Analysing Usage Patterns and Carbon Emissions of Public EV Charging Sessions in Munich: A Data-Driven Optimization Approach Using Machine Learning

Master‘s Thesis of Sebastian Stein

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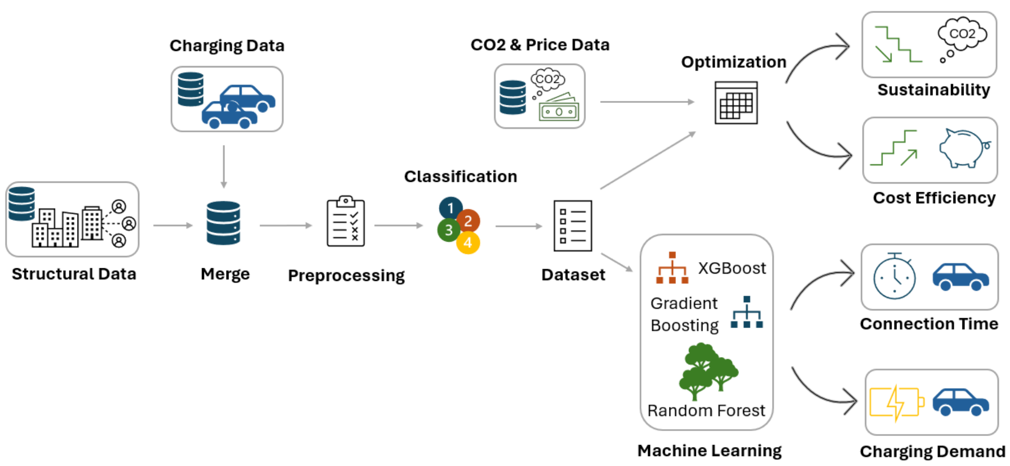
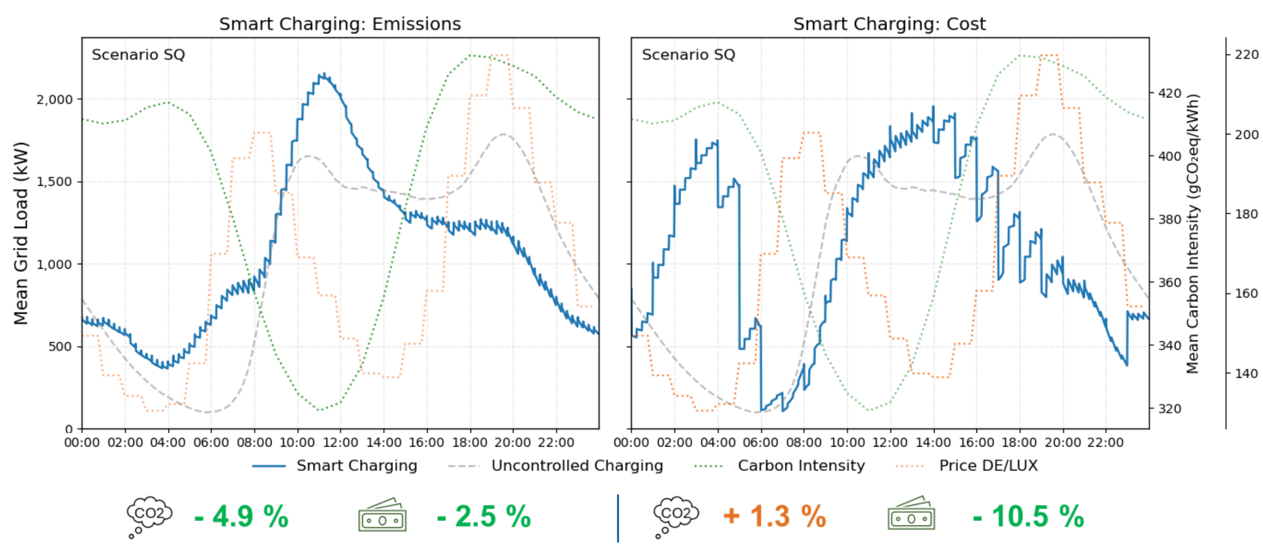


Graphical representation of modeling framework

The rapid adoption of electric vehicles (EVs) is a pivotal strategy for mitigating climate change and reducing greenhouse gas emissions in the transport sector. However, the growing electric vehicle (EV) fleet poses significant challenges for energy grids, necessitating innovative solutions to manage increased electricity demand effectively. This thesis focuses on the potential of smart charging (SC) strategies to address these challenges within the context of public EV charging infrastructure in Munich. Using detailed charging session records provided by Stadtwerke München (SWM) for 2021 to 2022, along with structural data, historical CO2 intensity of the German electricity mix, and spot market energy prices, we analyze the status quo of public EV charging behavior in Munich. Key objectives include quantifying ecological and techno-economic parameters, assessing the potential of two SC strategies, and evaluating the predictability of charging behavior using machine learning models.

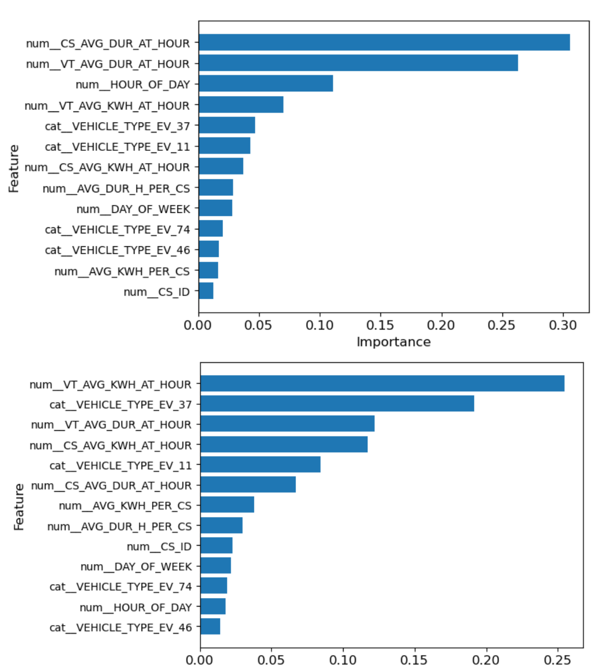
The findings indicate a moderate potential for improved sustainability and saving costs, while SC generally positively affects the distribution of the energy load. CO2-optimized charging generally depletes the typical two peaks and instead produces a larger peak of 2.15 MW that is shifted one hour from the morning peak to 11:30 h. As a result, the charging demand around the evening peak, where prices are highest during the day, is also reduced. In contrast, cost-driven charging shifts a large share of charging to night times between 01:00 to 05:00 h, coinciding with the lowest energy prices.



Potential of Smart Charging at public EV charging stations in Munich

Connection Time	
MAE	1.58 h
SMAPE	49.5 %
R2	0.45

Charging Demand	
MAE	4.42 kWh
SMAPE	44.6 %
R2	0.29



Results and feature importance of machine learning prediction

This thesis proposes a machine learning framework to identify and understand patterns in the charging behavior of EVs, which is essential for improving scheduling strategies. The best predictive models demonstrate that temporal and vehicle-specific patterns are central in predicting charging behaviors. Our predictive accuracy falls short of those in the literature from which we derive suggestions for improvement and propose to use our results as a benchmark for future development. We therefore consider this thesis as a contribution to the broader understanding of the importance of localized, data-driven approaches and advanced modeling techniques needed to fully realize the potential of public EV charging infrastructure in Munich, aligning ecological goals with techno-economic feasibility.

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