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Key components for potential sustainable Vehicle-to-Grid business models: the case of the Netherlands

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Abstract

The shifts towards more use of electric vehicles and more use of renewable energy sources create the need for Vehicle-to-Grid (V2G) technology. However, there are no sustainable V2G business models determined yet. Therefore, this research focused on what the key components are for such business models. By applying a qualitative approach, eleven experts were interviewed regarding the development of sustainable V2G business models. Three themes (business environment, business model, sustainability), twenty-six categories, and 229 codes were determined. This research showed a synthesis of the key components in a business model framework. The results showed that the business environment is vital and that the Dutch market is at the moment not ready to be commercial but also has potential. This research contributes to the scientific literature by providing a comprehensive view of the key elements of a sustainable V2G business model.

Keywords:
Vehicle-to-Grid, business model, sustainability, business environment, expert-interviews, the Dutch market

1. Problem introduction

Vehicle-to-Grid (V2G) is a concept in which a charger operates bidirectionally. In this way, electric vehicles (EVs) can also be discharged to inject the energy from the batteries back to the energy grid. This idea to use EVs for supporting the energy grid, raised from the Vehicle-to-grid (V2G) pioneers Willett Kempton and Letendre (1997). The shifts towards more use of EVs within the vehicle fleet and more use of renewable energy sources (RES) in the utility industry characterizes the need for V2G (W. Kempton & Tomic, 2005).

Although the attention to V2G is high, the focus on business models is low. The study of Sovacool, Noel, Axsen, and Kempton (2018) provided an overview of the current state-of-art regarding feasibility studies of V2G. This study is a literature review based on 197 peer-reviewed studies published between January 2015 and April 2017. It shows that a low proportion (4,6%) of the studies focused on financing and business models, which refers to the analysis of market segments and business mechanisms that capture the value of V2G services.

The objective of this research was to obtain knowledge of potentially sustainable business models for V2G. This research used the Netherlands as a scope to focus on. The potential of V2G strongly depends on which market conditions and revenue streams are considered (Kiaee, Cruden, and Sharkh (2015); (L. Wang, Sharkh, & Chipperfield, 2016)). Each country/region could have different market conditions, and it is assumable that each country/region could have different involved actors. Therefore, determining a

scope that focuses on a country or region was significant. In the Netherlands, the number of registered electric vehicles (EVs) increased to approximately 222,000 in June 2020, while this number was 29,000 in the year 2014 (RVO, 2020a). At the same time, the installed capacity of solar photovoltaics increased from 1,500 megawatts (MW) to 4,400 MW and wind energy generation rose by 4% to 36 petajoules (PJ) in 2018 (CBS, 2019). This makes the Netherlands an exciting scope to focus on. The reason for the importance of sustainable business models is because V2G enables society to become more sustainable and have more than only economic profits. Such technologies can be defined as sustainable innovations, and therefore, they need sustainable business models to be able to penetrate the market (Boons & Lüdeke-Freund, 2013).

The research followed a qualitative approach. In the stage of this research, the aim was more based on understanding complexity, constructing new insights, and profoundly analyzing and developing V2G business models for the Netherlands. This aim characterized the use of a qualitative approach (Atieno, 2009). The primary method was to conduct semi-structured interviews. This is useful when there is, to some extent, knowledge about a topic that is under investigation but which still requires further details (Wilson, 2013). For obtaining detailed information regarding the development of sustainable V2G business model(s) this was important. Because the benefits of gaining knowledge from experts were that previously unknown insights could be gathered. Since semi-structured interviews make this more possible (Wilson, 2013), this method was appropriate to apply for.

This paper continues by describing the methodology of the research. After that, the theoretical lens of the study is described, which was the basis for the expert-interviews. Thereafter, the results are provided in which sustainable V2G business models have been shown. In the end, a conclusion is given, which discusses the limitations and future research recommendations as well.

2. methodology

The primary research method for analysing this research question was to conduct semi-structured interviews with experts in the field of V2G. These interviews were transcribed and coded to analyse the results and determine the critical components for a potential sustainable V2G business model. Before the expert-interviews, three methodologies were applied, which were stepping stones to the expert-interviews.

2.1 Literature review

To find a theoretical framework that can be applied for V2G business models, search terms as "sustainable, profitable, viable" and "business models" and "Vehicle-to-Grid, V2G" had been used. Since the literature regarding sustainable V2G business models was scarce, the literature review had further also explored the basics and requirements for developing a sustainable business model. A literature review was conducted by using "sustainable" and "business models" as search terms and Scopus as a database. The findings of this literature were used to construct a framework that shows the elements for a sustainable V2G business model.

2.2 Actor-analysis

The exploration of the actors' environment, which influences the success of new technology, needs high attention (Hermans & Thissen, 2009). An actor-analysis was applied to explore the actors who are involved in the Dutch energy market, and particularly the actors within the EV charging and V2G market. Furthermore, the relationships were explored, which can differ from regulatory to commercial relationships. By doing this, the core actors and relationship for V2G services were determined. Additionally, the actor analysis helped to detect the actors who have the potential to provide V2G services. This actor-analysis has been used to enrich the theoretical lens of the sustainable V2G framework.

2.3 Case studies

The case studies helped to gather insights regarding current business models that are developed around V2G. The cases that have been used were companies that have participated in dutch V2G pilot projects and which could share their insights regarding their business models. By analysing these business models, ideas were gathered to develop sustainable V2G business models within the Netherlands. These insights helped to enrich the theoretical lens of the sustainable V2G framework.

2.4 Literature review technological developments

The literature was also searched about what technological developments could impact a V2G business model. Search terms as "technology trends, technological development, technology progress" and "electric vehicles" were used. A literature review helped to focus on the technological developments and future trends of EVs. The development of these technologies and their impacts on the potential of V2G business models were explored.

2.5 Semi-structured interviews

All these methodologies shaped the lens of the expert-interviews. In total, eleven experts were interviewed. The sampling was focused on key actor groups that were determined by the actor analysis. From these actor groups, employees who have expertise in V2G were contacted. Thereby, people with V2G knowledge from academia or research agencies were contacted. The interview set-up was based on the theoretical lens that was shaped by the methodologies which were described before. From the interviews, insights were gathered related to how the different elements of a sustainable V2G business model can be satisfied. Table 1 shows the experts and their relation with V2G.

Table 1: overview experts

Expert codes	**Relation with V2G**
E.1	Business developer at a company which supplies EV charging and V2G equipment.
E.2	Operational in the sector of electric transport and formerly employed by an energy company in which the expert has participated in V2G projects.
E.3	Formerly employed by an automotive company in which the expert has participated in V2G projects.
E.4	Project manager and an expert in V2G at a knowledge and innovation center in which they do research on smart charging infrastructure.
E.5	Researcher at an university of applied sciences in which the expert has conducted user research for various V2G research projects.
E.6	Project manager at an energy company which operates as a charge point operator but also as an energy supplier and balance responsible party. They are working on V2G pilots.
E.7	Employee at a company which is a balance responsible party and a balancing service provider. They are working on V2G projects and searching how to serve the Dutch TSO.
E.8	Product developer at a sustainable energy supplier company in which the expert is involved electrical mobility and providing flexibility to the grid.
E.9	Employee at a governmental agency in which the expert is involved in electrical mobility. The expert has also done research on how legislation and policy hampers V2G.
E.10	Employee at distribution system operator in which they are proponents of smart charging and also thinking about the possibilities of V2G.
E.11	Employee at a company which operates as charge point operator and mobility service provider. They have participated in many V2G pilots and developed their own V2G charging infrastructure which is in pre-commercial stage.

3. Theoretical lens

3.1 Lack of sustainable V2G business model studies

Currently, financial studies mostly focus on reviewing the effects of V2G. Habib, Kamran, and Rashid (2015) determined and reviewed the various benefits in terms of more reliable, efficient, and stable grids and impediments such as battery degradation. Moreover, the study of Niesten and Alkemade (2016) described that additional benefits could be gathered related to financial and environmental aspects as well as more participation in electricity systems. There are also a couple of studies that monetized the effects of V2G by modelling methods, but as Sovacool et al. (2018) mentioned, the result of these studies could be inconsistent. While some of these studies showed clear cost-saving and net revenue potentials (Salpakari, Rasku, Lindgren, and Lund (2017); Noori, Zhao, Onat, Gardner, and Tatari (2016)), other studies showed slighter cost-savings (L. Wang, Sharkh, & Chipperfield, 2016) and even more costs for aggregators in some situations (Kiaee, Cruden, & Sharkh, 2015). However, there are indirect effects which are not monetized and the potential of V2G strongly depends on which market conditions and revenue streams are considered (Kiaee et al. (2015); (L. Wang et al., 2016)). Therefore, it is important to develop a business model that should be able to provide optimal revenue streams under certain market conditions.

The development of an appropriate business model that could satisfy a sustainable V2G service does not get a lot of attention. The reason for the importance of sustainable business models is because V2G enables society to become more sustainable and have more than only economic profits (Niesten & Alkemade, 2016). Such technologies can be defined as sustainable innovations and therefore they need sustainable business models in order to be able to penetrate the market (Boons & Lüdeke-Freund, 2013). However, the attention towards sustainable V2G business models is low. The study of San Román et al. (2011) intended to provide a regulatory framework and needs for business models in terms of infrastructure, involved actors, and commercial relationships. Still, this study did not aim to develop a sustainable business model. Although Brandt, Wagner, and Neumann (2017) developed and evaluated a business model for V2G, this study is based on the economic perspective of garage operators and Germany is used as a use case. Toquica, De Oliveira-De Jesus, and Cadena (2020) researched business opportunities for an EV aggregator and the ways to maximize its profit. Nevertheless, this research was from a regulatory perspective in which only one firm acts as an aggregator and Colombia is used as a use case. Y. Wang et al. (2017) built an evaluation system for smart grid services and evaluated two types of business models that are related to such services. However, to evaluate a business model for another country, it must be on beforehand established that such a business model features the requirements within that country.

Furthermore, the study of Niesten and Alkemade (2016) concluded that studies related to business models lack to include the roles of different actors, which is important by developing a business model for V2G. This study was a literature review about business models for V2G and showed the value streams considered for consumers, system operators, and aggregators. This study made clear that not all actors and relevant partnerships for V2G services are discussed in the literature. Thereby, Sovacool et al. (2018) described that V2G consists of different market segments that interrelate with consumer behaviour, which could result in separate business models. But this is omitted in studies as well (Sovacool et al., 2018).

The main findings showed that the development of sustainable V2G business models is poorly addressed while developing sustainable business models for V2G services appeared to be important. Considering relevant actors and relationships are assumed necessary in the literature but at the same time this does not get a lot of attention in business model studies. Which consumer groups are involved are neglected either, while this is significant since it could result in different business models. There is also a lack of insights about V2G business models in practice, which could be due to a lack of commercially available V2G services. However, the situations about current V2G business models that are applied could provide insights into developing sustainable V2G business models. Furthermore, insights from experts or key market players are missing, while these insights are important for exploring the feasibility of novel

technologies. In researching a potential sustainable V2G business model, these insights from experts could be helpful because there is currently no sustainable V2G business model on the market yet.

3.2 Sustainable V2G business model framework

The framework developed by Reinhardt, Christodoulou, García, and Gassó-Domingo (2020) has been used as a basis for the sustainable V2G framework. This framework consists of three main parts: the business environment, sustainable archetypes, and business model. For the part of business model, the business model canvas developed by Osterwalder and Pigneur (2010) has been used. The business model canvas has been used because it is comprehensive, widely applied, and it provides additional attention to customer segments and key partnerships that appeared to be unattended in current V2G business model studies. Furthermore, some V2G specific sustainability components were added to the framework, which were derived from the literature. Figure 1 shows the initial sustainable V2G business model framework, which is used as a theoretical lens.

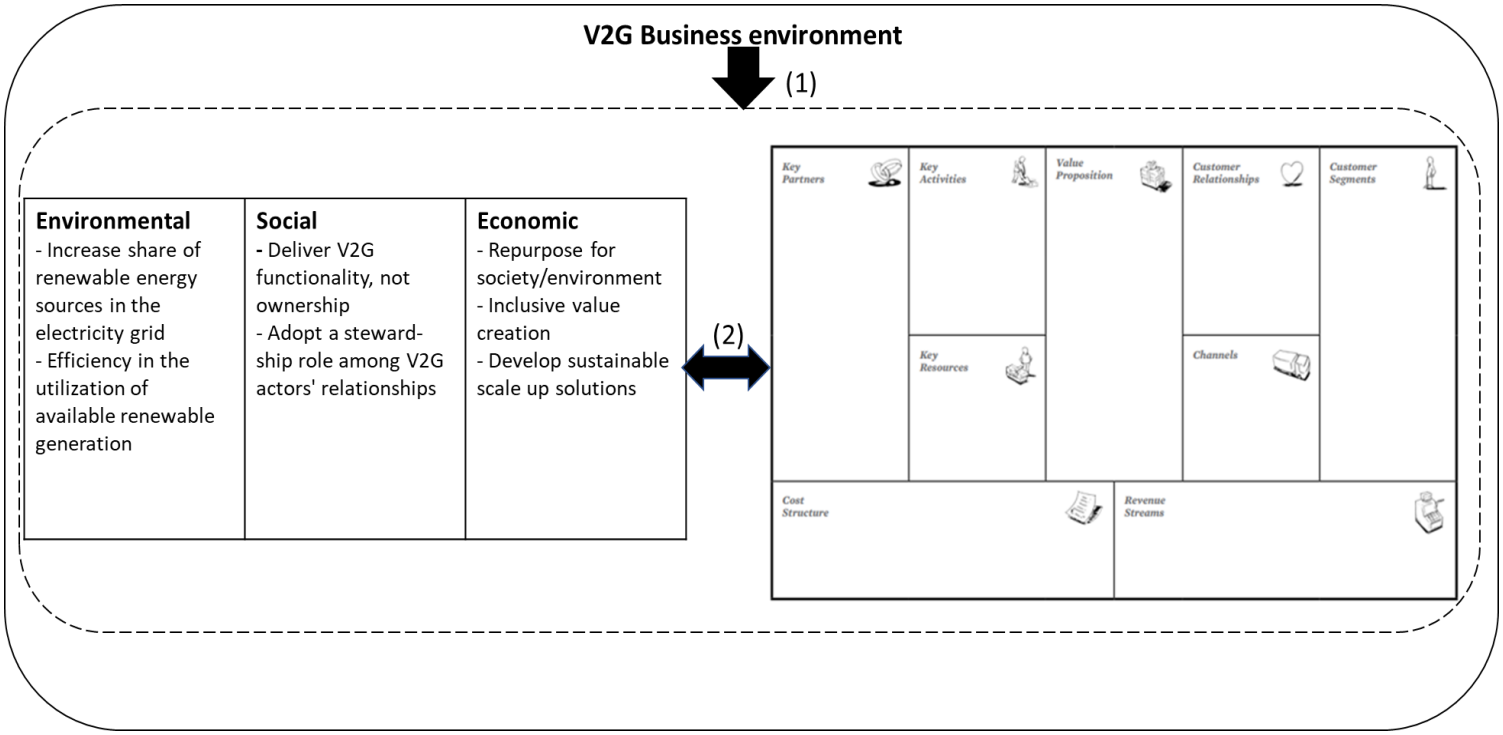

Figure 1: Theoretical V2G framework

The aim was to fulfil these elements presented in the framework (Figure 1) by addressing the sustainable archetypes that are relevant to V2G and the associating content for the elements within the business model canvas. Thereby, exploration was needed for the factors of the business environment in which the business model could be developed.

(1) This arrow represents the impact of factors in the business environment on a sustainable V2G business model. Business activities can be related to the business environment. This results in organizational activities that are conforming the business environment and therefore have an impact on sustainable business models (Reinhardt et al., 2020). This could be factors such as regulatory policies, market trends, or macro-economic factors (Reinhardt et al., 2020). The business environment could in a way create hinders or potentials for the underlying business model (Boons & Lüdeke-Freund, 2013). Hence, engaging in interaction with the business environment requires extra efforts during the creation of sustainable business models (Evans et al., 2017). The following sections, consisting of an actor-analysis, case studies, and an analysis of the technological developments, detailed the business environment.

(2) This arrow represents the interaction of the business model with sustainable archetypes. When researching sustainable business models, these archetypes are needed to broaden and unify the research agenda for making business models more sustainable (Bocken et al., 2014). There is a possibility that none of these archetypes, a combination of archetypes, or all of the archetypes are existing for a company (Reinhardt et al., 2020). The initial sustainable V2G archetypes in the theoretical V2G framework are further used in the expert-interviews (see appendix C). The aim was to explore which of these or other sustainable archetypes apply for a V2G service provider, to what extent they matter, and which of them are essential to have as evaluation criteria.

3.3 Actor analysis

The actor analysis helped to find actors who are important for a sustainable V2G business model. This importance could be because of the institutional relationships or because of potential partnerships with a V2G service provider. These actors were further used for contacting experts.

The actors that appeared to be significant were chare point operators, mobility service providers, distribution system operators, transmission system operator, balance responsible parties, governmental agencies, energy suppliers, electric vehicle supply equipment suppliers, electric automobile industry, aggregators, EV drivers, and municipalities. Appendix A shows the role of these actors in detail.

Furthermore, the actor-analysis showed that there are institutional and also standardization issues. Thereby, which actors could satisfy the role of V2G service provider could not be determined yet. The ways how consumers (EV-drivers) play a role in a V2G business model is also explored. Three segmentations could be made: the financial segment in which consumers give more importance to financial incentives, the social segment in which consumers give more importance to incentives as contributing to sustainability, and the functional segment in which consumers give more importance to having flexibility in the choices whether and how to use its EV for V2G.

3.4 Case studies

The cases that were used were MijnDomein, Jedlix, and SBPF. From the case studies, it can be noticed that business models around V2G are not determined yet. Companies are still in the research phase and the aim is mainly about understanding the technology and its impact. The role of V2G service provider is determined neither. The pilot projects commonly use shared vehicles in their pilots.

The SBPF case also showed that the bi-directionality of V2G could be used beyond its original intention. Whereas V2G is a technology that is triggered by supporting the energy grid, the SBPF case showed that a bi-directional charger could be used for cases as vehicle-to-off-grid.

The Jedlix case showed the issue to use AC- or DC-charging. While AC-charging assumes that the EVs must be capable of discharging with alternating current (AC), DC-charging assumes that an off-board charger should convert it to AC to make it less complicated for the EV.

Thereby, it appeared that technical barriers in terms of V2G infrastructure costs and availability could still be problematic. Institutional barriers in terms of legislation, and standardization issues in terms of unready protocols, are also been experienced in these pilot projects. Furthermore, from the case studies, it appeared that it not clear whether revenue can be gathered from supporting DSOs by congestion management.

3.5 Technological developments

There are two ways the technological developments could influence a V2G business model. One way is the development in the electric vehicle types itself. Types of EVs that can be used for V2G are the plug-in hybrid electric vehicles (PHEVs), fuel cell electric vehicle (FCEVs), and battery electric vehicle (BEVs) because they make use of energy sources (C. Liu, Chau, Wu, & Gao, 2013). Although the

potential of BEVs seems the highest because of the increasing trend in numbers, battery capacity, and accessibility, the FCEV and PHEV still have benefits like the reduction of range anxiety.

The second way is the development of other technologies that could influence a V2G business model. The emerging technologies which associate with V2G are shared vehicles, autonomous vehicles, and wireless charging. Although these technologies are under research, studies have no many attention on the integration of these technologies regarding how they will impact each other.

These issues create questions in how these technological developments will influence the potential of sustainable V2G business models in the Netherlands.

4. Results

The theoretical lens formed the basis for the interview set-up with the experts. These interviews were recorded, transcribed, and coded in order to analyse the results. The results showed that there are three themes (business environment, sustainability, and business model) and 26 categories, which include the key components for a sustainable V2G business model. Based on the insights of each category, the key components for a sustainable V2G business model was constructed (figure 1). An expert validated a draft version of this figure in an online meeting. Based on the recommendations of the expert, figure 2 was further detailed in several use cases. These use cases were Public V2G charging, V2G for homeowners (Vehicle-to-Home), and V2G for office building/building owners (Vehicle-to-Building). For V2G, both the Vehicle-to-Home and Vehicle-to-Building use cases are assumed local (on microgrid), which results in that the V2G business model would focus on peak shaving (storing energy when energy generation is high and using it when energy consumption is high) and load balancing building (balancing energy need of charge points and building). The sustainable V2G business model for each case has been shown in Figures 3, 4, and 5.

There was also a distinction made in the value proposition and customer categories called macro- and micro-segmentation. The macro segmentation represents the customers to who the V2G service is offered and from who revenue is expected to be generated from. The micro-segmentation represents the end-users who need to be convinced to make use of V2G services.

Hereby, in the use cases of Vehicle-to-Building and public V2G charging, the term end-user does not particularly have to refer to a private EV driver. It could also refer to a fleet-owner like a lease driver, in such a case, it is better to make agreements with the lease company. This also counts in other forms in which the EV driver is not the private owner of the vehicle and there is a fleet-owner. The micro segmentation also covers the social and financial segment of end-users which were derived from section 3.3 and addressed by the experts. Socio-economic characteristics of end-users, which refers to characteristics like how many vehicles they have, what their travel patterns are, and what their commuting distances are, are also covered in the micro-segmentation

The relationship of themes, business environment, sustainability, and business models are represented by arrows. The first arrow represents the impact of the business environment on the business model. The second arrow represents the sustainable archetypes that are underlying to the V2G business model or that are results of a working sustainable V2G business model.

The third arrow represents the evaluative criteria of the sustainability categories, which a business model must satisfy, at least, to penetrate the market. Hereby, the economical category could be of key importance for a sustainable V2G business model. The component that V2G is commercial and also contributes to a sustainable society is a leading criteria to have been satisfied.

However, the institutional, technical, and standardization issues make the Dutch market not mature enough to be feasible for a V2G business model.

The institutional barriers make it challenging to earn money from congestion markets by serving distribution system operators (DSOs) with congestion management. This is because DSOs are under heavy regulation. They may not use batteries and they cannot apply dynamic price structuring because

of legislations. This makes the application of V2G at the DSO market for now too complicated. Multiple taxes that must be paid for each charging session after the car is discharged also create a barrier for a V2G business model.

Whereas public V2G charging has also to deal with municipal regulation regarding restrictions on the occupation of charge points, Vehicle-to-Home and Vehicle-to-Building cases do not have to face such rules. What particularly disturbs the Vehicle-to-Home case is the netting arrangement by which energy generation from solar panels can be virtually stored in the energy grid. The Vehicle-to-Building case could be feasible because building owners or businesses could also save money from lower grid connection tariffs, for which the regulatory issues are less a bottleneck.

Regarding standardization, the main issues are that there are no open data communication protocols for V2G. This is expected to be enabled by ISO-15118, but this is not ready at the moment. Currently, only the CHAdeMO protocol connectors are compatible with V2G, while Tesla and CCS protocols are commonly applied in the Netherlands. There is also no V2G charging infrastructure environment, which negatively contributes to the standardization of V2G.

Regarding the technical barriers, the battery capacity of vehicles are not very high, there is no commercially available vehicle fleet which is capable of V2G, and the V2G infrastructure costs are too high at the moment.

Although the V2G market is not mature at the moment, there is potential for a sustainable V2G business model due to the increasing trend of EVs, increasing grid congestion, and decreasing costs for V2G charging infrastructure. Also, the netting arrangement is expected to be expired from 2023 on and the prevention of multiple taxes is expected to happen soon as well. This will have a positive impact on the development of sustainable V2G business models.

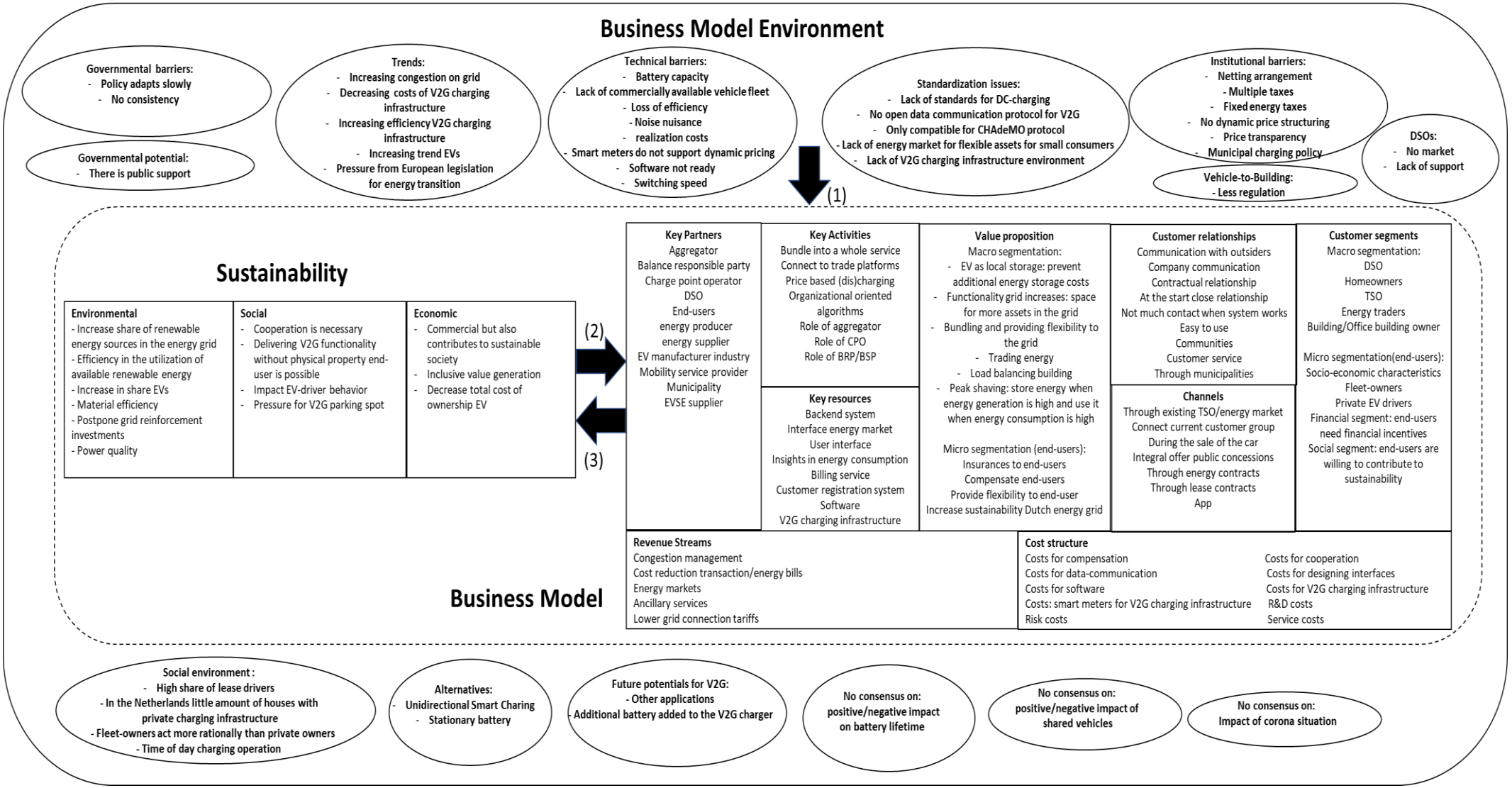

Figure 2: key components sustainable V2G business models

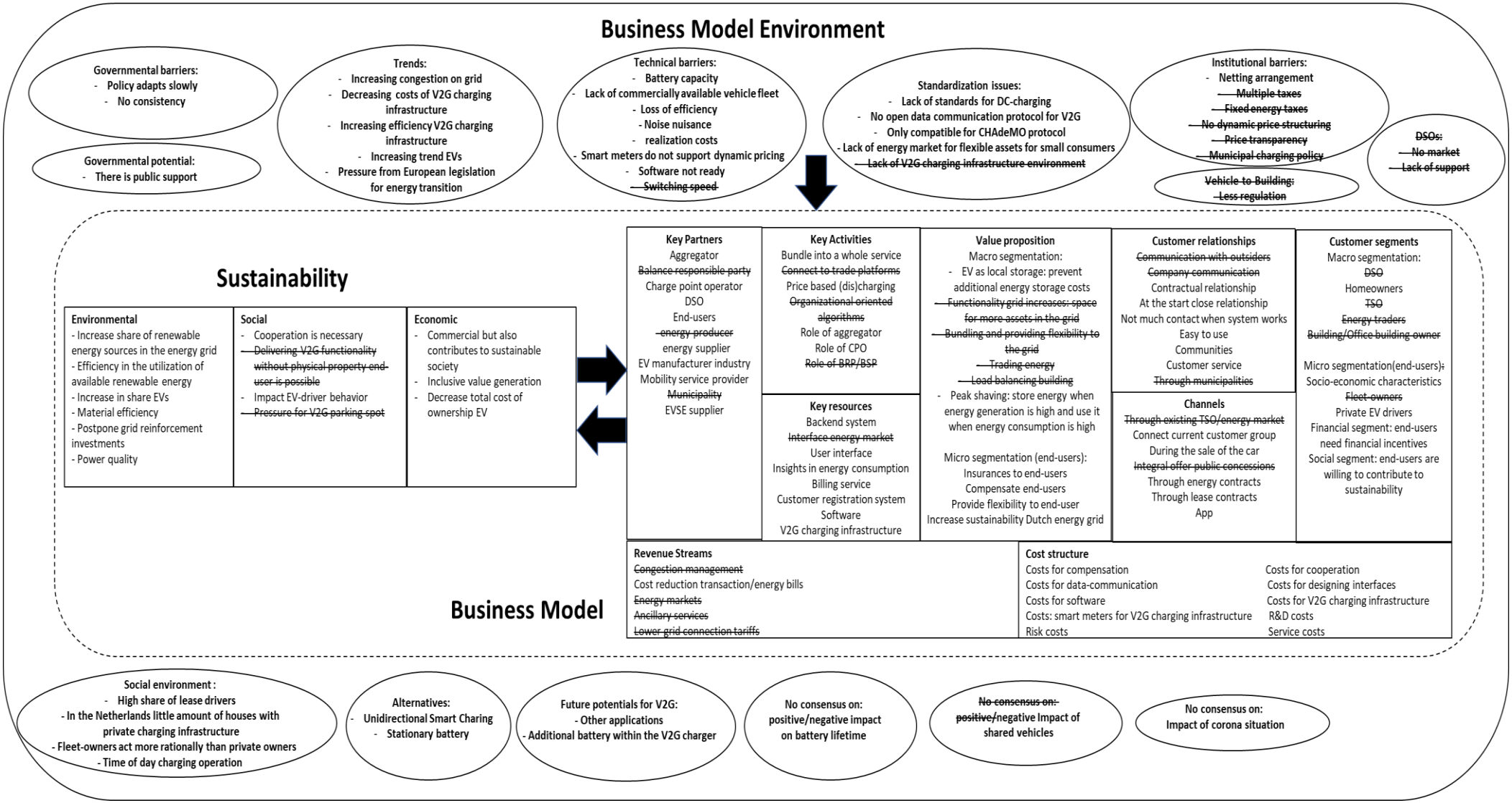

Figure 3: sustainable business model Vehicle-to-Home use case (local)

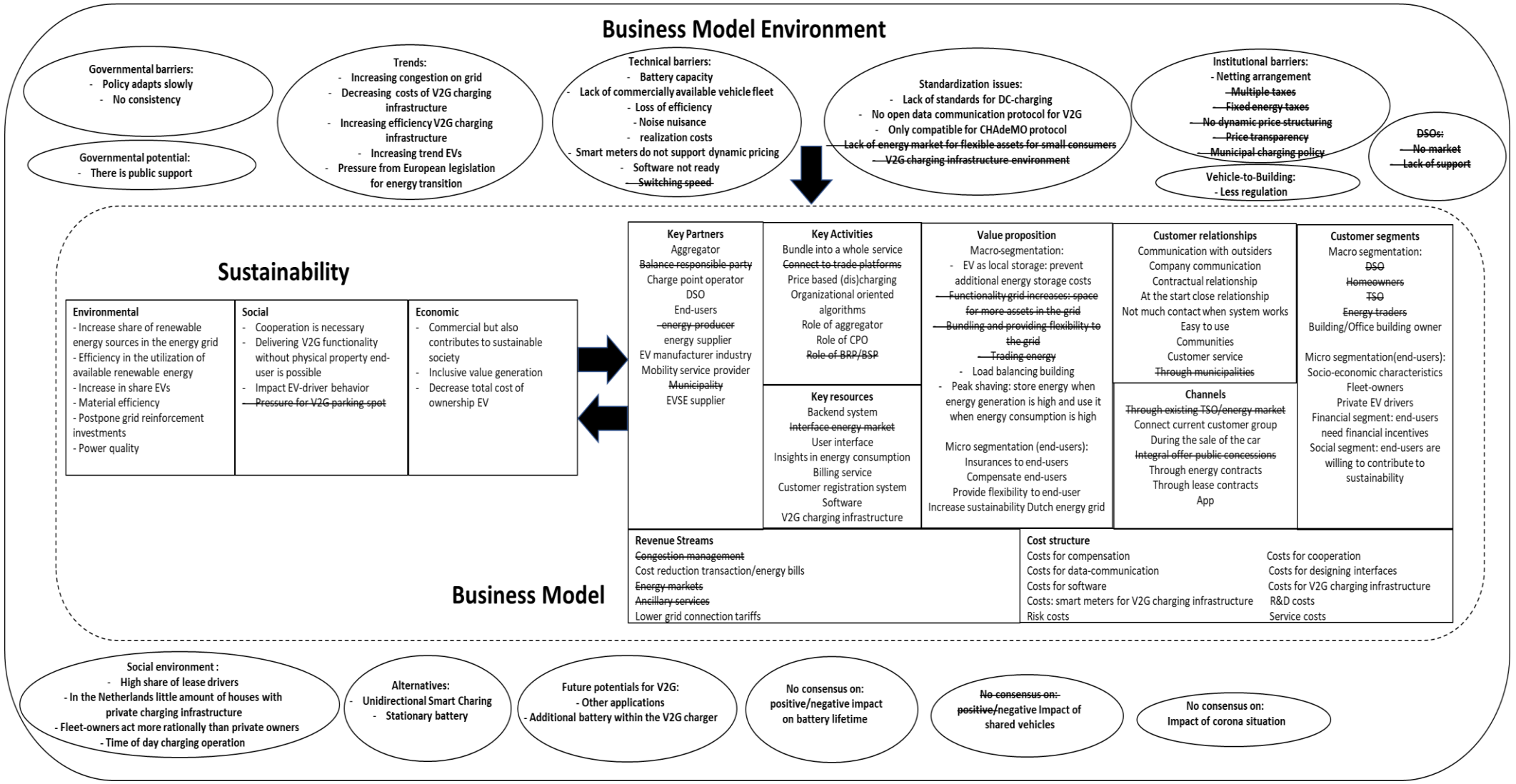

Figure 4: sustainable business model Vehicle-to-Building use case (local)

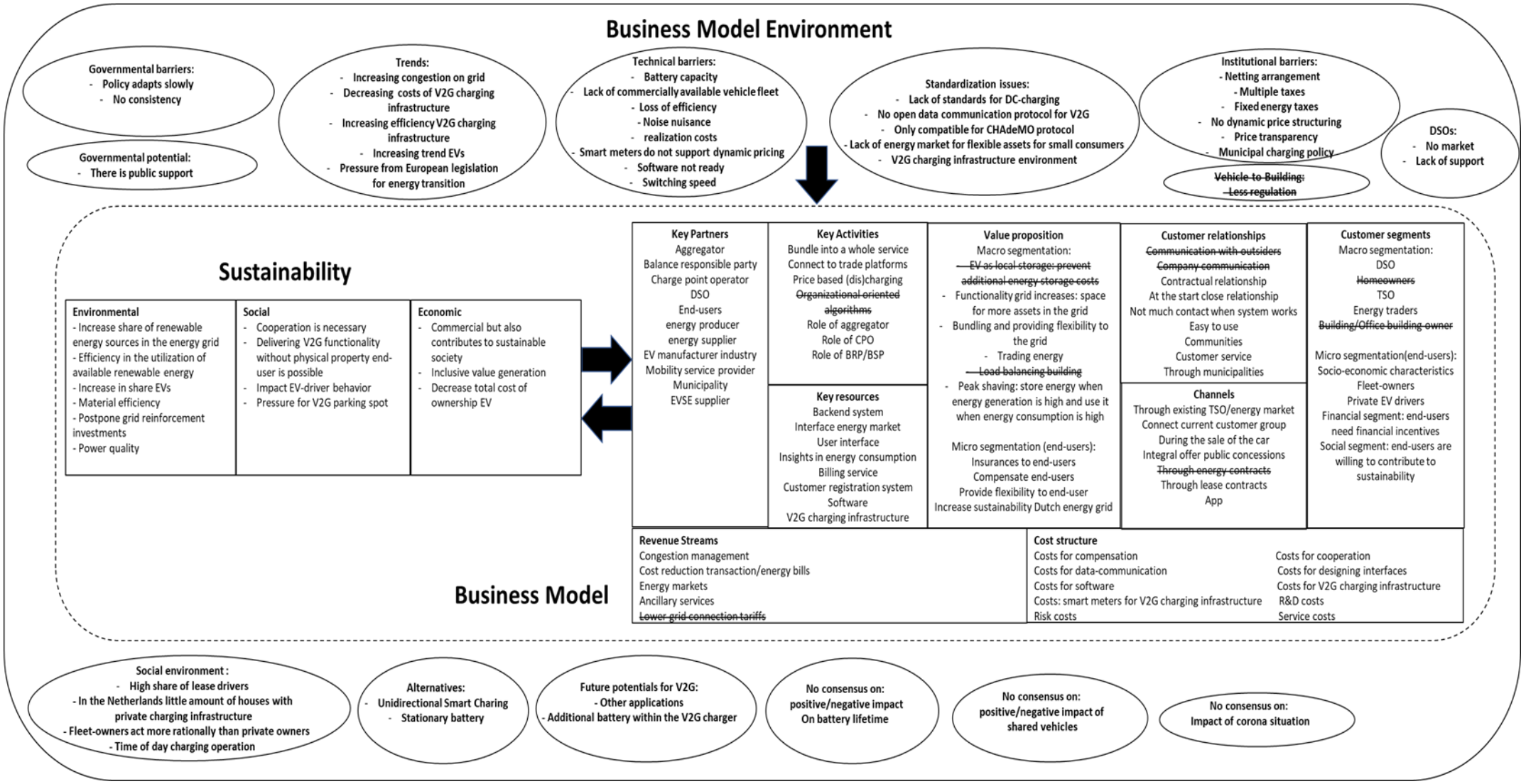

Figure 5: sustainable business model public V2G charging

5. Conclusion and discussion

5.1 Conclusion

This research aimed to find the key components for potential sustainable V2G models for the Netherlands. A sustainable V2G business model is developed, which was not developed yet by applying a qualitative approach and conducting expert-interviews. The use of such an approach was new in this field. The results showed that the business environment is vital and that the Dutch market is at the moment not ready to be commercial but also has potentials. This business model also showed the key themes, categories, and components for a sustainable V2G business model. Although, the components could differ per use case, customer segment to which these services would be offered, and which country market the V2G business model is operating in. The themes and categories that are constructed could be the basis for each sustainable V2G business model. So, this research contributes to the scientific literature by providing a comprehensive view of the key components and also of the key actors for a sustainable V2G business model.

5.2 Limitations

This research had several limitations. One limitation was the lack of an expert from a transmission system operator (TSO), which is a key player for delivering ancillary services and the lack of an expert from a municipality. Moreover, a limitation of this research is the perspective that has been used. The interview was conducted by semi-structured questions, which followed the same perspective for each expert-interview. So, actor's specific questions were not asked, which in particular could be important for the automobile industry, governmental agencies, and the DSOs because the attitudes of these actors towards V2G are not obvious.

Another limitation was that the research was limited to the Netherlands. This was necessary because the market conditions in which a V2G business model will operate is vital. So, the market conditions must be determined. The available timeframe for this research did not allow for widening the scope to multiple countries and therefore the choice was made to focus on one specific country.

5.3 Recommendations

With this research, managerial implications and recommendations for policy and future research could be given. The recommendations for policy are based on three dimensions: solve institutional issues, contribute to the use of open data, and incentivize the market until V2G is commercially feasible.

Managerial implications are in the first place that V2G associates with a lot of R&D, investment costs, risks, and cooperation. It is important to be aware of this. However when it is operationally feasible, its realization costs decrease, and it becomes widely applied, then it could be profitable because the costs are mainly those investment costs. This makes the V2G market complicated but also promising due to the ability to generate revenue through V2G services. Thereby, the business environment is a primary contributor to the success of V2G. How this business environment develops is something to be alert on. It is also important to make V2G easily accessible and easy to use for the end-user. Therefore, offering the V2G option during the sale of an EV is an important channel to reach the end-users. V2G technology is also developing beyond its initial intention. V2G technology may be applied in other cases than the ones for which business models are intended to be designed for. To keep this in mind and search for such opportunities could make a company that is involved in the V2G market more competitive.

A recommendation for future research is to use qualitative research to shed light on the perceptions and attitudes of different automotive companies, governmental agencies, and DSOs on V2G. Another recommendation is to conduct similar studies for other countries, which could allow seeing how key components for sustainable V2G business models differ for other countries. A recommendation for future research is also to look into what the impacts of the expiration of the netting arrangement will be for V2G. Thereby, research on whether V2G can contribute to the adoption of EVs and/or solar panels is recommended. Research towards the calculation of business cases for a sustainable V2G business model per use case is also recommended. Research towards other use cases than of the ones determined in figure 3,4,5 could be recommendable either. Lastly, it is recommended to conduct research on battery degradation, the impact of shared vehicles on V2G, and the impact of the corona situation on V2G.

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Appendix A

Governmental agencies

The Ministry of Infrastructure and Water Management (I&W is not directly involved in the regulation of the energy market. However, it stimulates sustainable energy transition by helping local governments with guidelines to prioritize renewable energy in spatial planning (Rijksoverheid, 2020). The ministry can also provide grants to municipalities that can be used for investments, which stimulate the use of sustainable energy. The Ministry of Economic Affairs and Climate Policy has an SDE+ arrangement which subsidizes institutions to produce sustainable energy (RVO, 2020). Moreover, it is directly involved in the regulation of the Dutch energy market and it also imposes ministerial regulations concerning the financial management of grid operators.

Municipalities

The ministry can also provide grants to municipalities that can be used for investments, which stimulate the use of sustainable energy. For instance, the ministry of I&W granted twenty million euros for pilot projects regarding climate adaptation (Nieuwenhuizen, 2020) and five million euros to twenty-one municipalities for smart charging poles (Rijksoverheid, 2019). This means that municipalities and local governments are involved in the Dutch energy market as well. Municipalities are also potential location owners of charge points.

Energy suppliers

Energy suppliers are responsible for offering energy to the customer and need permission which is regulated by the ACM. For providing this permission, the ACM has set-up requirements, which are based on reliable service, secure supply, supply obligation, and reasonable prices, conditions and customer treatment.

Transmission system operator (TSO)

The TSO is often monopolistic and heavily regulated. TenneT is designated as the TSO for the Netherlands. Because TenneT has been designated as TSO of the high-voltage grid Netherlands, it has additional statutory duties. These duties include responsibility to provide system services. System services means that TenneT must resolve large-scale interruptions in the transport of electricity and maintain the energy balance between electricity supply and demand. The duties include also responsibilities for securing a reliable and safe electricity supply, importing and exporting electricity, and maintaining the system of programme responsible parties (TenneT, 2020b).

Distribution system operator (DSO)

DSOs are responsible to carry electricity from the substation to the end-users (customers). They carry low-voltage electricity and operate in regional level. DSOs have to maintain the affordability, security of supply, and safety of the energy grid.

Balance responsible parties (BRP)

TenneT can place responsibility to recognized BRPs to ensure the balance of electricity production and demand (TenneT, 2020a). These BRPs inform TenneT (daily) about the planned transactions for the next day and the grid network they will use for transport. The sum of all transactions of each BRP is named as energy program. The DSOs inform TenneT about the actual values of electricity which are consumed and imported per BRP. The difference between the energy program and the actual measured values is the imbalance. Imbalance leads to power shortages and surpluses which must be prevented and which makes balancing therefore necessary (TenneT, 2020a).

Charge point operator (CPO)

The CPO is an actor who bears technical and administrative responsibility for managing, maintaining and operating the charging station. The administrative responsibility of the CPO is based on the operation of administrative procedures such as providing access, roaming, and billing to MSP. The technical responsibility is based on technical maintenance, which is often done by the manufacturer.

Mobility service provider (MSP)
When using a public charging station there are various CPOs. To still get one bill at the end of the month, it is required for EV drivers to identify themselves by using a unique id at charging stations. This id is provided by MSP's. MSP is an actor with who the EV driver has a contract. This contract concerns all services which are related to the EV operation. It is typical that the MSP includes some other actors, like an energy supplier or CPO, and has a close relationship with a DSO. A car manufacturer could satisfy such a role as well. The MSP verifies contract IDs from its customers received from the clearinghouse, other MSPs or CPOs.

Electric vehicle supply equipment (EVSE) supplier
EVSE must be compatible to charge EVs by a charge station which features appropriate hardware and software. EVSE manufacturers are the producers of this hard- and software. Although EVs are increasingly penetrating the market, the EV share within the vehicle fleet is still low. Which makes the demand for EVSE low (Ghotge et al., 2019). At the moment, there is a lack of commercially compatible V2G EVSE (MacLeod & Cox, 2018).

Automotive industry (EV OEM)
The state of the market for V2G compatible cars is low either. Currently, the variety of commercially available vehicles for V2G is very restricted and the major EV OEMs do not advertise their timescales to implement V2G (MacLeod & Cox, 2018). There are also warranty issues for EV OEMs regarding V2G operation such as the provision of warranty for the car battery. MacLeod and Cox (2018) provided the current V2G compatible vehicles in Europe: Mitsubishi Outlander PHEV sports utility vehicle, Nissan Leaf BEV passenger car and the Nissan ENV-200 BEV light commercial vehicle. While the Mitsubishi has no warranty, the Nissan cars have partially been provided warranty in the UK.

Aggregator
An aggregator can play a key role in V2G services (San Román, Momber, Abbad, & Miralles, 2011). An EV aggregator enables the optimization of EV resources, by storing it and thereafter charging or discharging it in certain periods, restricted to driving constraints that are imposed by EV owners. The advantages of an EV aggregator are that it can take responsibility for software functionality, equipment and regulatory interactions as well as take risks for issues that are associated with underperformance (Noori, Zhao, Onat, Gardner, & Tatari, 2016). Aggregators create and capture value by aggregating supply and demand for EV electricity and by intermediating transactions between different consumers of V2G services (Niesten & Alkemade, 2016).

V2G service provider
During traditional EV charging, the charging operation starts when the car is connected to the charge point and ends when the battery is fully charged. With V2G, on the other hand, the V2G service operator knows if there is a power peak by communication channels with the grid. For example, the V2G service operator gets informed when there is a lot of energy generation from wind turbines. By communication with the DSO, it can also be known if there is high demand for power. For instance, the V2G service operator gets informed, when many people start connecting their cars at the same time as they use electricity at home. With these communication flows and additional communication with EV drivers, the V2G service operator can manage the power consumption.