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Multi-actor Business Model Analysis of Uncoordinated Electric Vehicle Charging Compared to Local Load Management

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Abstract

Electric vehicles have the potential to tackle energy and climate change challenges. Different studies and papers have already identified to which extent the electrification of drivetrains can contribute to an abatement of pollutant emissions in the urban environment. Despite the fact that the transportation electrification offers these progressive opportunities, the expected increasing market share of electric vehicles entails some challenges. As the amount of electric vehicles in the market rises to substantial amounts, an additional burden on the distribution grid can be expected when these vehicles are connected to the grid and charged under an uncoordinated, fit-and-forget, strategy, resulting in voltage issues and power congestion. The intelligent coordination of the charging process of electric vehicles can provide an answer to the issue of local grid constraints. By the coordination of the charging process, the impact on the distribution grid can be mitigated by making more efficient use of the available capacity while satisfying the individual user requirements. The implementation of intelligent coordination of electric vehicle charging involves adjustments to the current market design since there are additional market transactions required for communication and remuneration for the influencing of the charging profile. Within this context, the EVCITY project analyses the market designs of both the uncoordinated charging, and the local load management charging strategy. with e3-value, a multi-actor business model methodology.

Keywords: business model, load management, dynamic charging

1 Introduction

Global concerns on the exhaustion of fossil fuels and pollutant emissions have increased the interest in sustainable transportation as electrified transport systems seem to be one of the big candidates to strive towards the ambitious EU energy and climate change goals [1]. However, in order to receive the full benefits of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), some challenges have to be overcome. In literature it is frequently proven that as the market share of electric vehicles (EVs) is increasing to substantial amounts, a significant impact on the power system can be expected [2], [3]. Especially on the distribution level, the additional electricity demand of the EVs can affect the electricity grid in a negative manner, resulting in both voltage issues and power congestion. These issues are detrimental to the reliability and safety of the distribution grid and induce the grid to be operated non-compliant to the EN50160 standard [4]. The overall negative grid impact of EVs can be relieved by implementing coordination of the charging of EVs according to the grid capabilities. Within this context, the additional energy demand for EV charging can even be turned into an opportunity for the grid, e.g. by offering ancillary services [5], [6] or by balancing the generation of intermittent renewables. The coordinating and influencing the charging profile of EVs must however always be performed in accordance with the requirements of the individual vehicle owner.

The EVCITY project, a KIC InnoEnergy funded project, aims at providing a guideline for cities and all stakeholders involved in the roll-out of EVs and supporting infrastructure. As the current value chain is expected to change significantly due to the introduction of new functionalities and business opportunities with regard to load coordination of EVs, the EVCITY guideline strives to offer a proposition on how to organise a multi-actor business model.

Business models relating to EV services are featured by a multi-actor participation since the involved stakeholders originate from both the electricity supply chain as the e-mobility market [7]. When many stakeholders, with their individual role and responsibility, are involved, business models can become rather complex. A business model methodology designed to cope with this complexity and multiplicity of actors and market transactions is e3-value [8]. This methodology enables the graphical representation of business models and identification of economic exchanges. The goal is to provide an overview of the different stakeholders that take part in the concept of an electric mobility ecosystem and give an indication on how they interrelate with each other.

Within this paper the e3-value methodology is applied to two charging strategies, being an uncoordinated charging strategy, fit-and-forget charging, and a local load management strategy. In the latter scenario the DSO is appointed a proactive role where he seeks and remunerates flexibility for the purpose of the management of local grid constraints.

Within this paper the multi-actor approach within the EVCITY project is described in Section II. This section gives an overview of the EVCITY approach towards EV charging services, an introduction to the used business modelling methodology and the selected business scenarios. Section III defines the elaboration of the selected scenarios, uncoordinated and coordinated charging strategies. Finally, some conclusions are drafted.

2 Multi-actor approach EVCITY

The topic of business cases seems to be taking on a central role in the context of electric mobility. This is even more applicable when new value-adding services are introduced to the EV charging market, causing a cost reduction for the customer and improving the customer acceptance by generating benefits. The tendency towards new EV charging concepts induces the current energy market to change rapidly. It is essential to explore the occurring and expected market shifts more in detail.

2.1 Introduction to EVCITY

To reduce the environmental and health impact of individual transport in urban areas, an integrated approach is needed for a conversion to a sustainable electrified transport system, based on local renewable energy sources (RES). This transition must be associated with a user-friendly, grid-efficient and cost-effective integration of EVs. In order to assist cities and urban areas to reach these objectives, the EVCITY project is developing a manual with recommendations and guidelines on how to approach the roll-out of EVs and related charging infrastructure. The state-of-the-art on new mobility concepts and service models, to further support the introduction of EVs, are studied [9]. From the funnel of innovative ideas on value-adding products and services with regard to EV charging, the coordinated charging service provision is elected the key focus point of the project for which the detailed business model analysis is performed.

2.2 e3-value methodology

In order to be able to compare the reference market design, where vehicles are charged according to an uncoordinated fit-and-forget strategy, with a more elaborate market design, enabling intelligent charging coordination, a distinctive methodology must be used. The business modelling tool which allows for a comparative analysis of market structures to be drafted is e3-value. This is due to the fact that the methodology uses a distinct terminology (e.g. actors, market segments, value objects and value exchanges) and standard modelling concepts for describing which

stakeholders exchange objects of economic value with whom.
e3-value is a conceptual modelling approach, especially designed to represent complex, networked business models in a graphical, comprehensive manner.
Via this business model methodology it is possible to represent all economic value exchanges between the different stakeholders involved. Additionally, the market modelling methodology is based on the reciprocity principle, meaning that for each transaction between stakeholders there must be a reverse value exchange, assuming rational acting stakeholders.

2.3 Business scenarios and involved actors

The selection of the business scenarios within the EVCITY project was performed, given the context of an expected distribution grid impact of EVs at large degrees of market penetration and the related elaboration of new EV charging concepts and services.
Different possible charging strategies were identified which offer the opportunity to relieve the expected grid impact, e.g. voltage droop control and peak shaving [10]. Within this paper these intelligent charging strategies are bundled and referred to as coordinated charging strategies. In order to detect the additional market transactions or shifts in existing stakeholder relations, the market model for the coordinated charging strategies is compared with the uncoordinated charging scenario. The uncoordinated charging scenario, which entails vehicles to be charged immediately when connected to the grid, is considered the reference scenario.
For the elaboration and description of the business models the actors involved must be recognised. Different scientific studies and position papers focus on the identification and description of the roles of possible market players [11], [12]. Within the EVCITY project the "ISO/IEC 15118-1 – vehicle to grid communication interface" is used as starting base [13]. The interpretation of each stakeholder, involved in the deployment of EV charging, is depicted in Table 1. In addition, also stakeholders from the electricity supply chain, e.g. Distribution System Operator (DSO), Transmission System Operator (TSO) and electricity retailer, are involved in the e-mobility ecosystem.

Table 1: involved actors and their roles

Involved actor	Definition
Electric Vehicle Supply Equipment (EVSE) Operator	The EVSE Operator is responsible for the operation of the charging equipment starting from the point of common coupling with the DSO.
Electric Vehicle Service Provider (EVSP)	An EVSP provides charging services to EV users by gathering services from multiple providers. Typically the EVSP will include some of the other actors, e.g. EVSE Operator and electricity retailer.
EV Owner/User	The EV User is the person or legal entity using the EV. In most cases this will be the same actor as the EV Owner, the administrator of the vehicle.
Clearing House	The Clearing house is considered to be the entity mediating between clearing partners, e.g. EVSE Operator and EVSP. The clearing is performed to provide validation services for roaming regarding contracts of different electricity retailers.
Market Place Operator	The Market Place Operator is the actor responsible for the access and operation of the marketplace, a (software) environment where providers of value-adding services, with regard to EV charging, can present their services.

3 Multi-actor business models

For the elaboration of the multi-actor business models for both the uncoordinated and coordinated charging scenarios, a complete unbundling of the previous identified roles is assumed, meaning that each of the roles is considered independent. However, it can be noted that in real market settings, some roles will be combined or bundled for i.a. cost efficiency, benefit optimization or market simplification reasons. In Table 1 the example of combining the roles of an EVSP and an electricity retailer or EVSE Operator was already mentioned.

Furthermore the presented business models can introduce market roles which are, in the current market phase of EVs, not mandatory. Though, as the market share of EVs is rising these roles become a prerequisite for a good market operation. When, for example, the number of EVSPs and EVSE operators in the e-mobility market increases as a result of an upsurge of the amount of EVs, the costs of managing the contracts between these players becomes a key issue. The role of a Clearing House gives an efficient answer to this issue by acting as the sole clearing counterparty.

3.1 Uncoordinated charging scenario

If the uncoordinated charging scenario is considered, only the core transactions necessary for fit-and-forget EV charging must be displayed in the e3-value model. The relevant market model is depicted in Figure 1. Within this scenario only market transactions occur which relate to the provision of standard charging services, however, the total market design is already rather complex and multifaceted. For a better understanding of the displayed market relations, an explanation of the used color code is presented in Table 2. Within this table, all fundamental market transactions, necessary for EV charging, are bundled into a number of core categories.

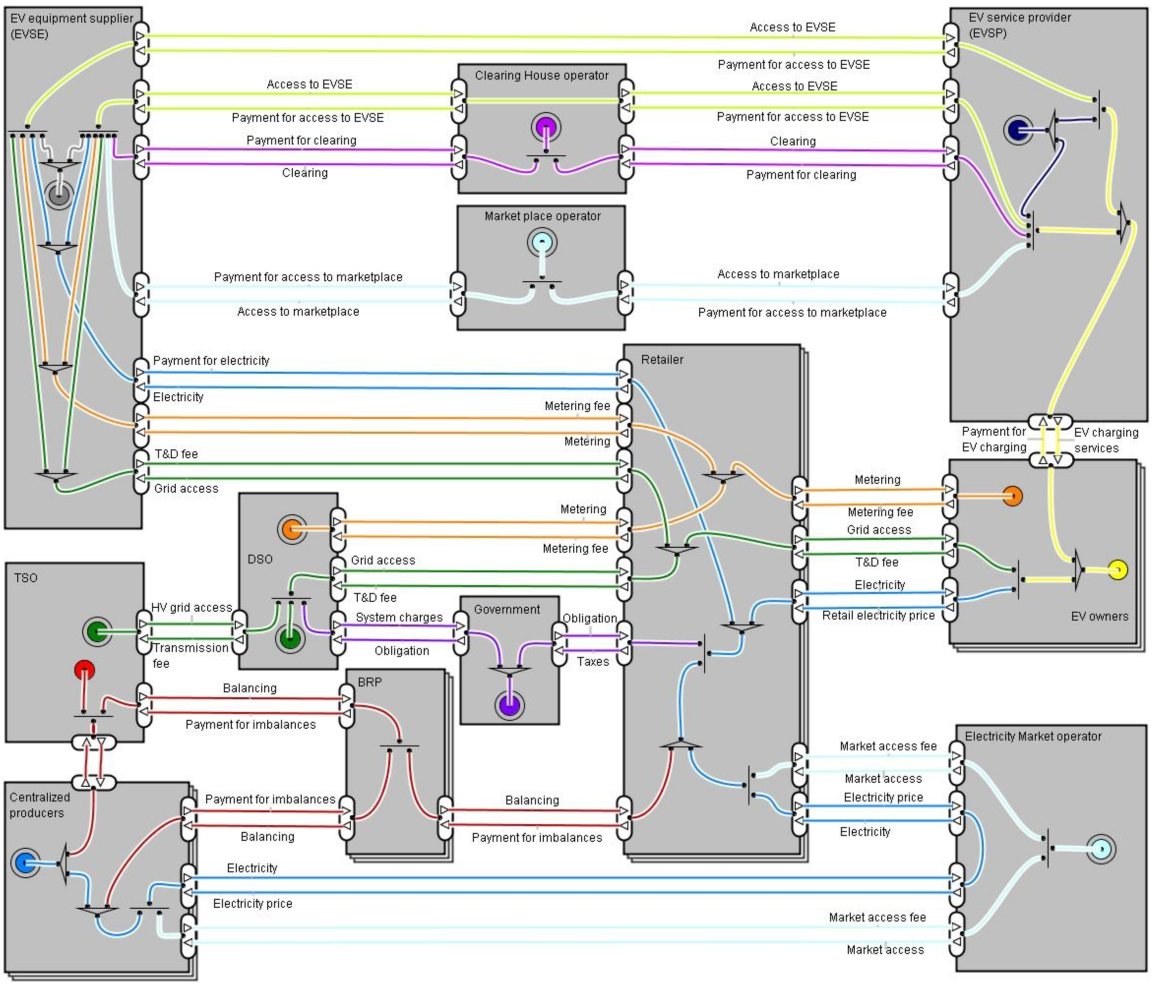

Figure 1 e3-value model for the uncoordinated charging scenario

Table 2: Color legend for the e3-value model

(yellow)	Charging request of EV owner
(blue)	Electricity transactions
(green)	Grid access
(orange)	Metering
(red)	Balancing
(light cyan)	Market access
(magenta)	Clearing
(yellow-green)	Access to EVSE
(violet)	Government charges
(dark blue)	Communication and management by EVSP
(grey)	Communication and management by EVSE operator

The intention to charge the EV starts with a request for charging services from the EV owner. The need for charging services is in the model thus displayed as a start stimulus, indicated in yellow. When looking for actors to satisfy this need, the EV owner has different options to choose from. The preference for a specific option is influenced by the location of charging.

If the EV is to be charged at home, the EV owner can opt to enter into an additional contract agreement with his standard electricity supplier. In this case the vehicle can be charged either via the standard domestic socket, IEC61851 Mode 2 charging, or via dedicated IEC61851 Mode 3 charging equipment, which can be offered by the standard electricity supplier or an independent provider.

Additionally, the EVSP can provide charging services at the home location of the EV owner. In order for the EVSP to be able to satisfy the charging request from the EV owner, dedicated charging equipment must be installed, enabling the separate metering of the electricity used for charging. This must be ensured for billing reasons. Furthermore, the installed charging infrastructure at home must be provided with an individual European Article Numbering (EAN). Currently only one electricity provider can be assigned to a single EAN-connection point. The requirement for a separate EAN numbering thus stems from the fact that the standard electricity supplier for the domestic electricity demand is not necessarily the same as the electricity provider for EV charging.

For charging at other premises, public and semi-public charging, The EVSE Operator, as administrator of the charging station, which could be one or multiple charging bases, is responsible for the purchase of electricity. The provision of the charging service will most likely be performed by the EVSP. The transaction costs for allowing the standard electricity supplier to provide electricity, for the purpose of EV charging, at these locations can become significant as each charging session of each EV owner the relevant electricity supplier must be identified.

In order to be able to satisfy the charging request from the EV owner, the EVSP needs to ensure some transactions, e.g. contractual agreement with the EVSE operator, access to the Clearing House if a bilateral contract does not comply, own management and communication capabilities and access to the marketplace.

The EVSE operator is considered the administrator and owner of the charging infrastructure, excluding the case where the EV owner uses charging equipment from his standard electricity supplier. The EVSE Operator is thus assumed to be the responsible party for the EAN-connection and is responsible to enter into a contract with an electricity supplier.

Different clearing partners (i.e. EVSE Operator and EVSP) request access to the platform of the Clearing House Operator in order to receive validated data and other information for specific purposes (e.g. billing). The Clearing House enables a more efficient and accessible market design as transaction costs for contract handling are significantly reduced and the service delivery and payment are ensured. The membership of the Clearing House is subjected to a fee.

As market models for EV charging services require the involvement of actors active in the current electricity supply chain, also these stakeholders are displayed as participants in the business model.

In brief, the electricity is generated by centralized producers and sold on the electricity wholesale market to different market players. Decentralized producers and prosumers can also be considered for the provision of electricity, however these options are omitted from the e3-value model.

Electricity producers have the obligation to assign a Balancing Responsible Party (BRP), who is considered to be responsible for maintaining the balance of his general portfolio. Likewise, the electricity retailer has to appoint a BRP for the electricity obtained for the electricity markets and sold to the customer, being the EV owner or the EVSE Operator. If the BRP is unable to maintain the balance within his specific portfolio of electricity generation and consumption, he is required to pay imbalance fees to the TSO, the actor responsible to preserve the balance of the control area.
In the uncoordinated charging scenario, the DSO and TSO are just considered the power system stakeholders responsible for the delivery and transportation of the requested electricity.

3.2 Coordinated charging scenario

Within the coordinated charging scenario the DSO desires to solve local grid constraints by influencing the charging process of the EVs. It is assumed that the DSO is willing to pay for these EV charging services.
The new market design and transactions which occur between the different stakeholders within the coordinated charging scenario are presented on the graphical model displayed in Fig. 2.
Besides the basic EV charging transactions mentioned in the uncoordinated charging model, depicted in Fig. 1, the e3-value model for coordinated charging also contains transactions for the management of constraints. The relevant interactions are displayed in black and are categorized ‘load management transactions’, see Table 3.
Despite the fact that the DSO is the actor requesting the intelligent coordination of the charging process, the remuneration for the charge control is received by the EV owner through a different actor. Depending on the actor providing the charging services the stakeholder compensating for the charge control can be the EVSP or the standard electricity supplier.

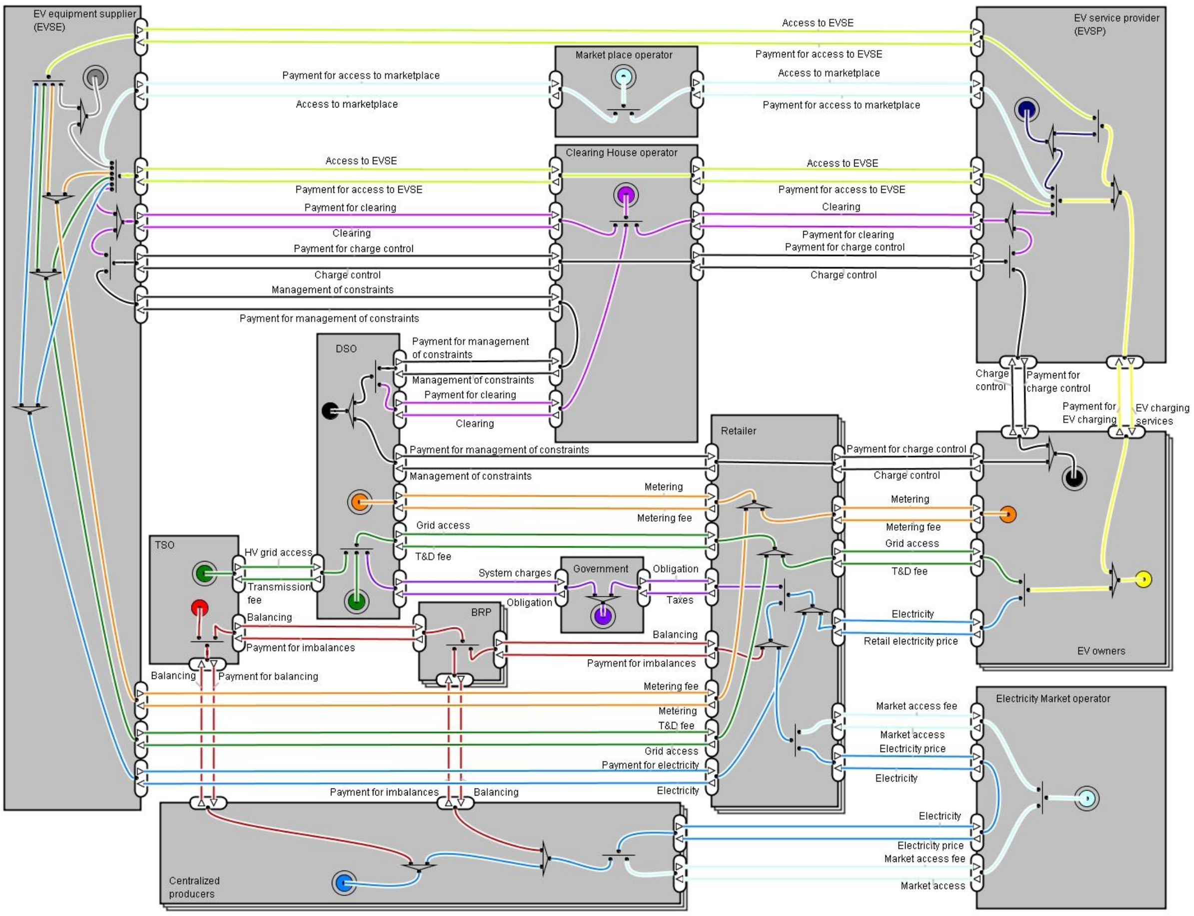

Figure 2 e3-value model for the coordinated charging scenario

Table 3: Color legend for additional transactions for coordinated charging

⬤	Load management

The implementation of a remuneration structure when the EV user uses his home connection to charge at home via a standard electricity socket or dedicated charging equipment is relatively straightforward as the number of stakeholders involved is limited. In this case the EV user is compensated by his standard electricity supplier, since this actor is considered the Single Point Of Contact (SPOC). The electricity supplier in return retrieves the compensation from the DSO, the party eventually benefitting from the charge control. There are different options plausible when working out a remuneration strategy, however, a discount is expected the least complex to implement.
If the EV user relies upon an EVSP for the provision of charging services, the essential transactions for remuneration are more complex. For EV users to be remunerated by the DSO for the coordination of the charging process, the DSO has to search for the EVSE operators connected to the low-voltage distribution grid in consideration. This information can only be provided through a Clearing House. After the relevant EVSE operators are identified, these EVSE operators have to check, again via the independent Clearing House, which EVSPs have clients connected to their charging infrastructure whose nominal charging rate was modified. In the end, the EV user is remunerated for the EV charging coordination through the EVSP. The compensation is received, through the Clearing House, from the EVSE operator. The EVSE Operator in turn receives a compensation from the DSO, through the same clearing entity.
The e3-value model which represents the possibility of coordinated EV charging, stresses the importance of the implementation of a Clearing House. The Clearing House in this case not only increases the accessibility between both the EVSE Operator and the EVSP but is also required in order to facilitate an efficient provision of various EV charging services, including charge control, by different actors.
Furthermore, the market architecture with regard to coordinated EV charging services is complex, however it can be simplified by incorporating different roles in a single player (e.g. EVSE operator and EVSP).

Conclusions

The EVCITY project aims at facilitating the efficient integration of EVs in the current market design while respecting the different constraints, being i.a. the limited distribution grid capacity, the questionable user acceptance and cost-efficiency of EVs.
Within this context, value adding services and products are defined of which the coordinated EV charging is considered to be of primary importance.
By using the e3 value business modelling methodology, the market adjustments to the current market design triggered by the management of the charging profile can be analysed and described.
The comparative analysis mainly indicated the importance of the implementation of a Clearing House as the entity mediating between different clearing partners, since this actor can increase an efficient market operation and avoid escalating transaction cost.

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