Machine Learning Approaches for Electricity Markets Trading (EPEX spot)

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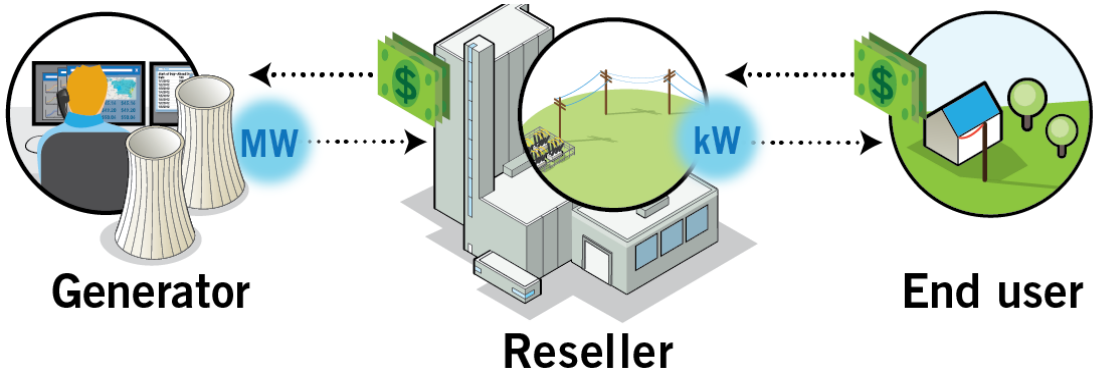
Introduction | French Electricity Market

What is the electricity market?

Where do they trade?

What is EPEX?

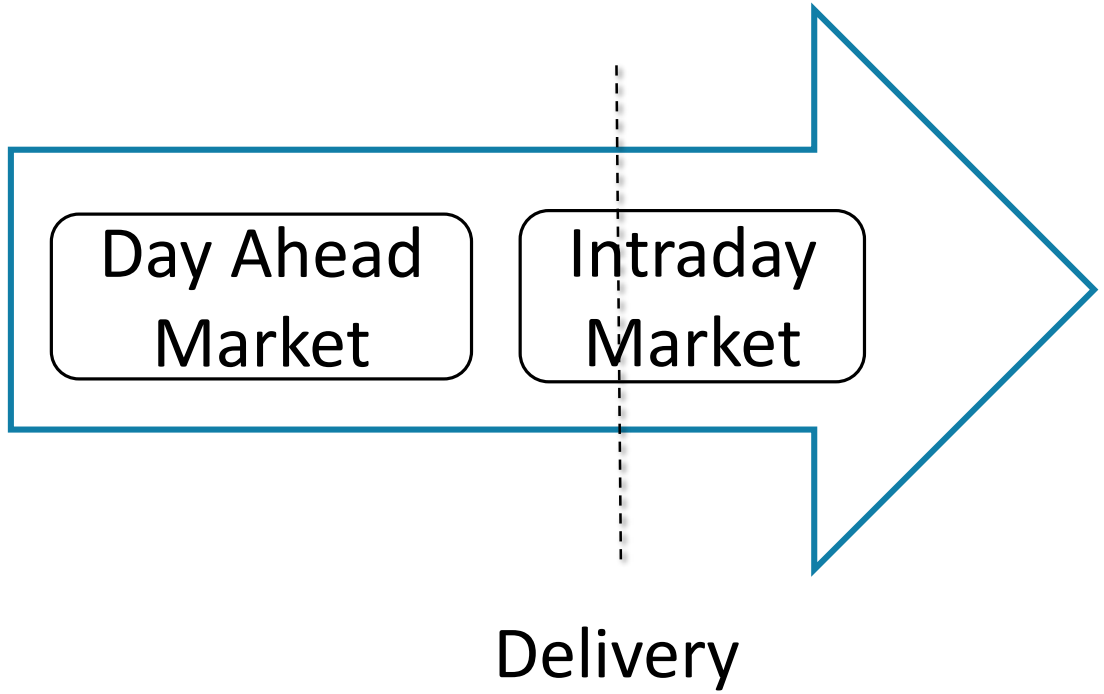
Electricity power sources in France?



Introduction | Market Design | Day Ahead Market

One day before delivery

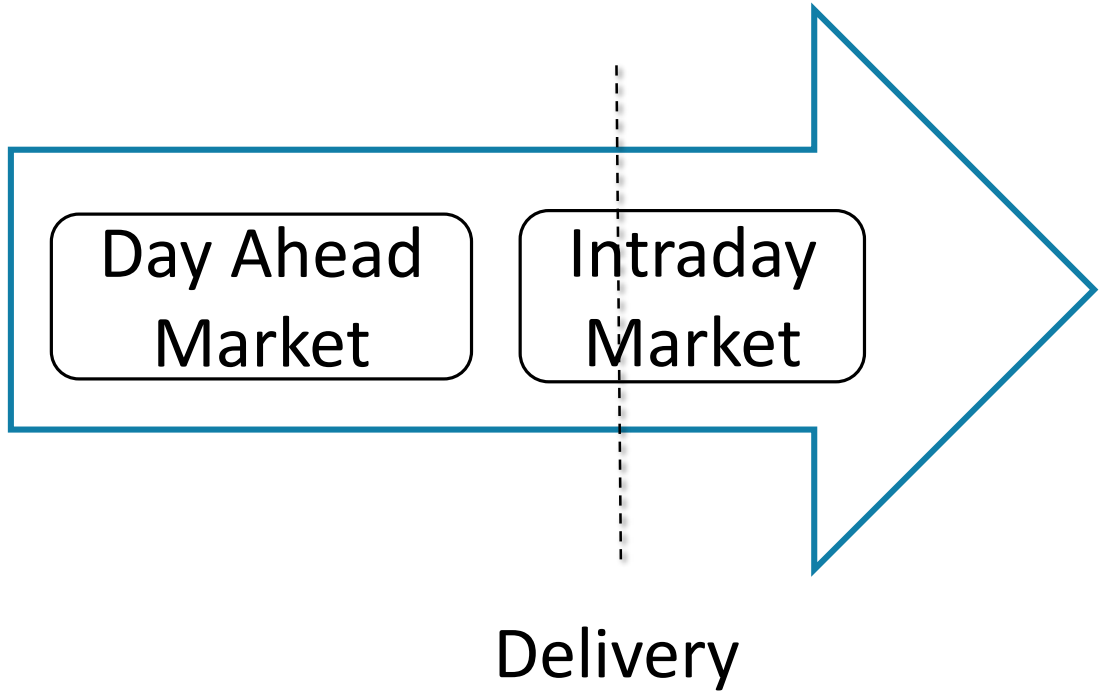
Submit orders
until 12 a.m. day-ahead



Introduction | Market Design | Intraday Market

Trade on delivery day

Continuous market



Introduction | Managerial Problems

How can we trade between the Day Ahead and Intraday Market and make profit?

What drives prices? Is it possible to find patterns?

Introduction | Trading Strategy

Predicting model
INTRADAY > DAY AHEAD

YES → Buy day ahead
Sell intraday

NO → No trading

Introduction | Financial Metrics

Price difference = Intraday price – Day ahead price

Trading fee = 0.16 * Number of trades

Model Gain/Loss = Trade With Model – Without Model

Introduction | Model Profit/Loss Example

TIME	MONDAY DAY AHEAD	TUESDAY INTRADAY	PRICE DIFF
14:00	10	15	5
15:00	20	30	10
16:00	20	35	15
17:00	10	10	0
18:00	10	5	-5
19:00	15	5	-10

Gain/Loss (Without using model)

15 – 0.96 = **14.04 €**

Introduction | Model Profit/Loss Example

TIME	MONDAY DAY AHEAD	TUESDAY INTRADAY	PRICE DIFF
14:00	10	15	5
15:00	20	30	10
16:00	20	35	15
17:00	10	10	0
18:00	10	5	-5
19:00	15	5	-10

Gain/Loss (Without using model)

15 – 0.96 = **14.04 €**

Gain/Loss (Using model)

25 – 0.32 = **24.68 €**

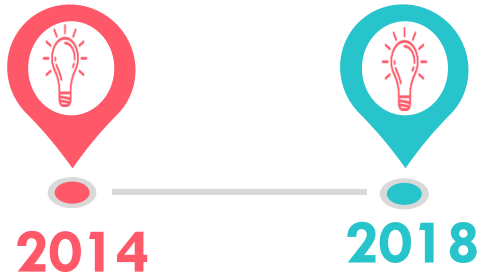
Model Gain/Loss = 10.64 €

Introduction | Data Sources

epexspot — France & Germany

WORLD WEATHER ONLINE

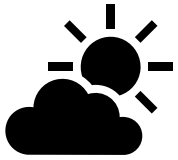
- Solar
- Wind



France Holiday data

Introduction | Variables

Date & Time (7 variables)
Holidays, Hour of day, Day of Week, Week of year, ...

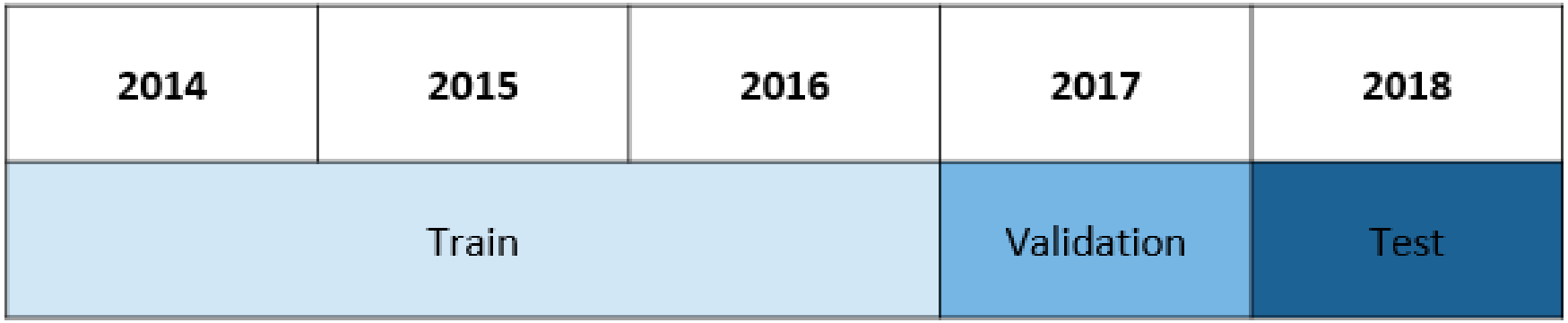


Weather (171 variables)
Temperature, Pressure, Total Snow, Wind Speed, ...

Lagged Price Differences & Intraday & Dayahead Price (42 variables)
Lagged prices for French and German markets
[24, 48, 72 ,…, 168 hours]

Methodology

Goal: Predicting if the Price Difference is positive in the next 1 month



Walk-Forward Validation
Rolling Forward Timeline on 2017 and 2018

Methodology | Target Variable Definition

Model	Threshold	Price Difference (€)
1	> 0.0 SD	> 0.32 €
2	> 0.5 SD	> 3.48 €
3	> 1.0 SD	> 6.64 €
4	> 1.5 SD	> 9.80 €
5	> 2.0 SD	> 12.67 €
6	> 2.5 SD	> 16.13 €
7	> 3.0 SD	> 19.30 €

Example: Model 1

Price Difference > 0.32 €

X1,X2,X3,...	Price Difference (€)	Target
...,...,...,...	2.96	1
...,...,...,...	0.73	1
...,...,...,...	-10.35	0
...,...,...,...	7.06	1

Methodology | Target Variable Definition

Model	Threshold	Price Difference (€)
1	> 0.0 SD	> 0.32 €
2	> 0.5 SD	> 3.48 €
3	> 1.0 SD	> 6.64 €
4	> 1.5 SD	> 9.80 €
5	> 2.0 SD	> 12.67 €
6	> 2.5 SD	> 16.13 €
7	> 3.0 SD	> 19.30 €

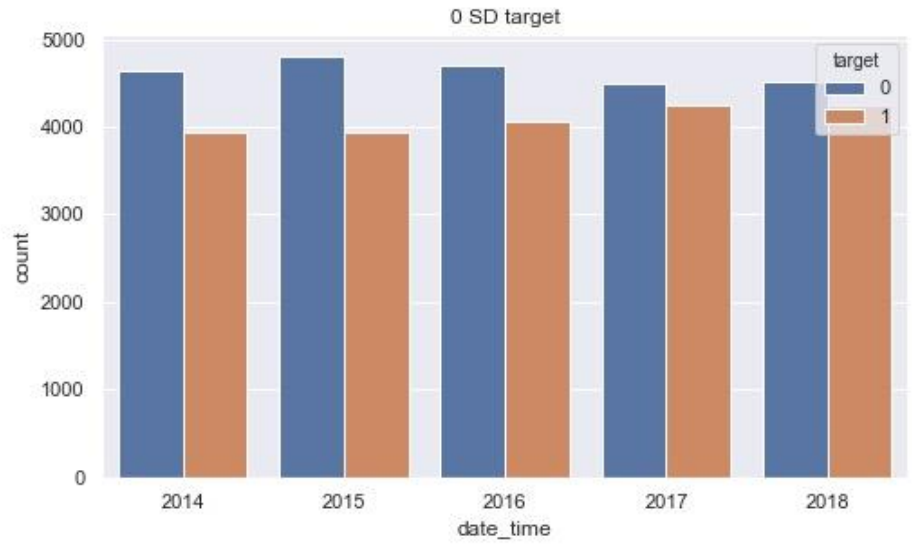
Example: Model 3

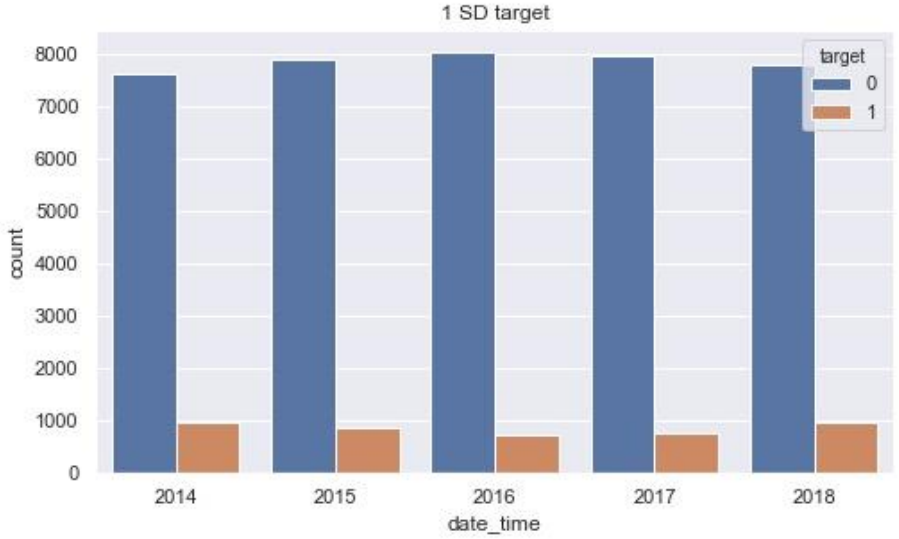
Price Difference > 6.64 €

X1,X2,X3,...	Price Difference (€)	Target
...,...,...,...	2.96	0
...,...,...,...	0.73	0
...,...,...,...	-10.35	0
...,...,...,...	7.06	1

Methodology | Target Variable Definition

Notice imbalanced classes problem! (0 SD & 1 SD)





Random Over Sampling, SMOTE, …

Results | Baseline (without model) – 2017

Strategy:

For every hour block in 2017

Buy in Day Ahead Market, Sell in Intraday Market

Trading volume 1 MWh

Total number of transactions = 8,752 trades

Total gain/loss (without model) = 3,009.85 €

Results | Select Best Model on Validation set – 2017

All models were trained with:

- 7 Different target thresholds
- Random Oversampling technique

Best result for each algorithm

Model	Average AUC	Annual Gain (€)
Logistic Regression	0.54	3,552.80
Random Forest	0.53	2,738.46
Extreme Gradient Boosting	0.52	3,714.92
Light Gradient Boosting Machine	**0.56**	**4,522.23**

Model result	4,522.23 €
Baseline	3,009.85 €
Model Gain	**1,512.38 €**

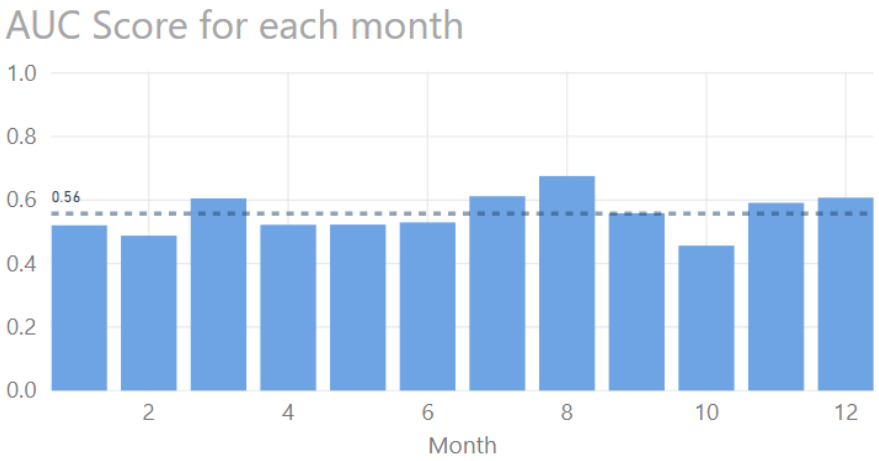
51% more profit than baseline

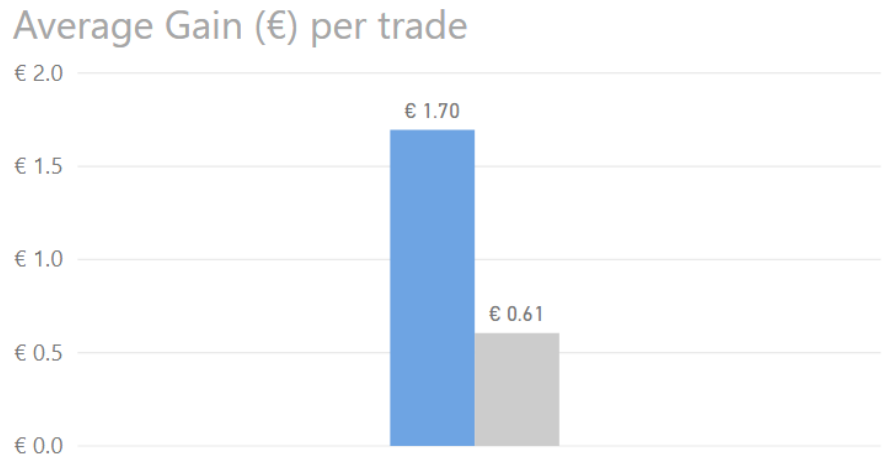
Results | Select Best Model on Validation set – 2017

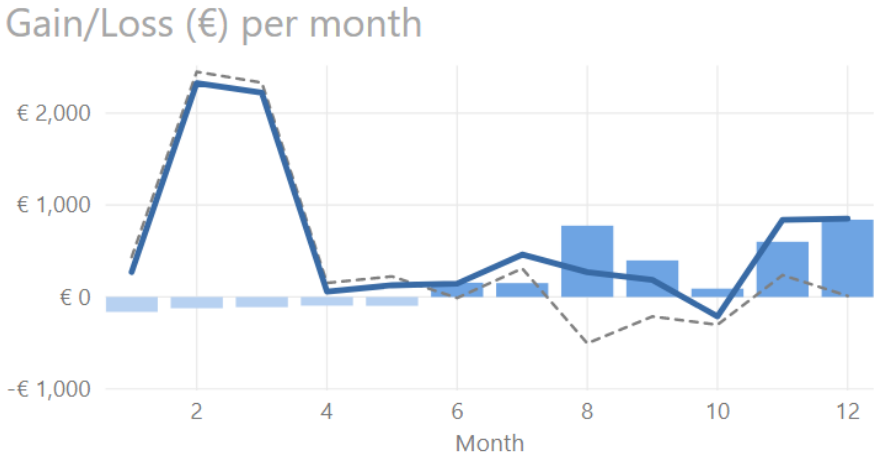
Closer look into Light Gradient Boosting Machine results

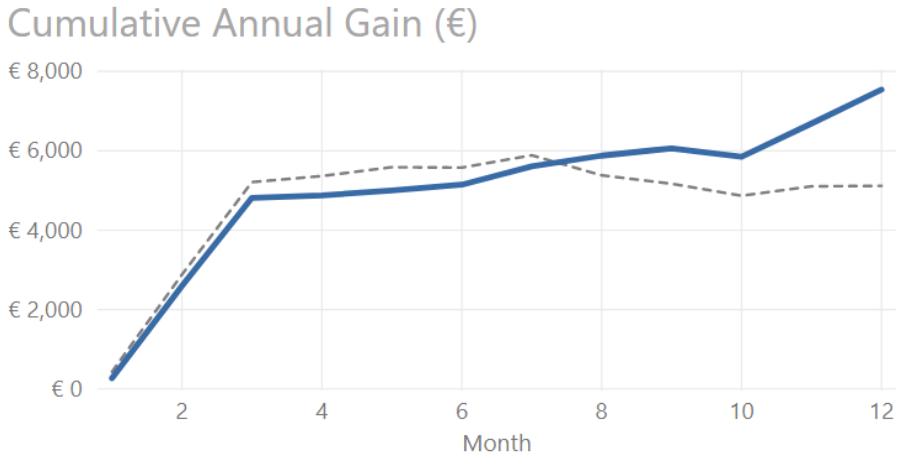
Model	Threshold	Average AUC	Profit (€)
1	**> 0.0 SD**	**0.56**	**1,512.38**
2	> 0.5 SD	0.53	586.16
3	> 1.0 SD	0.59	1,125.68
4	> 1.5 SD	0.56	925.19
5	> 2.0 SD	0.61	112.33
6	**> 2.5 SD**	**0.70**	**1,110.16**
7	> 3.0 SD	0.60	314.64

Results | Evaluation Best Model on Test Set – 2018









Results | Evaluation Best Model on Test Set – 2018

Closer look on Positive Predictions

Number of Trades the Model Predicted Correctly
True Positives : 2112

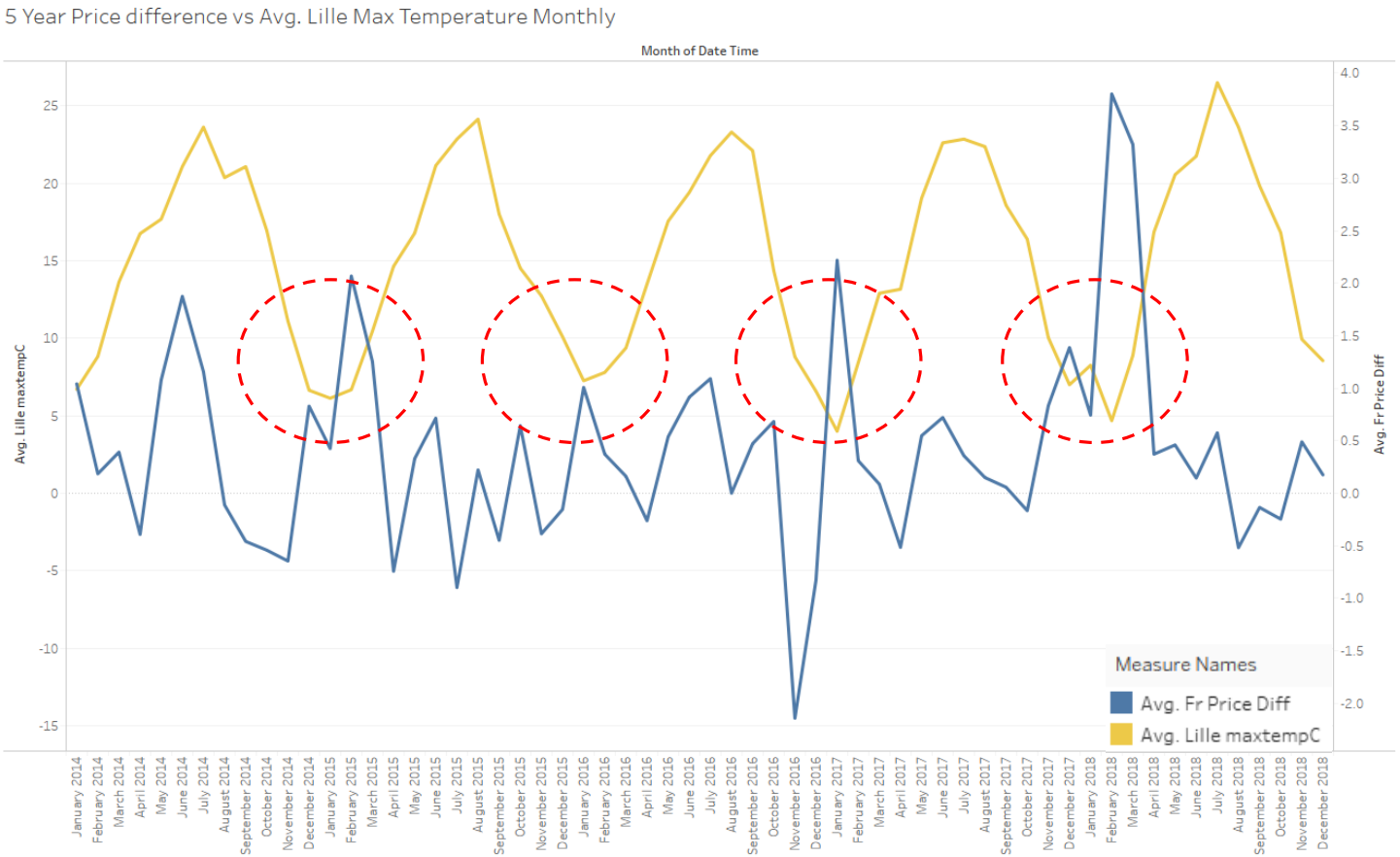
Number of Trades the Model Predicted Wrong
False Positives : 1640

Results | Evaluation Best Model on Test Set – 2018

	Baseline	**Model**
total trades	8752	3752
total gain	€ 5,117.69	**€ 7,542.06**

Apply to test data of year 2018, it proved that **using model helped increase 47% profit** compare to baseline without the model.

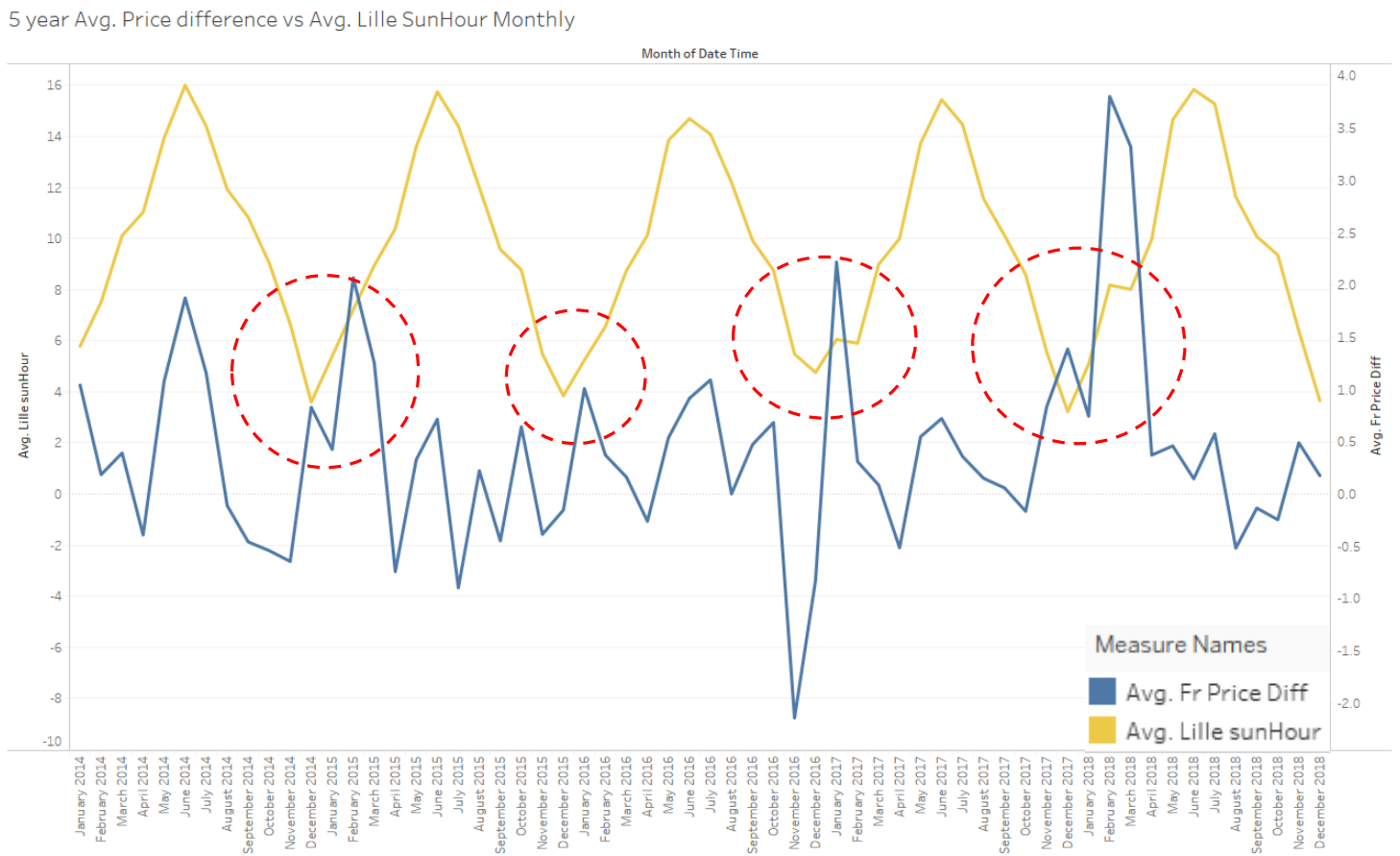
Variable Importance | Maximum Temperature



When **max temperature** moves close to 5 degC

Price difference **rises**

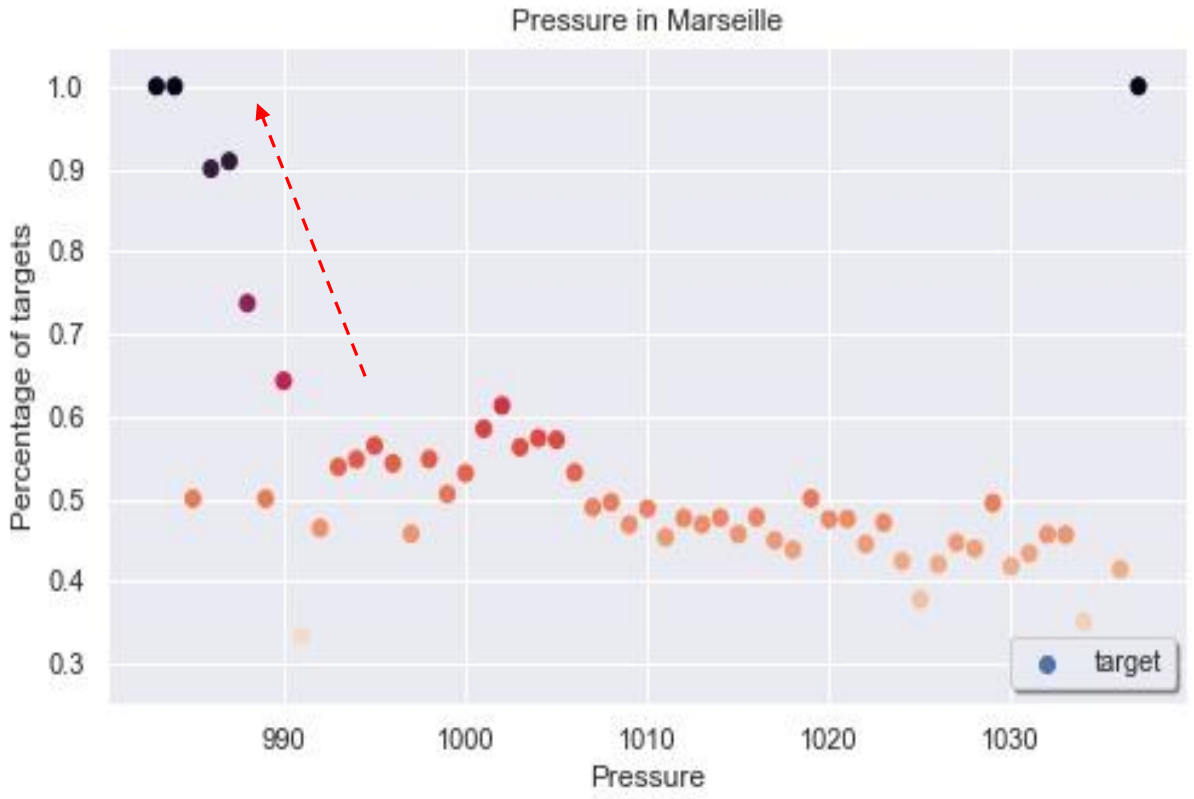
Variable Importance | Number of Sun Hours



When **total sun hour** moves closes to 4 hours/day

Price difference **rises**

Variable Importance | Pressure



Positive targets **increases**

When pressure in Marseille goes **below** 990 millibar

Model Usage

Retrain the model monthly and predict the target daily

Take action based on the predicted result daily

Model assumption is based on 1 MWh volume

Make sure not to disturb the market equilibrium!

Conclusion

Implementation of the prediction model helps increase profits by **47% in 2018** for trading in the French electricity market.

Combining **weather data** with historical EPEX data helps to find price difference patterns between intraday and day ahead.

Thank You!

Appendix | Models Performance on Validation – 2017

4 Different Models/Algorithms

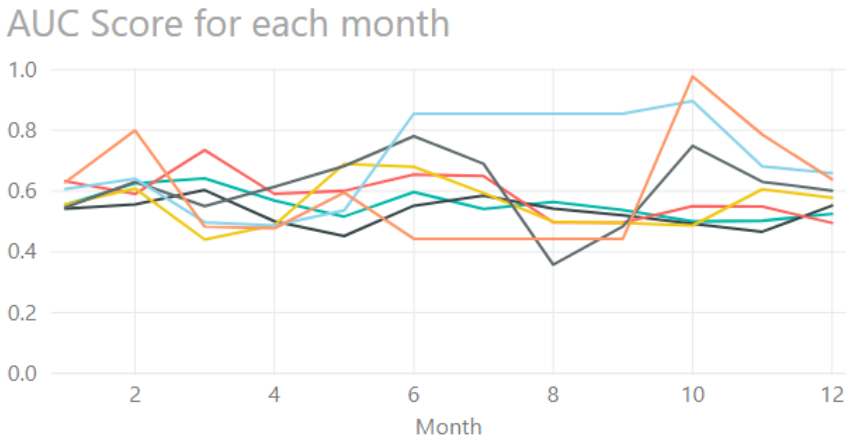
Model	Average AUC	Annual Gain (€)	Threshold	Target Incidence (%)	True Positive	False Positive	True Negative	False Negative	Total Trades	Profit (€)
Logistic Regression	0.54	3,552.80	> 0.5 SD	21.4%	860	2083	4793	1016	2943	542.95
Random Forest	0.53	2,738.46	> 0 SD	48.6%	1629	1366	3128	2629	2995	(271.39)
Extreme Gradient Boosting	0.52	3,714.92	> 0.5 SD	21.4%	376	670	6206	1500	1046	705.07
Light Gradient Boosting Machine	0.56	4,522.23	> 0 SD	48.6%	2172	1726	2768	2086	3898	1,512.38

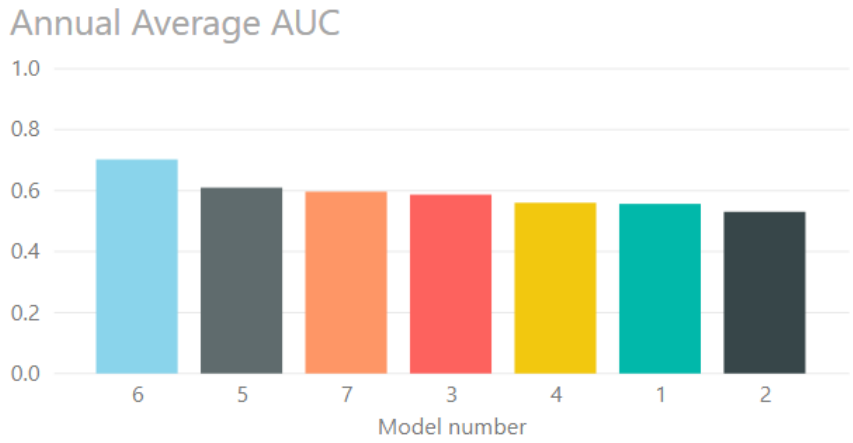
Appendix | Models Performance on Validation – 2017

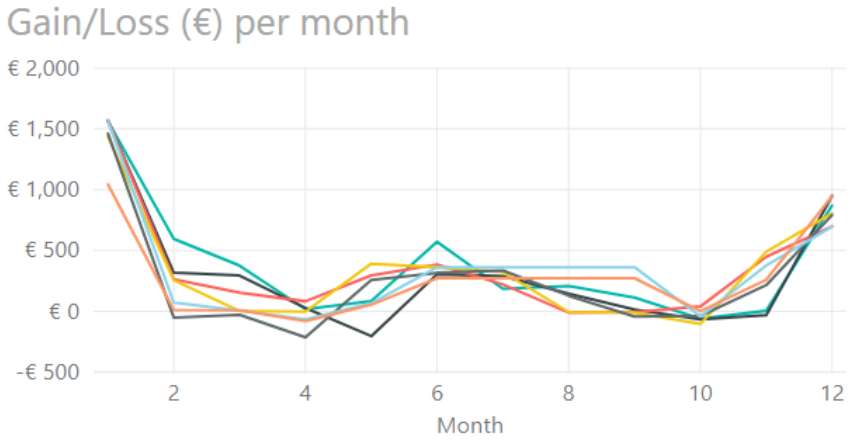
Light GBM Model – 7 Different Target Thresholds

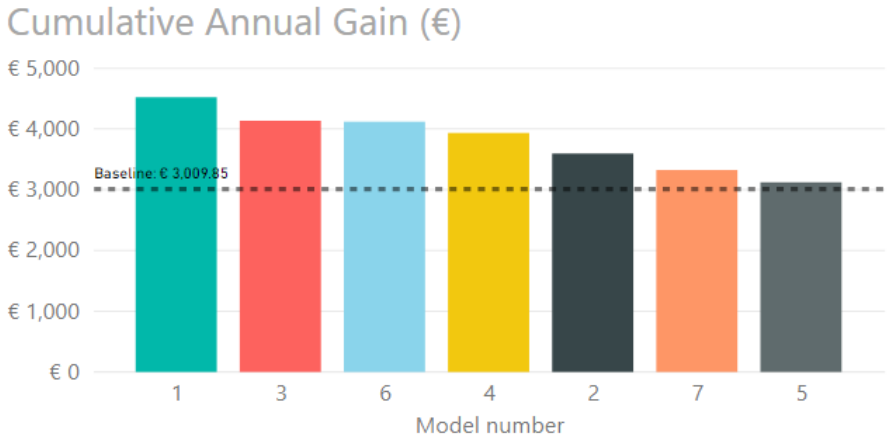
Model	Threshold	Target Incidence (%)	Average AUC	Profit (€)	True Positive	False Positive	True Negative	False Negative
1	> 0.0 SD	48.6%	0.56	1,512.38	2,172	1,726	2,768	2,086
2	> 0.5 SD	21.4%	0.53	586.16	882	2,190	4,686	994
3	> 1.0 SD	8.7%	0.59	1,125.68	498	2,605	5,387	262
4	> 1.5 SD	4.6%	0.56	925.19	276	2,516	5,834	126
5	> 2.0 SD	2.5%	0.61	112.33	160	2,412	6,124	56
6	> 2.5 SD	1.5%	0.70	1,110.16	118	2,080	6,469	37
7	> 3.0 SD	1.1%	0.60	314.64	61	1,580	7,027	36

Appendix | Models Performance on Validation – 2017









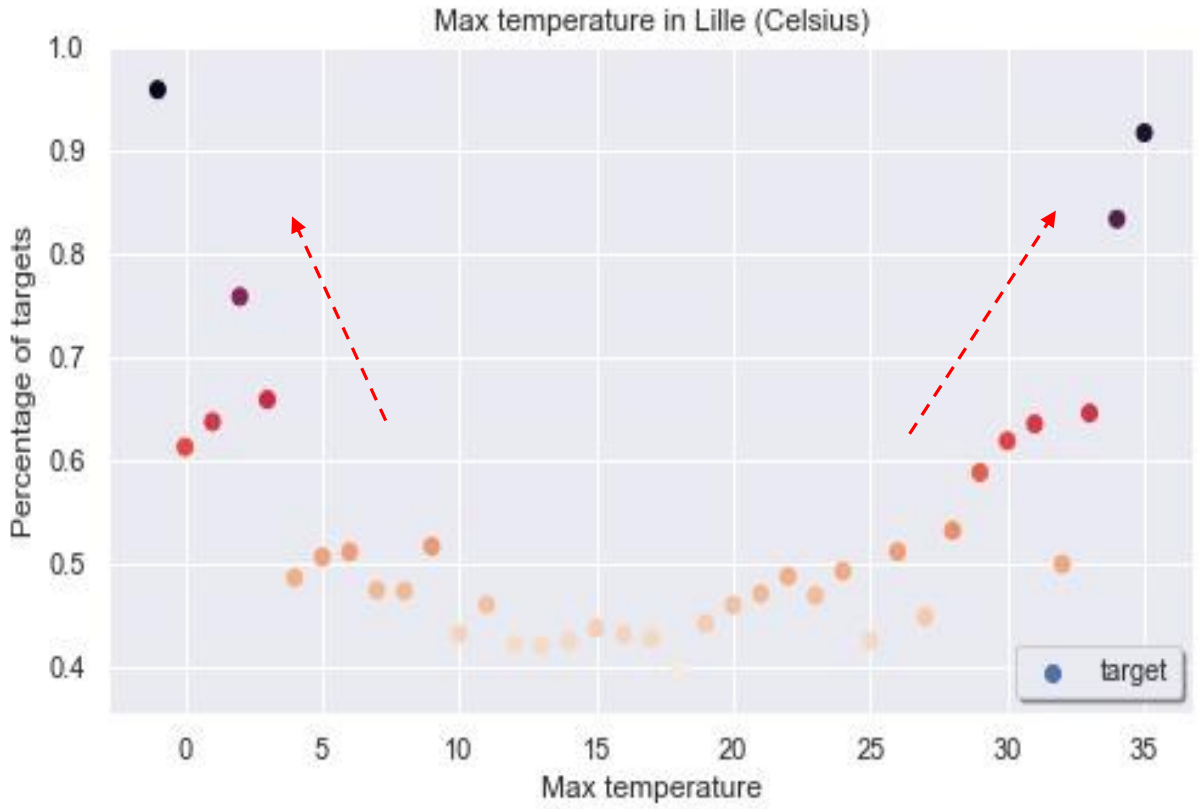
Appendix | Best Model Performance by Month on Test – 2018

Light GBM Model

Target Threshold > 0.0 SD

Month	Target Incidence (%)	AUC Score	True Positive	False Positive	True Negative	False Negative	Total Trades	Profit (€)
1	58.74%	0.52	247	161	146	190	408	(162.20)
2	59.08%	0.49	347	247	28	50	594	(122.37)
3	52.10%	0.61	218	126	227	166	344	(110.61)
4	48.82%	0.52	69	56	312	282	125	(94.37)
5	49.46%	0.52	148	134	242	220	282	(96.27)
6	42.92%	0.53	195	235	176	114	430	155.35
7	50.27%	0.61	189	104	266	185	293	150.85
8	41.80%	0.68	248	193	240	63	441	775.02
9	48.33%	0.56	97	60	312	251	157	397.74
10	42.74%	0.46	41	92	334	277	133	90.77
11	39.03%	0.59	125	115	324	156	240	600.39
12	48.52%	0.61	188	117	266	173	305	840.07
Total			**2112**	**1640**	**2873**	**2127**	**3752**	**2,424.37**

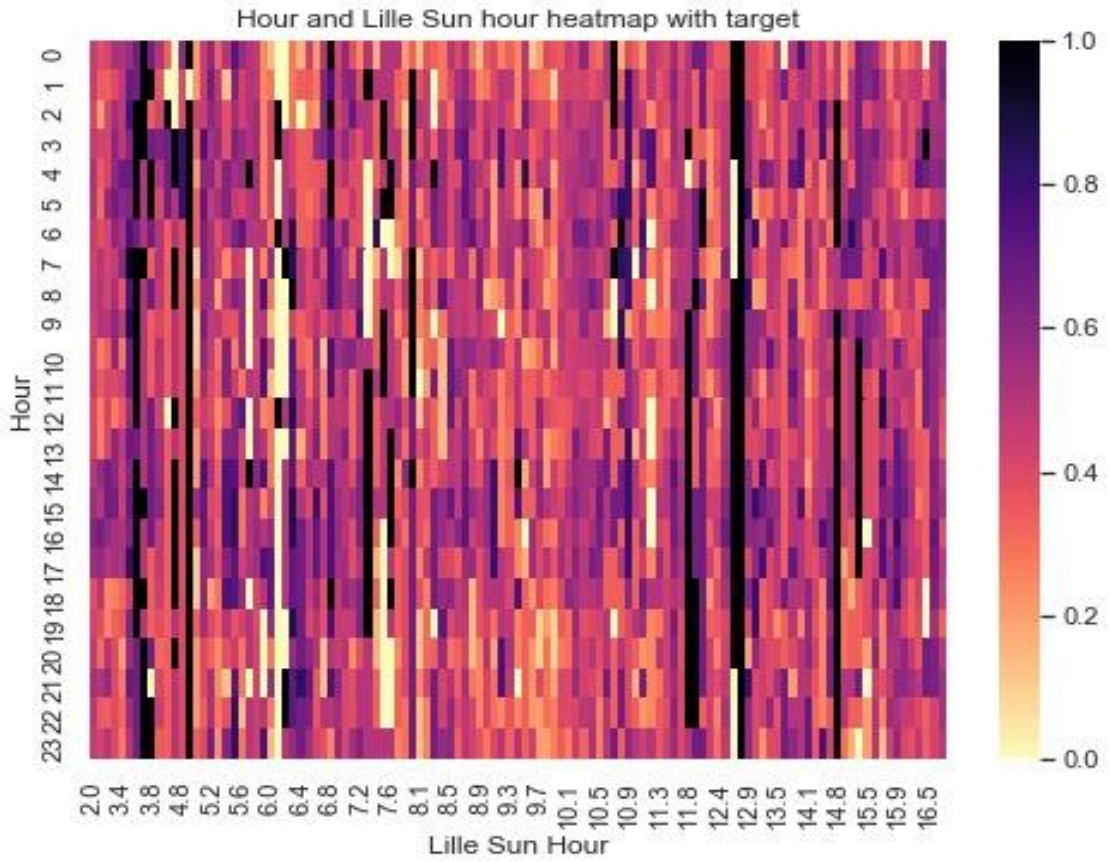
Appendix | Variable Importance | Maximum Temperature



Positive targets **increase**

When the maximum temperature in Lille are below 5 or above 25 degC

Appendix | Variable Importance | Number of Sun Hours

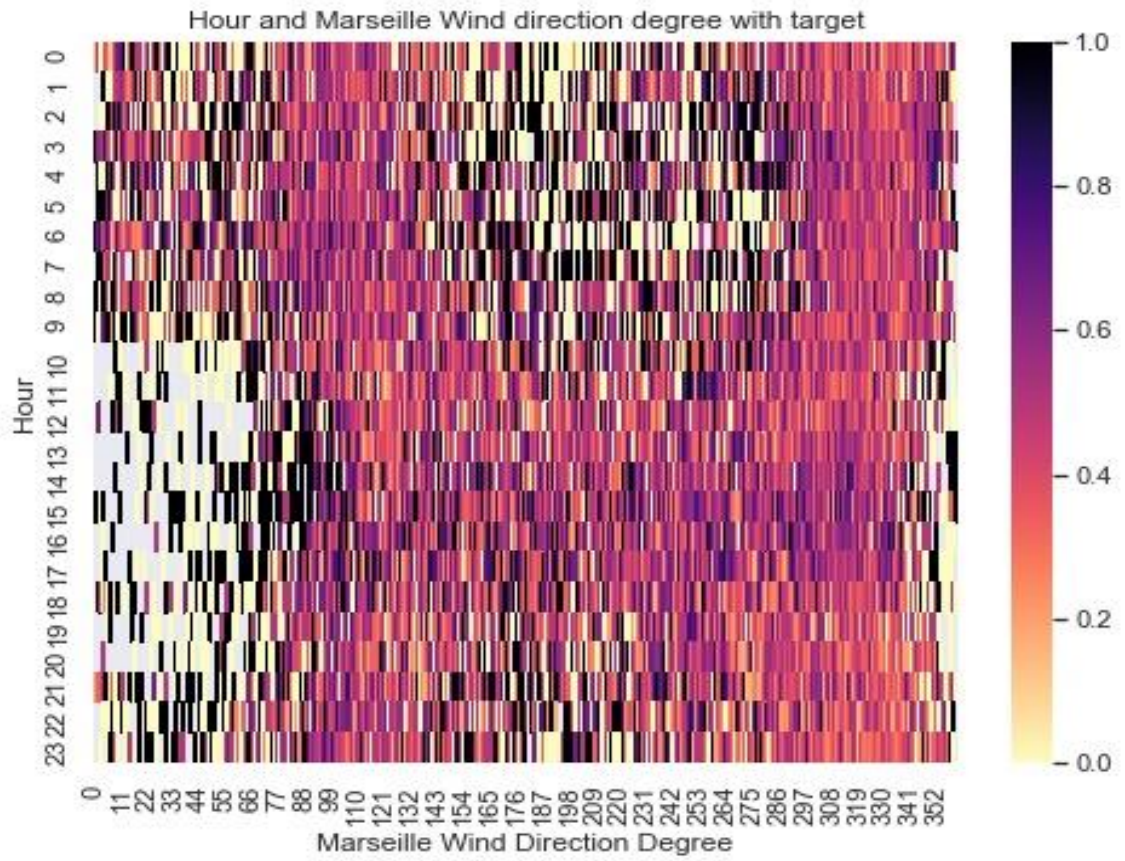


Higher % targets

When the **number of sun hours in Lille** are around

3.5, 11.8, 12.5, 14.8 hours.

Appendix | Variable Importance | Wind Direction



Lower % targets

When the **wind direction in Marseille** are between

0-70 degree, at 10-23 hr

150-250 degree, at 22-08 hr