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ScienceDirect
Energy Reports 8 (2022) 449–455
www.elsevier.com/locate/egyr

7th International Conference on Advances on Clean Energy Research, ICACER 2022 April 20–22, 2022, Barcelona, Spain

Profitability of V2X under uncertainty: Relevant influencing factors and implications for future business models

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Received 10 October 2022; accepted 14 October 2022
Available online 28 October 2022

Abstract

Intelligent, bidirectional charging strategies (vehicle-to-X, V2X) are a crucial part of the decarbonization of the transport sector. To facilitate the successful rollout of business models associated with V2X, we identify revenue potentials for different use cases, additional costs, and resulting profits for future years. Our assessments result in ranges of profits for different V2X types with the spread of profits providing a measure of uncertainty. The profit analysis shows that some V2X types can most certainly become profitable in the near future. For vehicle-to-home (V2H), for instance, profits of 390 € per vehicle and year in 2040 are determined, if viewed optimistically. Other V2X types (vehicle-to-business, V2B, and vehicle-to-grid, V2G) are subject to high uncertainties, where high as well as low or no profits are possible for future years. External circumstances are found to be of great impact regarding V2X profitability with user type and location being most relevant. Based on this, we derive business model implications and draw conclusions for a well-considered business model design. To mitigate uncertainties and increase the change of profitability, the focus of business model development should be on customer segments, revenue streams and value propositions.

Peer-review under responsibility of the scientific committee of the 7th International Conference on Advances on Clean Energy Research (ICACER 2022).

Keywords: Bidirectional charging strategies; Electric vehicle integration; Revenue potentials; Additional costs; Vehicle-to-home; Vehicle-to-business; Vehicle-to-grid; Business model design

1. Introduction

At present, E-mobility is considered as a well-suited mean to decarbonize private transportation [1]. For customers to buy and use electric vehicles (EVs), high initial costs and possibly limited mobility constitute critical obstacles [2]. For the electric grid, potential power peaks due to simultaneity in EV charging poses a threat [3,4]. The technology of bidirectional charging, or vehicle-to-X (V2X), where electricity can pass from the EV to another entity and vice versa, offers a way to overcome these obstacles and to advance the expansion of E-mobility. It promises

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https://doi.org/10.1016/j.egyr.2022.10.324

Peer-review under responsibility of the scientific committee of the 7th International Conference on Advances on Clean Energy Research (ICACER 2022).

to compensate for high initial costs and other obstacles through additional revenues. We distinguish between three V2X types: applying the technology directly at the home of an EV owner (vehicle-to-home, V2H), or at a commercially used site (vehicle-to-business, V2B), or feeding electricity into the grid regardless of the exact location (vehicle-to-grid, V2G).

To harness economic advantages of V2X, fitting business models are needed. Apart from maximizing profits, such business models must face and mitigate uncertainties due to several technical novelties and possibly further user constraints. In this paper, we thus present a methodology to determine the range of potential profits for V2X use cases within a reasonable margin of certainty. Based on a profitability analysis, we draw conclusions as to which elements of business models should be designed most thoroughly. Our investigations are part of the 'Bidirectional charging management' (BCM) project, which analyses technical, economic, and regulatory issues of bidirectional charging [5].

2. Methodology

To assess V2X charging strategies under uncertainty, we devised a multi-step methodology presented in Fig. 1. In a first step, the scope of investigation is set by selecting relevant use cases for V2X charging strategies of EVs. Criteria for the selection process are feasibility, data availability, and expected relevance based on anticipated additional revenues. To provide reliable revenue potentials in the second step, we simulated V2X charging strategies with the optimization objective of minimizing costs (i.e. maximizing revenues) for various user types and circumstances as well as for different years. Based on these sensitivities, we specified spans of revenue potentials for each use case per vehicle and year, where the differences in costs between unmanaged charging and optimized V2X charging strategies constitute additional revenues. The third step involves listing all relevant components that evoke additional costs for EV owners and users compared to unmanaged charging. We determined the differential costs of those components for present and future years. All relevant components, whose additional costs are not quantifiable for now, are taken into consideration during subsequent analyses.

In the fourth step, the spans of revenue potentials and additional costs are combined to develop a general profit range. For this purpose, we matched maximum additional costs with minimum revenues for a lower limit and minimum additional costs with maximum revenues for an upper limit, which represent the absolute extremes of potential profits for the respective charging strategies. Additionally, we developed two consistent profit paths to obtain an indication of potentially realistic profits: one path of an optimistic development with promising revenues at moderate costs, and another path displaying attenuated revenues at high costs. In the fifth step, the profitability of the respective use cases is examined and placed in the context of future implementation. By examining various profit sensitivities (variations of input parameters), the most relevant influencing factors affecting the profitability are derived. The sixth step aims to transfer the findings of the previous step to the field of business models. We link profitability prospects and influencing factors to elements of potential business models, defined as building blocks by Osterwalder et al. [6]. Business elements that are subject to strong economic uncertainties are identified and examined. On this basis, strategic options, that can be applied when designing business models in the field of V2X charging strategies to reduce uncertainties and thus to improve the prospects of success, are derived.

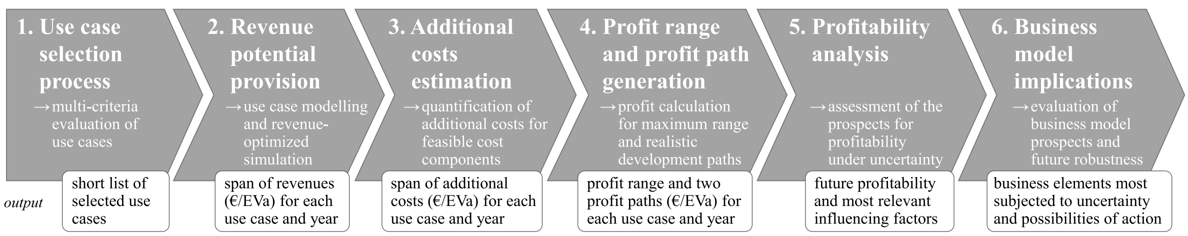

Fig. 1. Schematic representation of the methodology.

3. Profitability analysis

To start the analysis of V2X profitability, we selected the most promising use cases based on the aforementioned criteria from a list of potentially relevant use cases identified in the BCM project [7]. To reduce complexity, each of the three V2X types is represented by one selected use case. For V2H, we selected the use case of increased photovoltaic (PV) self-consumption. For V2B, peak shaving to reduce the overall demand peak constitutes the most relevant use case. For V2G, the use case of optimized arbitrage trading in spot markets (intraday and day-ahead) is selected. We assume that for every charging point exactly one EV is in use. Revenues, costs, and profits are presented as the difference between unmanaged charging and bidirectional charging with real prices related to the year 2021. All investigations are conducted for Germany and its regulatory framework. The base year is 2020. Future analyzed years are 2025, 2030, 2035 and 2040.

3.1. Revenue potential

To determine realistic spans of additional revenues for the three V2X types, we used three different modeling approaches and ran multiple simulations with different sensitivities for each model. The three models and parameter configurations for relevant simulation runs are described in previous publications [8–11]. For the revenue spans presented in Table 1, we selected suitable simulation runs for the upper and lower revenue limits for V2H, V2B, and V2G respectively.

Table 1. Additional revenue span for V2X in $€_{2021}$/(EV a) compared to unmanaged charging.

	2020	2025	2030	2035	2040
V2H	100–350	150–500	200–600	200–600	200–600
V2B	0–1000	0–1100	0–1200	0–1300	0–1400
V2G	0	50–500	60–600	70–700	80–800

The lowest spread of additional revenues is determined for V2H, where we determined moderate to high additional revenues. Here, simulation results are generally sound and reliable due to detailed modeling [8,11]. In contrast, V2B simulation results display the highest spread of revenues and thus the highest uncertainty caused by highly variable potentials for demand peak reduction and power prices depending on the exact location [9,11]. While we found that very high revenues are possible, we cannot dismiss the possibility that no additional revenues are generated at present and in the future. For V2G, zero additional revenues are determined in 2020, as the German regulatory framework is not yet prepared for a viable implementation of such use cases. For future years and a different plausible regulatory classification of a bidirectional EV, we found that additional revenues range from relatively low to high amounts per EV and year [10,11].

3.2. Additional costs

We identified the following relevant cost components of V2X use cases evoking additional costs for EV owners:

1. purchase of EVSE fitted for V2X use cases
2. installation of EVSE fitted for V2X use cases
3. installation and operation of metering equipment
4. additional hardware/software for V2X use cases
5. purchase of EV fitted for V2X use cases
6. operation of EV fitted for V2X use cases
7. operation of EV supply equipment (EVSE) fitted for V2X use cases
8. processes of registration, permits and/or contracts additionally necessary for V2X use cases

Additional costs are quantified for components one to four. Various configurations of installation are considered, each of which requires different metering equipment and installation effort, resulting in minimum and maximum additional costs [11]. For the three V2X types, the spans of additional costs turn out to be identical, such that no distinction between V2H, V2B, and V2G is made. Except for the costs of metering equipment, all cost components are initially attributed with prices per unit. For comparability, we converted these one-time costs into equivalent annual costs (EACs) by dividing the net present value by the present value of annuity factor. We assume a real interest rate of 1.7% based on a nominal interest rate of 3% and an inflation rate of 1.3% (German average of the last ten years [12]). Components' lifespans are set to 20 years for minimum and 15 years for maximum costs [13]. Table 2 shows the resulting differential EACs.

Table 2. Additional costs span for V2X in €$_{2021}$/(EV a) compared to unmanaged charging.

	2020	2025	2030	2035	2040
EVSE purchase	340–400	120–160	80–115	65–90	50–70
EVSE installation	50–70	5–25	5–25	5–25	5–25
Metering equipment	20	20	20	20	20
Additional hardware	5–35	5–35	0–35	0–35	0–35
Total	415–525	150–240	105–195	90–170	75–150

The highest additional costs of all components by some margins are the EVSE purchase costs, which mainly result from the extra power inverter required for V2X. For 2020, V2X-EVSE purchase costs are estimated at 6000 € per unit based on [14], whereas standard unmanaged EVSEs are sold at 300 to 700 € per unit [15]. For future years, we consulted with EVSE manufactures and bulk purchasers. A span of 2800 to 2300 € per unit in 2025 and 1400 to 1000 € per unit in 2040 was agreed upon for EVSEs suitable for V2X. For EVSE installations, we considered working time costs of technicians including journey time as well as material costs. Among the cases of different configurations and circumstances at the charging point, two extreme cases are identified: The maximum case, where neither an electricity nor a network cable is available and empty conduits with two wall openings must be laid (∼1530 €). The minimum case, where electricity and network connections are already in place (∼550 €). Here, additional costs mainly result from the network connection to be provided for V2X charging. Additional costs in absolute terms span from 60 to 350 €, which is a moderate amount in comparison to the absolute installation costs.

Regarding metering equipment for V2X, we considered costs for additional modern measuring devices and smart meter gateways (SMGWs), which are mandatory under certain circumstances in Germany [16]. At least one additional modern measuring device is needed in any case, including the case of minimum costs, the price of which is 20 €/a. For the case of maximum costs, we assume a SMGW to be mandatory due to a high annual electricity consumption regardless of the use case. Hence, only the one additional modern measuring device must be installed in both cases. For additionally needed hardware or software, we agreed on the approach in the BCM project that either an optocoupler (∼100 €), an additional smart energy meter (∼450 €), or a SMGW is required for a functioning V2X charging strategy [11]. For the minimum case, a SMGW is assumed to be installed in 2030, such that additional costs are zero from 2030 on, whereas maximum additional costs remain relatively high for all years.

Additional costs of components five to eight are set to zero in this paper. For the EV purchase price, we decided to exclude additional costs in consultation with the vehicle manufacturer in the BCM project, as additional costs due to V2X technology are to be allocated through appropriate margins in a revenue plan. For additional operating costs of EV and EVSE, exact values were not available to us either from manufactures or from literature. Likewise, it is not yet apparent whether and, if so, what costs could arise for additional organizational and administrative efforts. As additional costs of these components are not quantified during this step, the respective stakeholder must account for them in their profit calculations.

3.3. Range of profits

The general profit range for V2H, V2B, and V2G use cases is directly derived from the spans of revenue potentials and additional costs and shown in Fig. 2. The two consistent profit paths are also displayed, which we developed by using explicit values for additional revenue and additional costs. For the optimistic path, we chose revenue potentials and costs given excellent external circumstances (fitting regulation, good conditions on site, etc.) and well-suited user types (i.e. non-commuters). The less optimistic path, presented as gloomy path, results from revenue potentials and costs under poor external circumstances (regulatory obstacles, poor conditions on site, etc.) for less fitting user types (i.e. commuters). The results show that profitability can be achieved for all three types of V2X use cases, where profits generally increase with time. While in 2020, V2H and V2G use cases portray negative profits, from 2025 onwards profitability can be expected for many sensitivities. In 2040, even in the case of relatively negative development, such as in the gloomy path, only slightly negative profits are obtained.

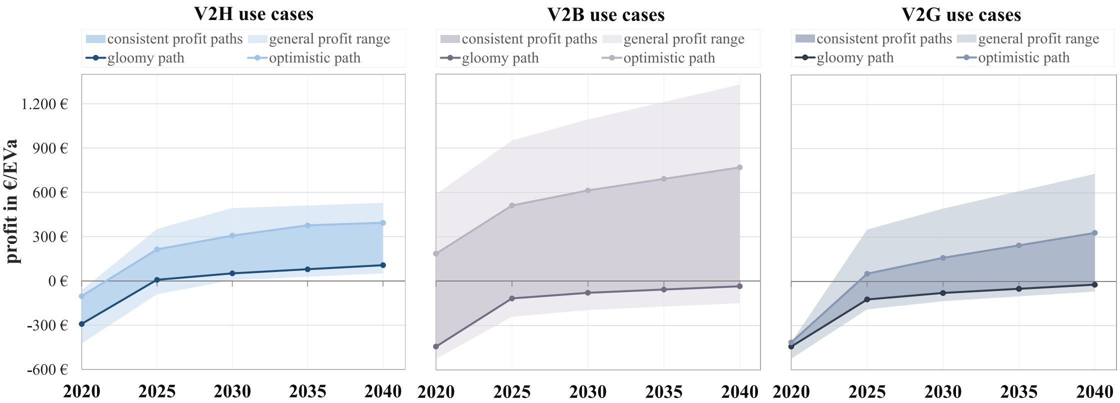

Fig. 2. General profit ranges and consistent profit paths for (a) V2H, (b) V2B, and (c) V2G use cases.

Differences between V2X types are found with regard to the range of profits, development over time, and the level of profits. V2H shows the smallest range of profits (maximum spread of 490 €/(EV a)), which is mainly a result of the relatively high certainty of revenue potentials. In 2025 and all following years, profitability is achieved not only for the optimistic but also for the gloomy path indicating a bright prospect for the profitability of these use cases. As few stakeholders besides the owner of the property (usually also EV owner and user) are interested in a direct share of profits, the level of expected profits is sufficiently high for a profitable implementation with optimistic profits of 390 €/(EV a) in 2040.

For V2B, we determined a large range of profits (maximum spread of 1480 €/(EV a)). Both the highest positive and highest negative profits are obtained, which implies a high degree of uncertainty due to highly variable revenue potentials and a high dependency on input parameters. While V2B is already profitable today in optimistic terms, profitability is not expected by 2040 for the gloomy path. Yet, if V2B is profitable, the level of profits is high, such that up to 770 €/(EV a) in 2040 are generated in the optimistic path. Similar to V2H, few stakeholders must share these profits making V2B both highly compelling and risky at the same time.

V2G represents the middle ground in terms of profit uncertainty among the three V2X types, with a maximum profit spread of 800 €/(EV a), while the lowest level of profits is displayed. Due to high regulatory obstacles, V2G is categorically unprofitable in 2020. The optimistic path suggests positive profits from 2025 with optimistic profits reaching up to 330 €/(EV a) in 2040. The gloomy path projects a slightly unprofitable future up to 2040, such that profitability is not entirely certain for V2G, especially as necessary pooling and trading involves a large number of stakeholders, who most certainly must share the profits.

3.4. Most relevant influencing factors

The main influencing factors are those which affect the profitability of each V2X type the most. From a cost perspective, significant differences originate from the circumstances at the location, i.e. existing connections and metering technology. For revenues, user types are highly relevant for all three V2X types with non-commuters generally generating higher revenues than commuters. Location parameters are most relevant in the case of V2H and V2B. As discussed in [9], the dimensioning and feed-in tariff of the PV system and the household's electricity consumption are decisive factors for respective V2H revenues. For V2B, location-specific power prices, EV and EVSE characteristics and the specific load and EV profiles of commercial sites mainly shape the revenue potentials [11].

For V2G, we found that location parameters are less important, but EV parameters have a great influence, where the size of the EV's battery is most relevant for arbitrage trading. The regulatory framework (exemptions from levies and charges), price characteristics (spot market price spread), and limited vehicle availability are further important influencing factors [10].

4. Business model implications

For the investigation of business models, the point of perspective changes. Previously declared EV owners and users, from whose perspective costs were defined, become customers in the business model. Other relevant stakeholders are *key partners* apart from the actual provider of the business model. Simply put, business model creation comprises nine defining elements: *value proposition, key resources, key activities, key partners, customer segments, channels, customer relationships, revenue streams,* and *cost structure* [6]. Here, the *cost structure* differs from the additional costs stated above, as the provider faces different costs (e.g. technological development costs) than the customer (e.g. costs for acquisition and installation). Similarly, *revenue streams* are obtained through applied pricing strategies, whereas the previously presented revenue potentials constitute the sum of all possible revenues to be shared between all relevant stakeholders. In this section, we refrain from discussing the elements *cost structure* and *revenue streams* directly but derive broadly applicable implications through our assessment. Hence, no explicit business models are developed, and no respective provider is specified.

To start with, the profit analysis indicates that revenues and costs, and consequently the economic viability of the business model, are significantly dependent on the locality of implementation and the EV user type, which in turn is defined by the targeted customer. The choice of *customer segments* addressed by a business model thus has a great effect on its profitability prospects, such that a carefully considered targeting of *customer segments* can effectively mitigate economic uncertainties especially for V2H and V2B. *Customer segments* for V2X business models range from customers with large homes and large EVs to customers with small EVs and no own EVSE, and from purely profit-driven to sustainably motivated EV customers. For V2H, well-suited customers own a PV system with little to no feed-in tariff and have a high household electricity consumption. Such customers with own homes, own PV systems and an interest in large EVs are likely to generate reliable profits and should be targeted. For V2B, customers should be individually addressed. Here, commercial sites with highly volatile load profiles in regions with high power prices must be pinpointed, as such businesses are likely to generate high profits. For V2G, not the location but the EV user type itself is crucial to maximize profitability and mitigate uncertainty. In these cases, non-commuting customers with sufficiently large EVs should be primarily targeted.

Furthermore, *revenue streams* must be aligned with the *customer segments* and essential *key partners*. The expressed *value proposition* needs to take these relationships and resulting effects on profitability into account. As previously discussed, few stakeholders participate in the V2H use cases, where moderate to comfortable profits are anticipated from 2025 on. Thus, key stakeholders might claim a share of profits from 2025 on with a relatively high level of certainty, where sufficient margins are expected for each stakeholder. As a fitting pricing strategy, we suggest a subscription model, where customers pay part of the initial costs directly and the remaining part as well as service costs continuously through recurring fees. In turn, all revenues generated over the period of use belong to the customer. The *value proposition* can therefore include the likely prospect of profitability. Yet, the efficient, direct use of green, renewable electricity and the increase in self-sufficiency and autarky are at least as important to be mentioned.

In the case of V2B, where few stakeholders are involved, profitability is not entirely certain. The possibility of slightly negative profits is opposed by the opportunity of high profits depending on the individual circumstances. To motivate respective customers to consistently reduce relevant demand peaks, the largest share of the related revenues should be received by the customers. A fixed payment strategy can be defined, e.g. a one-time payment for hardware and software components with a reasonable margin for the provider, such that all generated revenues are allocated to the customer. In this way, the business model provider minimizes his own financial risk and can still state the prospect of relatively high profits in the *value proposition* with reference to a degree of uncertainty. Similarly, for V2G, profitability cannot be guaranteed with total certainty. Yet, as the profit range is small, uncertainty is low. Even in favorable circumstances, moderate profits are generated to be shared by the relatively large number of stakeholders. Under these premises, we suggest a pricing strategy in which all actively involved stakeholders participate in the continuously generation of revenues thereby sharing the economic risks. An "as-a-service" model is suitable, in which actively operating stakeholders can offer their services for a basic fee. A share of the generated revenues could be passed on to the customers, while the rest of the share is distributed proportionally among the *key partners*. Thus, an incentive is created for all participants to operate the use case in the most profitable way. For the *value proposition*, we suggest highlighting the prospect of actively participating in the spot markets. The potential of reducing direct emissions of EV charging due to an increasing correlation between spot market prices and greenhouse gas emissions for arbitrage trading could also be promoted.

5. Conclusions

Our findings show that V2X use cases could become profitable in the near future given the right circumstances. Revenue potentials are mainly dependent on external circumstances, especially location, EV type, and regulation, as well as user types, which is why substantial revenue variations are taken into account for the different V2X types. In terms of costs, purchase costs of EVSE fitted for V2X use cases constitute inevitable additional costs for V2X users. Location parameters have the greatest influence on other relevant additional costs. Regarding the profit analysis, profitability for V2H is most probable in the near future at a sufficiently high level of expected profits. V2B profits are subject to significant uncertainties, which especially depends on the circumstances at the exact location. Yet, V2B can result in high profit prospects for individual cases. V2G may become profitable in the medium term with profits at a mediocre level and moderate uncertainty. The strength of these use cases is the independence from the exact location of the EVSE.

From a business model perspective, suitable and well-considered business models can reduce economic uncertainties through design choices that lead to profit prospects near the optimistic path. Well-targeted *customer segments* for the respective use cases have a major effect on reducing uncertainties in business models. Pricing strategies should be aligned with economic uncertainty to share both profits and risks resulting in different strategies should for different V2X types. Lastly, we recommend including additional non-monetary benefits in the *value proposition* besides the prospects of profit so that customers' expectations are not limited to financial factors alone.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgments

We thank our partners of the BCM project funded by the German federal ministry for economic affairs and climate action (BMWK) under the funding code 01MV18004C, who provided valuable input in the development of realistic cost ranges.

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Update

Energy Reports

Volume 11, Issue , June 2024, Page 2892

DOI: https://doi.org/10.1016/j.egyr.2024.02.043

Contents lists available at ScienceDirect

Energy Reports

journal homepage: www.elsevier.com/locate/egyr

Corrigendum to “Profitability of V2X under uncertainty: Relevant influencing factors and implications for future business models” Energy Rep. 8 (Supplement 16) (2022) 449–455

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The authors regret the change of the surname of the corresponding author. The surname changed due to marriage from “Dossow” to “Vollmuth”. The authors kindly ask to change the name in the corrigendum.

The authors would like to apologise for any inconvenience caus

DOI of original article: https://doi.org/10.1016/j.egyr.2022.10.324.
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https://doi.org/10.1016/j.egyr.2024.02.043

Available online 27 February 2024