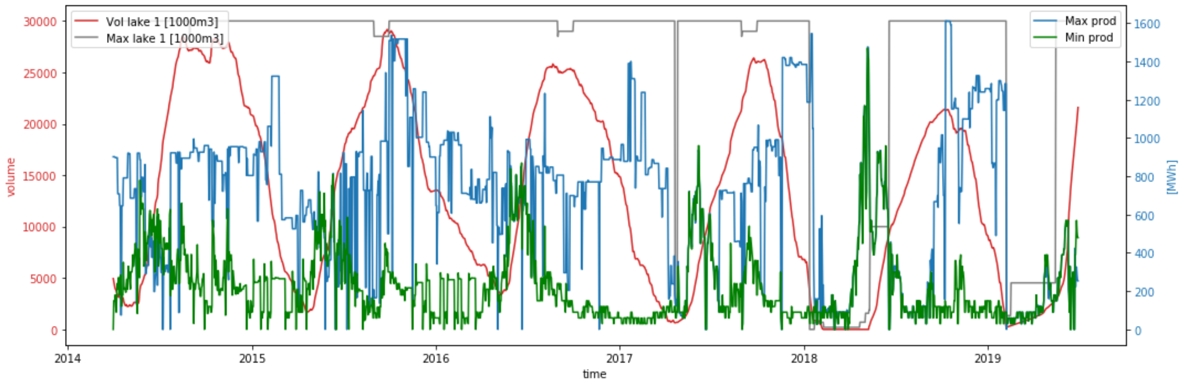
<matplotlib.legend.Legend at 0x19b9e381f28>

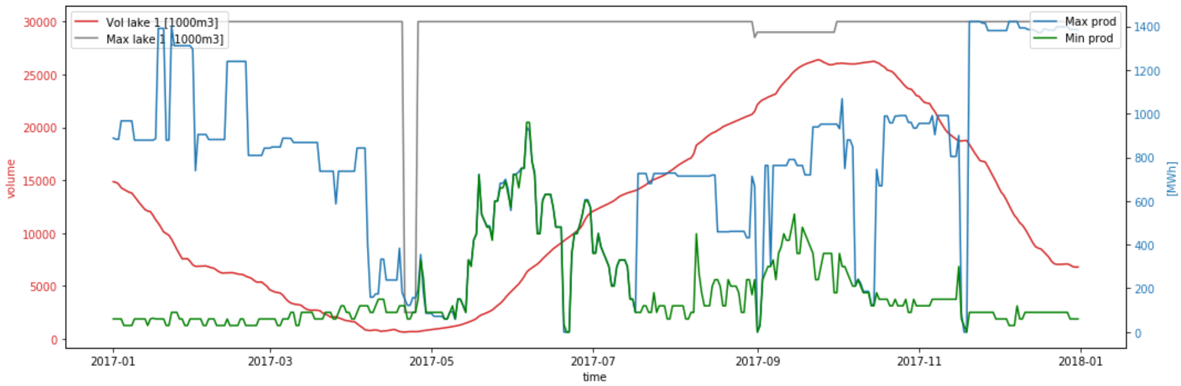


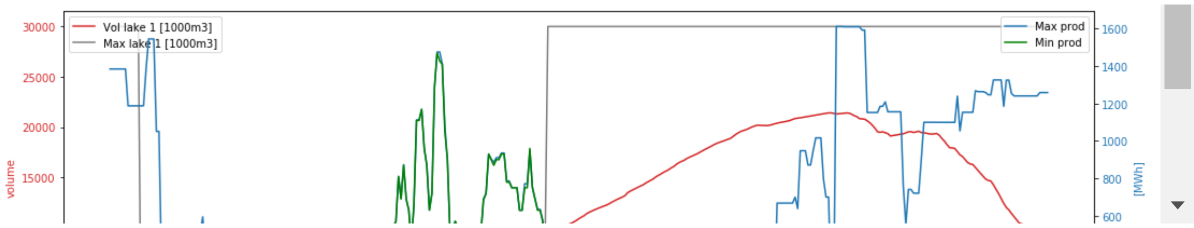
Entrée [21]:

```
# same with min and max prod
df["Year"] = df.index.year

for df_plot in [df,df[df["Year"]==2017], df[df["Year"]==2018]]:

    fig, ax1 = plt.subplots()

    color = 'tab:red'
    ax1.set_xlabel('time')
    ax1.set_ylabel('volume', color=color)
    ax1.plot('Vol lake 1 [1000m3]', data=df_plot, color=color)
    plt.plot('Max lake 1 [1000m3]', data=df_plot, color='grey' )
    ax1.tick_params(axis='y', labelcolor=color)
    plt.legend(loc='upper left')

    ax2 = ax1.twinx()  # instantiate a second axes that shares the same x-axis

    color = 'tab:blue'
    ax2.set_ylabel('[MWh]', color=color)  # we already handled the x-label with ax1
    ax2.plot('Max prod', data=df_plot, color=color)
    ax2.plot('Min prod', data=df_plot, color='green')
    ax2.tick_params(axis='y', labelcolor=color)

    fig.tight_layout()  # otherwise the right y-label is slightly clipped
    plt.legend(loc='upper right')
    plt.show()
```

executed in 960ms, finished 19:45:23 2019-09-15







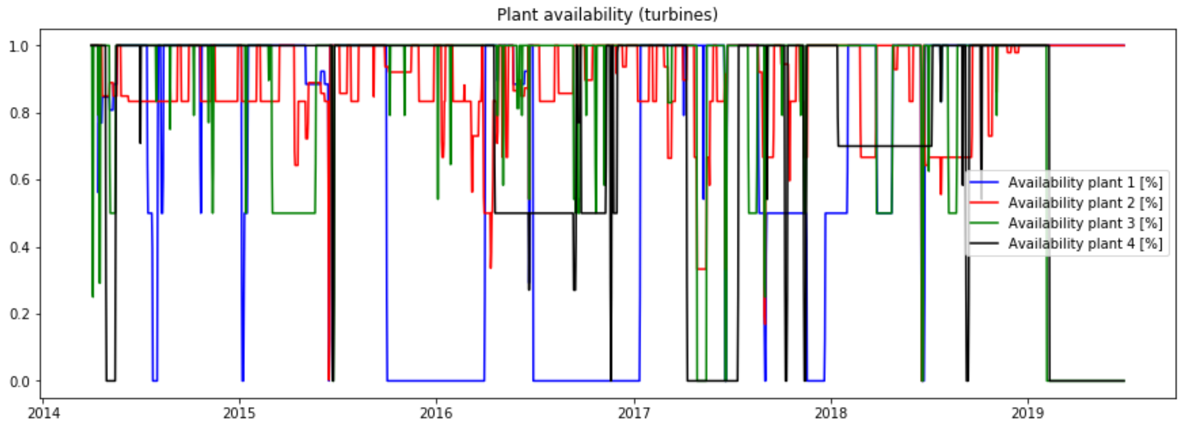
Entrée [22]:

```
# plot maximum power turbine constraints
plt.plot('Availability plant 1 [%]', data=df, color='blue' )
plt.plot('Availability plant 2 [%]', data=df, color='red' )
plt.plot('Availability plant 3 [%]', data=df, color='green' )
plt.plot('Availability plant 4 [%]', data=df, color='black' )

plt.title(label = "Plant availability (turbines)")
plt.legend()
```

executed in 321ms, finished 19:45:24 2019-09-15

Out[22]:

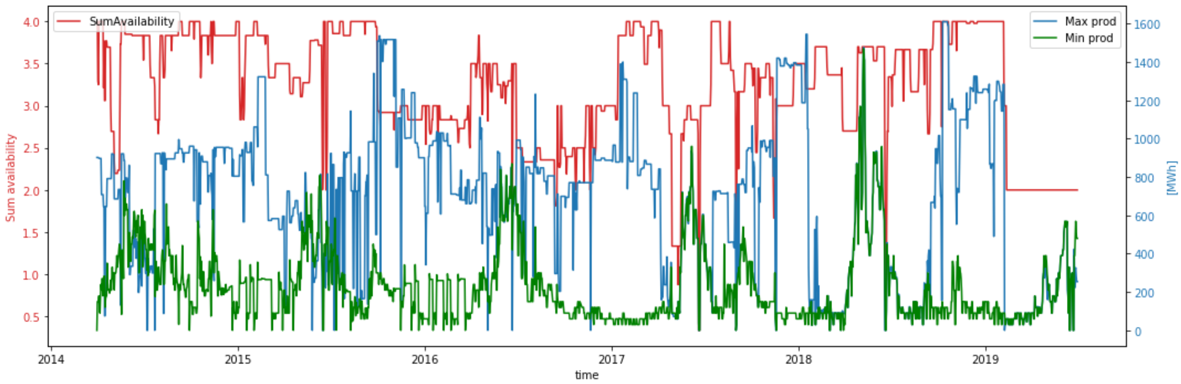
<matplotlib.legend.Legend at 0x19b9e4f19e8>

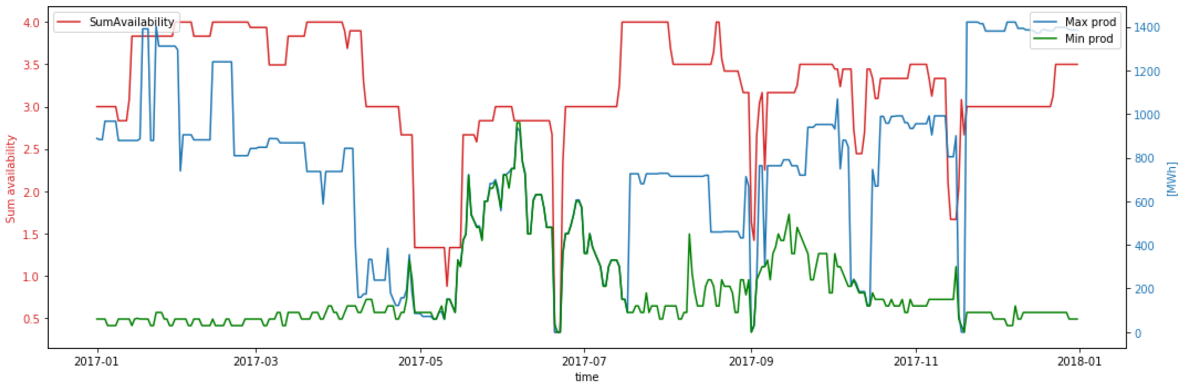


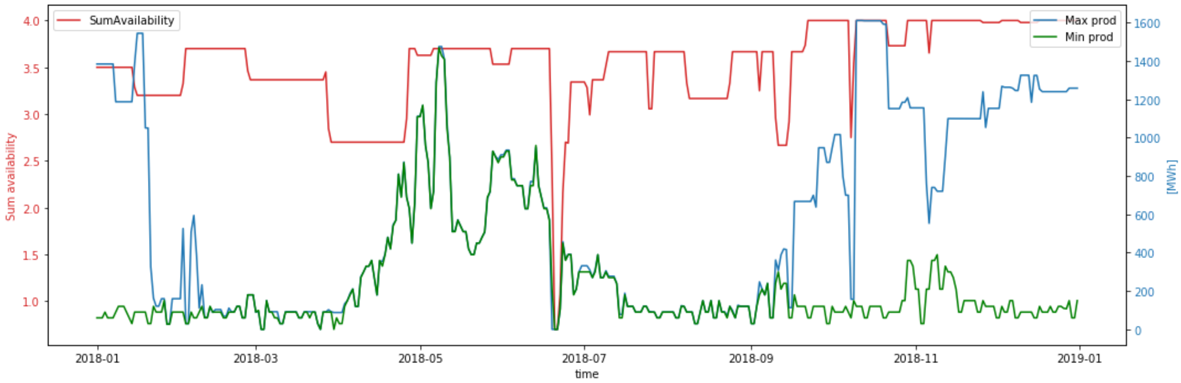
Entrée [23]:

```
# plot max availability of all turbines vs max production

df["SumAvailability"] = 0
for i in range (1,4+1):
    df["SumAvailability"] += df['Availability plant '+str(i)+' [%]']

# plot sum of turbine constraints vs max production
#plt.plot('SumAvailability', data=df, color='blue' )
#plt.title(label = "Sum of all plant availabilities (turbines)")
#plt.legend()

for df_plot in [df,df[df["Year"]==2017], df[df["Year"]==2018]]:
    fig, ax1 = plt.subplots()

    color = 'tab:red'
    ax1.set_xlabel('time')
    ax1.set_ylabel('Sum availability', color=color)
    ax1.plot('SumAvailability', data=df_plot, color=color)
    ax1.tick_params(axis='y', labelcolor=color)
    plt.legend(loc='upper left')

    ax2 = ax1.twinx()  # instantiate a second axes that shares the same x-axis

    color = 'tab:blue'
    ax2.set_ylabel('[MWh]', color=color)  # we already handled the x-label with ax1
    ax2.plot('Max prod', data=df_plot, color=color)
    ax2.plot('Min prod', data=df_plot, color='green')
    ax2.tick_params(axis='y', labelcolor=color)

    fig.tight_layout()  # otherwise the right y-label is slightly clipped
    plt.legend(loc='upper right')
    plt.show()
```

executed in 941ms, finished 19:45:35 2019-09-15







1.3.3 Identify inconsistent data: days when minimum production constraint is larger than maxium authorised

Entrée [31]:

```
# Events when min production is lower than max allowed production, torance of 50 (84 events
NRGThreshold = 50
MinGtMax= df[df['Min prod']-df['Max prod'] >NRGThreshold ][['Min prod','Max prod']]

print ("Number of inconsistent values (min prod > max prod): %d" %(MinGtMax.size))
MinGtMax.head()
```

```
Number of inconsistent values (min prod > max prod): 208
```

Out[31]:

	Min prod	Max prod
Date		
2014-04-16	283.0	75.6
2014-05-17	330.0	132.0
2014-05-18	270.0	132.0
2014-06-04	510.0	291.0
2014-06-05	360.0	291.0

Entrée [95]:

```
# define input features
df_input_features = df.filter(['Inflow lake 1 [m3]', \
       'Inflow lake 2 [m3]', 'Inflow lake 3 [m3]', 'Inflow lake 4 [m3]', \
       'Vol lake 1 [%]', 'Max lake 1 [1000m3]', 'Availability plant 1 [%]', \
       'Availability plant 2 [%]', 'Availability plant 3 [%]', \
       'Availability plant 4 [%]', 'Weekend'], axis=1)

# force Weekend column to numeric value
df_input_features['Weekend'] = df_analysis['Weekend'] .astype(int)
# display simple stasticss of data frame
display(round(df_input_features.describe(),2))
```

	Inflow lake 1 [m3]	Inflow lake 2 [m3]	Inflow lake 3 [m3]	Inflow lake 4 [m3]	Vol lake 1 [%]	Max lake 1 [1000m3]	Availability plant 1 [%]	Availability plant 2 [%]	Availabili plant 3 [
count	1917.00	1917.00	1917.00	1917.00	1917.00	1917.00	1917.00	1917.00	1917.
mean	279.38	55.39	172.24	86.18	0.44	26305.37	0.71	0.89	0.
std	393.60	89.28	155.39	100.92	0.31	9228.22	0.42	0.14	0.
min	-210.00	-482.00	-208.00	-224.00	0.00	0.00	-0.00	0.00	0.
25%	42.00	8.70	69.00	37.30	0.15	30000.00	0.50	0.83	1.
50%	119.00	31.00	119.40	59.30	0.43	30000.00	1.00	0.94	1.
75%	376.00	75.00	228.00	116.00	0.70	30000.00	1.00	1.00	1.
max	3951.60	471.00	985.60	1349.70	0.97	30000.00	1.00	1.00	1.

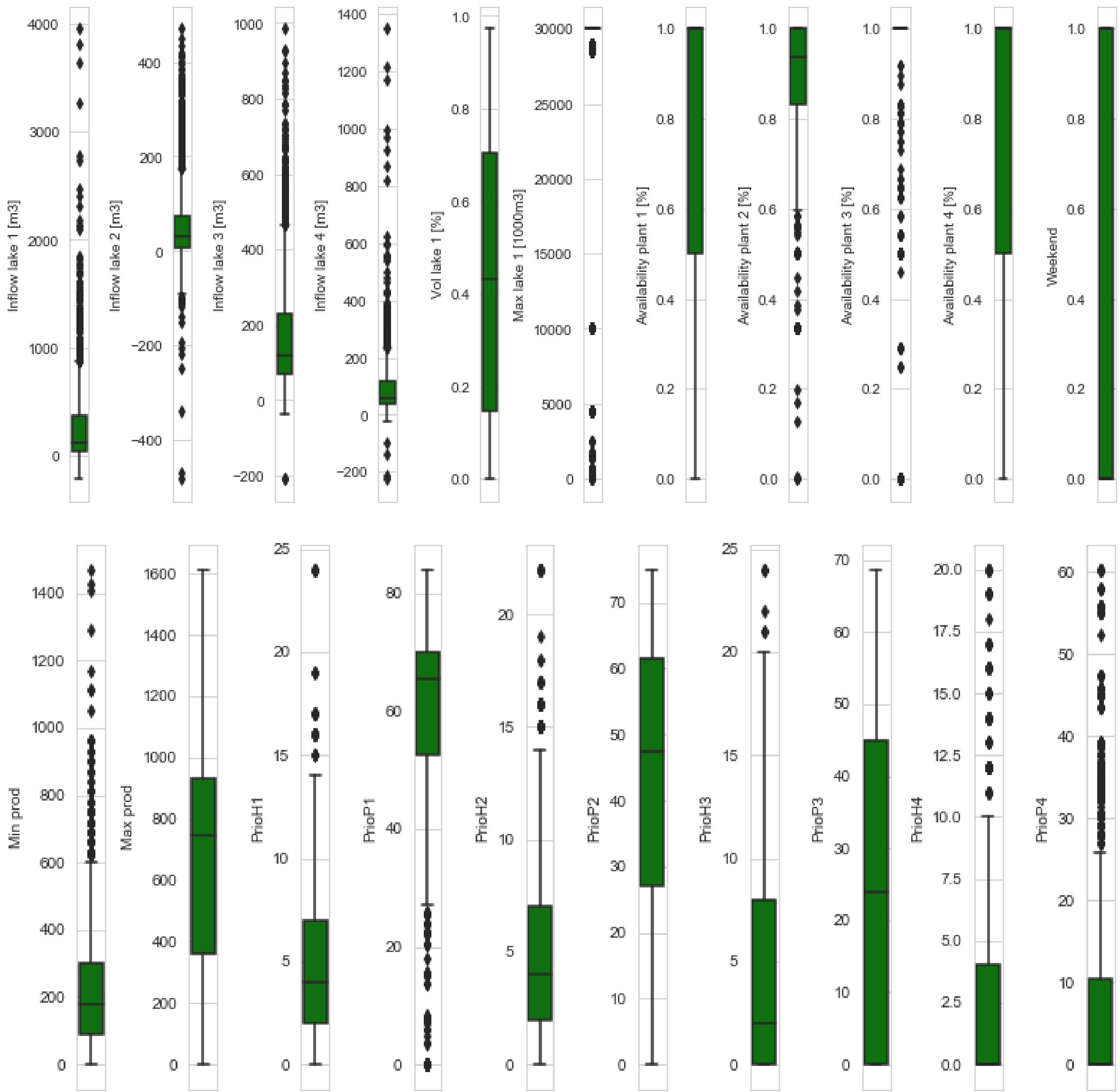
Entrée [82]:

```
# define output features
df_output_features = df.filter(['Min prod','Max prod',  \
                                'PrioH1', 'PrioP1', 'PrioH2', 'PrioP2', \
                                'PrioH3', 'PrioP3','PrioH4', 'PrioP4' ], axis=1)

# display simple statsticss of data frame
display(round(df_output_features.describe(),2))
```

	Min prod	Max prod	PrioH1	PrioP1	PrioH2	PrioP2	PrioH3	PrioP3	PrioH4	PrioP4
count	1917.00	1917.00	1917.00	1917.00	1917.00	1917.00	1917.00	1917.00	1917.00	1917.00
mean	228.44	696.30	4.68	59.03	4.87	42.46	3.86	24.06	2.52	8.06
std	194.11	389.93	3.32	16.40	3.95	21.27	4.31	21.59	4.16	14.10
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25%	90.00	362.10	2.00	52.50	2.00	27.00	0.00	0.00	0.00	0.00
50%	180.00	748.50	4.00	65.40	4.00	47.40	2.00	24.00	0.00	0.00
75%	300.00	933.60	7.00	69.90	7.00	61.50	8.00	45.00	4.00	10.50
max	1470.00	1612.17	24.00	84.00	22.00	75.00	24.00	68.65	20.00	60.30

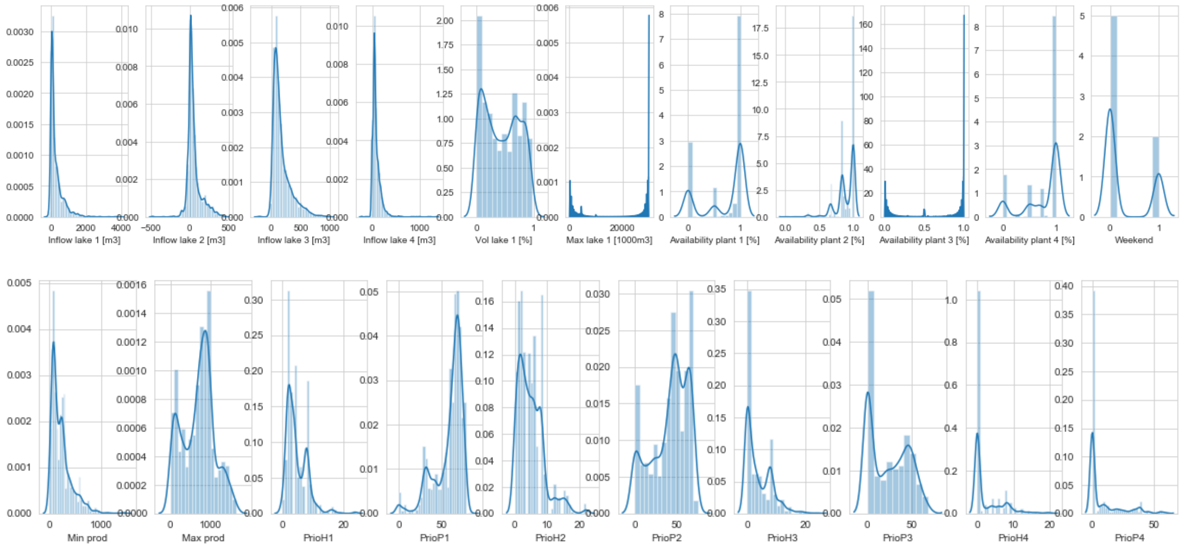
Entrée [84]:

```
for df_plot in [df_input_features, df_output_features]:
    l = df_plot.columns.values
    number_of_columns=len(df_input_features.columns)
    number_of_rows = len(l)-1/number_of_columns
    plt.figure(figsize=(number_of_columns,5*number_of_rows))
    for i in range(0,len(l)):
        plt.subplot(number_of_rows + 1,number_of_columns,i+1)
        sns.set_style('whitegrid')
        sns.boxplot(df_plot[l[i]],color='green',orient='v')
        plt.tight_layout()
```



Entrée [88]:

```
for df_plot in [df_input_features, df_output_features]:
    l = df_plot.columns.values
    number_of_columns=len(df_input_features.columns)
    number_of_rows = len(l)-1/number_of_columns
    plt.figure(figsize=(2*number_of_columns,5*number_of_rows))
    for i in range(0,len(l)):
        plt.subplot(number_of_rows + 1,number_of_columns,i+1)
        sns.distplot(df_plot[l[i]],kde=True)
```



Entrée [116]:

```
df.columns
```

Out[116]:

```
Index(['Date', 'Min prod', 'Inflow lake 1 [m3]', 'Inflow lake 2 [m3]',
       'Inflow lake 3 [m3]', 'Inflow lake 4 [m3]', 'Vol lake 1 [%]',
       'Max lake 1 [1000m3]', 'Availability plant 1 [%]',
       'Availability plant 2 [%]', 'Availability plant 3 [%]',
       'Availability plant 4 [%]', 'SDL [MWh]', 'Weekend', 'Max prod',
       'PrioH1', 'PrioP1', 'PrioH2', 'PrioP2', 'PrioH3', 'PrioP3', 'PrioH4',
       'PrioP4', 'BaselineMaxProd', 'Vol lake 1 [1000m3]', 'Year',
       'SumAvailability'],
      dtype='object')
```

Entrée [117]:

```
# define sub set for statistical analysis
df_analysis = df.filter(['Min prod', 'Max prod', \
       'PrioH1', 'PrioP1', 'PrioH2', 'PrioP2', 'PrioH3', 'PrioP3', 'PrioH4','PrioP4', \
       'Inflow lake 1 [m3]', 'Inflow lake 2 [m3]', 'Inflow lake 3 [m3]', 'Inflow lake 4 [m3
       'Vol lake 1 [%]', 'Max lake 1 [1000m3]', 'Availability plant 1 [%]', \
       'Availability plant 2 [%]', 'Availability plant 3 [%]', \
       'Availability plant 4 [%]', 'SumAvailability','Weekend'], axis=1)

# force Weekend column to numeric value
df_analysis['Weekend'] = df_analysis['Weekend'] .astype(int)
```

Entrée [33]:

```
# display simple stasticss of data frame
display(round(df_analysis.describe(),2))
```

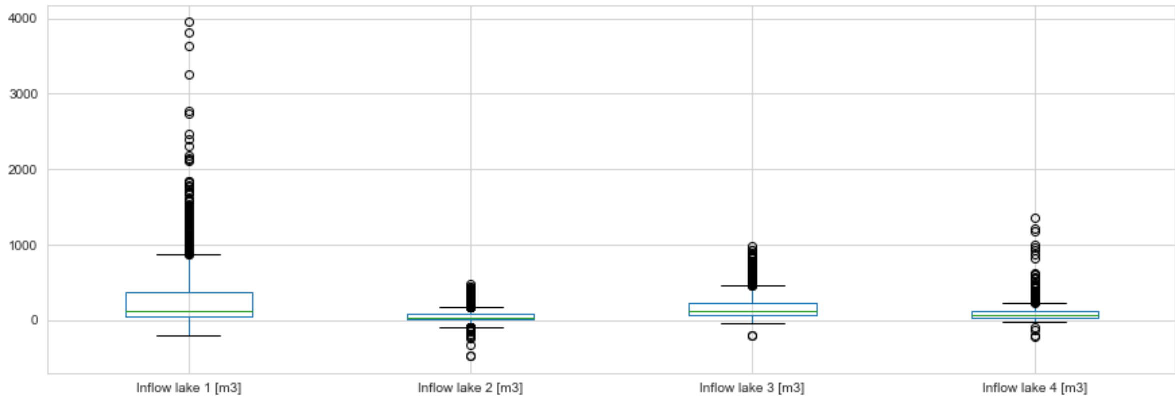
	Min prod	Inflow lake 1 [m3]	Inflow lake 2 [m3]	Inflow lake 3 [m3]	Inflow lake 4 [m3]	Vol lake 1 [%]	Max lake 1 [1000m3]	Availability plant 1 [%]	Availability plant 2 [%]
count	1917.00	1917.00	1917.00	1917.00	1917.00	1917.00	1917.00	1917.00	1917.00
mean	228.44	279.38	55.39	172.24	86.18	0.44	26305.37	0.71	0.89
std	194.11	393.60	89.28	155.39	100.92	0.31	9228.22	0.42	0.14
min	0.00	-210.00	-482.00	-208.00	-224.00	0.00	0.00	-0.00	0.00
25%	90.00	42.00	8.70	69.00	37.30	0.15	30000.00	0.50	0.83
50%	180.00	119.00	31.00	119.40	59.30	0.43	30000.00	1.00	0.94
75%	300.00	376.00	75.00	228.00	116.00	0.70	30000.00	1.00	1.00
max	1470.00	3951.60	471.00	985.60	1349.70	0.97	30000.00	1.00	1.00

Entrée [85]:

```
# Inflows: draw boxplots
df_analysis.boxplot(column= [ 'Inflow lake 1 [m3]', \
       'Inflow lake 2 [m3]', 'Inflow lake 3 [m3]', 'Inflow lake 4 [m3]'])
```

Out[85]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x19a0a63ae10>
```



Entrée [86]:

```
# Draw boxplots for daily energy min and max
df_analysis.boxplot(column= [ 'Min prod','Max prod'])
```

Out[86]:

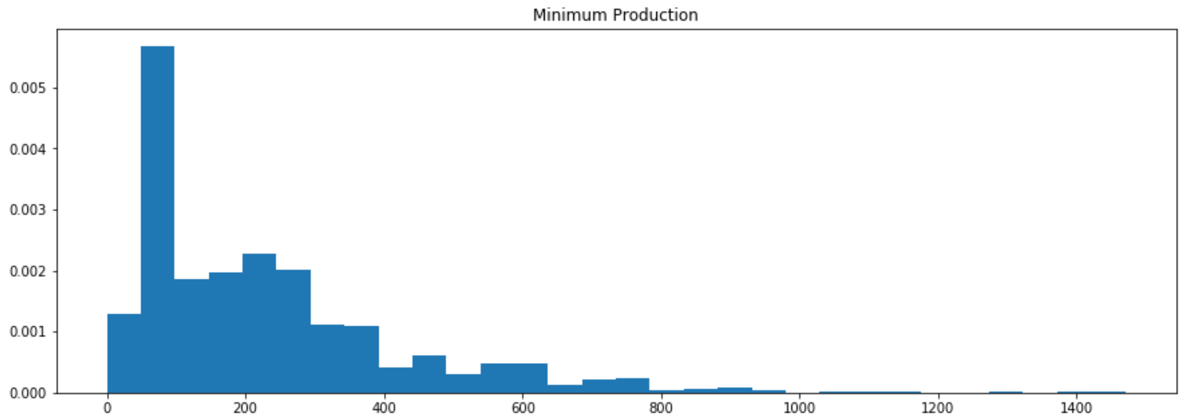
```
<matplotlib.axes._subplots.AxesSubplot at 0x19a0ad0fe10>
```

Entrée [27]:

```
plt.hist(df["Min prod"], density=True, bins=30)
plt.title('Minimum Production distribution')
```

Out[27]:

```
Text(0.5, 1.0, 'Minimum Production')
```

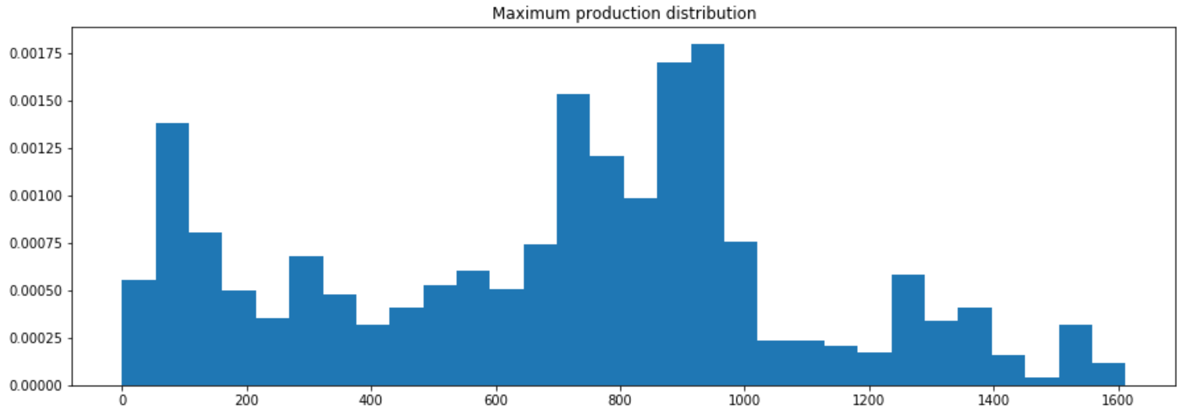


Entrée [47]:

```
plt.hist(df['Max prod'], density=True, bins=30)
plt.title('Maximum production distribution')
```

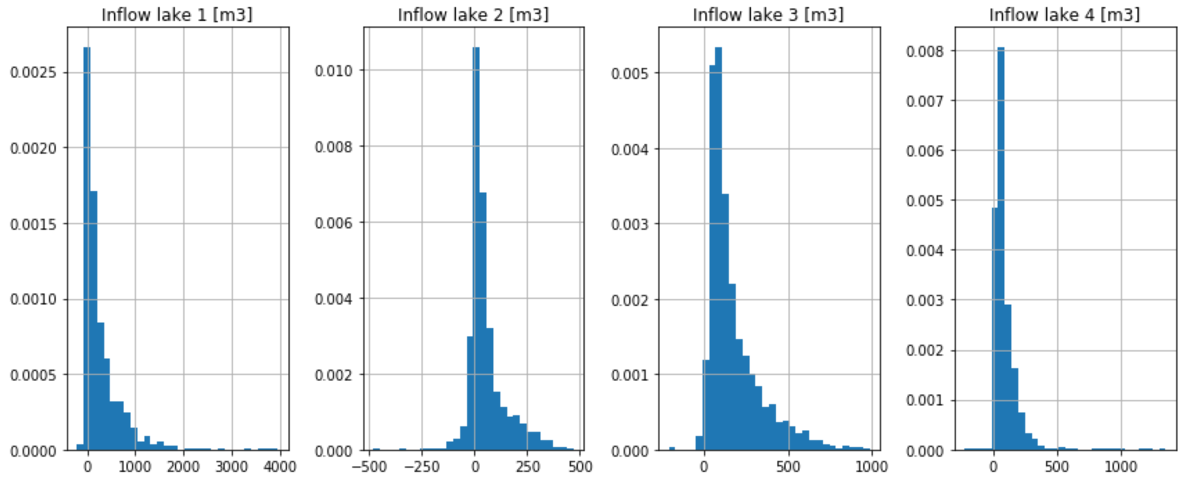
Out[47]:

```
Text(0.5, 1.0, 'Maximum production distribution')
```



Entrée [29]:

```
fig, ax = plt.subplots(nrows=1, ncols=4, figsize=(12,5))  # 1 rows, 4 columns
for i in range(1,5):
    df.hist(column ="Inflow lake "+str(i)+" [m3]", density=True, bins=30, ax=ax[i-1])

plt.tight_layout()
```



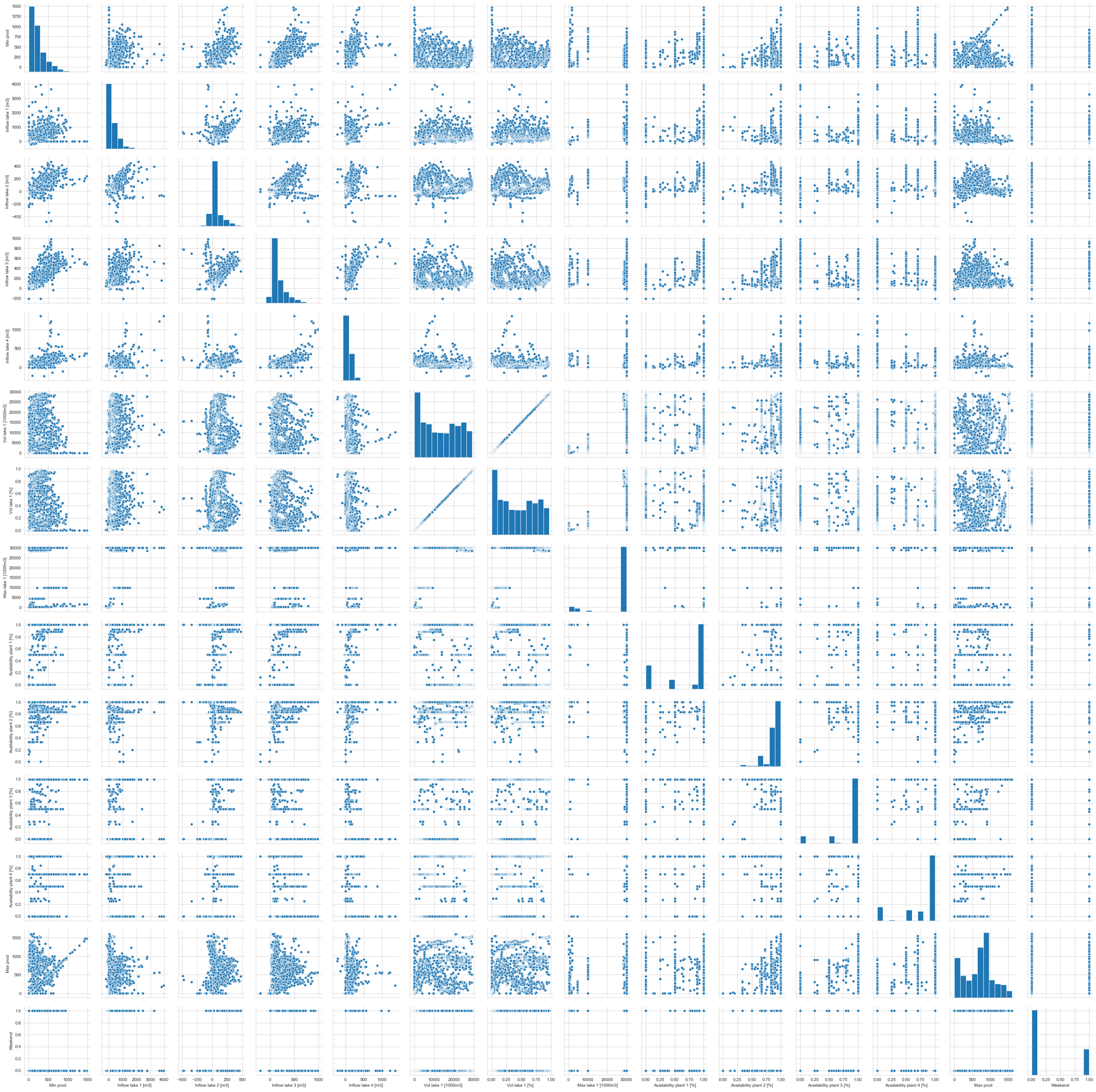
Entrée [112]:

```
## %matplotlib inline
# Basic correlogram
plt.figure(figsize=(22, 22))
sns.pairplot(df_analysis)
```

Out[112]:

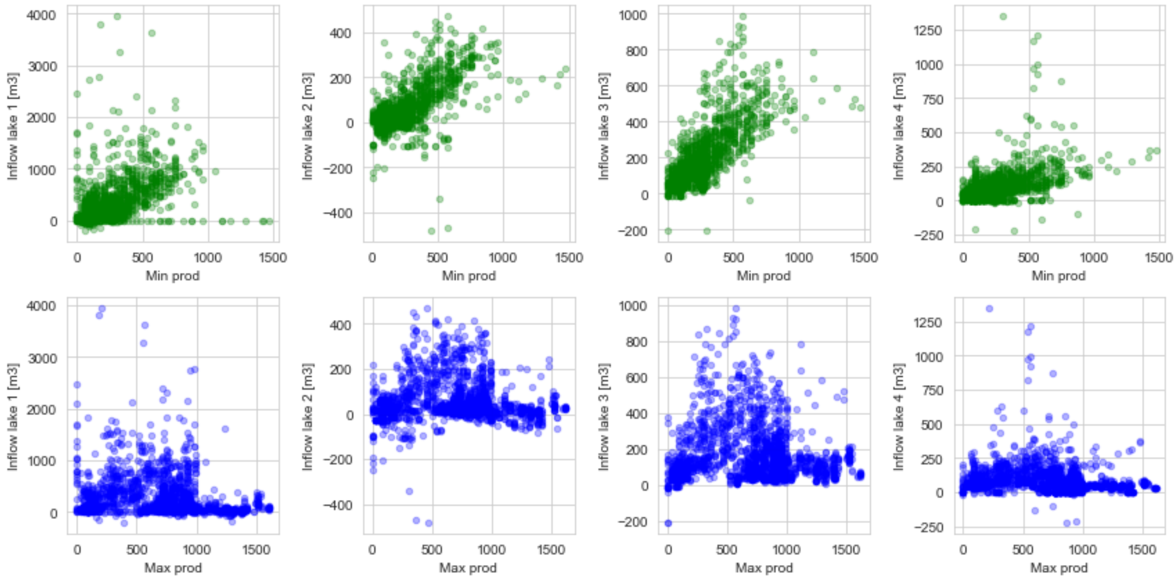
<seaborn.axisgrid.PairGrid at 0x19a0acef0b8>

<Figure size 1584x1584 with 0 Axes>



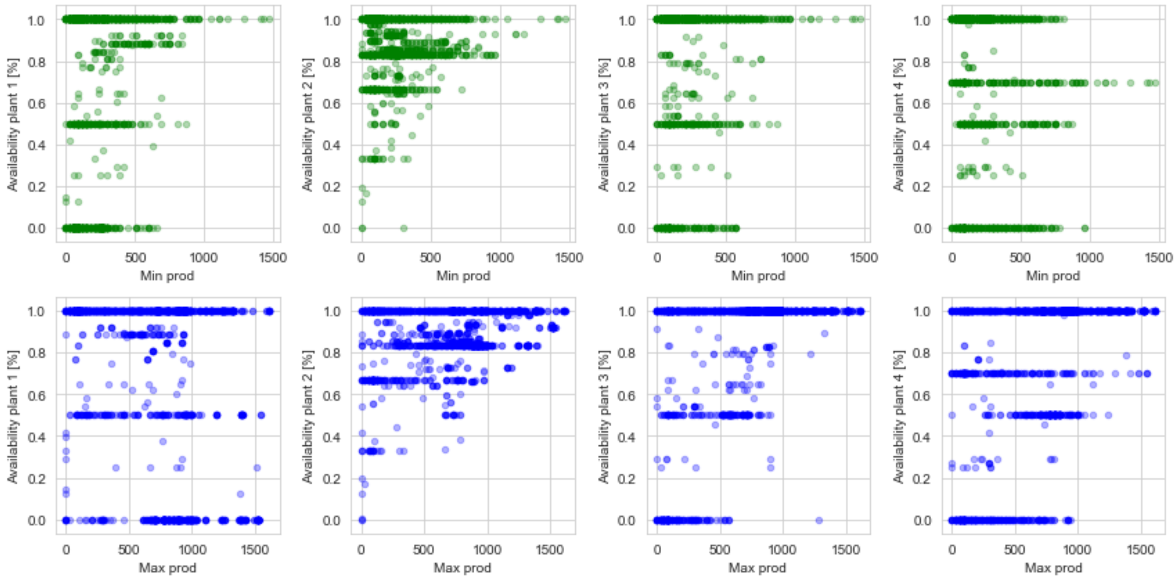
Entrée [96]:

```
# display scatter plots of output features as a function of lake levels

fig, ax = plt.subplots(nrows=2, ncols=4, figsize=(12,6))  # 2 rows, 4 columns
#loop over lakes (1 to 4)
for i in range(1,4+1):
    # Plot min production in green color
    df.plot.scatter(x='Min prod', y='Inflow lake '+str(i)+' [m3]', ax=ax[0, i-1],  c='g', a
    # Plot Variante Prio max production in red color
    df.plot.scatter(x='Max prod', y='Inflow lake '+str(i)+' [m3]', ax=ax[1, i-1],  c='b', a

plt.tight_layout()
```



Entrée [154]:

```
# display scatter plots of output features as a function of plants availability

fig, ax = plt.subplots(nrows=2, ncols=4, figsize=(12,6))  # 2 rows, 4 columns
#loop over plants (1 to 4)
for i in range(1,4+1):
    # Plot min production in green color
    df.plot.scatter(x='Min prod', y='Availability plant '+str(i)+' [%]', ax=ax[0, i-1],  c=
    # Plot Variante Prio max production in red color
    df.plot.scatter(x='Max prod', y='Availability plant '+str(i)+' [%]', ax=ax[1, i-1],  c=

plt.tight_layout()
```

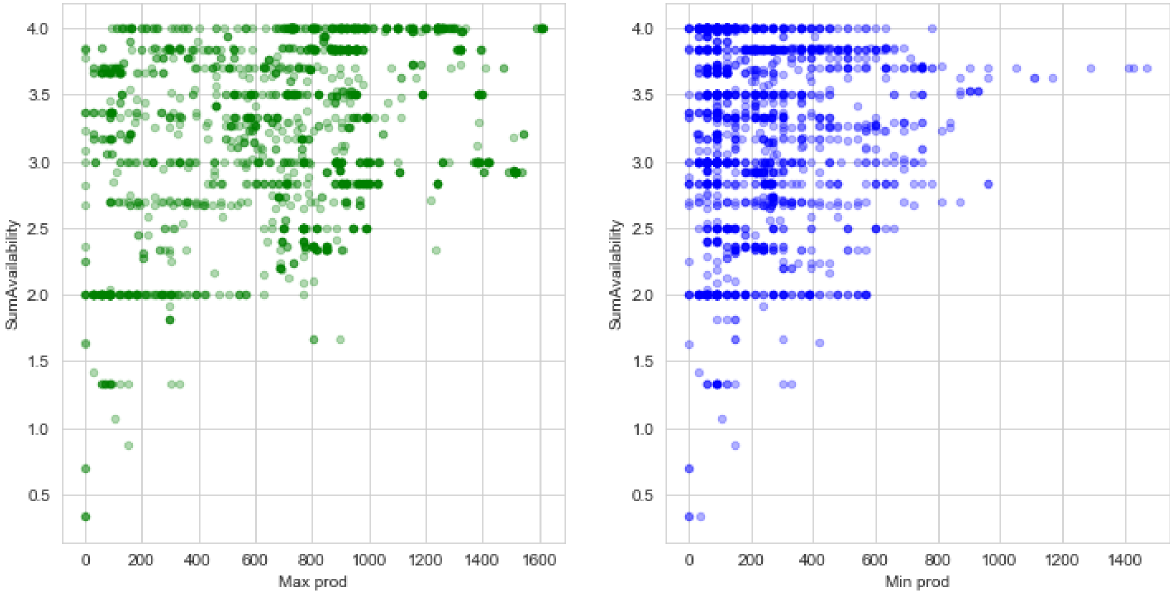


Entrée [111]:

```
## plot min and max production vs total turbine availability
fig, ax = plt.subplots( ncols=2, figsize=(12,6))  # 1 rows, 2 columns
df.plot.scatter(x='Max prod', y='SumAvailability',  ax=ax[0], c='g', alpha=0.3)
df.plot.scatter(x='Min prod', y='SumAvailability',  ax=ax[1], c='b', alpha=0.3)
```

Out[111]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x19a0ee01f60>
```

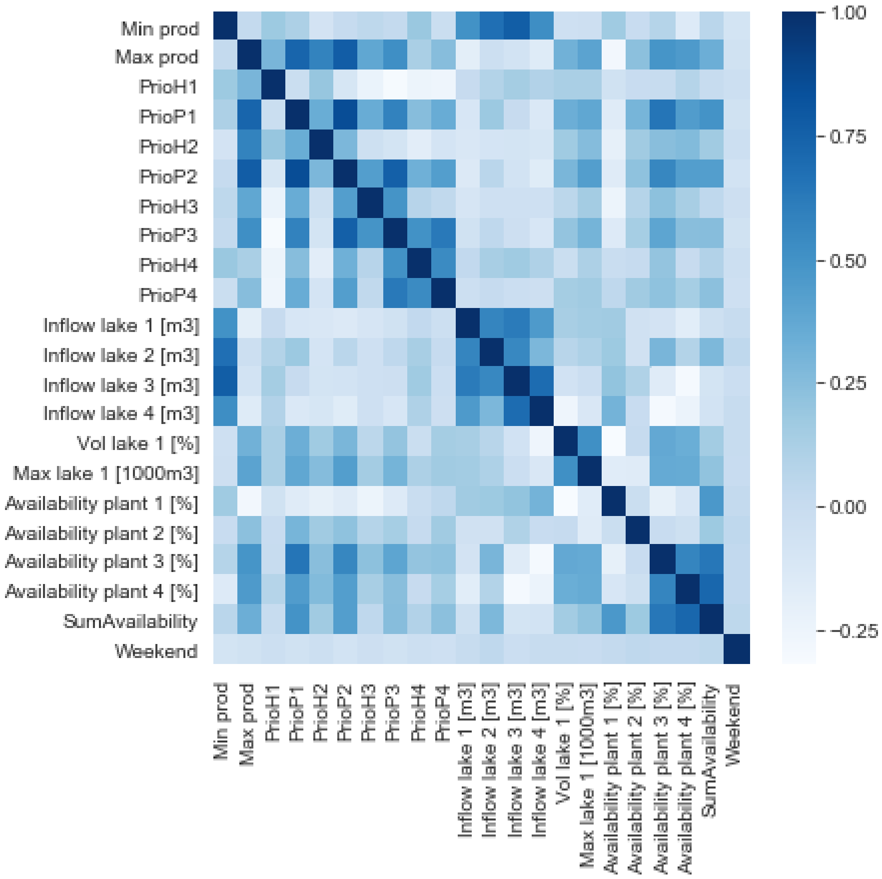


Entrée [119]:

```
# correlation maxtix
plt.figure(figsize=(6,6))
sns.heatmap(df_analysis.corr(),cmap='Blues',annot=False)
```

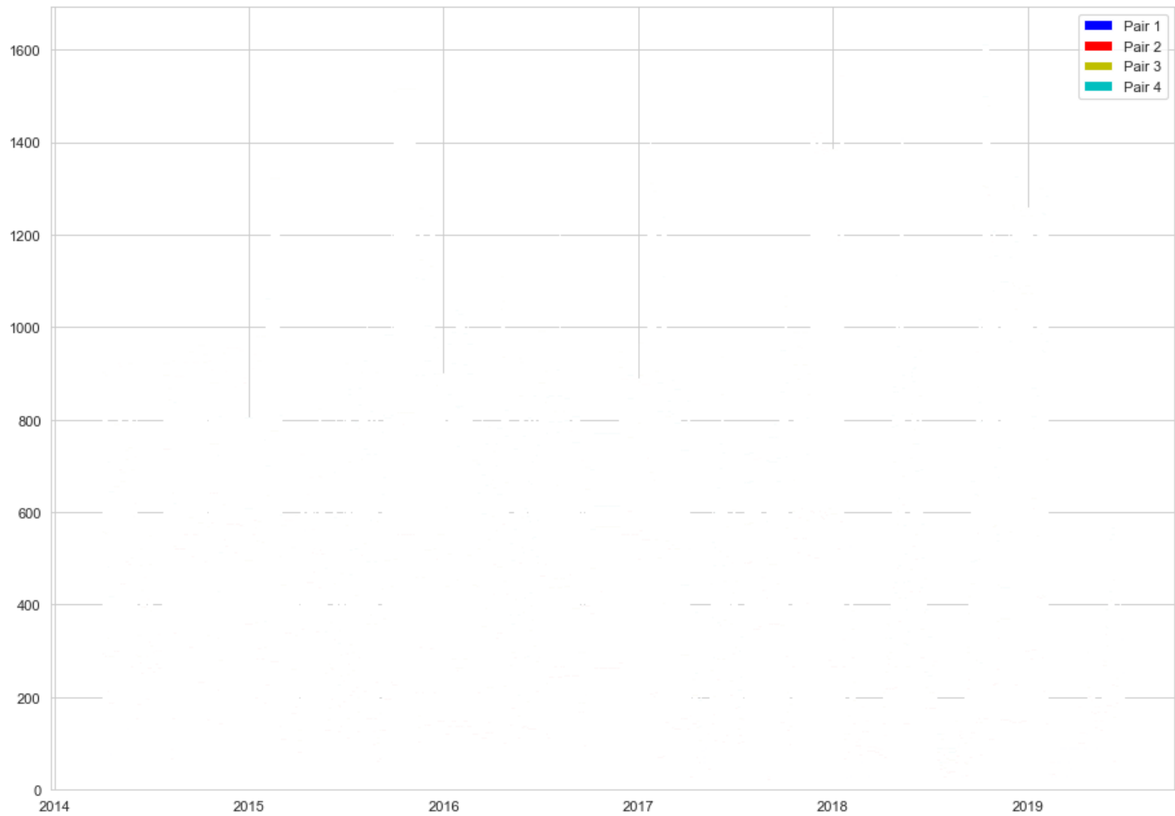
Out[119]:

<matplotlib.axes._subplots.AxesSubplot at 0x19a0cbe7390>



Entrée [87]:

```
# Analysis of power values (4 pairs)
# plot stacked graph, with different colors for each pairs
FromPoint = 0
ToPoint = round(len(df.index))
df_plot = df.iloc[FromPoint:ToPoint, :]

# Compute prediction energy by pair, i.e. nb of hours times power (from 1 to 8 pairs)
for i in range(1, 4+1):
    HourIndex = "PrioH"+str(i)
    PwrIndex  = "PrioP"+str(i)
    PowerVar  = df[HourIndex]*df[PwrIndex]
    # Add column to dataframe
    New_Col_Name = "EnergyPair"+str(i)
    df_plot.insert(len(df.columns),New_Col_Name, PowerVar)

fig=plt.figure(figsize=(14, 10), dpi= 80, edgecolor='k')
plt.bar(df_plot.index, df_plot.EnergyPair1, color = 'b', label="Pair 1")
plt.bar(df_plot.index, df_plot.EnergyPair2, color = 'r', bottom = df_plot.EnergyPair1, labe
plt.bar(df_plot.index, df_plot.EnergyPair3, color = 'y', bottom = df_plot.EnergyPair1+df_pl
plt.bar(df_plot.index, df_plot.EnergyPair4, color = 'c', bottom = df_plot.EnergyPair1+df_pl
plt.legend(loc='upper right')
plt.show()
```



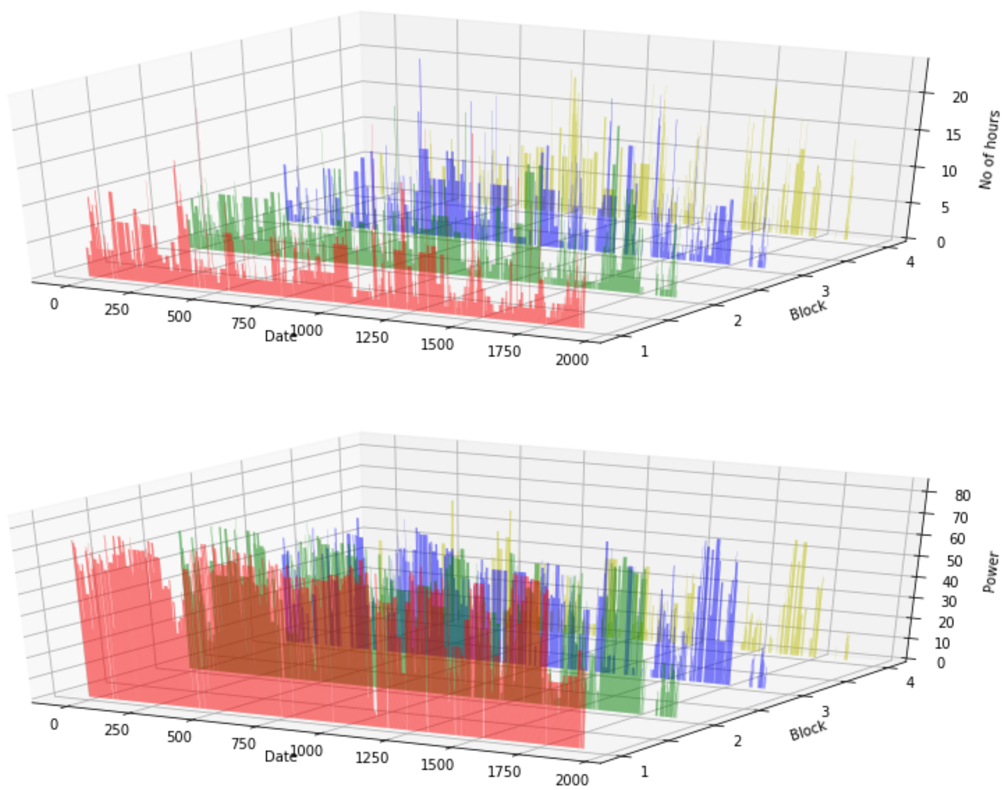
Entrée [ ]:

```
# same but use shades of colour to represent power intensity
import matplotlib.colors as colors
import matplotlib.cm as cm

norm = colors.Normalize(0, df_plot.PrioP1.max())
color_values1 = cm.Reds(norm(df_plot.PrioP1.tolist()))
color_values2 = cm.Reds(norm(df_plot.PrioP2.tolist()))
color_values3 = cm.Reds(norm(df_plot.PrioP3.tolist()))
color_values4 = cm.Reds(norm(df_plot.PrioP4.tolist()))

fig=plt.figure(figsize=(14, 10), dpi= 80, edgecolor='k')
plt.bar(df_plot.index, df_plot.EnergyPair1, color = color_values1, label="Pair 1")
plt.bar(df_plot.index, df_plot.EnergyPair2, color = color_values2, bottom = df_plot.EnergyP
plt.bar(df_plot.index, df_plot.EnergyPair3, color = color_values3, bottom = df_plot.EnergyP
plt.bar(df_plot.index, df_plot.EnergyPair4, color = color_values4, bottom = df_plot.EnergyP
plt.legend(loc='upper right')
plt.show()
```

Entrée [27]:

```
# plot power blocks in 3d
from mpl_toolkits.mplot3d import Axes3D
import matplotlib.pyplot as plt
import numpy as np

for blockType, zLabel in zip(["PrioH", "PrioP"], ["No of hours", "Power"]):
    fig = plt.figure()
    ax = fig.add_subplot(111, projection='3d')
    for c, z in zip(['r', 'g', 'b', 'y'], [1,2,3,4]):
        xs = range(len(df.index)) #range(len(df.index)) #np.arange(20)
        ys = df[blockType+str(z)] #np.ones(len(df.index)) #np.round(df[z]) #np.random.rand(

        # You can provide either a single color or an array. To demonstrate this,
        # the first bar of each set will be colored cyan.
        cs = [c] * len(xs)
        cs[0] = 'c'
        ax.bar(xs, ys, zs=z, zdir='y', color=cs, alpha=0.8, linewidth=0)

    ax.set_xlabel('Date')
    ax.set_ylabel('Block')
    ax.set_zlabel(zLabel)
    ax.set_yticklabels(["","1", "","2", "","3","", "4"])

    plt.show()
```

executed in 22.6s, finished 20:23:39 2019-09-15



Entrée [ ]:

```
# plot power in 3D, along date and "hour of day" axes
```

Entrée [65]:

```
# helper function to make 24 hour vector out of blocks list
# returns a dataframe with 24 hours vectors as lines in a dataframe , from the blocks recei
def get24hoursEnergyVector(prefixHour, prefixPower, dfInput, prefixOutputCols = ""):
    # create result dataframe
    resCols = []
    dfResult = pd.DataFrame(index=dfInput.index, columns = [prefixOutputCols+str(i) for i i

    for myIndex in dfInput.index:
        iVectorIndex = 0
        resVect = np.zeros(24)
        for iPair in range(1,4+1):
            NbHours = int(dfInput.loc[myIndex,prefixHour+str(iPair)])
            Power = dfInput.loc[myIndex,prefixPower+str(iPair)]
            resVect[iVectorIndex:iVectorIndex+NbHours] = Power
            iVectorIndex = iVectorIndex + NbHours
        dfResult.loc[myIndex] = resVect
    return dfResult
```

executed in 6ms, finished 20:49:02 2019-09-15

Entrée [90]:

```
len(x)
```

executed in 4ms, finished 21:04:36 2019-09-15

Out[90]:

24

Entrée [147]:

```
yTicks
```

executed in 5ms, finished 21:40:15 2019-09-15

Out[147]:

[]

Entrée [151]:

```
x = range(24) #np.linspace(-6, 6, 30)
y = range(24) #df.index[(df.index>='2018-09-21') & (df.index<='2018-09-28')]

X, Y = np.meshgrid(x, y)

dfvect24h = get24hoursEnergyVector("PrioH", "PrioP", df, prefixOutputCols = "P")

# create a table containing 24 x 7 power values
Z = np.zeros((len(y), len(x)))
yTicks = [(df.iloc[c+201,]["Date"]).strftime('%Y-%m-%d') for c in range(24)]
for yDate in y:
    for noHour in x:
        val = dfvect24h.iloc[yDate+201,]["P"+str(noHour)]
        Z[yDate, noHour] = val
Z.shape
```

executed in 2.56s, finished 21:43:31 2019-09-15

Out[151]:

```
(24, 24)
```

Entrée [ ]:

executed in 8ms, finished 21:30:06 2019-09-15

Entrée [152]:

```
fig = plt.figure()
ax = plt.axes(projection="3d")
ax.plot_wireframe(X, Y, Z, color='green')
ax.set_xlabel('x')
ax.set_ylabel('y')
ax.set_zlabel('z')

ax = plt.axes(projection='3d')
surf = ax.plot_surface(X, Y, Z, rstride=1, cstride=1,
                cmap=plt.cm.jet,  edgecolor='k', linewidth=0.2, antialiased=True)
ax.set_title('Power values');

# Add a color bar which maps values to colors.
fig.colorbar(surf, shrink=0.5, aspect=5)

ax.set_yticklabels(yTicks)
plt.show()
```

executed in 277ms, finished 21:43:34 2019-09-15