One price fits it all? Implications of a fixed price scheme on EV charging in Norway

Fabian Brockmann, Mario Guajardo

NHH Norwegian School of Economics
Bergen, Norway
Fabian.Brockmann@nhh.no

***Abstract*— This paper explores the potential impacts of introducing a fixed electricity price in Norway, replacing the current dynamic zone-pricing scheme. Dynamic pricing has allowed households to optimize their electricity consumption for many years, especially with the widespread adoption of electric vehicles (EVs). While dynamic pricing has provided savings and benefits for EV users and grid operators, Norwegian policymakers are considering a shift to a fixed pricing scheme, arguing that it would offer lower and more stable costs for the population. A key question in this debate is how such a change would affect EV charging costs, particularly for smart charging users. To address this, the study utilizes real-world datasets on EV charging sessions and hourly electricity prices. By combining these datasets with a simulation and optimization framework, we analyze how a fixed price would impact EV charging costs and the price differences across Norwegian bidding zones. We also demonstrate how a time-of-use pricing model can provide a predictable and beneficial pricing structure for flexible electricity consumption.**

***Index Terms*—Electric vehicles, Energy consumption, Electricity grids, Smart devices**

I. INTRODUCTION

In many countries, private households pay flat-rate electricity prices rather than dynamic pricing, which adjusts to current market conditions. This is largely due to concerns about the potential benefits versus the costs of implementing such systems, as well as fears about unexpectedly high bills. However, dynamic pricing can offer monetary savings for consumers and benefits for suppliers, such as reduced peak capacity investments, better operational planning, and cost-reflective pricing. By shifting electricity demand from peak to off-peak hours, dynamic pricing can also help reduce investment in new infrastructure [1]. In contrast, Norway has implemented dynamic real-time pricing during many years, with nearly 99% of households holding dynamic electricity contracts [2]. These contracts enable hourly billing, allowing households to adjust their electricity consumption based on price fluctuations, leading to lower electricity bills and more efficient electricity usage [2-4], particularly during price crises [5].

Norwegian households also have a unique characteristic compared to many other countries: the highest market share of electric vehicles (EVs) worldwide, with 96% of all new vehicles being electric [6]. Additionally, most Norwegians have the possibility to charge their electric vehicles at home, with 92% of EV owners charging at least once per week at home [7]. To manage this, many households have invested in wall boxes—controllable, internet-connected charging stations that allow users to schedule EV charging loads.

These wall boxes allow to perform the so often called “smart charging” approach. Research on smart charging started due to concerns about the potential implications that EV charging may have on the electrical grid [8]. Nowadays, smart charging is a broad term that refers to algorithms or optimization problems that schedule EV charging loads with all kinds of objectives. Algorithms aim to minimize electricity costs [9], reduce battery degradation [10], optimize grid operation [11], or combine multiple objectives [12].

In Norway, digital platforms offer smart charging services to help users automate the schedule of charging through wall boxes. The objective is to minimize electricity costs while holding grid constraints. Research has shown that not only the cost of EV owners may be significantly reduced by this smart charging strategy, but also the grid operation may benefit from a peak-shaving effect [2].

However, following the electricity price crisis, Norwegian policymakers have been under pressure to reduce electricity costs for households and increase bill predictability. Currently, there is broad political support for introducing a fixed price for all consumers, replacing the fluctuating dynamic pricing system. Under this proposal, a single fixed price, referred to as "Norgespris" ("Norway’s price"), would apply across all five pricing zones in Norway. This price is intended to reflect the average electricity price in the country.

While a fixed price tariff offers stability, it also removes the opportunity to benefit from dynamic pricing, which can help reduce electricity bills [13]. With a fixed price, electricity costs remain the same regardless of fluctuations in supply and demand, preventing EV owners from taking advantage of lower prices during off-peak hours. As a result, the fixed price system may reduce incentives for EV owners to engage in smart charging. This raises the question of how a fixed price would impact EV charging costs and the incentives to adopt a smart charging strategy.

As day-ahead electricity prices vary across different Norwegian bidding zones due to factors such as the availability of cheap hydroelectric energy in northern parts of Norway, we may hypothesize a decrease in electricity prices for some zones and an increase for others under the fixed price, compared to the current dynamic pricing system. Since price-insensitive EV charging (i.e., plug-and-charge) is often done upon arrival at home, when electricity prices are typically high, we may hypothesize EV users who rely on plug-and-charge to benefit from the new pricing system. In contrast, users of smart charging might incur higher costs under the fixed pricing scheme. Thus, in addition to analyze how the different charging strategies would be affected by the new pricing scheme, a related question is how to make the EV charging costs more predictable and stable while keeping incentives for efficient use of electricity. To address these questions, this study conducts a numerical analysis of EV charging costs in Norway, based on a simulation and an optimization model. As the penetration of electric vehicles continues to grow in many countries worldwide, this study aims to provide insights that extend beyond the Norwegian context.

The rest of the paper is organized as follows: Section II outlines the materials and methods, Section III presents and discusses the results, and Section IV concludes with final remarks.

II. MATERIALS & METHOD

We model EV charging by considering two key aspects. First, using charging session data from [14], we develop a simulation model to sample charging sessions according to different charging strategies. The charging strategy determines how electricity usage is managed throughout the session. In this study, we focus on two strategies: Plug-and-Charge (PaC) and Smart charging. With the PaC strategy, charging begins immediately after plug-in time, and continues until the battery charging requirement is reached. In contrast, the Smart charging strategy optimizes charging by selecting times when electricity prices are lowest within the time window available for charging.

We analyzed the data from [14], assuming that the properties of charging sessions vary between weekdays and months. The variation between weekdays is driven by different travel patterns associated with various activities, such as commuting to work from Monday to Friday. The variation across months is influenced by factors like the efficiency of EVs in different temperatures, with colder months typically leading to higher electricity demands due to reduced efficiency. For example, Figure 1 illustrates the monthly electricity usage per EV, highlighting how winter months result in increased electricity consumption. Other factors, such as mobility needs and vacation periods, also contribute to these patterns. Figure 2 presents the resulting workflow of the simulation.

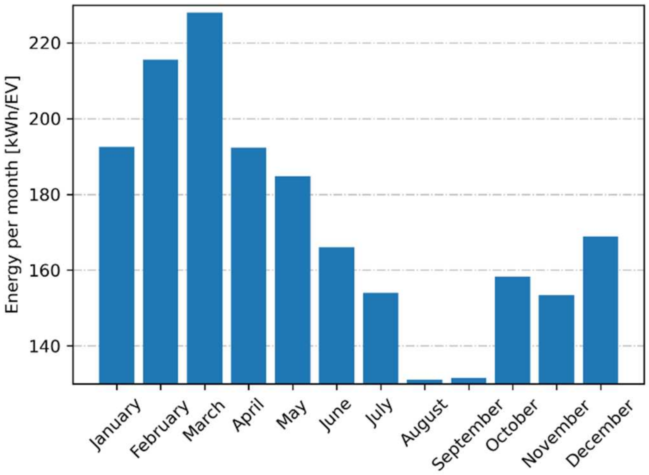

Figure 1. *Monthly electricity consumption per EV.*

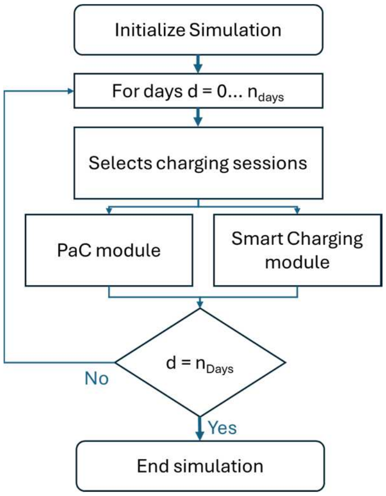

Figure 2. *Workflow of simulation.*

The charging strategies used in this model are the previously described Plug-and-Charge and Smart charging approaches. Under the Plug-and-Charge strategy, the EV begins charging immediately upon being plugged-in and continues until the required charging amount is reached. In contrast, the Smart charging strategy is framed as an optimization problem, which is solved to find the optimal charging schedule. This optimization problem is solved individually for each charging session.

For each charging session, let T represent the set of time periods (in hours) within the session. The objective is to minimize the total charging cost C for the session, as given by equation (1). Let π_t denote the dynamic day-ahead price at time t, and let x_t represent the charging load of the EV at time t. Each charging session requires a total charging amount D, which must be fully met during the session, as expressed in constraint (2). The charging load x_t is constrained by the maximum power P^{max} that the charging device can deliver. Additionally, since the power flow is unidirectional, the charging load must be non-negative. The corresponding lower and upper bounds are expressed in (3).

$$C = \min_{x} \sum_{t \in T} \pi_t x_t \tag{1}$$
$$\sum_{t \in T} x_t = D \tag{2}$$
$$0 \leq x_t \leq P^{max} \tag{3}$$

These simulation and optimization approaches are described in more detail in [15]. The computational implementation of these approaches requires data. We use two datasets in this study. First, to run the simulation we utilize the charging session data from [14]. This allows us to create charging sessions to run the optimization model (1-3). The prices used in the objective function of this model, are taken from the day-ahead prices perceived in the five bidding zones of Norway during each hour of the year 2024, published in [16]. By solving the model, we can determine the optimal charging schedule for the Smart Charging strategy and calculate the average electricity price paid by EV owners using this strategy. For owners using the Plug-and-Charge strategy, calculating the average is straightforward after running the simulation, as no optimal schedule is needed.

We compare these charging costs to a fixed price which applies to all five electricity bidding zones. To calculate this price, we calculate the weighted average price among all five zones. Let Y be the set of all hours t within a year, Z be the set of zones, $\pi_{t,z}$ the day-ahead electricity price at time t in zone z, and $l_{t,z}$ be the load at time t in zone z. The weighted average electricity price is calculated as:

$$p^{fixed} = \sum_{z \in Z} \sum_{t \in Y} \pi_{t,z}\, l_{t,z} \;/\; \sum_{z \in Z} \sum_{t \in Y} l_{t,z} \tag{4}$$

We also propose a new pricing scheme to replace the fixed price. This scheme is designed to account for daily fluctuations in electricity prices while maintaining stability and predictability for end consumers, addressing the current criticisms of the existing dynamic pricing model. In alignment with the reviewed pricing schemes by [1], we suggest a time-of-use (TOU) pricing structure. Let H be the set of all hours throughout the year. The TOU price for each hour h of the day is calculated as the weighted average price across all zones and across all time periods in the year, as follows:

$$p_h^{TOU} = \sum_{z \in Z} \sum_{h \in H} \pi_{h,z}\, l_{h,z} \;/\; \sum_{z \in Z} \sum_{h \in H} l_{h,z} \tag{5}$$

III. RESULTS & DISCUSSION

A. Dynamic price & fixed price

First, we calculate the weighted average price, referred to as the "fixed price" (Equation (4)), which is determined to be 4.2 c€/kWh for the year 2023. This price is primarily influenced by the pricing zones with higher electricity prices and greater electricity consumption, especially NO1 and NO2, each accounting for around 26% of total electricity consumption in Norway. In contrast, the smallest bidding zone, NO4, has an average electricity price significantly below the new fixed price, at 2.5 c€/kWh. As a result, consumers in NO4 would face an increase of approximately 71% in their electricity costs under the fixed price system compared to their current day-ahead prices. In total, this amounts to an additional cost of about €352,600,282 for the year 2023 for zone NO4.

Figure 3 provides an overview of the simulation study results, including the weighted average price in each pricing zone and the new fixed price. As anticipated, EV owners who use a smart charging strategy pay below the average price of their respective pricing zone and below the fixed price. According to the dataset, the average EV owner charges 2,076 kWh of electricity per year. Therefore, a difference of 1 c€/kWh between the average charging costs under the day-ahead price and the new fixed price translates to an additional cost of approximately €21 annually. In contrast to international comparisons, total electricity cost savings in Norway are relatively low due to the generally low cost of electricity. For example, studies from Germany report electricity cost savings of around 5 ct€/kWh for households with electric vehicles that switch from a fixed to a dynamic pricing scheme [17].

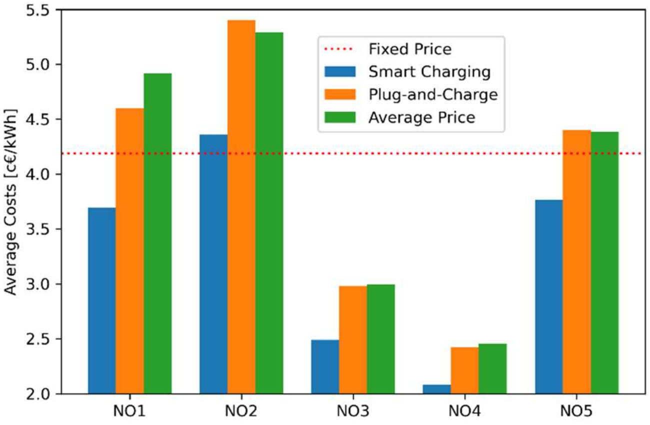

Figure 3. *Average Costs based on day-ahead prices.*

Contrary to expectations, EV owners using a plug-and-charge strategy do not always benefit from the fixed price scheme, and those using a smart charging strategy do not always face higher costs. In electricity price zones with very low prices (NO3 and NO4), the fixed price is significantly higher than the dynamic pricing costs, leading to higher charging costs for EV owners in these zones. Conversely, in the high-price zone NO2, the fixed price results in lower charging costs, even for plug-and-charge users. For zones NO1 and NO5, with average prices, the expected outcome holds: plug-and-charge users benefit from the fixed price, while smart charging users experience higher costs under the fixed pricing scheme.

Another notable observation is that EV owners using the plug-and-charge strategy do not always incur higher charging costs than the average electricity price in their respective zones. This might seem counterintuitive, as the plug-and-charge strategy is typically associated with charging during peak price hours, particularly in the afternoon. The drivers to explain these results are the duration of the charging process and the timing of when the EV is plugged in. On a typical day in Norway, electricity prices are characterized by low rates at night, a price peak in the morning, lower prices around noon, and a second peak in the afternoon. On average, a charging session lasts for 12 hours, with 2.65 hours spent on actual charging. Most EV charging begins when the vehicle is plugged-in after returning home from work or similar activities. As a result, the initial electricity consumption occurs at a high price, but as the session continues, cheaper electricity is used. Additionally, the morning price peak is often as high as or higher than the afternoon peak when charging typically begins, contributing significantly to the weighted average electricity price. Figure 4 illustrates this relation between the electricity price and the load from a plug-and-charge strategy. It also shows how Smart Charging schedules electricity consumption towards low-price hours during the night and noon time.

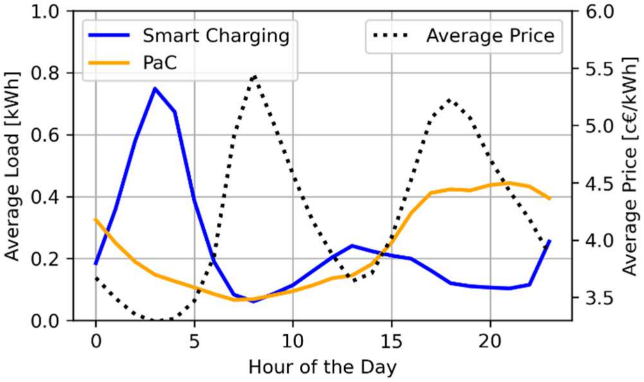

Figure 4. *Average charging loads and prices in NO1.*

B. *Time-of-use price*

We now evaluate the proposed TOU price, as described in Section II (Equation 5). This pricing scheme maintains the same overall system costs while allowing households and flexible consumers who charge during low-price hours to benefit from reduced rates. Figure 5 illustrates the TOU price, with lower rates during the night and higher peaks in the morning and afternoon

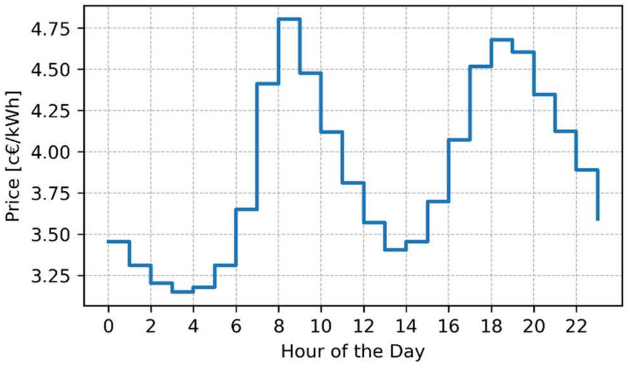

Figure 5. *Proposed TOU price.*

Since the proposed TOU price applies uniformly across all Norwegian bidding zones, the charging costs for an electric vehicle will be identical across these zones. In our simulation, the average electricity cost under the Plug-and-Charge strategy is 4.0 c€/kWh, while the average cost under the Smart Charging strategy is 3.5 c€/kWh. The difference between these two prices demonstrates how our proposed pricing mechanism ensures that users of smart energy devices continue to benefit from lower costs within a unified system price. At the same time, the pricing scheme remains stable and predictable. This approach incentivizes consumers who adjust their usage to low-price hours, while those who charge during peak demand periods contribute to covering the higher costs.

Table 1 compares the cost differences between EV owners using Plug-and-Charge and those using Smart Charging under the proposed TOU price, as well as across all Norwegian zones under the dynamic price. The comparison reveals that the average percentage and total cost savings from Smart Charging versus Plug-and-Charge are lower under a TOU price than under a dynamic price. However, under the fixed price scheme, cost savings are zero. The TOU price provides a balance, offering predictability and stability while allowing flexible consumers, such as EV owners, to adjust their electricity consumption and reduce electricity costs.

Table 1. *Changes charging costs under different charging strategies.*

Pricing	Zone	Change in [%]	Change in [c€/kWh]
Dynamic price	NO1	19.6	0.90
	NO2	19.3	1.05
	NO3	16.5	0.49
	NO4	14.1	0.34
	NO5	14.4	0.64
TOU price	All Zones	12.8	0.50

IV. CONCLUSION

The debate between flat and dynamic prices has received attention worldwide for many years. Likewise, the advent of electric vehicles at massive scale around the world is posing questions on how they may affect electrical grids. Norway, a pioneer country in both respects, with private households perceiving dynamic electricity prices (strongly aligned to the day-ahead price of electricity) and a very high penetration of electric vehicles, is experiencing a hot debate about whether to switch back to a fixed price scheme. To shed light on how the potential fixed price scheme would affect EV charging costs and charging behaviors, this study has contributed with a quantitative analysis based on simulation and optimization, using real-world data from the country.

Our results show that EV owners in the northernmost electricity bidding zones experience higher charging costs under the fixed price scheme. This is because the fixed price is primarily influenced by the high costs in other zones. In contrast, in the high-price zones of Norway, the new fixed electricity price would be sufficiently low relative to the current cost of smart charging under dynamic pricing. In Norwegian zones with average price levels, the fixed price behaves as expected: EV owners who previously minimized costs with a smart charging strategy will now face higher costs under the fixed price, while those owners using a plug-and-charge strategy will perceive lower costs under the fixed price.

The main incentive for adopting smart charging currently is the potential to save on electricity costs. The new fixed pricing scheme would raise questions about whether EV owners would keep their behavior. As a result, some EV owners may switch to a plug-and-charge practice, which would lead to higher costs. However, these additional costs would be absorbed by the fixed electricity price, causing the fixed price to increase. This raises overall electricity costs, which is contrary to the intended purpose of the fixed pricing scheme. Furthermore, smart charging has shown to reduce electricity losses in the electrical grid, as it aligns with periods of lower demand, which are typically associated with lower prices. This makes smart charging not only cost-effective for consumers but also beneficial for grid efficiency. If smart charging becomes less relevant under a fixed price system, grid efficiency could decline, potentially leading to higher investments in grid expansion. Therefore, we also studied a time-of-use pricing scheme, where the price changes each hour to reflect daily market price fluctuations. This pricing structure is stable and predictable for households while still allowing them to align consumption with the variations in market prices. Under this scheme, smart charging remains a cost-effective option for EV owners, although the electricity cost savings are lower compared to the current dynamic pricing scheme.

For policymakers, our study demonstrates that the current market scheme, which uses dynamic pricing for private households, is an efficient way to allocate electricity costs based on household consumption patterns. Flexible consumers, such as EV owners, are rewarded with lower charging costs for responding to market signals. However, under the proposed fixed price ("Norgespris"), this incentive would be removed, leading to higher charging costs in most areas of Norway. In exploring a compromise between fixed and fully dynamic pricing schemes, this article has also evaluated a time-of-use pricing model. In comparison to the fixed price scheme advocated by policymakers, the TOU pricing structure continues to offer lower costs to those consumers who utilize their flexibility.

Future research could investigate the effects of EV charging loads on overall electricity prices and explore potential incentive systems to encourage households to consume electricity during off-peak periods. These systems must be simple enough for households to understand, yet sophisticated enough to accurately reflect real electricity prices.

V. REFERENCES

[1] G. Dutta and K. Mitra, “A literature review on dynamic pricing of electricity,” Journal of the Operational Research Society, vol. 68, no. 10. Informa UK Limited, pp. 1131–1145, Oct. 2017. doi: 10.1057/s41274-016-0149-4.

[2] E. Bjørndal, M. Bjørndal, E. Kjerstad Bøe, J. Dalton, and M. Guajardo, “Smart home charging of electric vehicles using a digital platform,” Smart Energy, vol. 12. Elsevier BV, p. 100118, Nov. 2023. doi: 10.1016/j.segy.2023.100118.

[3] H. Saele and O. S. Grande, “Demand Response From Household Customers: Experiences From a Pilot Study in Norway,” IEEE Transactions on Smart Grid, vol. 2, no. 1. Institute of Electrical and Electronics Engineers (IEEE), pp. 102–109, Mar. 2011. doi: 10.1109/tsg.2010.2104165.

[4] M. Hofmann and K. B. Lindberg, “Evidence of households’ demand flexibility in response to variable hourly electricity prices – Results from a comprehensive field experiment in Norway,” Energy Policy, vol. 184. Elsevier BV, p. 113821, Jan. 2024. doi: 10.1016/j.enpol.2023.113821.

[5] M. Hofmann and K. B. Lindberg, “Residential demand response and dynamic electricity contracts with hourly prices: A study of Norwegian households during the 2021/22 energy crisis,” Smart Energy, vol. 13. Elsevier BV, p. 100126, Feb. 2024. doi: 10.1016/j.segy.2023.100126.

[6] Digitaliseringsdirektoratet. “Datahotell”. https://hotell.difi.no/? dataset=vegvesen/kjoretoyinfo2

[7] E. Figenbaum, S. Nordbakke. “Battery electric vehicle user experiences in Norway’s maturing market”. https://www.toi.no/getfile.php?mmfileid=50956

[8] J. García-Villalobos, I. Zamora, J. I. San Martín, F. J. Asensio, and V. Aperribay, “Plug-in electric vehicles in electric distribution networks: A review of smart charging approaches,” Renewable and Sustainable Energy Reviews, vol. 38. Elsevier BV, pp. 717–731, Oct. 2014. doi: 10.1016/j.rser.2014.07.040.A. Visakh and S. Manickavasagam Parvathy, “Energy-cost minimization with dynamic smart charging of electric vehicles and the analysis of its impact on distribution-system operation,” Electrical Engineering, vol. 104, no. 5. Springer Science and Business Media LLC, pp. 2805–2817, Feb. 23, 2022. doi: 10.1007/s00202-022-01511-w.

[9] T. Montes, F. Pinsach Batet, L. Igualada, and J. Eichman, “Degradation-conscious charge management: Comparison of different techniques to include battery degradation in Electric Vehicle Charging Optimization,” Journal of Energy Storage, vol. 88. Elsevier BV, p. 111560, May 2024. doi: 10.1016/j.est.2024.111560.

[10] N. Leemput, F. Geth, J. Van Roy, J. Büscher, and J. Driesen, “Reactive electricity support in residential LV distribution grids through electric vehicle charging,” Sustainable Energy, Grids and Networks, vol. 3. Elsevier BV, pp. 24–35, Sep. 2015. doi: 10.1016/j.segan.2015.05.002.

[11] Maigha and M. L. Crow, “Electric Vehicle Scheduling Considering Co-optimized Customer and System Objectives,” IEEE Transactions on Sustainable Energy, vol. 9, no. 1. Institute of Electrical and Electronics Engineers (IEEE), pp. 410–419, Jan. 2018. doi: 10.1109/tste.2017.2737146.

[12] Maigha and M. L. Crow, “Electric Vehicle Scheduling Considering Co-optimized Customer and System Objectives,” IEEE Transactions on Sustainable Energy, vol. 9, no. 1. Institute of Electrical and Electronics

Engineers (IEEE), pp. 410–419, Jan. 2018. doi: 10.1109/tste.2017.2737146.

[13] J. Stute, S. Pelka, M. Kühnbach, and M. Klobasa, “Assessing the conditions for economic viability of dynamic electricity retail tariffs for households,” Advances in Applied Energy, vol. 14. Elsevier BV, p. 100174, Jul. 2024. doi: 10.1016/j.adapen.2024.100174.

[14] Å. L. Sørensen, I. Sartori, K. B. Lindberg, and I. Andresen, “Electric vehicle charging dataset with 35,000 charging sessions from 12 residential locations in Norway,” Data in Brief, vol. 57. Elsevier BV, p. 110883, Dec. 2024. doi: 10.1016/j.dib.2024.110883.

[15] F. Brockmann, M. Guajardo, “Smart Charging costs in the times of the energy price crisis”, Bergen, Norway, Working Paper, FOR 13/2024, Dec. 2024. Available: https://openaccess.nhh.no/nhh-xmlui/handle/11250/3170501

[16] Entsoe. "Transparency Platform". https://newtransparency .entsoe.eu/

[17] J. Stute and M. Kühnbach, “Dynamic pricing and the flexible consumer – Investigating grid and financial implications: A case study for Germany,” Energy Strategy Reviews, vol. 45. Elsevier BV, p. 100987, Jan. 2023. doi: 10.1016/j.esr.2022.100987.