# Conformalizing an LSTM to Optimize Revenue for a Renewable Energy Operator using Conditional Value at Risk

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Daniel Moore, Laila Saleh

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We optimized the market trading of a renewable energy generation operator with conditional value at risk based on probabilistic forecasts made with a conformalized Long Short-term Memory (LSTM) recurrent neural network. This work demonstrates an end-to-end work flow of how field data can be ingested, analyzed, and exploited to reduce risk exposure for the operator. Obviously this is financially beneficial to the individual operator, but taken to a larget scale this methodology increases the incentive for renewable generation participation which should drive cost and emmissions down. This work carried out on a small number of features with great results, so it is expected that further studies and more advance models with the same architecture would provide better yield.

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# 1 Introduction

What is the problem

## 1.1 Motivation

Why do we want to do this

## 1.2 Objectives

What are we going to do

## 1.3 Literature Review

What have other people done

# 2 Data Analysis

What do we know?

Table 1: Data from RebaseAPI

| | DateTime | Solar | Wind | TotalEnergy | DAP | SSP |
|---|---|---|---|---|---|---|
| | DateTime | Float32 | Float32 | Float32 | Float32 | Float32 |
| 1 | 2024-03-09T07:00:00 | 102.87 | 737.58 | 840.45 | 45.53 | 43.65 |
| 2 | 2024-03-09T08:00:00 | 512.099 | 739.36 | 1251.46 | 42.13 | 10.0 |
| 3 | 2024-03-09T09:00:00 | 870.875 | 751.816 | 1622.69 | 38.01 | 86.9 |
| 4 | 2024-03-09T10:00:00 | 1211.29 | 768.994 | 1980.28 | 38.05 | 86.9 |
| 5 | 2024-03-09T11:00:00 | 1443.02 | 773.194 | 2216.21 | 39.97 | 85.676 |

Table 2: Ennergy Data Summary

| | variable | mean | min | median | max |
|---|---|---|---|---|---|
| | Symbol | Float32 | Float32 | Float64 | Float32 |
| 1 | Solar | 236.681 | 0.0 | 0.381154 | 1443.02 |
| 2 | Wind | 518.782 | 0.0 | 665.679 | 826.22 |
| 3 | TotalEnergy | 755.463 | 0.0 | 778.769 | 2216.21 |
| 4 | DAP | 59.4672 | -18.2 | 62.015 | 112.23 |
| 5 | SSP | 61.9252 | -65.0 | 63.195 | 175.844 |

## 2.1 Data Summary

## 2.2 Data Visualizations

What do we see?

Table 3: Data from VisualCrossing

| | DateTime | temp | windspeed | winddir | cloudcover |
|---|---|---|---|---|---|
| | DateTime | Float32 | Float32 | Float32 | Float32 |
| 1 | 2024-03-09T07:00:00 | 6.0 | 22.2 | 72.0 | 100.0 |
| 2 | 2024-03-09T08:00:00 | 6.1 | 25.9 | 74.0 | 100.0 |
| 3 | 2024-03-09T09:00:00 | 6.2 | 25.5 | 74.0 | 100.0 |
| 4 | 2024-03-09T10:00:00 | 6.7 | 23.5 | 72.0 | 100.0 |
| 5 | 2024-03-09T11:00:00 | 6.9 | 26.3 | 82.0 | 100.0 |

Table 4: Weather Data Summary

| | variable | mean | min | median | max |
|---|---|---|---|---|---|
| | Symbol | Union… | Any | Any | Any |
| 1 | DateTime | | 2024-02-29T23:00:00 | 2024-03-19T10:30:00 | 2024-04-06T23:00:00 |
| 2 | temp | 8.21836 | -2.3 | 7.7 | 19.0 |
| 3 | windspeed | 16.0126 | 0.9 | 15.3 | 41.2 |
| 4 | winddir | 172.188 | 3.0 | 178.0 | 359.0 |
| 5 | cloudcover | 73.9165 | 0.0 | 93.7 | 100.0 |

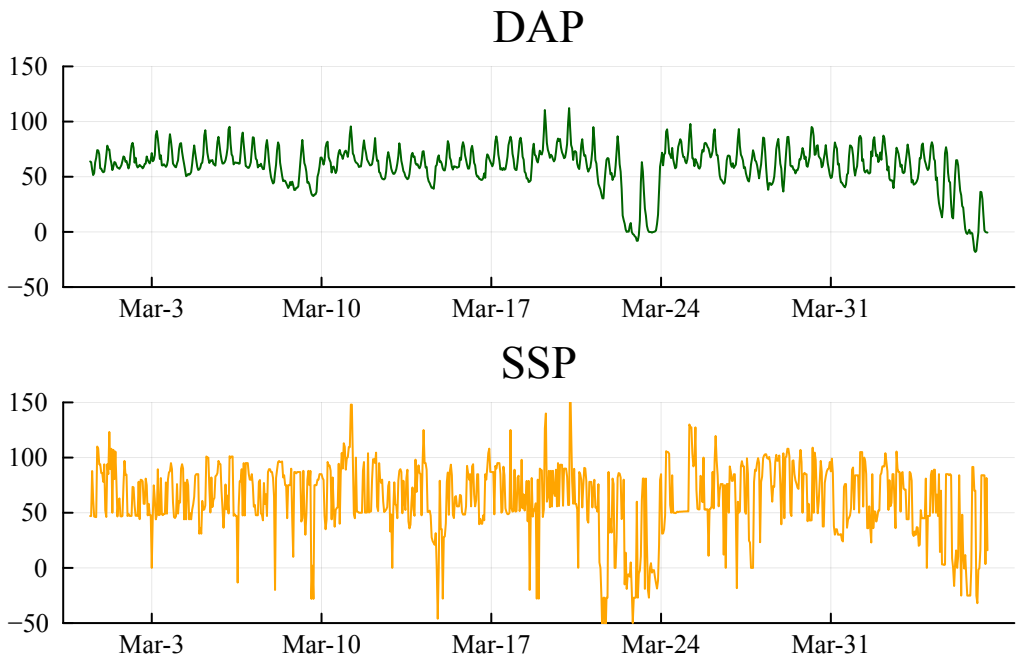


Figure 1: March 2024 Energy Prices

## 3 Long Short-Term Memory Model

What is an LSTM ## Training How did we make one? ## Performance Is it any good?

## 4 Conformalizing LSTM

What are conforal predictions? Why are they good ## How to? How did we conformalize the LSTM?

### 4.1 Performance

Is it any good?

## 5 Conditional Value at Risk

What is CVAR

Why do we do it?

### 5.1 Implementation

How did we do it?

### 5.2 Performance

Was it any good?

## 6 Conclusions

Was any of this worth while?

What did we learn?

What could others do?