Evaluating Deep Learning Pipelines for Predicting Electricity Prices in Renewable-Dominated Markets

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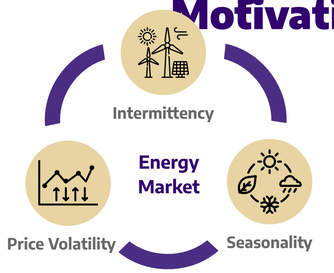
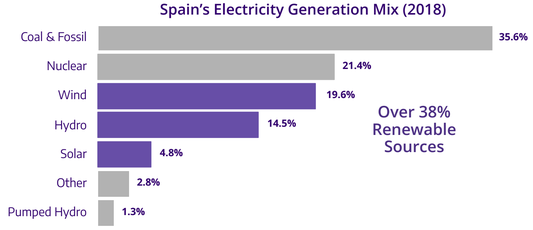
Background & Motivation



Study Area

Renewable energy ***intermittency*** combined with ***seasonal*** demand fluctuations can lead to electricity price ***volatility*** in the energy market

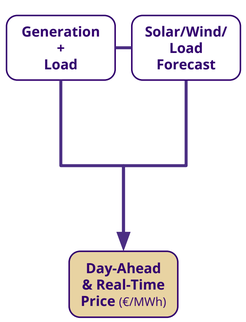
Spain's Electricity Generation Mix (2018)



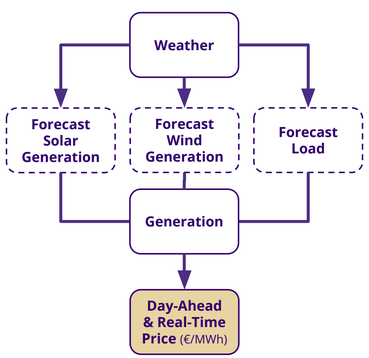
Research Objective

Evaluate end-to-end and multi-stage deep learning pipelines comparing CNN+BiLSTM and Transformer architectures to predict Day-Ahead and Real-Time Electricity Prices

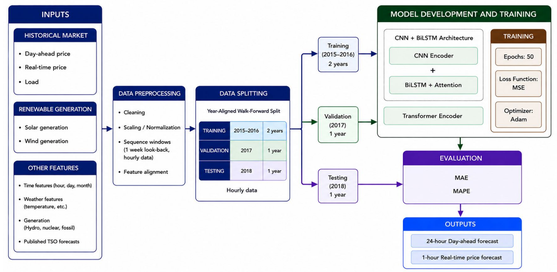
End-to-End



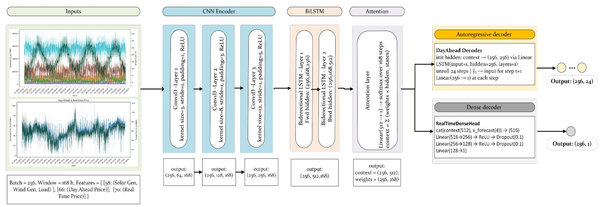
Multi-Stage



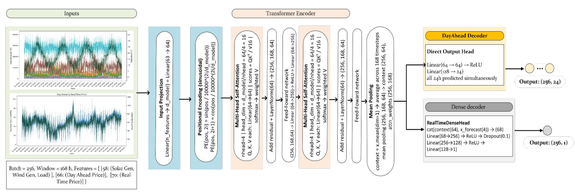
Methodology



CNN+BiLSTM Architecture



Transformer Architecture



Pipeline Comparison

Day-Ahead Price Prediction Evaluation

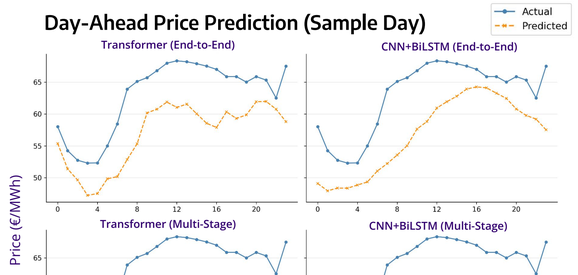
Pipeline	Architecture	Training Time (minutes)	MAE (€/MWh)	MAPE (%)
End-to-End	**Transformer**	**1.65**	**6.49**	**15.53**
Multi-Stage	Transformer	5.45	11.54	31.87
End-to-End	CNN+BiLSTM	2.58	8.72	20.38
Multi-Stage	CNN+BiLSTM	15.16	11.00	31.44

Real-Time Price Prediction Evaluation

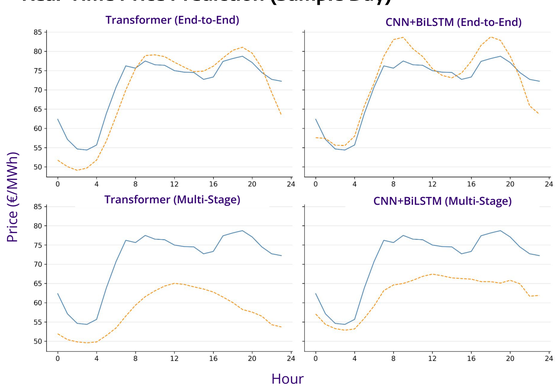
Pipeline	Architecture	Training Time (minutes)	MAE (€/MWh)	MAPE (%)
End-to-End	Transformer	1.62	3.45	6.21
Multi-Stage	Transformer	5.37	11.64	18.89
End-to-End	**CNN+BiLSTM**	**2.05**	**2.91**	**5.09**
Multi-Stage	CNN+BiLSTM	16.43	8.13	13.77

Prediction Performance

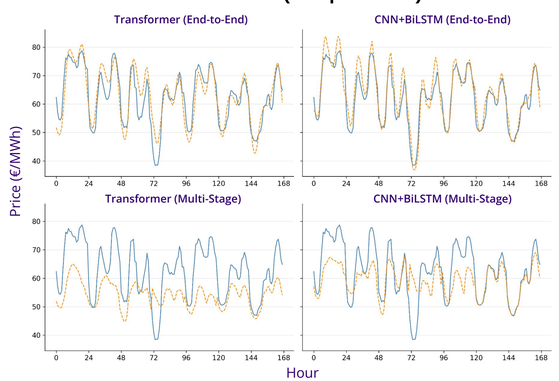
Day-Ahead Price Prediction (Sample Day)



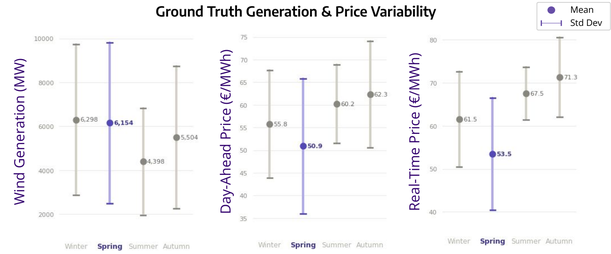
Real-Time Price Prediction (Sample Day)



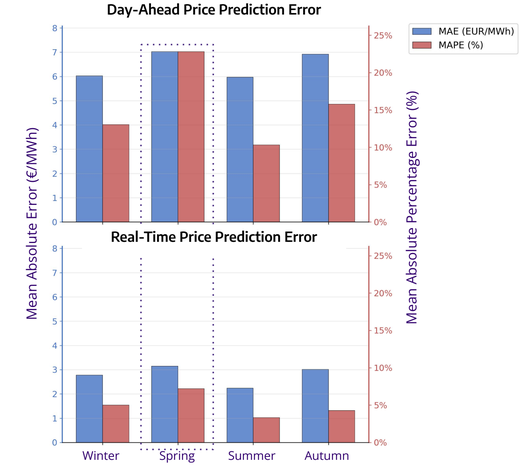
Real-Time Price Prediction (Sample Week)



Seasonality Analysis



Day-Ahead Price Prediction Error



Higher wind generation ***variability*** in Spring drives electricity price ***swings*** resulting in larger model prediction ***errors***

Key Takeaways

1. End-to-end pipeline demonstrates higher predictive performance for both day-ahead and real-time price prediction
2. Real-time price prediction generally has lower errors across both pipelines
3. Seasonal variability in renewable generation impacts model's ability to learn price dynamics
4. Data sparsity in temporal horizon and relevant features impacts accurate forecasting of renewable generation and load
5. Longer training times affect hyperparameter tuning impacting model fitting thus reducing predictive performance