Day-ahead electricity consumption forecasting in Quebec

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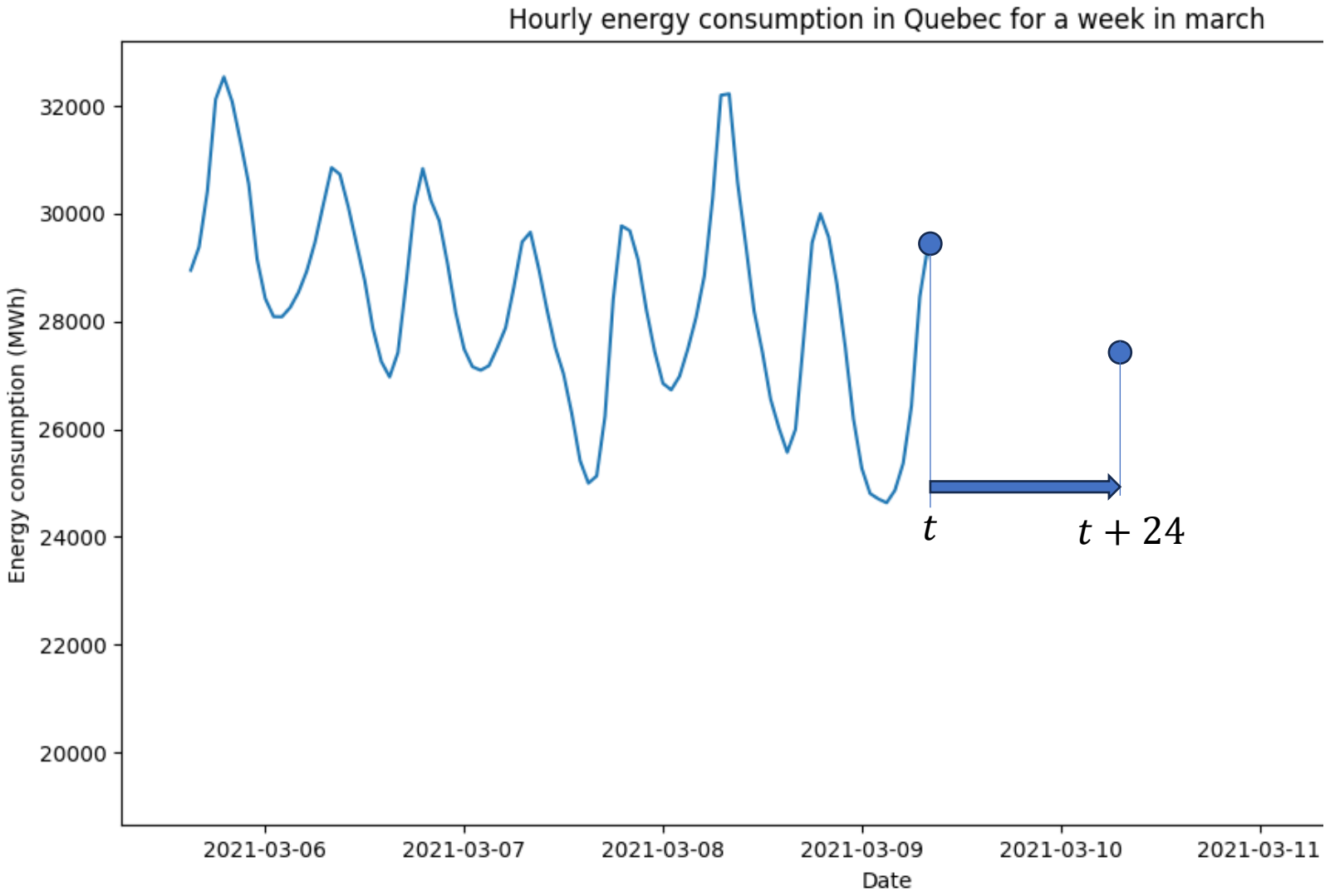
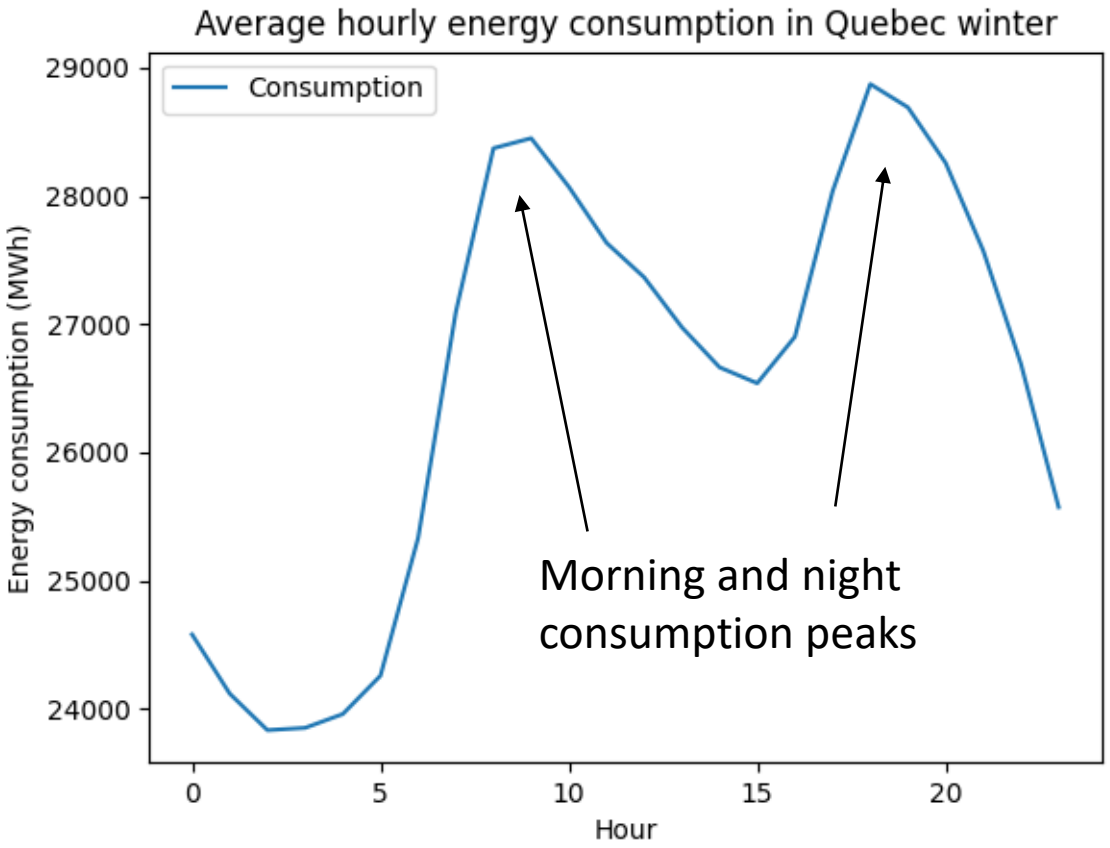
July 11 update

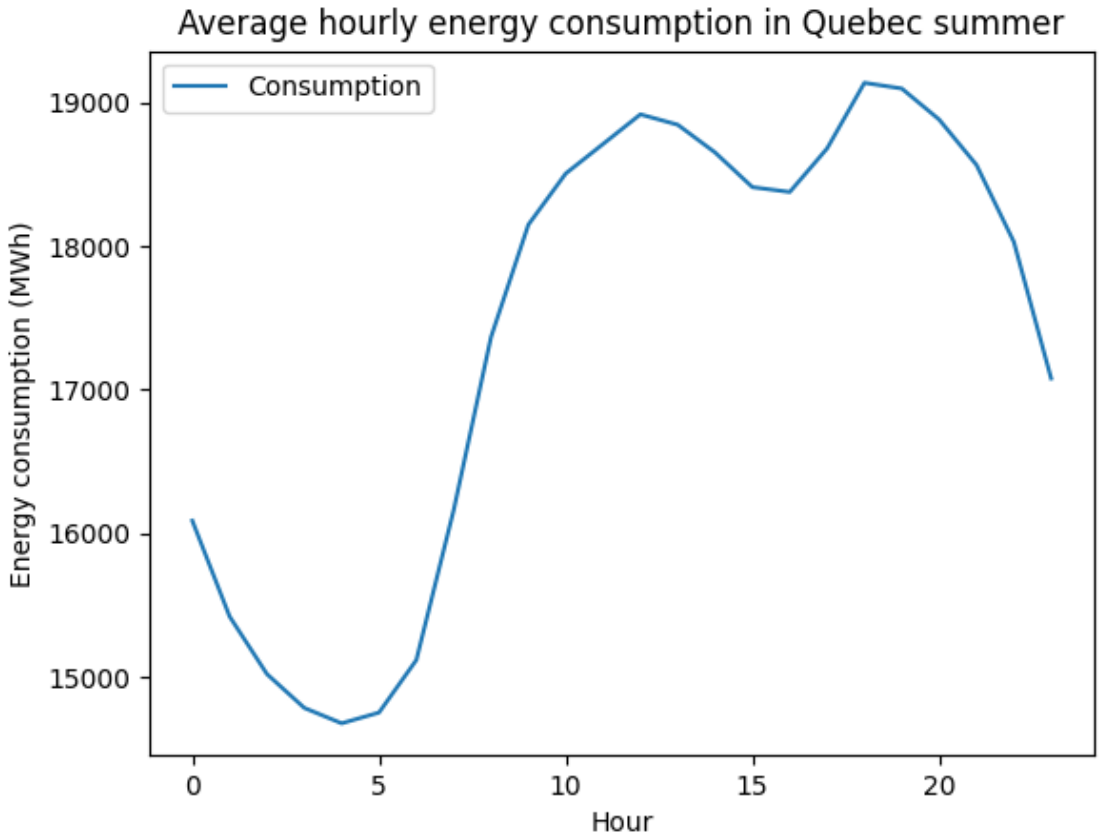
Day-ahead consumption forecasting



- Electricity production planning.
- Distribution.
- Exportations, importations.

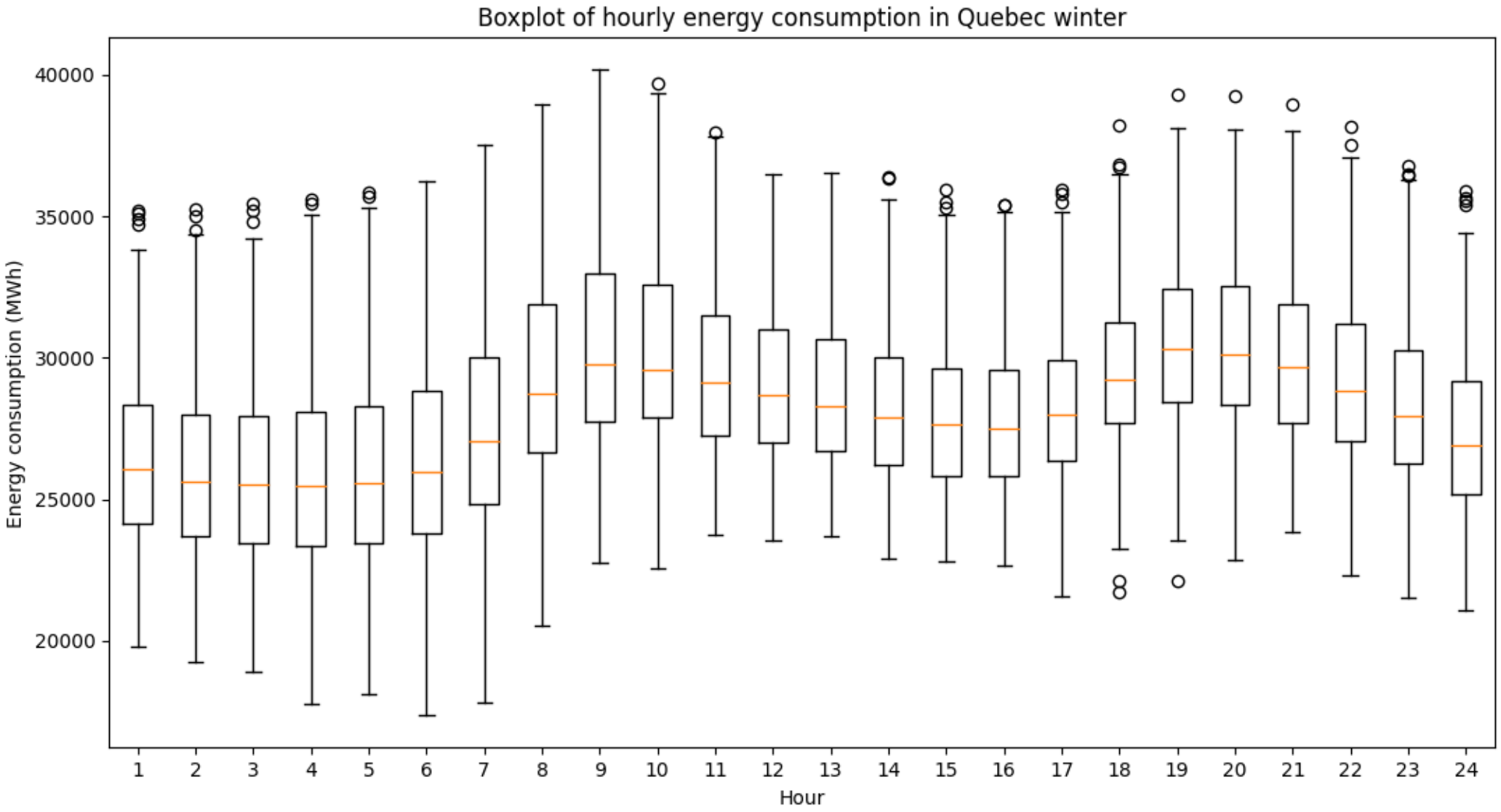
Data analysis – hourly consumption patterns





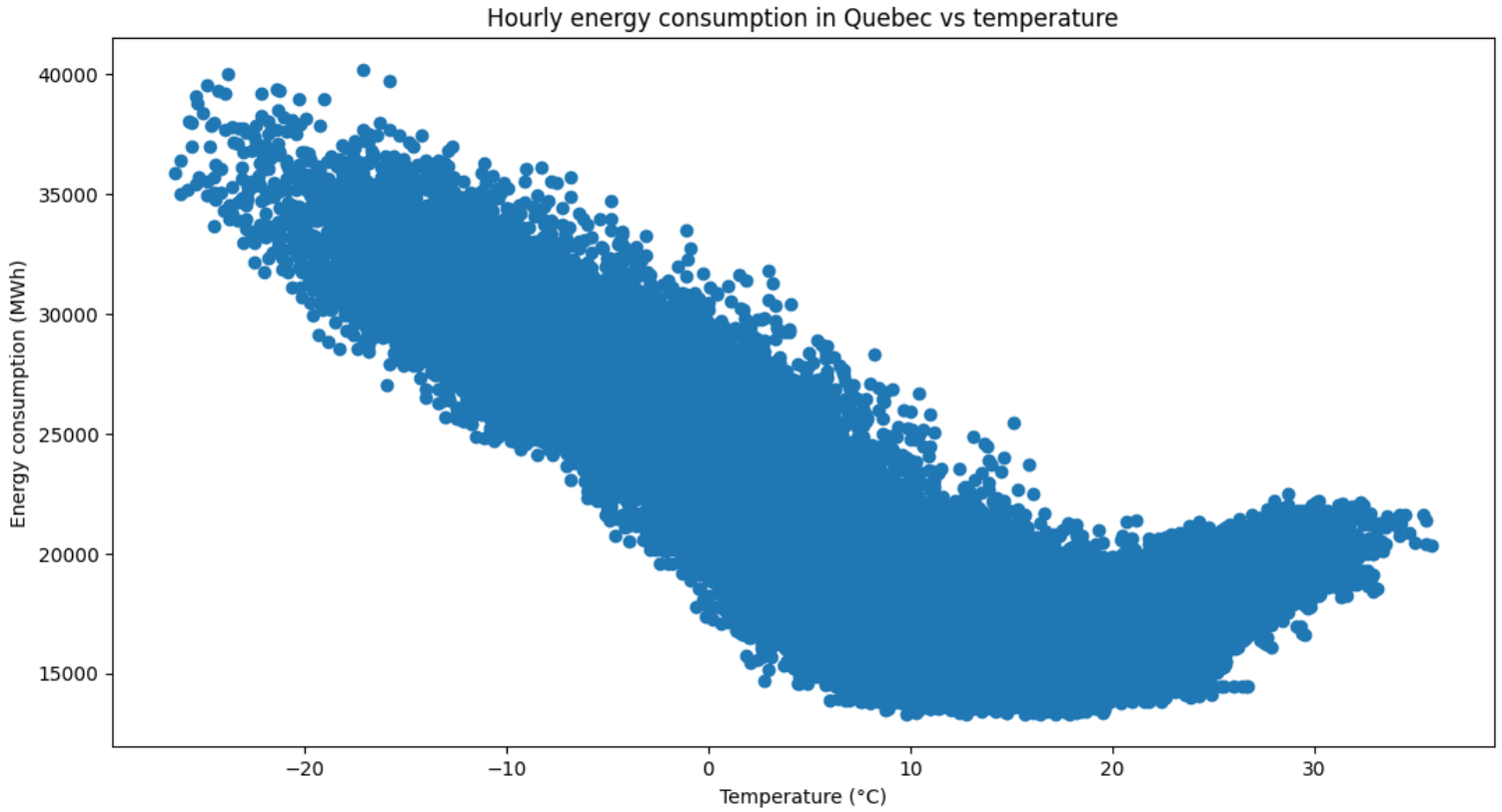
- Electricity consumption differs depending on the hour.

Data analysis – hourly consumption patterns

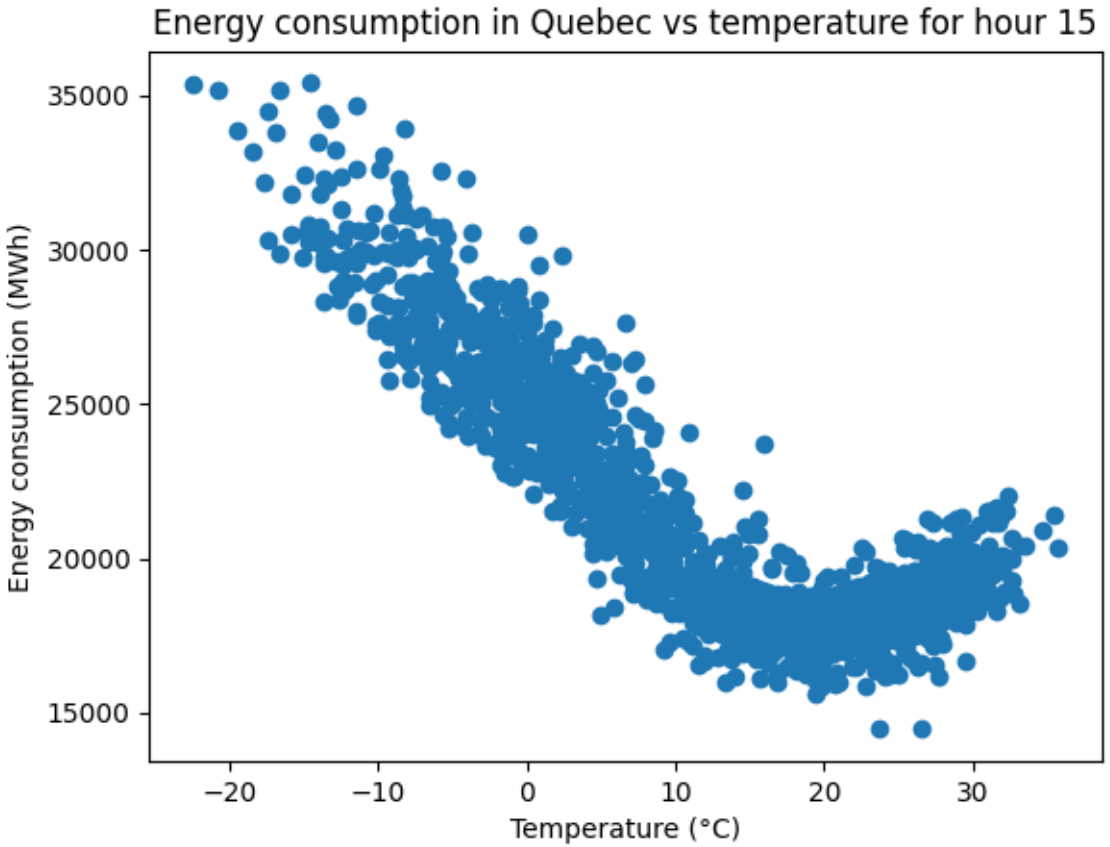


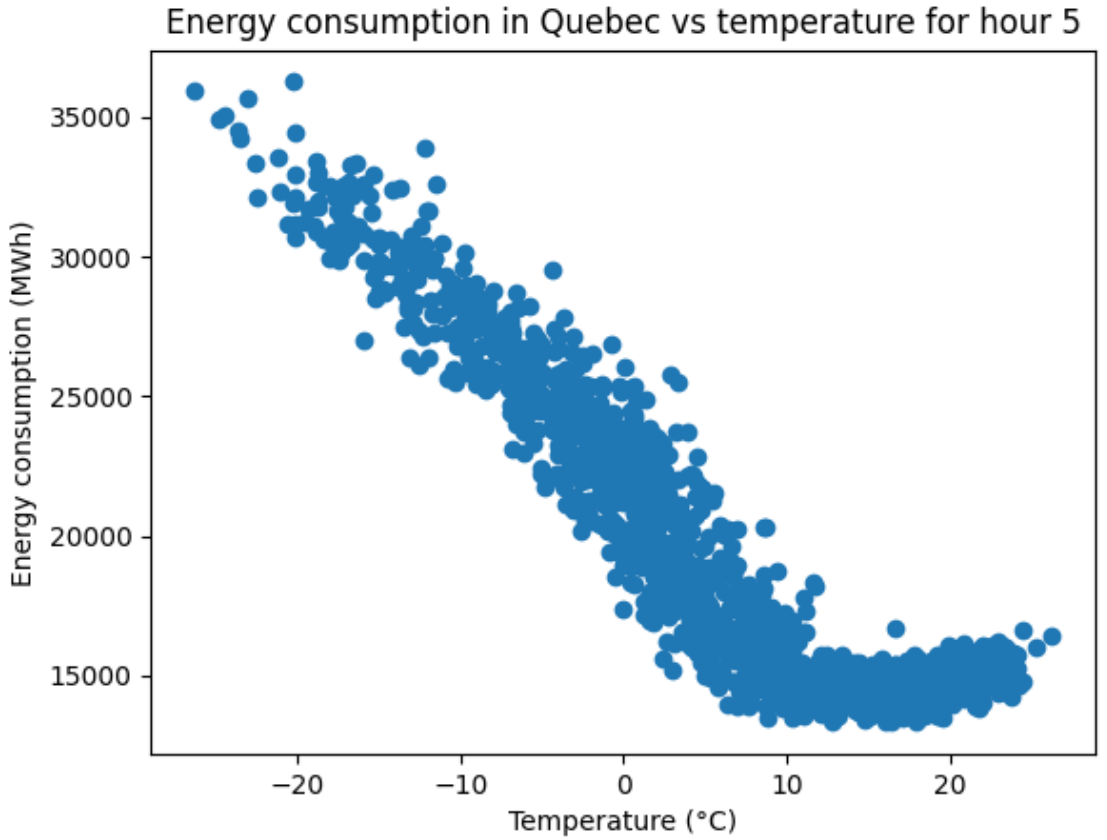
Data analysis – temperature effect

- In Quebec, electricity consumption is highly correlated with temperature
  - Winter: Electric heating
  - Summer: Air conditioning



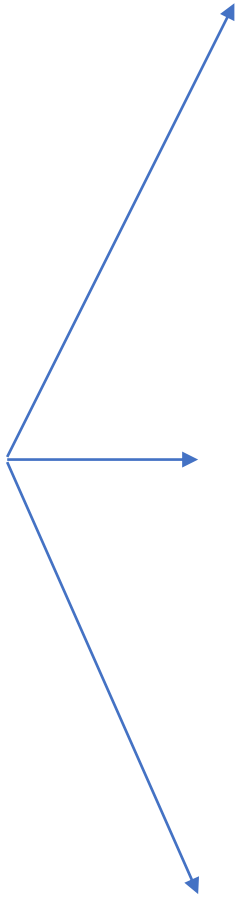
Data analysis – temperature effect





Model

date_time	temp	demand
2019-01-03 00:00:00	-13.4	28844.38
2019-01-03 01:00:00	-13.6	28388.10
2019-01-03 02:00:00	-13.7	28173.16
2019-01-03 03:00:00	-14.1	28392.68
2019-01-03 04:00:00	-14.0	28613.17
...	...	...
2022-12-31 19:00:00	6.2	23381.99
2022-12-31 20:00:00	6.3	22627.35
2022-12-31 21:00:00	6.0	22004.14
2022-12-31 22:00:00	5.3	21469.17
2022-12-31 23:00:00	4.3	21021.14



date_time	temp	demand
2019-01-03 01:00:00	-13.6	28388.10
2019-01-04 01:00:00	-1.6	25779.78
2019-01-05 01:00:00	1.1	21949.25
2019-01-06 01:00:00	1.2	21498.25
2019-01-07 01:00:00	-12.9	26658.05
...	...	...
2022-12-26 01:00:00	-7.0	26354.44
2022-12-27 01:00:00	-4.6	26127.44
2022-12-28 01:00:00	-3.5	26784.03
2022-12-29 01:00:00	-0.6	24308.67
2022-12-30 01:00:00	6.0	21702.44

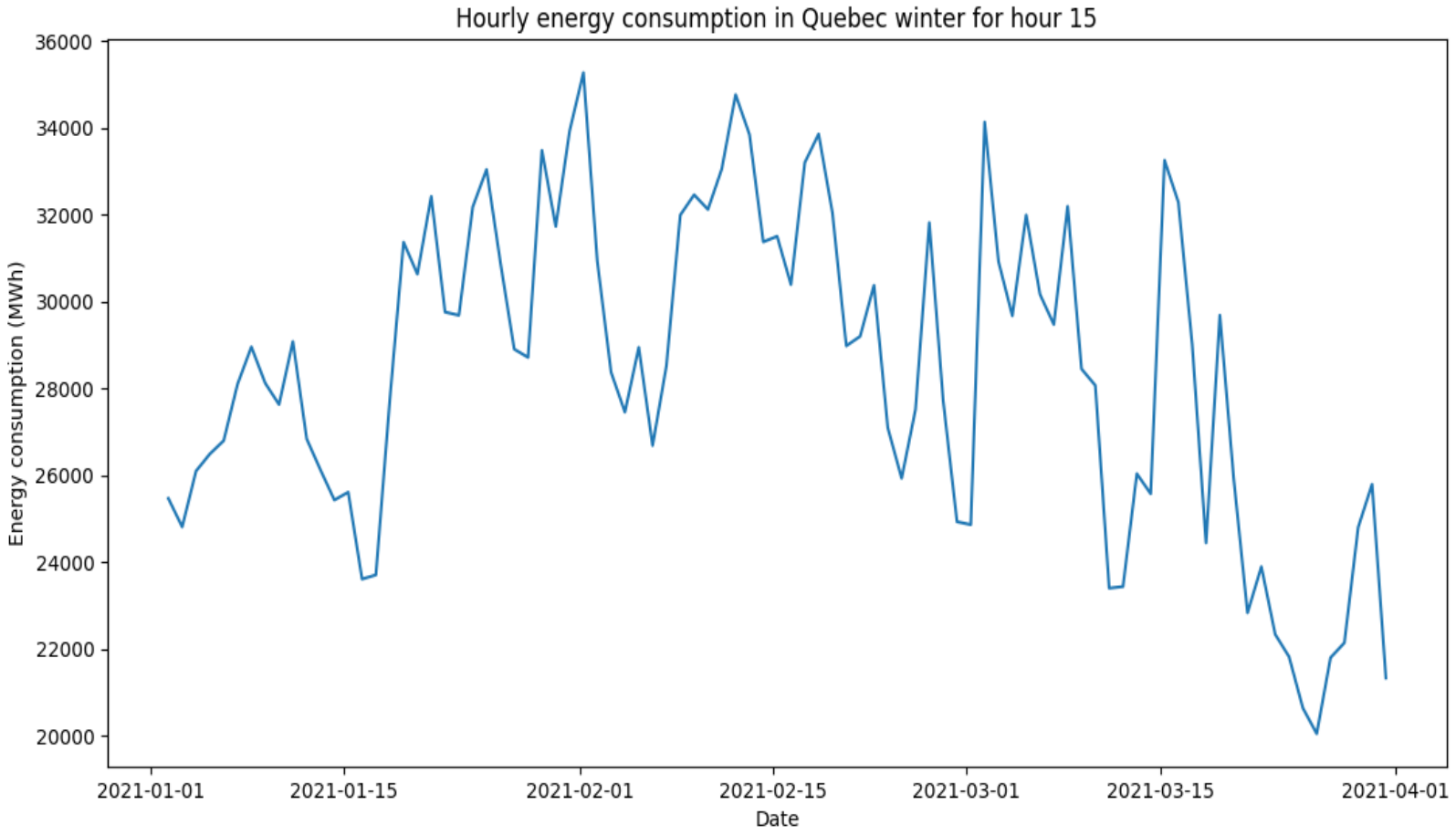
date_time	temp	demand
2019-01-03 02:00:00	-13.7	28173.16
2019-01-04 02:00:00	-1.3	25532.46
2019-01-05 02:00:00	0.7	21656.77
2019-01-06 02:00:00	1.2	21274.81
2019-01-07 02:00:00	-13.4	26848.81
...	...	...
2022-12-26 02:00:00	-7.5	26154.11
2022-12-27 02:00:00	-4.8	25840.09
2022-12-28 02:00:00	-3.2	26494.32
2022-12-29 02:00:00	-1.2	24098.08
2022-12-30 02:00:00	5.8	21523.90

⋮

date_time	temp	demand
2019-01-03 23:00:00	-3.8	27767.21
2019-01-04 23:00:00	2.0	23436.87
2019-01-05 23:00:00	1.5	22503.15
2019-01-06 23:00:00	-11.2	27381.07
2019-01-07 23:00:00	-11.2	29786.04
...	...	...
2022-12-26 23:00:00	-4.5	27166.05
2022-12-27 23:00:00	-4.7	27987.84
2022-12-28 23:00:00	-0.1	25664.46
2022-12-29 23:00:00	5.9	23097.65
2022-12-30 23:00:00	7.6	21418.83

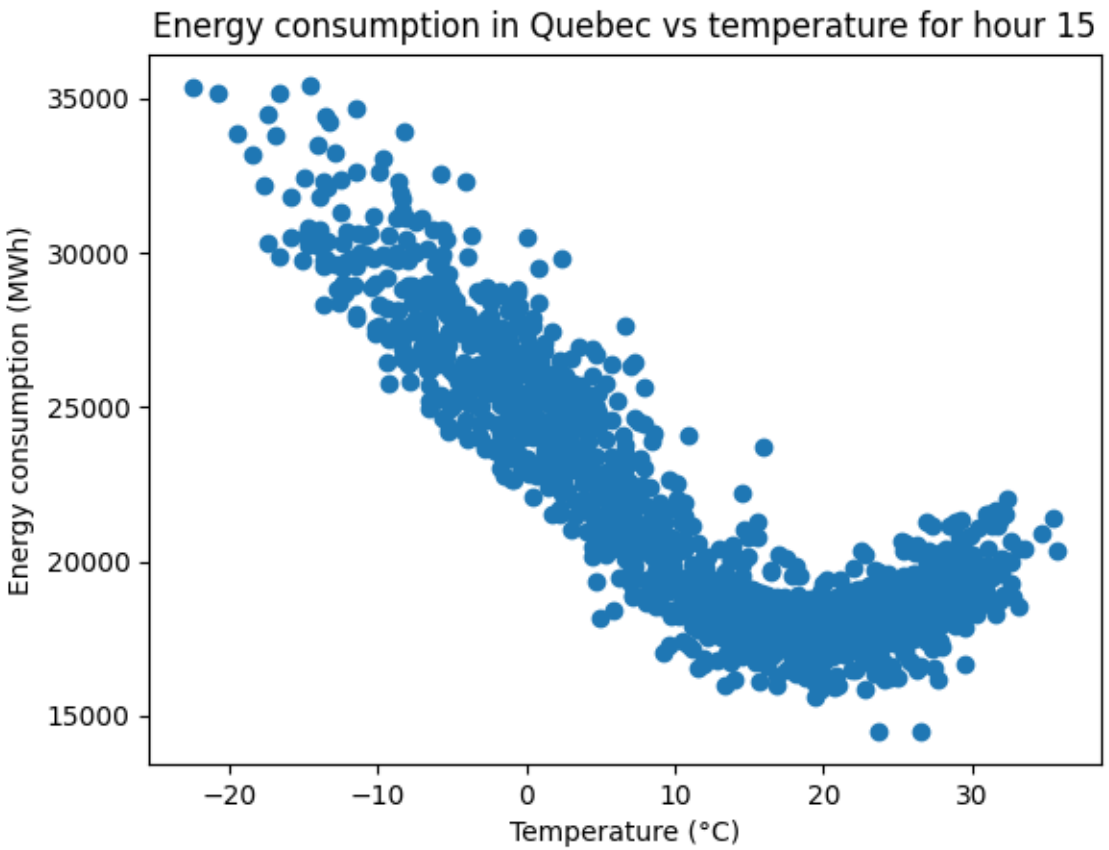
- One model for every hour. (24 different models)

Model



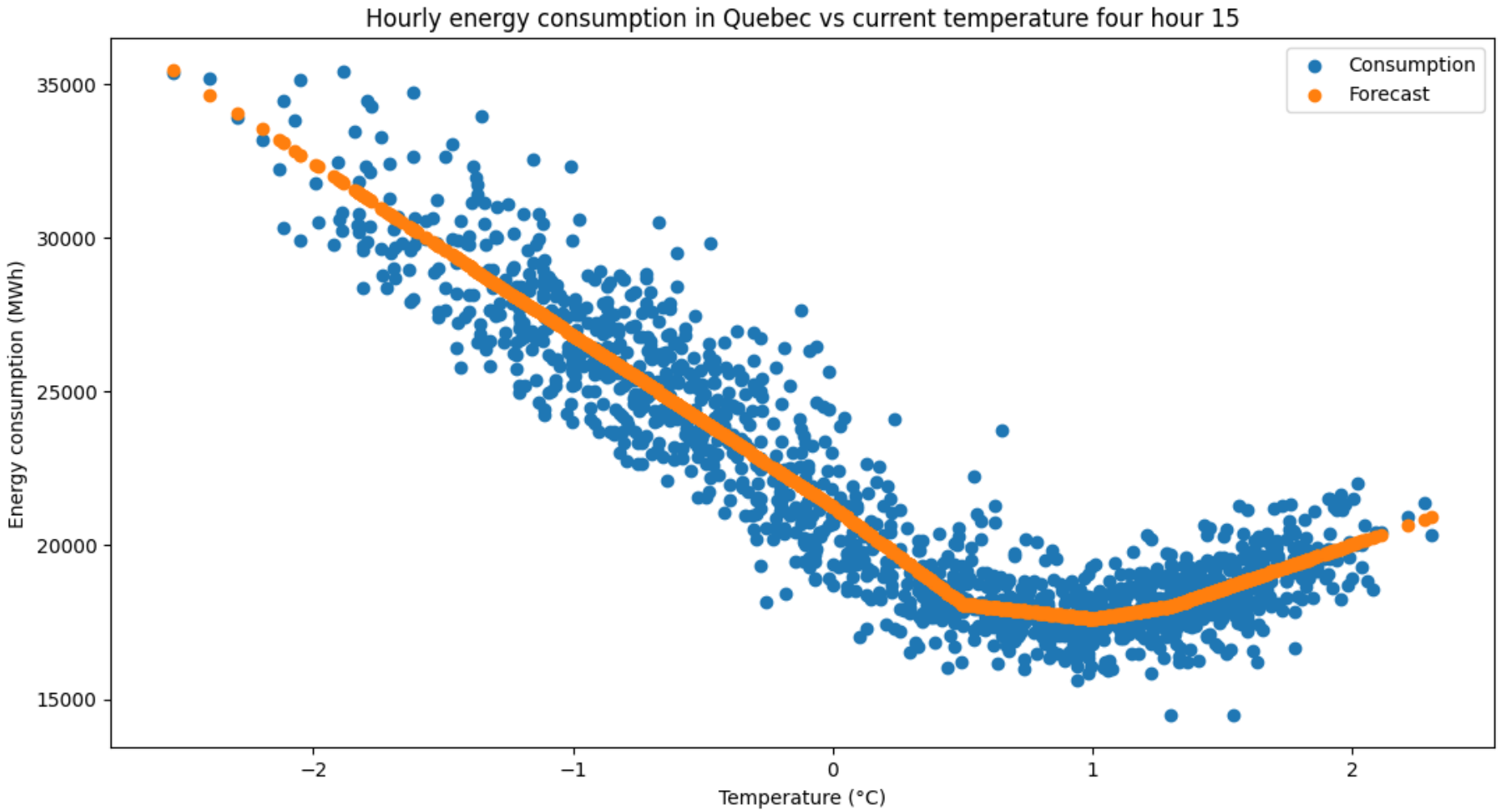
- Simplified the problem to forecasting a time series one step ahead instead of 24 steps ahead.

Model



- Energy consumption is strongly correlated to current temperature.
- Address change in concavity – Regression splines.

Model


Hourly energy consumption in Quebec vs current temperature four hour 15
Consumption
Forecast
Energy consumption (MWh)
35000
30000
25000
20000
15000
−2
−1
0
1
2
Temperature (°C)

Model - predictors

- Lagged temperatures
- Type of day
- Cloud cover

Lagged temperatures

- We suspect electricity demand at time t is correlated with previous temperatures.

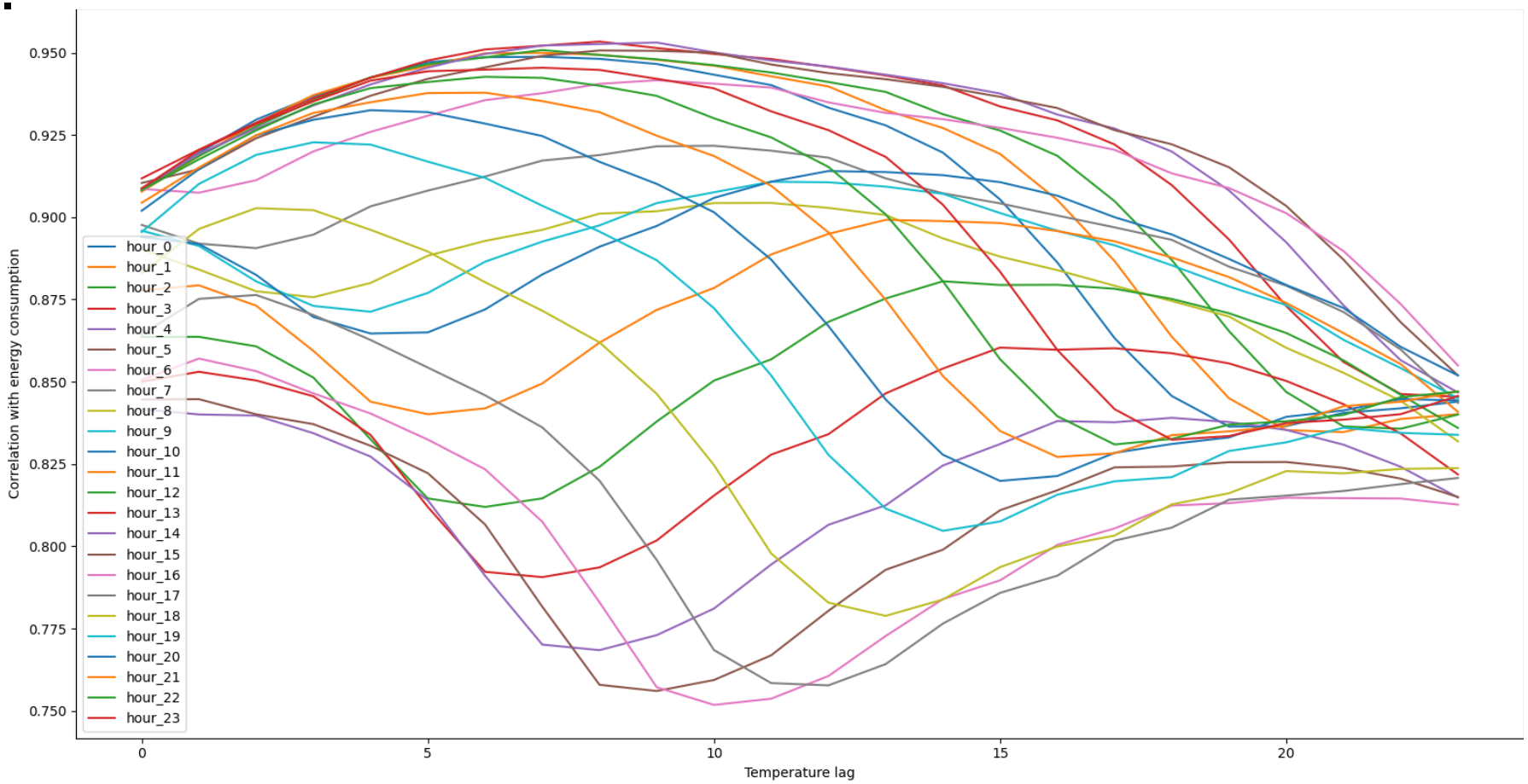
- Calculate correlation between current electricity and temperature lag T_{t-i} for $i = 0, 1, \ldots, 23$.

scaled_temp	-0.891469
temp_1	-0.903481
temp_2	-0.914695
temp_3	-0.924125
temp_4	-0.933414
temp_5	-0.935920
temp_6	-0.938199
temp_7	-0.939478
temp_8	-0.938004
temp_9	-0.933994
temp_10	-0.931269
temp_11	-0.928791
temp_12	-0.924372
temp_13	-0.920191
temp_14	-0.910985
temp_15	-0.904521
temp_16	-0.895179
temp_17	-0.878886
temp_18	-0.858411
temp_19	-0.834624
temp_20	-0.816761
temp_21	-0.807875
temp_22	-0.807362
temp_23	-0.809053

Correlation coefficient between current electricity consumption and previous temperatures for hour 2.

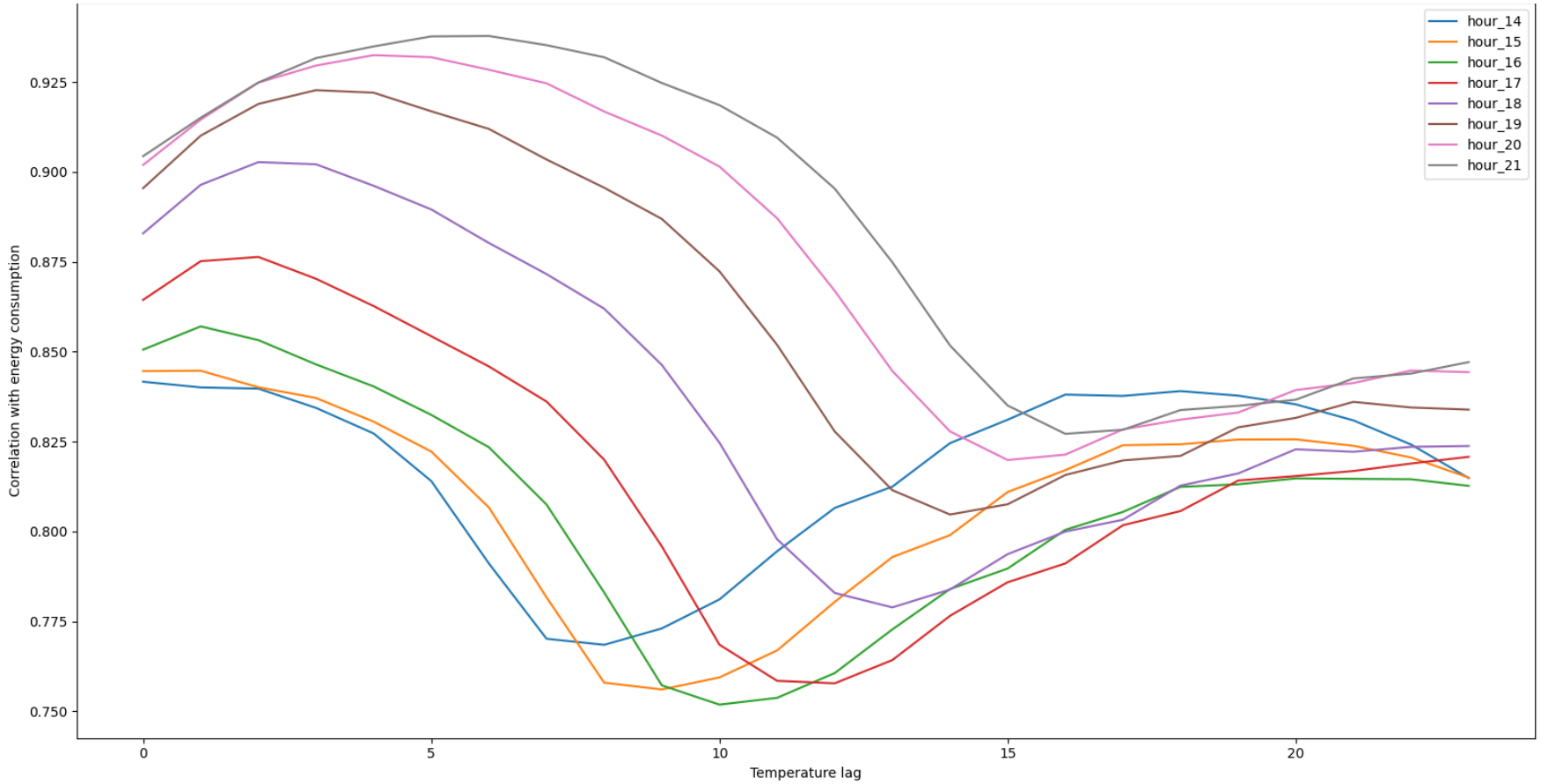
Lagged temperatures

- Plot correlation between current consumption and temperature lag T_{t-i}.



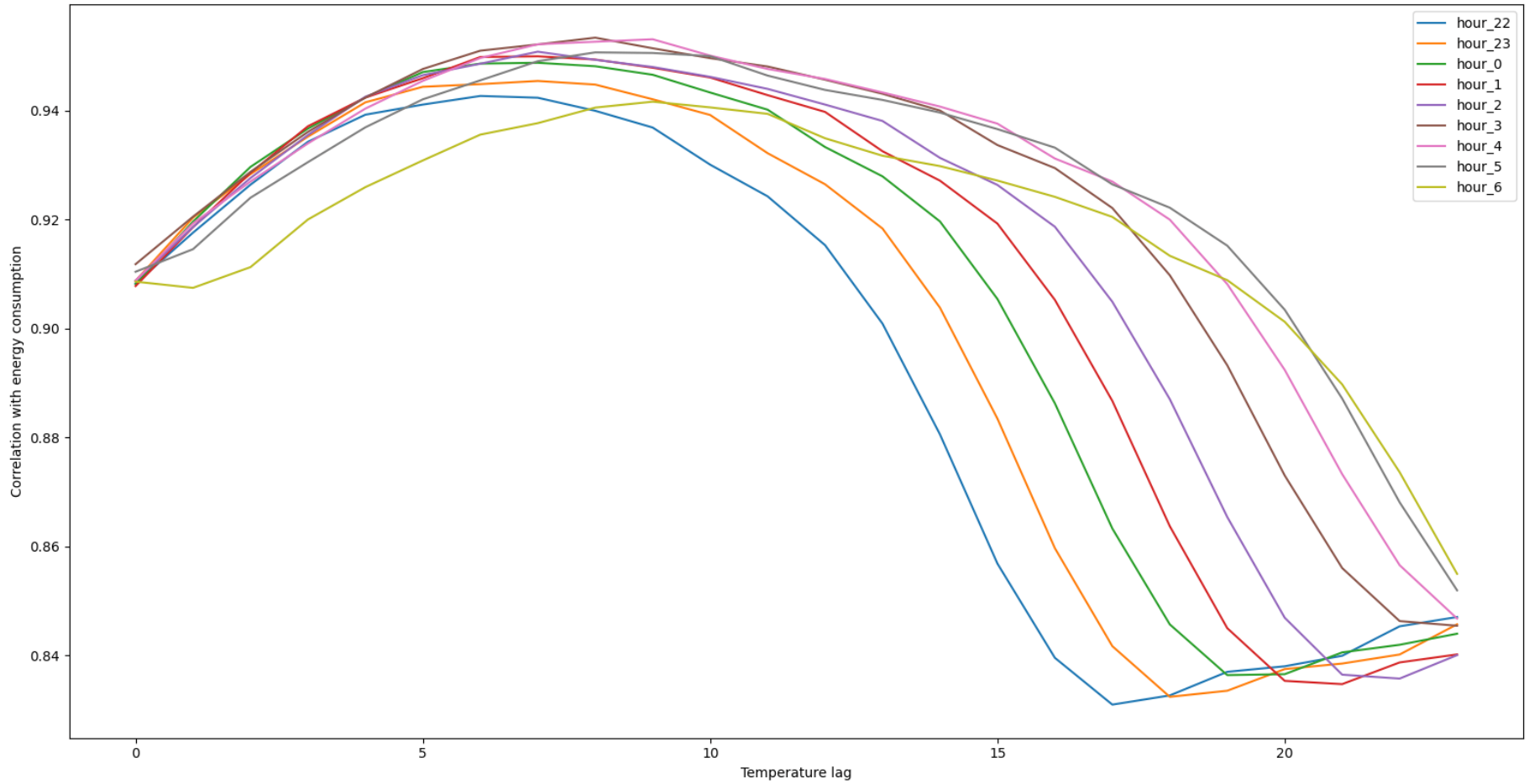
Lagged temperatures

- Hours 14 - 21



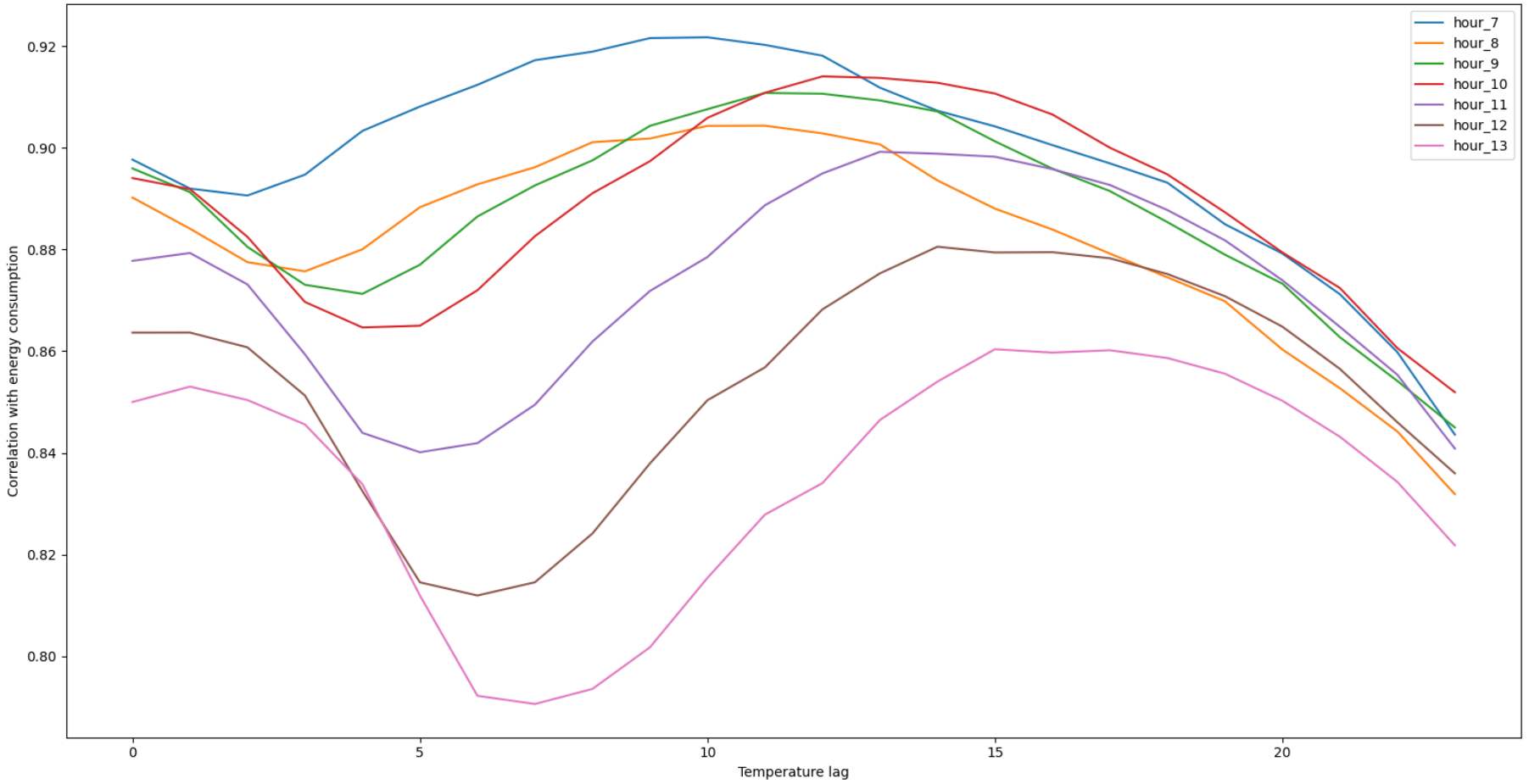
Lagged temperatures

- Hours 22 - 6



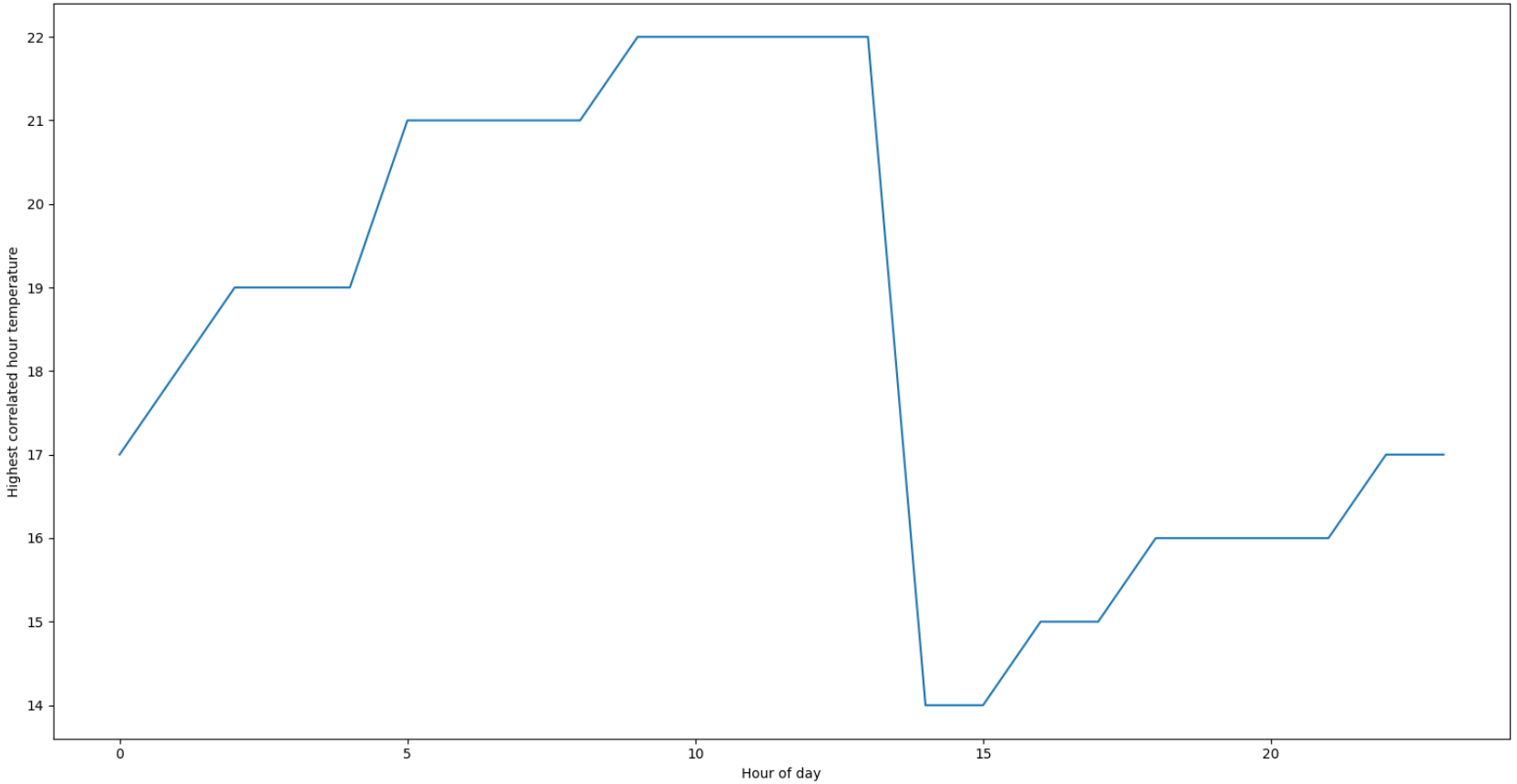
Lagged temperatures

- Hours 7 - 13



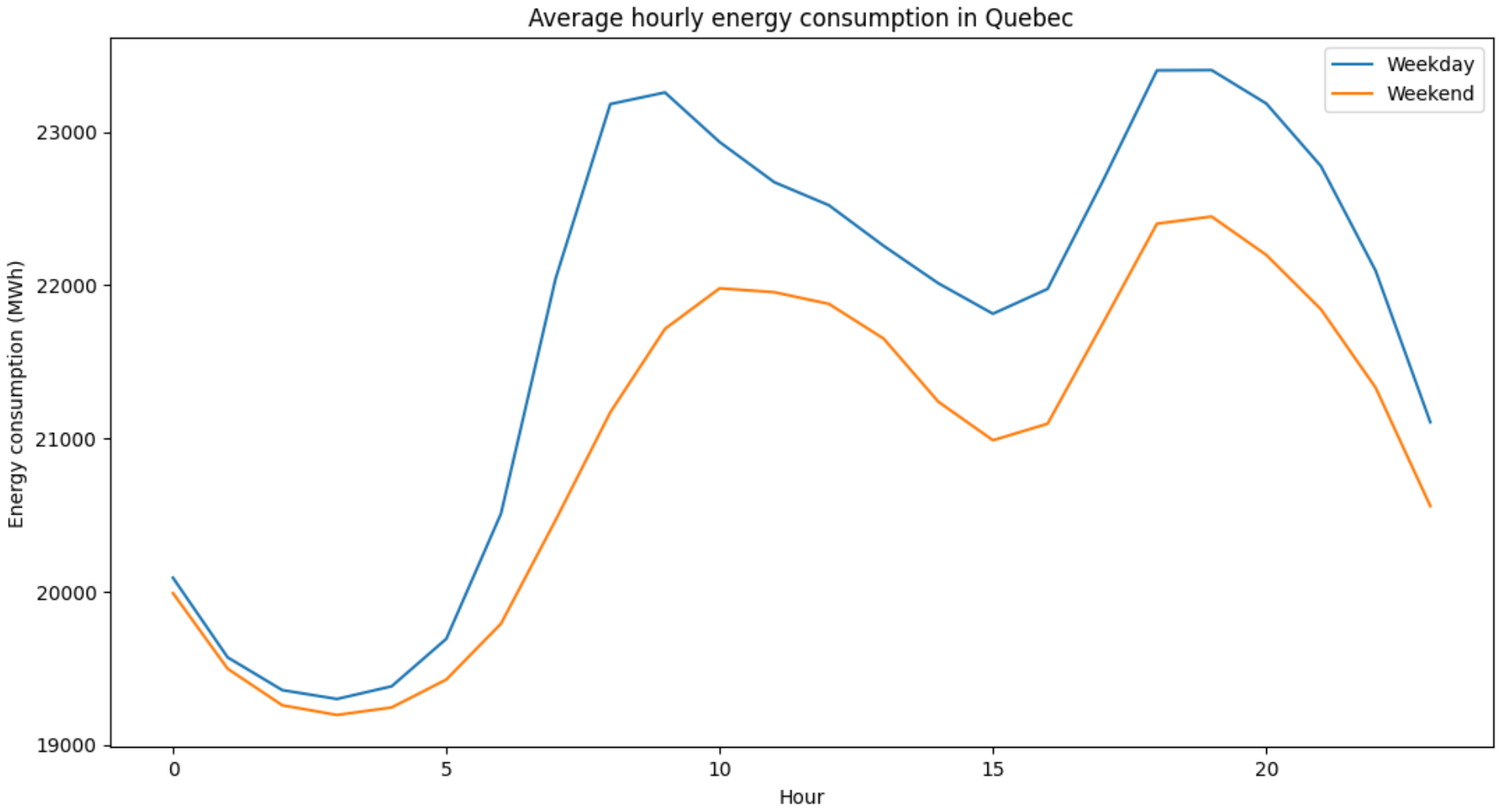
Lagged temperatures

- Plot highest correlated hourly temperature for every hour of the day.



- Include this T_{t-i}, T_t and $T_{t-i} * T_t$ in model.

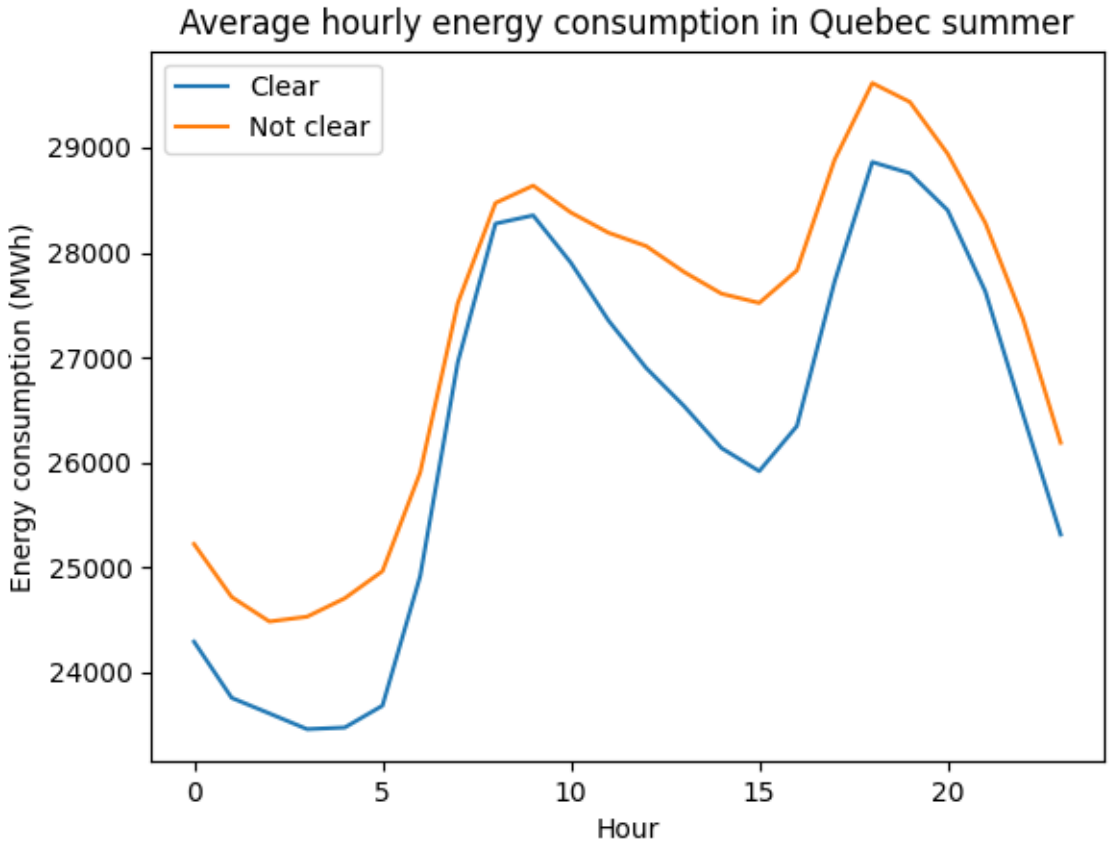
Type of day



- Binary encoding weekday (0) and weekend day (1).

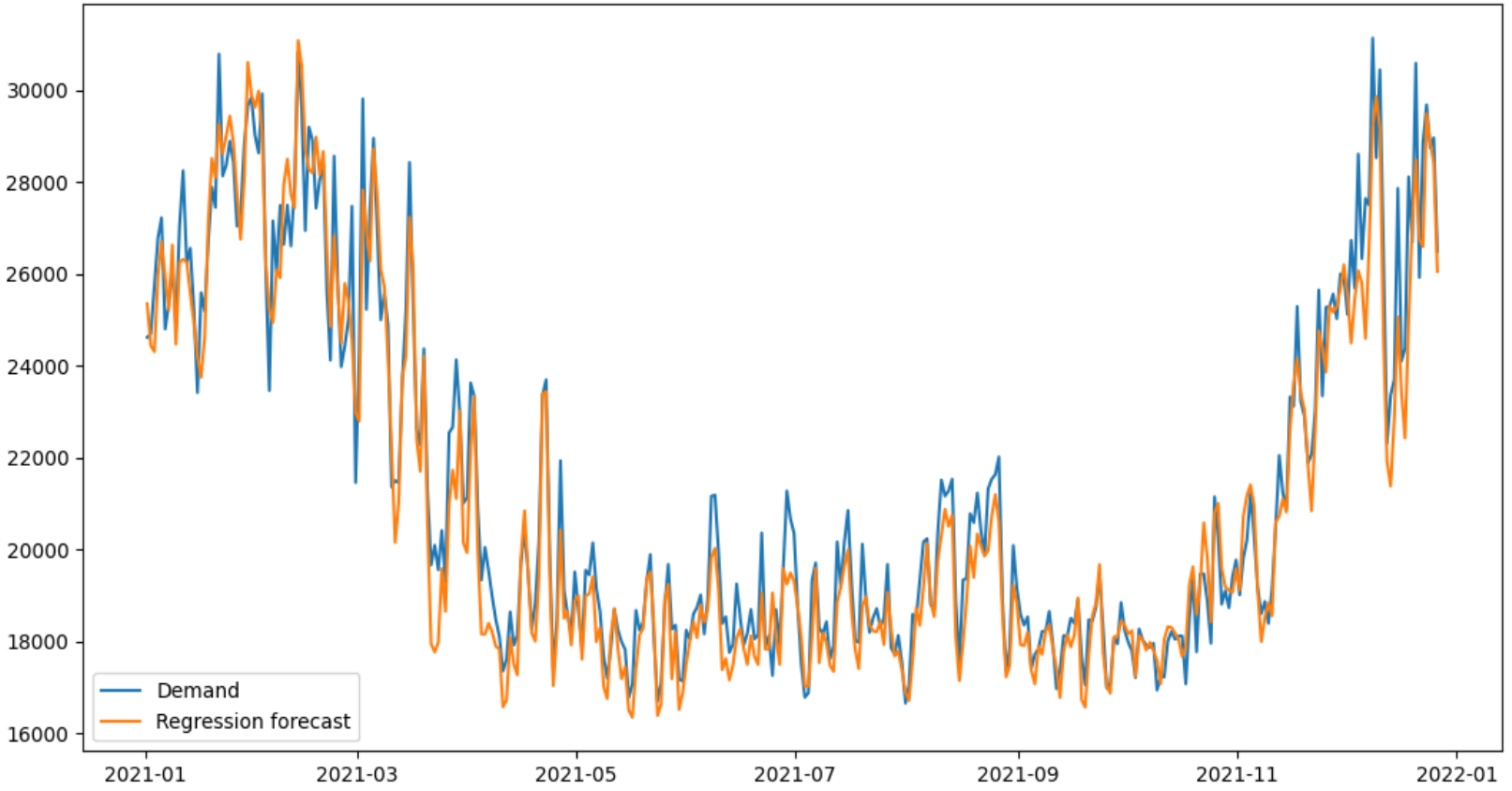
Cloud cover

- Binary encoding if sky is clear (1) or not (0).



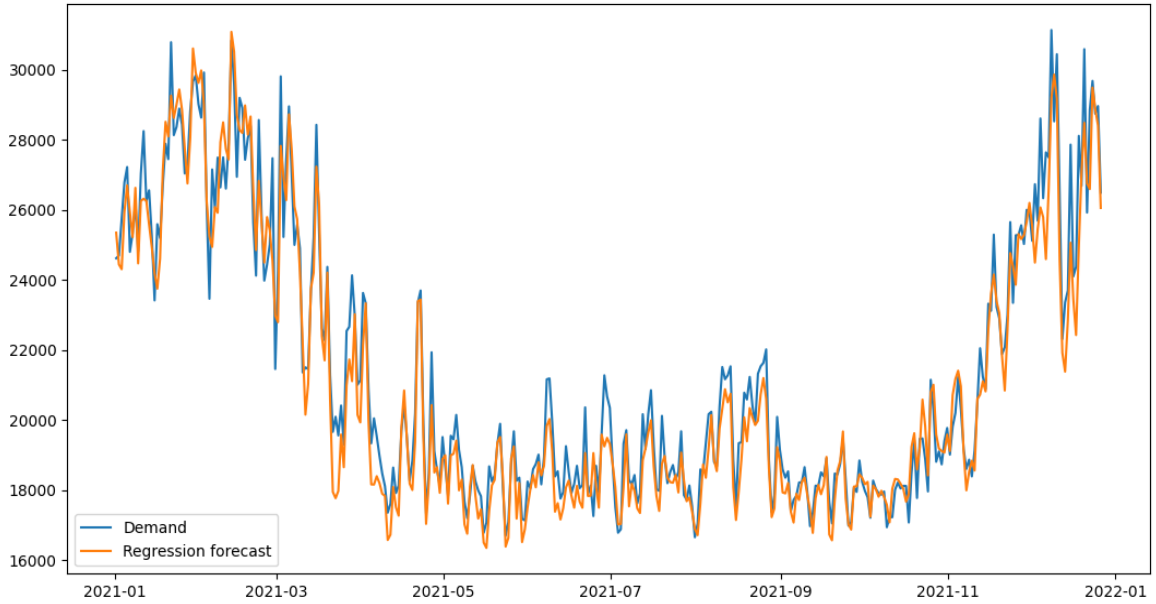
Model – Least squares regression

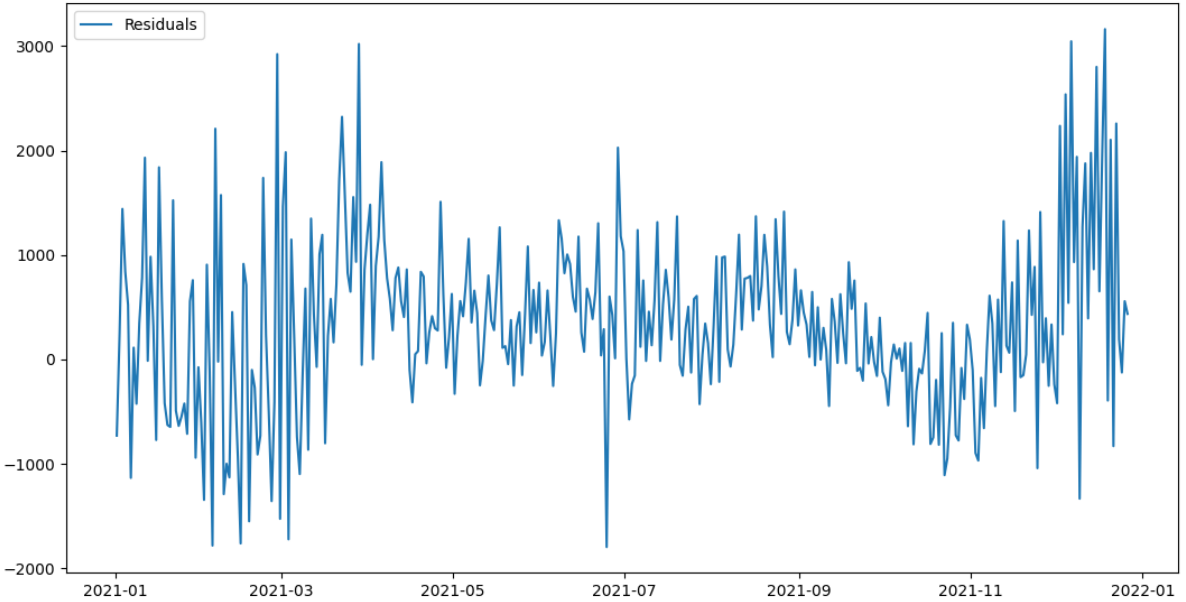
- For one hour: $y_t = \boxed{\beta_0 + \beta_1 X_t} + \eta_t + \epsilon$
- Fit on data from 2019 – 2021.



Model – Correction with ARMA process

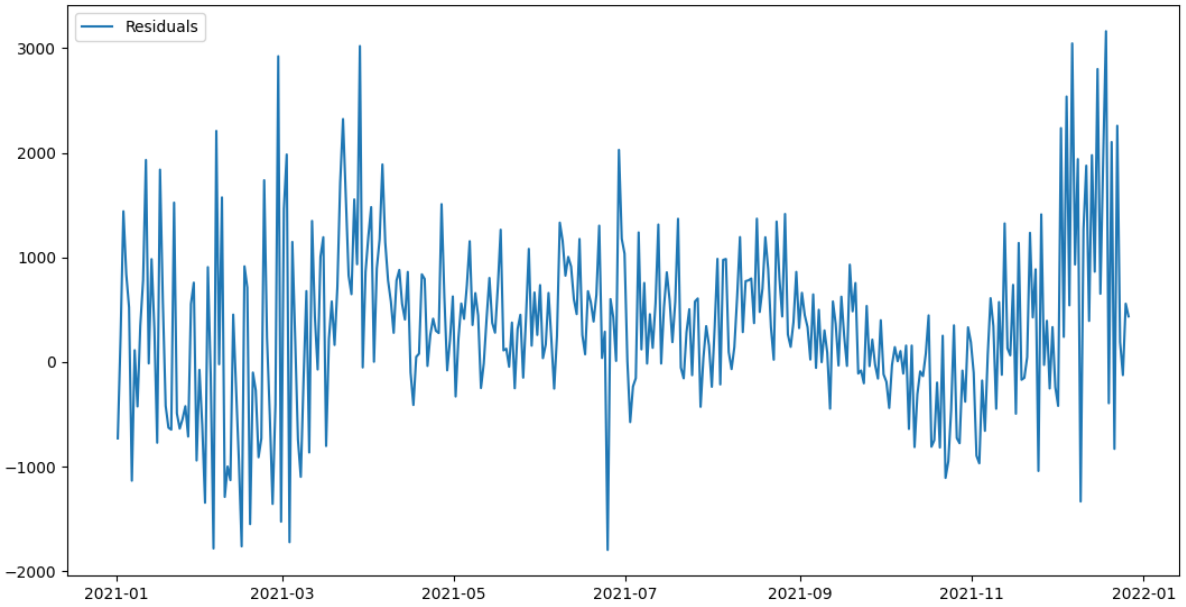
- For one hour: $y_t = \beta_0 + \beta_1 X + \boxed{\eta_t + \epsilon}$
- Fit on the residuals of the regression model for 30 days prior.





Model – Correction with ARIMA process

- For one hour: $y_t = \beta_0 + \beta_1 X + \boxed{\eta_t + \epsilon}$

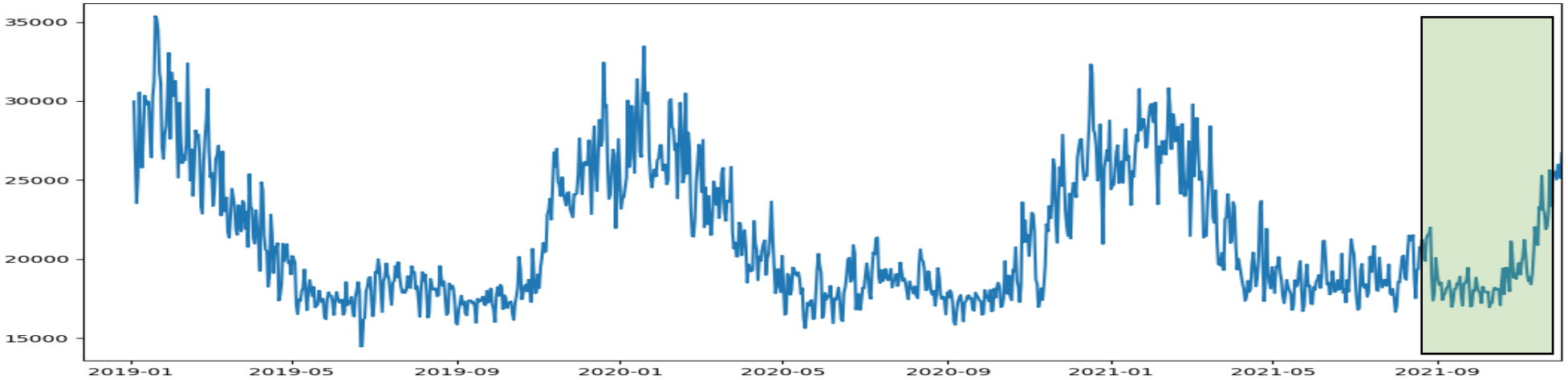


ARMA(1, 1)

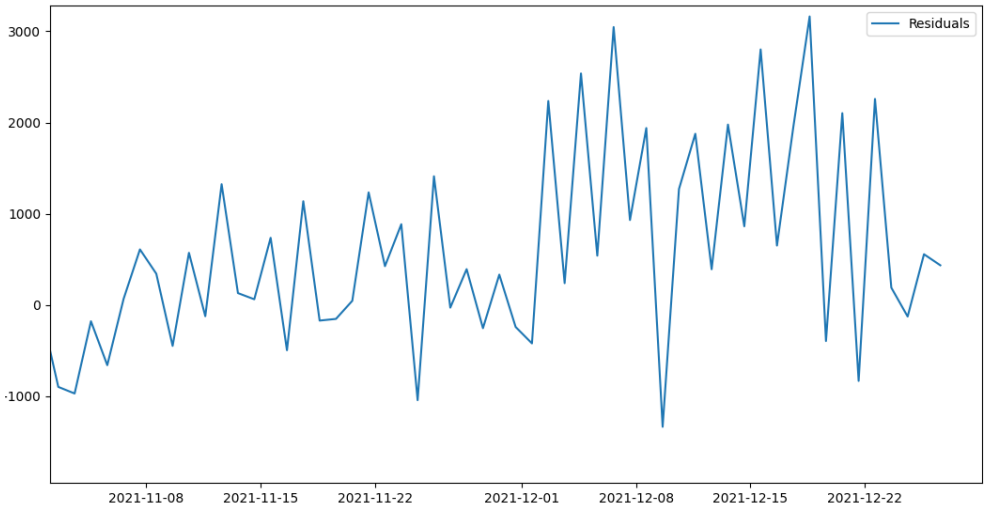
$$\eta_t = \psi X_{t-1} + \theta \epsilon_{t-1} + \epsilon_t$$

- Update regression forecast with short term residual forecast.

Model – Correction with ARIMA process



Fit regression on
2+ years data

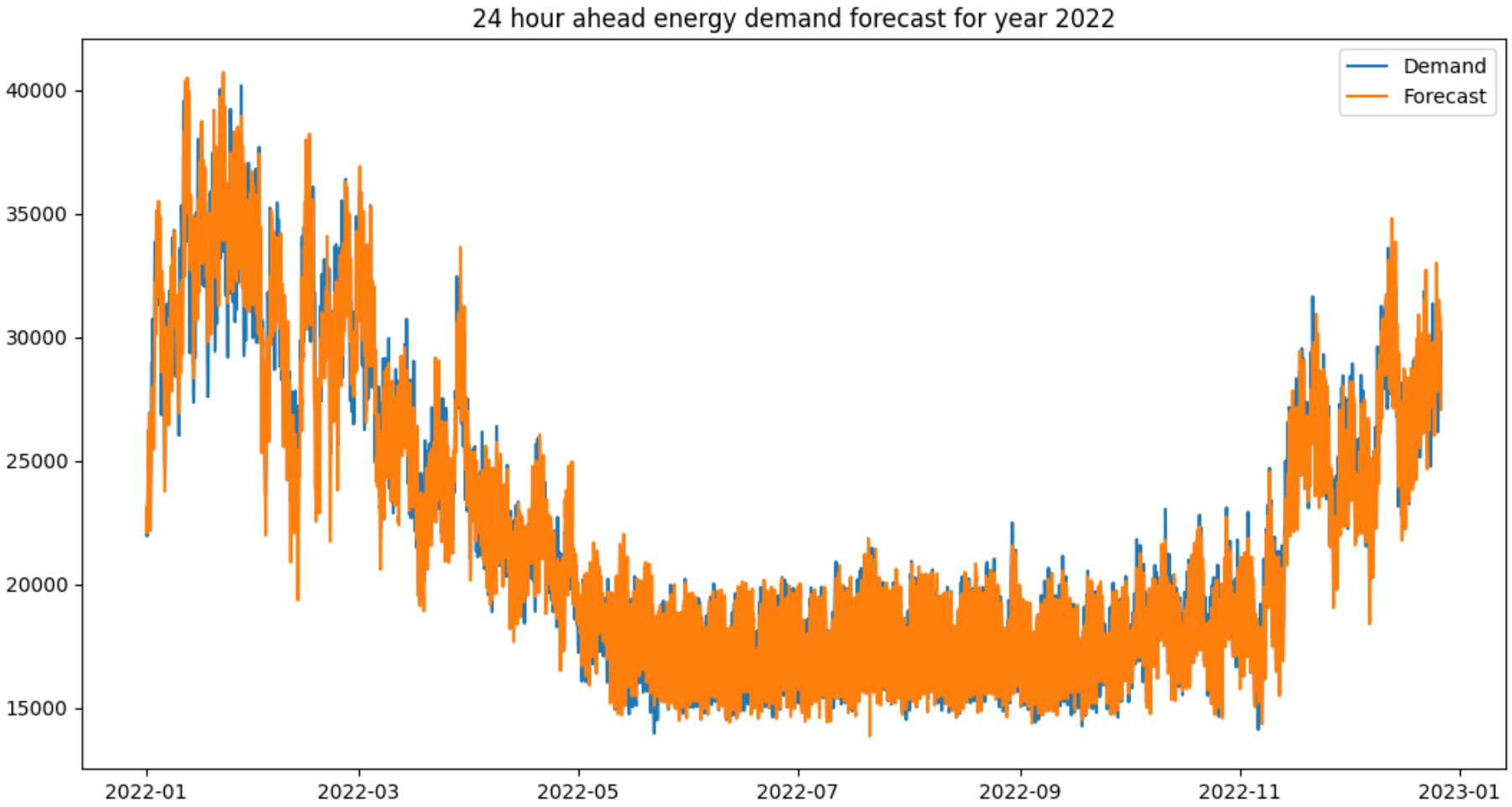


Model residuals
from the
regression model
on 30 days data

Forecast =
regression forecast + residual forecast

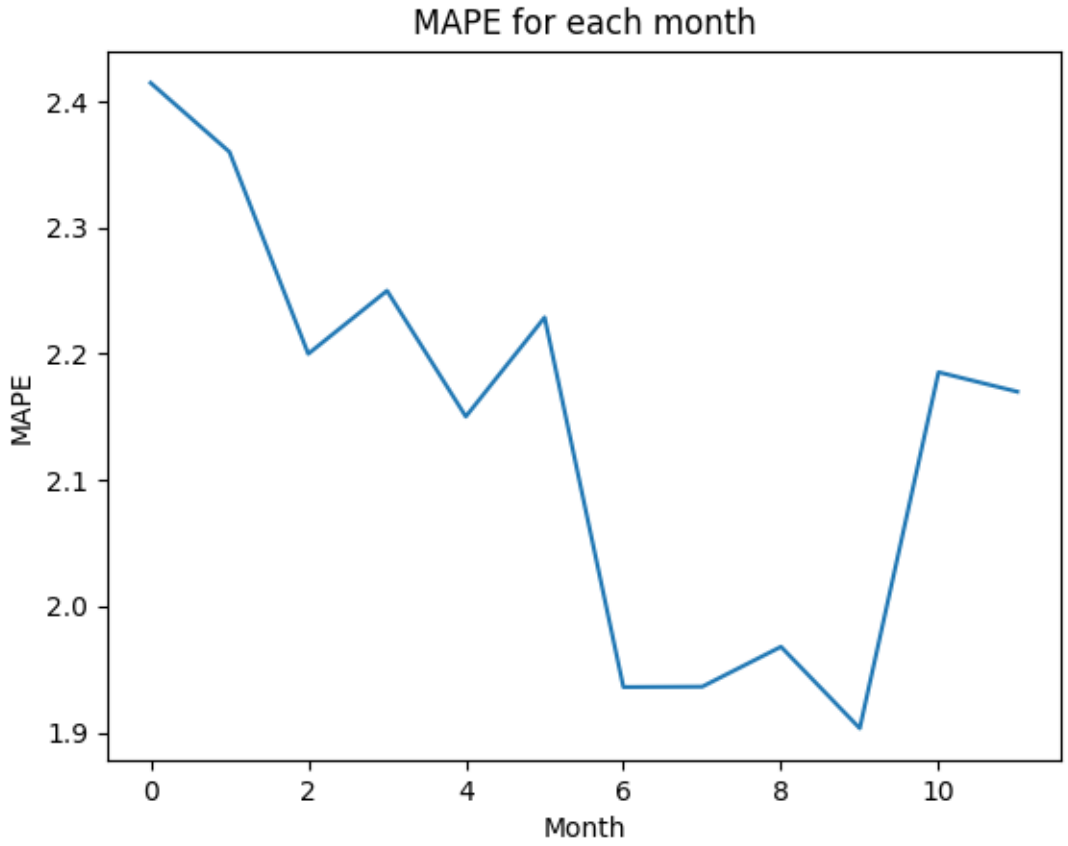
Results

Results

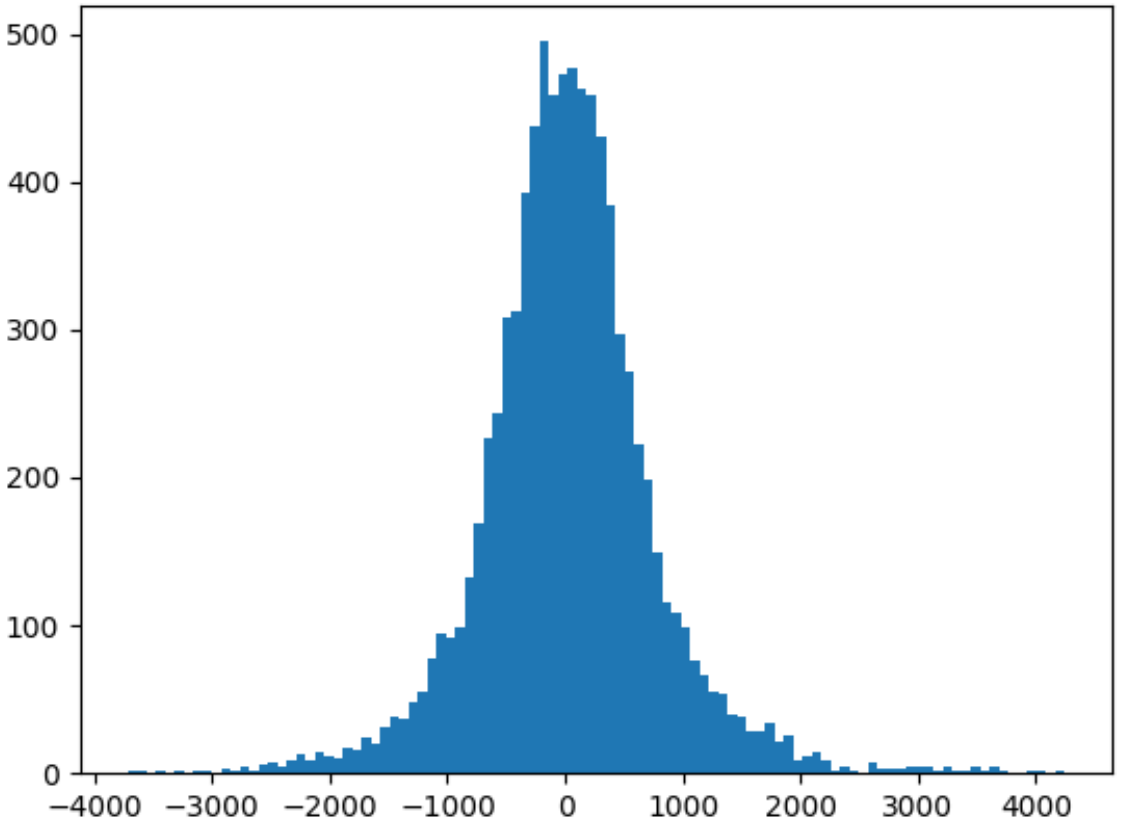

24 hour ahead energy demand forecast for year 2022
Demand
Forecast
40000
35000
30000
25000
20000
15000
2022-01
2022-03
2022-05
2022-07
2022-09
2022-11
2023-01

Results

- MAPE: 2.26%
- RMSE: 734 MWh
- Forecasts within 1500 MWh: 97.4%
- Forecasts within 1000 MWh: 88.9%
- Forecasts within 500 MWh: 72.3%



Results



- Some large errors…