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► **To cite this version:**

Alix Dupont. Optimal Price Menu Design of Electric Vehicle Charging Stations. PGMO days 2023, PGMO; Electricité de France (EDF), Nov 2023, Palaiseau, France. hal-04434929

HAL Id: hal-04434929

<https://hal.science/hal-04434929v1>

Submitted on 2 Feb 2024

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Optimal Price Menu Design of Electric Vehicle Charging Stations

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Keywords: Electric vehicles, charging station, price design, optimization

The growing adoption of Electric Vehicles (EVs) presents many challenges and opportunities for the Charging Station Operators (CSOs), who are called to determine their pricing strategies considering the EV user charging behavior. Related literature, such as [1, 2], considers a CSO who sets prices for different delays in the time required to charge. However, EV users are supposed to give personal information such as their departure time, which also constrains them to leave at the announced departure time (with potential overstay penalties).

In this work, we consider that the EV users arriving at a charging station view charging more as an opportunity rather than as an indispensable need; hence, the parking duration depends only on their on-site activities. Arguably, this behavior is likely to be more common in the future (in the presence of high EV penetration and high charging point availability). In such settings, an appropriate CSO “price menu” proposal would consist of different prices for different levels of charging rates (unlike cases where prices are associated with different delay completion times).

We formulate the proposed price menu design problem as a bi-level optimization problem. At the lower level, the EV users decide to choose one of the options in the menu or they may choose not to charge. Their choice depends on their utility and the price per charging rate offered in the menu. At the upper level, the CSO designs the prices per charging rates. We provide analytical and numerical results on the optimal price menu design, considering in the upper level (i) the maximization of the CSO’s profit, and (ii) the maximization of the *social welfare*. We investigate the properties of the optimal price menu under both *complete information* of the EV users utility, and *incomplete information*, where the CSO has only knowledge on the distribution of the utility across the EV users population. In the latter, the bi-level optimization problem yields to a Mixed Integer Linear Programming (MILP) in both the CSO’s profit and *social welfare* maximization cases.

References

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- [2] O. Wu, S. Yucel, Y. Zhou, *Smart Charging of Electric Vehicles: An Innovative Business Model for Utility Firms*, Manufacturing & Service Operations Management, 24(5):2481-2499, 2021.