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An overview on charging tariff schemes and incentives: the eCharge4Drivers project

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Abstract

This paper provides an overview of the charging tariffs and e-mobility schemes adopted in different EU cities based on a survey conducted within the EU project eCharge4Drivers. The outcomes of the survey are presented and analysed in order to extract a generalised tariffication formula which allows any eMobility Service Providers (eMSPs) or Charging Point Operators (CPOs) to explore different options to overcome the issues that might affect their CP management strategy. In conclusion, guidelines on how this formula can be adjusted to serve a variety of daily operational and planning needs of eMSPs and CPOs are provided.

Keywords: electric vehicles, charging tariffs, incentives, tariffication

1. Introduction

There is the need for substantial changes in the transport system of a city in order to achieve the transition to more sustainable and green urban mobility towards reducing city road congestions, direct emissions, noise pollution as well as improving accessibility (U.S. Access Board, 2023). Tariff structures define and model the behavior of charging station users as well as define the main source of income for eMSP's. Even though in some areas tariff structures are simple due to premature development of EV sector or due to a specific willingness of keeping it simple to users, these can have a large impact in the habits of users and influence the way in which these behave. For this reason, tariff structures play a crucial role in the charging ecosystem. In this direction, the design and establishment of new charging tariffication and incentives schemes for charging in a public charging network should be carefully considered either

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for the promotion of the e-mobility concept in cities with premature level of EV deployment or to ensure the sustainability of the investment in new infrastructures which will serve the increasing charging needs.

To encourage EV adoption, countries have used different kind of incentives from both technology specific policies, such as subsidies to EV consumers, and technology neutral policies, such as emissions-based vehicle taxes (Roca, 2021). Such incentives are designed and implemented at different governance levels, from EU legislation that provides a framework promoting low-emission vehicles, through national measures such as introducing lower taxes for electric vehicles, to local incentives such as free inner-city parking and use of road lanes normally reserved for public transport. Basically, the incentives cover the processes related to the purchase of electric vehicles and the processes of the use of electric vehicles/charging sessions.

There are different pricing models (Bairrão et al., 2022; European Alternative Fuels Observatory, 2023; Hildermeier et al., 2023; Majcher, 2021) which can be adopted by CPOs in order to define prices that best fit their business plan for promoting or incentivising the usability of their charging network:

- Standard pricing is the simplest pricing model including one price for all stations in a time-based (per hour or per minute) or energy-based (per kWh) scheme.
- Product pricing allows CPOs to create multiple different pricing products for their charging network, e.g. different prices in different areas, or for different sub-CPOs or per charging technology, etc.
- Flexible pricing allows CPOs to set up different price models, eg. time-based prices (dual or time-of-use tariffs), charging facility-based prices (AC or DC), EVSE based pricing different prices per location for on-street or off-street chargers or different prices per region, etc.
- Dynamic prices allow CPO to define a pricing scheme that varies in a hourly/daily basis

This paper analyses the outcomes of an extended survey, conducted within the framework of the EU project eCharge4Drivers, on charging tariff schemes and e-mobility incentives implemented in the different EU countries (Spain, Greece, France, Belgium, Italy, Luxembourg, Austria) and Turkey. The survey outcomes are analysed and a generic pricing formula which can be adopted by any CPO/eMSP is extracted.

2. Survey on e-mobility incentives and tariffs

The survey on the pricing policies and incentives being adopted in different cities and countries was conducted in two stages (Roca, 2021). Initially, a benchmark analysis conducted to identify the variety of incentive mechanisms for the purchase and the usage of EVs and/or the installation of charging stations implemented in different countries and regions. The incentives depend on national regulations, degree of maturity of the market, cultural values, etc., thus, different practices are adopted at regional level to best serve the charging expectations of local society. Afterwards, a survey was conducted as regards the tariff structures used by the local MSP's and CPO's in the project pilot areas. The scope of this survey was to better understand the motivation of the parameters used to define the pricing schemes and how the CAPEX and OPEX of the charging network is reflected in these pricing profiles.

For the scope of the survey, dedicated questionnaires (Roca, 2021) have been developed and bilateral meeting have been scheduled with CPOs and eMSPs in order to understand and analyse in depth their pricing strategy. The ultimate goal of this analysis is to conclude to a generic formula that any eMSP or CPO is able to define a tariff structure according to their users behaviour, constraints and revenue expectations.

2.1. Incentives for EVs

There are different types of financial incentives for purchasing an electric vehicle which are applied in EU countries (Table 1), and these have strong effect on customer's decision for not purchasing a conventional internal combustion vehicle (Roca, 2021). Indicative examples of such financial incentives are presented in the following paragraphs:

- EV Purchase Subsidies is applied in most EU countries to attract the attention of users willing to change their driving habits and shift to a more environmentally friendly vehicle. Different kind of purchase subsidies are determined for different EV categories (light vehicles, passenger vehicles, heavy duty vehicles, etc.), for different EV technologies (pure electric, plug-in electric vehicles, plug-in hybrid electric vehicles, etc) and for their environmental footprint (CO2 emission value). In most European countries, these incentives are provided not only for purchasing a new EV but also for leasing purposes. Moreover, some countries are providing extra financial support if EV purchase is combined with scrapping an old diesel or gasoline vehicle.

- Registration Tax Benefits are offered to promote EV adoption around Europe. This category of incentives is available in some EU countries and it may vary from zero value up to a rate that is below the baseline value for conventional vehicles. Such incentives are usually directly related with the CO2 emission value of the vehicle and if it is under the determined baseline value of CO2 emission level, it can be granted from tax obligations for a few years after registration.
- Ownership Tax Benefits: Similar with registration taxes, most of the European Countries provide ownership tax benefits for EVs. In most of the cases, electric vehicles are exempt from the annual ownership tax for a predefined period of years from their first registration.
- Company Tax Benefits: Companies pay reduced tax on EVs and according to CO2 emission level. Furthermore, special tax benefits are applied in case of leasing EVs as well.
- VAT Benefits: There is not a widespread incentive mechanism in Europe. Only in a few countries, company BEV's are exempt from VAT (eligible for pre-tax deduction).

Tax reductions have a strong impact on the EV adoption, along with the purchase subsides, since they decrease the overall operating cost during the operating stage. Apart from the abovementioned incentives which are provided for (plug-in hybrid) electric vehicles, there are also other regional incentives which are applied such as free parking, parking discounts and bus lane use, etc. For example, in Spain, incentives such as toll exemption on regional highways, free parking in selected cities and traffic lanes reserved for high occupancy circulation are available for electric vehicles.

Table 1. Incentive schemes of different European countries (Roca, 2021)

Country	Purchase subsidies	Registration tax benefits	Ownership tax benefits	Company tax benefits	VAT benefits
Austria	x	x	x	x	x
Belgium	x	x	x	x	
France	x	x	x	x	
Germany	x		x	x	
Greece	x	x	x	x	
Italy			x		
Luxembourg	x	x	x	x	
Spain	x	x	x	x	

2.2. Incentives for EV charging infrastructure

Apart from the (non-) financial incentives applied for purchasing an electric vehicle, there are also incentives for the charging infrastructures. It is not realistic to expect the acceptance of electric vehicles by the users without an adequate charging network and this is the reason why incentives are required for developing a critical mass of publicly available charging infrastructures. In this respect, incentives for charging infrastructures are of critical importance for both companies/end users and for promoting the e-mobility concept.

There are different incentive and support mechanisms for charging station infrastructures in various European countries (Roca, 2021). These support mechanisms are similar for public and private charging stations in some cases. Also, different incentive mechanisms are available depending on whether the charging station is managed by public, private, local authorities, or municipalities and whether the charging station is controllable or not. Also type (AC or DC) and output power of charger are important criteria to define incentive scheme.

Mainly, incentives for EV charging can be categorized as residential charging incentives and commercial charging incentives. Residential charging incentives are mainly related with private residents who are willing to install charging stations at their homes for private use. Commercial charging incentives apply to companies and public entities wishing to offer EV charging as a dedicated service (e.g., a municipality), additional service (e.g., supermarket car parks), or as a perk for employees (e.g., workplace charging). Generally, for the commercial charging, different levels of subsidies are available for the purchase and installation of public DC and AC charging infrastructures. The level of subsidies increases if the installed charging technology is DC and as the nominal charging power increases as well. Moreover, tax exemptions are also put in practice in some European countries. For example, a tax reduction per kWh applies to companies that provide electric vehicle charging on a commercial basis in Denmark.

2.3. Tariffication

In this section, the tariff structures and prices of the charging infrastructure are discussed. There are different parameters which can be utilised to structure a tariff scheme and they are tabularised in table 2, eg. Subscription fee, fixed price for charging technologies, average charging power, initial fee, location of CP, type of vehicle, time of the day, time or price-based prices, energy or time threshold above which additional charges are applied, parking time, etc. These parameters are exploited by the Charging Point Operators in different way and combinations in order to serve their business goals in the most efficient and sustainable way, e.g. boosting the usability of a charging network in an area by offering special discounts, penalising overparking time, etc.

There are different subscription fees in different EU countries. In Barcelona, the subscription fee for both on-street and off-street charging infrastructures varies between 25-45€/year for LEVs and 50-100 for passenger and medium heavy-duty vehicles. In Grenoble, the subscription fee varies between 12-30€/year. In Luxembourg, it varies between 27-169€/year or 7.99€/month. In Bari, the subscription fee is 25€/month. The tariff of the service is also high related to the type of charger and in some cases the charging price is fixed and depends on the charging technology (AC/DC). The price of charging in an AC (slow) charging infrastructure is lower than the one in a DC charger. In other case, there is a distinction between daytime and night-time charging (Barcelona, Grenoble). This is usually applied to better reflect the market energy prices and disincentivise the use of (high-power) charging infrastructures during high consumption periods to avoid high load peaks in the electricity grid which will request, consequently, costly grid reinforcements to mitigate them. In Greece, an initial fee is applied when a charging session starts which varies between 1-7€/session depending on the charging technology and the charging location (parking, hotel, marina, etc.).

Table 2. Parameters for structuring an EV charging tariff scheme (Roca, 2021).

Tariff depends on…	**Barcelona**	**Grenoble**	**Berlin**	**Luxembourg**	**Belgium**	**Bari**	**Greece**	**Turkey**
Subscription	x	x		x	x	x		
Type of charger		x	x	x	x	x	x	x
Average power								x
Initial fee							x	
Location of the CP	x						x	
Type of vehicle	x							
Time of the day	x	x						
Cost (€/kWh or €/min)	x	x	x	x	x	x	x	x
Minimum charge	x							
Energy threshold						x		
Time threshold		x						
Connection fee (when EV is fully charged)					x			
Discounts	x							x

3. Generalised tariff structure

3.1. Formula

This session defines a generalised formula on the top of which any tariff structure can be formulated by CPOs or eMSPs to optimally serve their business objectives (Roca, 2021). For the definition of the generalised formula, all the aforementioned parameters defined in the previous section were considered.

Any charging session can occur under a subscription contract or without it, thus, the first component of the generalized formula is the subscription. It can depend on the type of vehicle (motorbikes, vehicles, freight vehicles, etc), the type of user (taxi drivers, freight drivers, regular users, etc.) and modality i.e. flat rate or a tariff that depends on the use. Subscriptions are usually set on an annual basis but any time period can be considered instead, and also can include a registration fee. So, the subscription cost can be expressed as follows:

$$C^{C}{}_{i} = A_i Y + b_i \tag{1}$$

where *C* is the contract cost, *A* is the cost of the subscription (annual, monthly, etc.), *Y* is the payment interval (years, months, etc) and *b* is the registration fee. Therefore, for a certain contract *i* that depends on the type of vehicle, type of user and the modality, there will be different costs and registration fees. For the case in which the subscription includes a flat rate modality, this includes a certain amount of energy or time to charge regardless of the final use. If the charging time or energy is above the upper boundary defined by the subscription, an additional tariff may be charged. This can be expressed as follows:

$$S = T_{s,i} \cdot \max\left(0, kwh - kwh_{plan}\right) \tag{2}$$

or

$$S = T_{s,i} \cdot \max\,(0, t - t_{plan}) \tag{2}$$

where the additional cost $T_{s,i}$ is only charged if the amount of energy used (kWh)is higher that the planned (kWh_{plan}) in the subscription. This formula can also be expressed in at time basis as shown on the second form of the *S*.

In the case no flat rate applies, the tariff depends on each charging session j, considering the technology of the charging infrastructure (AC/DC), its location (on-street, off-street in car parks, etc), and charging starting time- this is important if different rates apply according to the time of the day. Each of these parameters set different values that should be used to calculate the final tariff. The variables that are used to calculate the tariff are: the duration of the charging session (d_s), the amount of energy charged (e_s), and the parking time at the charging point ($d_e \geq d_s$).

Therefore, for each contract i and each charging session j any tariff can be expressed as:

$$C_{i,j}{}^{s} = C^{cs}_{i,j} + T^{f}_{i,j} + \underbrace{m_{i,j} \cdot \max[(d_s - f_d)\,,0] +}_{\boxed{\text{Cost per time (Duration of session)}}} \underbrace{n_{i,j} \cdot \max\,[(e_s - f_e)\,,0]}_{\boxed{\text{Cost per energy (Energy charged)}}} \underbrace{+\, p_{i,j} \cdot \max\,[(d_e - f_p),0]}_{\boxed{\text{Cost of parking (Time parked)}}} + T^{excess}_{i,j}(t,e) \tag{3}$$

$C^{cs}_{i,j}$ is a booking fee that may be charged when booking. In most areas this value is zero but a booking fee could be charged to give more value to this option. By imposing a small fee on this concept, booking option might be user more properly by the users.

$T^{f}_{i,j}$ is the minimum charging that some eMSP apply to their clients. The minimum charge can be applied using a time or energy variable. This parameter is applied to increase the efficiency of use of the CP's.

$m_{i,j} \cdot \max[(d_s - f_d), 0]$ where m is the value that determines the cost of the charging session that depends on the time duration (price units/time). In most cases that a charging session is charged based on the time variable, the time metric applied is per minute (€/min). This value m is then multiplied by a mathematical expression that considers the additional duration of the charging session with respect to the minimum stay (f_d). This component of the pricing formula is applied by some eMSP's to ensure the efficient use of the charging stations. The minimum cost $T_{i,j}^{f}$ is applied regardless of the charging session duration.

$n_{i,j} \cdot \max[(e_s - f_e), 0]$ where n is the value that determines the cost of the charging session cost/energy) based on the amount of energy consumed e_s. The energy cost is considered only if the energy consumed is higher than an energy threshold (f_e) defined by eMSPs.

Finally, there could be an additional charge related to the parking duration (d_e) when this exceeds a specific parking duration (f_p).

Some eMSP's may as well charge if the duration of the session or the energy charged exceeds of certain values ($T_{i,j}^{excess}(t,e)$). In this case, there would be an additional expression that would consider a different cost (time or energy) that would be charged.

Finally, in some cases, an eMSP charges its clients using an energy metric at the beginning of the charge until a certain amount of energy is reached (or a percentage of the battery's State-of-Charge is reached, eg. 80%). After that, the client is charged additionally ($T_{i,j}^{excess}(t,e)$) in time- or energy- based framework.

3.2. Best practices

The proposed formula can be adjusted accordingly to mitigate the different operational issues that CPOs/eMSPs might be challenged. In the next paragraphs, different use cases are considered and how the proposed generalised formula can be adapted is discussed.

- Low use of the charging points: Some areas present low usability of the charging network. This situation can be caused by several factors including not only the EV penetration level but also the accessibility of the location, the type of charger, the tariff, etc.

  Solution:
  - Subscription: A_i possible reduction of prices or temporary promotions, increase of the kWh_{plan} or time t_{plan} given to charge for the same price
  - Tariff: $T_{i,j}^{f}$ If initial tariff is too large, this could be reduced (if this is the cause of low use). PHEV could start charging if the initial fee is reduced, $m_{i,j}$ reduce temporarily the fee, $n_{i,j}$ r educe temporarily the fee, $p_{i,j}$ not charging the parking space or providing some free of charge minutes.

- High rate of parked vehicles without charging: This is one of the major concerns of eMSP's, i.e. vehicles occupying a parking lot after the charging session has finished prevent other ones for charging reducing, thus, the number of charging sessions, reducing the income for the eMSPs.

  Solution:
  - Tariff: $m_{i,j}$ Increase the cost (if time tariff applies) after a certain amount of time (according to the charging station type), $n_{i,j}$ increase the cost (if energy tariff applies) after a certain amount of time (according to the charging station type), $p_{i,j}$ Increase the cost of parking spaces after a certain amount of time, $T_{i,j}^{excess}(t,e)$ after a certain amount of time, increase the charging costs (energy, time)
- High rate of "*no-show*" of booked charging sessions. In areas where booking option exists, having a high-rate of "*no-shows*" could reduce the efficiency of the system.

  Solution:
  - Tariff: $C_{i,j}^{cs}$ Place a cost for booking which only will be charged if user does not start the session. This would reduce the number of users making bookings for which they are unsure if they can follow.

- Very high use of charging points (low availability). Some areas, with a reduced number of CP's or with very high number of EV's can face situations in which CP's have very high demand. In such cases, the easy solution is to increase the number of CP's, but actions can be taken to increase even further the efficiency of a CP. It is not always possible to increase CP's in the most demanded locations. Some solutions might come from allocating the charging sessions along the entire day and night-time.

  Solution:
  - Tariff: $m_{i,j}$ Set a reduced cost at night time to help distribute the charging events, $n_{i,j}$ Set a reduced cost at night time to help distribute the charging events, $p_{i,j}$ Reduce or eliminate parking costs at low-use times
- High use of PHEV of the charging points. In the case in which a charging network allows PHEV but prefers a low usage of these type of vehicles to keep the availability to BEV users some measures could be considered.

  Solution:
  - Tariff: $C_{i,j}^{cs}$ Increase the booking cost for PHEV, $T_{i,j}^{f}$ Increase the minimum charge to a threshold in which small PHEV batteries pay above the energy charged.
- Long use of slow chargers at car parks (longer than required). Slow charging requires an amount of hours that can range from 4 to 8, but could be even higher for bigger batteries. In such cases, users leave vehicles for long time at car parks (or on-street if such a charger is located in a public space). Since long times are required, user can be tempted to leave their vehicles longer than required since these types of charges usually happen overnight. To reduce this situation, some actions can be taken.

  Solution:
  - Tariff: $p_{i,j}$ Apply a fee for the parking space after a reasonable amount of time, $T_{i,j}^{excess}(t,e)$ Increase the charging costs after a time period to disincentivise overparking.

4. Conclusions

Based on the benchmark analysis of the e-mobility incentives, making incentives available at the time of purchase, appear to be an effective solution to increase EV market share. The current financial incentives should not be removed in the short-term to keep encouraging potential buyers. Another crucial incentive for buyers is the availability of charging infrastructure. Governments should expand the scale of charging points to increase density as a key measure to incentivise EV's. As regards tariffication, all possible tariff structures have been defined through a generalized formula which will be further detailed in the full paper. This formula and the recommendations made, allows any eMSPs or CPOs to explore different options to overcome the issues that might be affecting their current CP management strategy.

The following remarks can be concluded:

- Making incentives available at the time of purchase or shifting the incentives to vehicle purchasing tax exemptions or reductions of similar value, appear to be effective solutions.
- Existing financial incentives should not be removed in the short-term.
- The deployment of charging infrastructure is a prerequisite for mass market adoption. The governments should promote and incentivise the development of public charging infrastructures since it is a key measure to popularize EVs and limit driving range anxiety. The "chicken & egg" problem is the most common issue between automotive industry and charging point suppliers as regards the market priority (EV critical mass or charging network adequacy). Also, non-financial incentive measures can promote the adoption of EVs by raising consumers' awareness of EVs.
- Incentives should not be complex. All the incentives should be understandable and customer friendly. Simpler incentive programs, which are publicly posted on government websites and distributed to all stakeholders and customers, would help alleviate this issue. It may be important to encourage users that the incentives applied remain active for at least a few years instead of temporary processes.

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