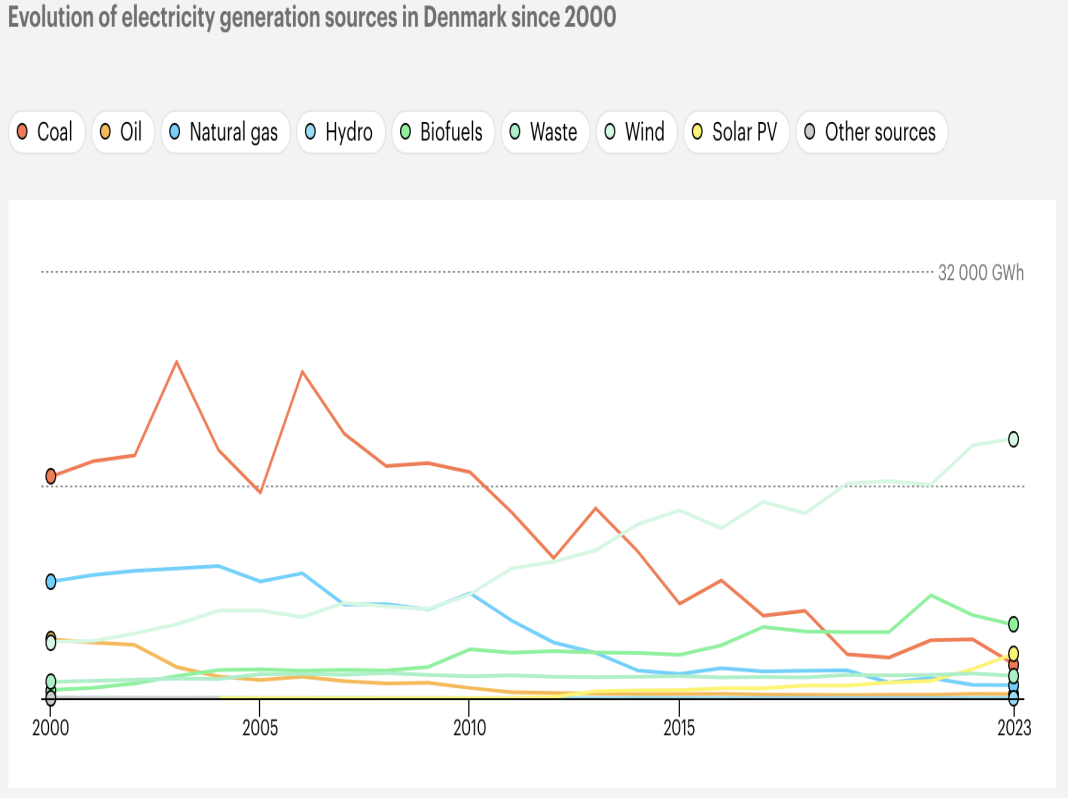
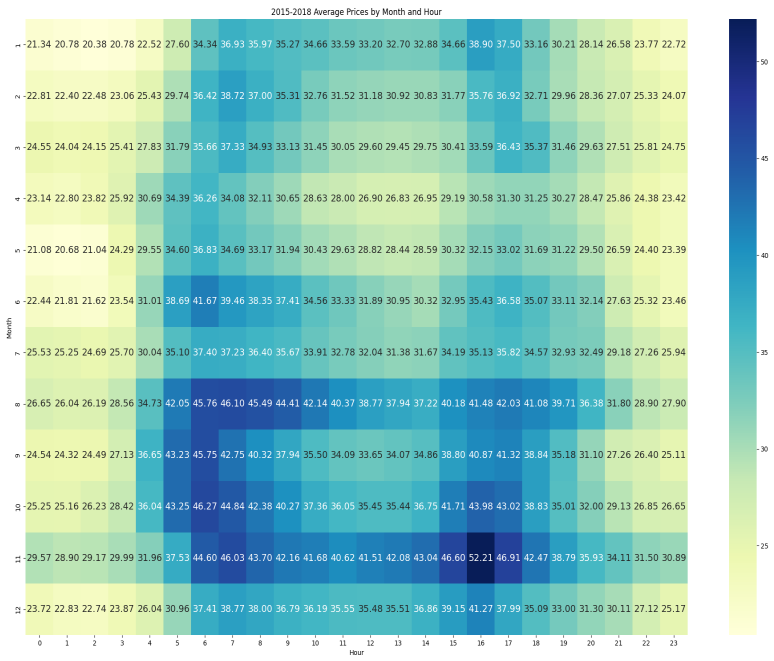
A View at the Denmark Electricity Market

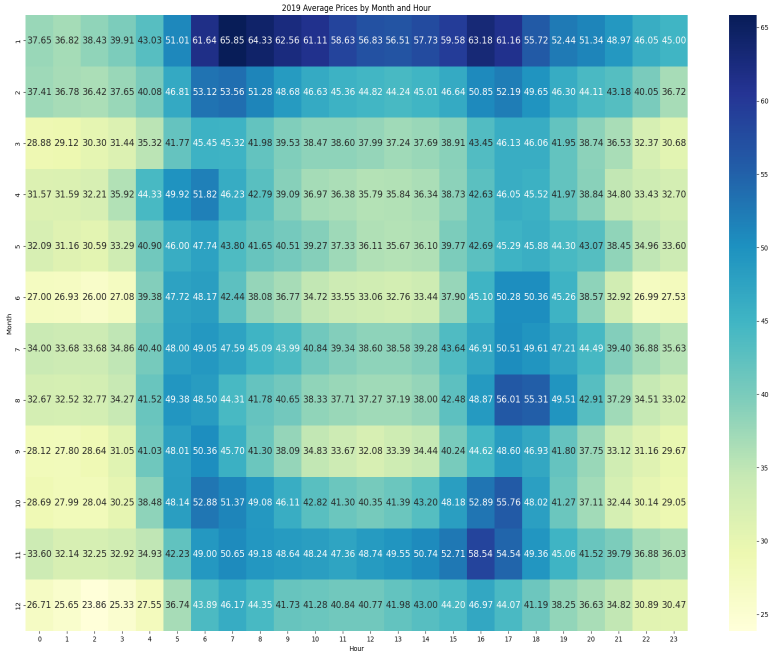


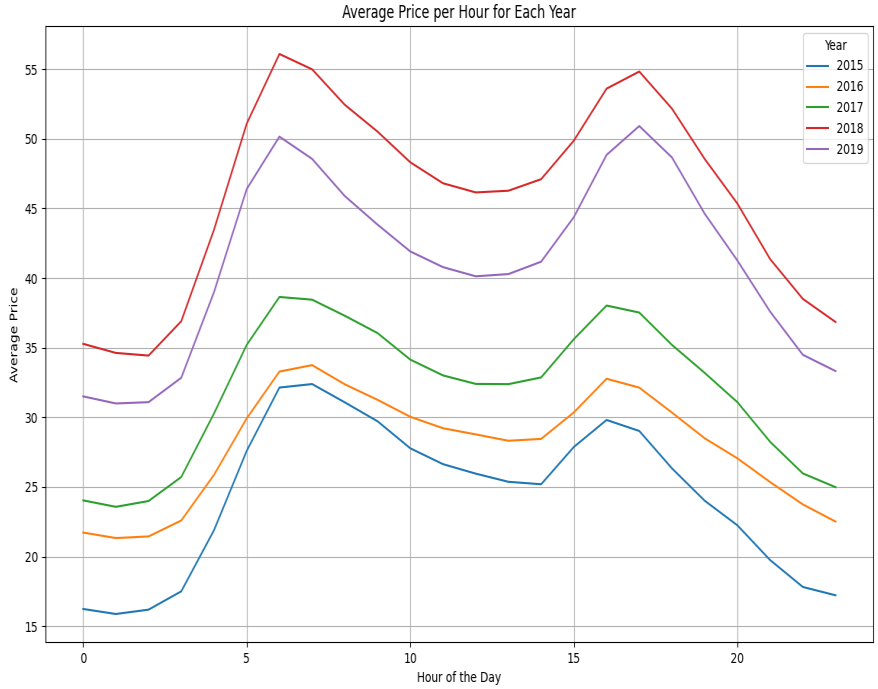
Project Overview

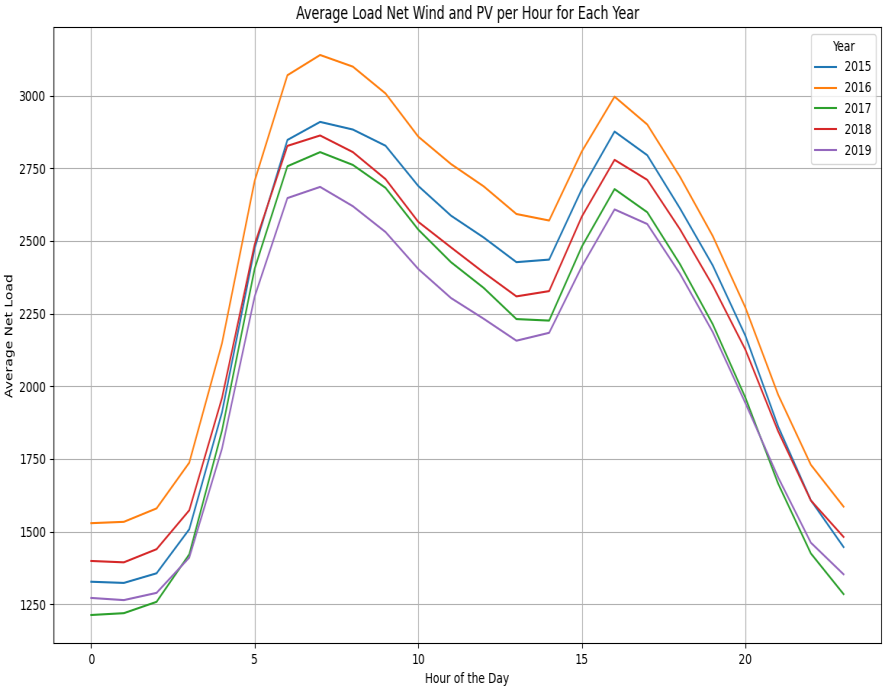
Over the past two decades, Denmark has seen a tremendous shift in their energy landscape. Since the year 2000, Denmark evolved from relying on coal for their electricity generation to relying primarily on wind, biofuels and solar energy. The high penetration of intermittent resources such as wind and solar present an opportunity for batteries and other forms of energy arbitrage. However, to perform a profitable arbitrage strategy, one must be able to reliably predict electrity prices. In this project, I use load, resource capacity, weather, and simualated capacity factor data to predict day ahead prices in DK1, a bidding zone in Denmark. This document presents the results and analysis of 3 XGBoost models as well as some vizualizations to gain a better understanding of the day ahead market in DK1.

Metric	2015-2018	2019
AVG Price	32.51	41.19
STDEV	14.40	11.94
Min	-53.62	-48.29
Max	144.33	109.45


2015-2018 Average Prices by Month and Hour
Month
Hour
1 21.34 20.78 20.38 20.78 22.52 27.60 34.34 36.93 35.97 35.27 34.66 33.59 33.20 32.70 32.88 34.66 38.90 37.50 33.16 30.21 28.14 26.58 23.77 22.72
2 22.81 22.40 22.48 23.06 25.43 29.74 36.42 38.72 37.00 35.31 32.76 31.52 31.18 30.92 30.83 31.77 35.76 36.92 32.71 29.96 28.36 27.07 25.33 24.07
3 24.55 24.04 24.15 25.41 27.83 31.79 35.66 37.33 34.93 33.13 31.45 30.05 29.60 29.45 29.75 30.41 33.59 36.43 35.37 31.46 29.63 27.51 25.81 24.75
4 23.14 22.80 23.82 25.92 30.69 34.39 36.26 34.08 32.11 30.65 28.63 28.00 26.90 26.83 26.95 29.19 30.58 31.30 31.25 30.27 28.47 25.86 24.38 23.42
5 21.08 20.68 21.04 24.29 29.55 34.60 36.83 34.69 33.17 31.94 30.43 29.63 28.82 28.44 28.59 30.32 32.15 33.02 31.69 31.22 29.50 26.59 24.40 23.39
6 22.44 21.81 21.62 23.54 31.01 38.69 41.67 39.46 38.35 37.41 34.56 33.33 31.89 30.95 30.32 32.95 35.43 36.58 35.07 33.11 32.14 27.63 25.32 23.46
7 25.53 25.25 24.69 25.70 30.04 35.10 37.40 37.23 36.40 35.67 33.91 32.78 32.04 31.38 31.67 34.19 35.13 35.82 34.57 32.93 32.49 29.18 27.26 25.94
8 26.65 26.04 26.19 28.56 34.73 42.05 45.76 46.10 45.49 44.41 42.14 40.37 38.77 37.94 37.22 40.18 41.48 42.03 41.08 39.71 36.38 31.80 28.90 27.90
9 24.54 24.32 24.49 27.13 36.65 43.23 45.75 42.75 40.32 37.94 35.50 34.09 33.65 34.07 34.86 38.80 40.87 41.32 38.84 35.18 31.10 27.26 26.40 25.11
10 25.25 25.16 26.23 28.42 36.04 43.25 46.27 44.84 42.38 40.27 37.36 36.05 35.45 35.44 36.75 41.71 43.98 43.02 38.83 35.01 32.00 29.13 26.85 26.65
11 29.57 28.90 29.17 29.99 31.96 37.53 44.60 46.03 43.70 42.16 41.68 40.62 41.51 42.08 43.04 46.60 52.21 46.91 42.47 38.79 35.93 34.11 31.50 30.89
12 23.72 22.83 22.74 23.87 26.04 30.96 37.41 38.77 38.00 36.79 36.19 35.55 35.48 35.51 36.86 39.15 41.27 37.99 35.09 33.00 31.30 30.11 27.12 25.17
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
25 30 35 40 45 50


2019 Average Prices by Month and Hour
Month
Hour
1 37.65 36.82 38.43 39.91 43.03 51.01 61.64 65.85 64.33 62.56 61.11 58.63 56.83 56.51 57.73 59.58 63.18 61.16 55.72 52.44 51.34 48.97 46.05 45.00
2 37.41 36.78 36.42 37.65 40.08 46.81 53.12 53.56 51.28 48.68 46.63 45.36 44.82 44.24 45.01 46.64 50.85 52.19 49.65 46.30 44.11 43.18 40.05 36.72
3 28.88 29.12 30.30 31.44 35.32 41.77 45.45 45.32 41.98 39.53 38.47 38.60 37.99 37.24 37.69 38.91 43.45 46.13 46.06 41.95 38.74 36.53 32.37 30.68
4 31.57 31.59 32.21 35.92 44.33 49.92 51.82 46.23 42.79 39.09 36.97 36.38 35.79 35.84 36.34 38.73 42.63 46.05 45.52 41.97 38.84 34.80 33.43 32.70
5 32.09 31.16 30.59 33.29 40.90 46.00 47.74 43.80 41.65 40.51 39.27 37.33 36.11 35.67 36.10 39.77 42.69 45.29 45.88 44.30 43.07 38.45 34.96 33.60
6 27.00 26.93 26.00 27.08 39.38 47.72 48.17 42.44 38.08 36.77 34.72 33.55 33.06 32.76 33.44 37.90 45.10 50.28 50.36 45.26 38.57 32.92 26.99 27.53
7 34.00 33.68 33.68 34.86 40.40 48.00 49.05 47.59 45.09 43.99 40.84 39.34 38.60 38.58 39.28 43.64 46.91 50.51 49.61 47.21 44.49 39.40 36.88 35.63
8 32.67 32.52 32.77 34.27 41.52 49.38 48.50 44.31 41.78 40.65 38.33 37.71 37.27 37.19 38.00 42.48 48.87 56.01 55.31 49.51 42.91 37.29 34.51 33.02
9 28.12 27.80 28.64 31.05 41.03 48.01 50.36 45.70 41.30 38.09 34.83 33.67 32.08 33.39 34.44 40.24 44.62 48.60 46.93 41.80 37.75 33.12 31.16 29.67
10 28.69 27.99 28.04 30.25 38.48 48.14 52.88 51.37 49.08 46.11 42.82 41.30 40.35 41.39 43.20 48.18 52.89 55.76 48.02 41.27 37.11 32.44 30.14 29.05
11 33.60 32.14 32.25 32.92 34.93 42.23 49.00 50.65 49.18 48.64 48.24 47.36 48.74 49.55 50.74 52.71 58.54 54.54 49.36 45.06 41.52 39.79 36.88 36.03
12 26.71 25.65 23.86 25.33 27.55 36.74 43.89 46.17 44.35 41.73 41.28 40.84 40.77 41.98 43.00 44.20 46.97 44.07 41.19 38.25 36.63 34.82 30.89 30.47
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
25 30 35 40 45 50 55 60 65


Average Price per Hour for Each Year
Year
2015
2016
2017
2018
2019
Average Price
Hour of the Day
55
50
45
40
35
30
25
20
15
0
5
10
15
20


Average Load Net Wind and PV per Hour for Each Year
Year
2015
2016
2017
2018
2019
Average Net Load
Hour of the Day
3000
2750
2500
2250
2000
1750
1500
1250
0
5
10
15
20