Vehicle-to-Grid Business Model – Entering the Swiss Energy Market

Reflection on the Main Success Factors
and on the Configuration of Business Model Components

Master Thesis

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"Crossing the grid parity will be a breaking point in our economy. This threshold is like 0 and 1 degree Celsius on the temperature scale, it's the difference between ice and water. In markets it is the difference between frozen up markets and liquid flows of capital into new opportunities of investments. […] Things take longer than you think they will and then they happen much faster than you thought they could" (Al Gore, TED-Speech, September 2016).

ABSTRACT[1]

Storage capacities support the large-scale diffusion of renewable energy sources. With the increasing electrification of automobiles, the Vehicle-to-Grid (V2G) technology serves as the enabler to use car batteries as short-term storage. While research has highlighted some technological challenges for the transition to low-carbon mobility in general, less attention has been given to the implications for business structures using V2G. Hence, the aim of this paper is to suggest guidelines for the configuration of a V2G business model in the Swiss market environment. Since V2G business models for the Swiss market have not been studied before, the thesis adopts a multiple-case study design and investigates the experiences of ten representatives and potential actors in a future V2G business model. The analysis provides several findings, subsumed in a success factor framework. The different hardware and software solutions enabling grid services are still premature and non-standardized. However, a consensus among most automobile manufacturers is about to bring change. Nevertheless, at this point in time it complicates the integration of EV batteries into the power grid, although markets with clients exist, who are willing to pay for V2G services. The findings suggest starting the business model in a closed charging environment with a fixed number of recurring users. To align the cost structure to the market potential, as the pool of potential users grows and the technology matures, a flexible business structure is crucial. A three-step roadmap illustrates the shift from solely 'demand response' programs to bidirectional charging, slowly approaching the open market. Due to the small value per user, multiple revenue sources are needed to operate profitable. Next to offering ancillary services, trading local flexibility in an experimental market design is a promising source of income. Other revenues are generated from industrial peak shaving and saved network distribution fees.

Keywords: *Vehicle-to-Grid, V2G, Renewable Energy Sources, Battery Storage, Swiss Energy Market, Business Models within Sustainable Technologies, Smart Grid, Ancillary Services*

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[1] **German Version of the Abstract**:
Speicherkapazitäten unterstützen die Verbreitung von Erneuerbaren Energien. Durch die Elektrifizierung des Personenwagens hat es die Vehicle-to-Grid (V2G) Technologie verstanden die Autobatterien als kurzfristige Speicherkapazität zu nutzen. Während die Forschung die technologischen Herausforderungen für die Energiewende, und zum Teil für ein V2G Konzept, definiert hat, fehlt es an Vorgaben für die Gestaltung eines Geschäftsmodelles. Das Ziel dieser Arbeit ist es Richtlinien für die Konfiguration eines V2G Geschäftsmodelles im Schweizer Markt vorzuschlagen. Weil V2G Geschäftsmodelle für den Schweizer Markt noch nie untersucht worden waren, prüft diese Arbeit mehrere Fallstudien und fragt zehn Praxispartner aus betroffenen Branchen um Rat. Die Forschungsergebnisse wurden in einem 'Success Factor Framework' zusammengefasst. Unreife Technologien, die notwendig sind um V2G Leistungen anzubieten, erschweren profitable V2G Geschäfts-modelle obwohl die angezielten Märkte bereits reif sind. Fehlende Standardisierung der notwendigen Hardware und Software erschweren den Anbietern das Skalieren und zwingen sie dazu in einem geschlossenem Infrastruktur Umfeld zu operieren. Eine Roadmap suggeriert eine schrittweise Öffnung des V2G Modells in drei Schritten und eine Skalierung erlauben. Um die Investitionen in die notwendige Hardware und Software zu tilgen ist das Potential mehrerer Einnahmequellen abzuschöpfen. Neben dem Regelenergiemarkt sorgt ein experimenteller Markt, auf dem Netz-Flexibilität gehandelt werden kann, als erfolgsversprechende Einnahme-quelle. Weitere Umsätze werden gewonnen durch das Einsparen von Stromspitzen im industriellen Sektor und durch das Einsparen von Netznutzungskosten durch einen erhöhten Eigenverbrauch von Strom aus PV Anlagen.

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AMI	Advanced Metering Infrastructure
A/S	Ancillary Service
CHF	Swiss Francs
DC	Direct Current
DES	Distributed Energy Storage
DoD	Depth of Discharge
DR	Demand Response
DRES	Distributed Renewable Energy Sources
DSO	Distribution System Operator
EV	Electric Vehicle
EVSE	Electric Vehicle Support Equipment
Hz	Hertz
IC	Internal Combusting
IEA	International Energy Agency
IRR	Internal Rate of Return
kWh	Kilowatt hour
MW	Megawatt
MWh	Megawatt hours
NEFZ	Neuer Europäischer Fahrzyklus
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid-Electric Vehicle
PV	Photovoltaic
PRL	Primary Regulation
RES	Renewable Energy Sources
ROI	Return on Investment
SOC	State of Charge
SRL	Secondary Regulation
TSO	Transmission System Operator
TRL	Tertiary Regulation
Wh	Watt hours
V2G	Vehicle-to-Grid

1. Introduction

1.1 Topic Description and Problem Definition

The automobile and power industry are undergoing a paradigm shift towards a more sustainable economy, driven by new environmental needs and a change of values in society. With the increasing scarcity and price of petroleum and the growing acceptance of global climate change as a critical environmental problem, policy makers, engineers and business leaders are searching for alternative energy solutions. The expansion of renewable energy sources (RES) is a main pillar to lower CO_2 emissions, however accompanied by challenges (Fournier et al., 2013). The two largest renewable energy sources likely to be widely installed in the near future, photovoltaic systems and wind turbines, are both intermittent. Applied at large scale they threaten the security of energy supply. The expansion of hydropower, to date the largest RES in Switzerland, is geographically limited and struggling with profitability issues (NZZ, 2016). As periodically volatile consumption meets weather-dependent production, the exact balancing of demand and supply is a complex challenge.
At low levels of penetration, the intermittency of RES can be handled by demand sided mechanisms such as demand response. However, as renewable energy from wind and solar power exceeds 10–30% of the total power supply, alternative sources are needed to match the fluctuating supply to the already fluctuating load (Kempton & Tomic, 2005). An additional threat to the power security are demand-sided fluctuations, caused by an increasing number of heating and mobile devices using electricity, such as heat pumps and electric vehicles (Battke & Schmidt, 2005). Matching demand and supply is one of the most critical issues in the transition to a low-carbon-emission energy supply system within the next decades.

Within a smart grid where electricity is consumed and stored intelligently, battery storage is an attractive solution to bridge intermittency and provide flexibility (Gordijn & Akkermanns, 2007). With the increasing electrification of the motorized transportation, powerful batteries of electric vehicles (EV) bring the opportunity to serve as short-term storage. In this context, the vehicle-to-grid (V2G) technology can be a key enabler to an intelligent integration of EVs into the grid. Commercializing the bidirectional charging solution creates synergies between the electricity and transport sector and follows the trend of an increasing amount of business models combining mobility with the electricity market (Engelken et al., 2016; Lund & Kempton, 2008). With the car battery as the connecting element, V2G systems 'kill two birds with one stone'. While the battery is used for storing energy produced by renewable power plants on-grid it's main purpose still is driving support off-grid. Using one battery for two applications, V2G has the potential to be a low cost way to provide electricity storage, thus making the use of renewable energy more practical on a large scale.
So far a handful of V2G pilot projects have been launched (Van der Kam & Van Sark, 2015; Kempton et al., 2008; BFE, 2007). Connecting the automobile to the grid not only brings opportunities, such as increased sustainability and power security, but also challenges.

Intelligent charging requires a completely new way of organizing the connection between the transport sector and the energy sector. While research has highlighted the technological challenges for the transition to low-carbon mobility in general, the vehicle and infrastructure design necessary for a V2G business model is still at issue (Sperling and Gordon, 2009). Even less attention has been given to the implications for business structure and organization. Scholars assume that innovative business models for sustainable mobility are diverse and context-dependent. However, with the absence of fully commercialized business models there is little understanding of their characteristics (Wells, 2010).

1.2 Objectives & Research Question

The main objective of this thesis is to suggest guidelines for a prototype business model embedding the V2G technology in the Swiss market environment. The best set of value proposition, value network and cost/revenue structure is proposed, given the technological state-of-art and considering the Swiss market environment.
For this purpose, three case studies are conducted. Evaluating profitability of the business model as a whole, the analysis focuses on identifying individual elements and structures suitable for the Swiss market environment.
Various interviews with representatives from potential value network members disclose the added value of a V2G business model for each stakeholder, the key success factors for implementing such a business model and best set of business model components. Thus, this Master thesis addresses a research gap in the area of sustainable energies by asking the following general research question as an orientation for this study:

RQ: What is the 'ideal' business model commercializing the vehicle-to-grid technology in the Swiss market environment.

This thesis aims to contribute towards theory and practice in the following ways:

(1) **Chapter 3:** What are system-wide benefits of V2G applications? What is the commercial value of energy services originated from V2G in Switzerland and who are parties interested in contributing to a V2G solution?
(2) **Chapter 4:** What are the main cost blocks and possible revenue sources? What do business models in foreign markets look like and how can they be adopted?
(3) **Chapter 6:** What are the challenges and success factors to offer V2G services profitable? What are business model components suitable for entering the Swiss market environment with a V2G services? What steps could a roadmap towards applying a V2G business model include?

1.3 Structure of the Thesis

The challenge of migrating from a theoretical V2G concept to actually integrating EVs into a power grid, lies the development of a viable framework. For this reason, this thesis starts with describing the real-world situation and then moves on to developing a suitable framework.

The thesis is structured into seven chapters, starting with an *Introduction*, which describes the current situation in the renewable energy and storage landscape. It outlines the theoretical and practical relevance of the research topic addressed in this thesis and identifies the research gap.

The chapter *Business Models within Sustainable Technologies* highlights the components of a business model and underpins the importance of cooperation for new business models in the energy business.

The next chapter *Motivation towards V2G and its Commercial Value* gives insight on the current understanding of V2G in literature. Firstly, it describes the system-wide benefits of V2G applications. Secondly, technical characteristics and socio-technical obstacles to the diffusion of V2G are presented. Thirdly the commercial value of V2G related services are discussed, followed by a detailed report on the motivation of potential partners for a cooperative business model.

The chapter *Business Cases* sheds light on possible ways to incorporate V2G into an existing business model. Business model components are assessed on their compatibility for the Swiss market environment. The evaluation includes an analysis of a business scenario on its profitability for each individual actor involved.

Following, the fourth chapter on the *Research Methodology* outlines the methodological path of the thesis. After the research design is described, the research process with the different phases of data selection, collection, analysis, and reporting is presented.

Subsequently, chapter six on the *Results* presents the findings of the interviews subsumed in a success factor framework including recommendations on the configuration of business model components and a roadmap towards introducing the V2G business model. Based on the main findings from the business cases and results from the interviews, the author suggests a ‘prototype’ business model.

The last chapter *Discussion and Conclusion* summarizes the findings of the study and highlights the theoretical contribution and practical implications of the thesis. Finally, concluding remarks follows a discussion on recommendations for further research projects.

2. Business Models within Sustainable Technologies

The flexible integration of EVs into the power grid and the emergence of businesses trying to seize this opportunity are destined to struggle with a problem particularly common with sustainable technologies. Despite being desirable for society, sustainable technologies still face difficulties in penetrating mainstream markets. One barrier relevant to new entrants and incumbents alike is the lack of market attractiveness (Johnson & Suskewicz, 2009). The benefit of avoiding environmental degradation is not a sufficient condition in itself to generate widespread customer acceptance. Therefore, it has been argued, that firms need an appropriate business model to create economic value beyond the positive impact on the environment. It is unclear, however, what the characteristics of an 'appropriate' business model are. In case of emerging technologies that business model is usually not yet apparent and requires a process of experimentation based on several alterations (Teece, 2010; Chesbrough, 2010). In this process a convergence of business models occurs, aligning the product to the customer needs and therefore creating legitimacy and customer acceptance for the emerging technology from all stakeholders (Aldrich & Fiol, 1994). With time successful business models often become, to some degree, 'shared' by multiple competitors. In this process, the V2G technology is still at an early stage of experimentation. It is also unsure if the V2G technology is the most efficient choice in providing grid services. However, this is not further discussed and could be the objective of another research project.

Proposing an adequate business model requires a holistic understanding what a business model consists of. In a broad sense, a business model describes the general way in which firms create and capture value. This generic view enables a categorization of various business model archetypes. One example of such an archetype is the razor-and- blade business model, dominating the printing industry. While the printing gadget serves as a shill and is sold at production costs, profits are made with high margins on ink cartridges. Within one archetypical business model, firms still have the choice to make unique choices and gain competitive advantage, implying a strategic perspective (Bohnsack et al., 2014).

On a more detailed level a business model consists of various components. Business model literature has not yet reached a common opinion as to which components exactly make up a business model. However, three key elements answering four questions appear on a regular basis: The value proposition, the value network and the cost/revenue structure (Bohnsack et al., 2014):

a. The **value proposition** answers the questions '*who is the target customer?*' and '*what is offered to the customer?*'. It reveals that the relationship between the firm and its customers is not built around a specific product or service, but rather by the exchange of values. Developing, a business model requires that the value that is exchanged should be critically assessed.
b. The **value network** answers the question '*how is the value proposition created and distributed?*'. The activities of a firm take place in a larger system. Various

stakeholders can be involved in the processes and activities along the configuration of the value creation. Together with the involved resources and capabilities these need to be orchestrated.

c. The **cost/revenue structure** answers the question '*why is the business model financially viable?'*. It contrasts revenue mechanisms with the cost structure and refers to the elementary question of the firm of how to make money. With a sound balance of cost and reward it provides feedback to the value creation and network.

The task most commonly attributed to the business model is that of explaining how the focal firm creates and captures value for itself and its various stakeholders within the ecosystem.

3. Motivation towards V2G and its Commercial Value in Switzerland

Before discussing the characteristics of a V2G business model in Switzerland, it is crucial to understand the potential of the technology and the local environment. In a first step, the author examines how bidirectional charging combined with mobile storage and the intelligence of a smart grid solves the issue of power insecurity caused by renewable energy sources. Secondly, the technical requirements of a V2G system are listed and socio-technological obstacles are highlighted. Then, the commercial potential of V2G services in Switzerland is estimated followed by the motivation of potential stakeholders to participate in a V2G business model that market.

3.1 Broader Strategic Context of V2G in Switzerland

3.1.1 Concept of V2G

The business opportunity of V2G originates from the increasing amount of fluctuating feed-in by renewable energy sources (RES). This problem can be solved from two ends. On the one side, increasing demand elasticity would help to align consumption to the ongoing generation. Demand response (DR) programs incentivize end-customers to postpone the consumption to a period of a higher availability of electricity, i.e. to a period with a lower price (Römer et. al, 2012). On the other side, security stock is activated when demand response programs reach their limits and the electricity supply is not able to meet the demand. For the first approach, a "smart grid" with advanced metering infrastructure is necessary, for the second approach decentralized electricity storage is considered to be the core enabler (Römer et. al, 2012). V2G incarnates both characteristics. Electric vehicles consume a large amount of electricity for driving support when compared to a household. With an intelligent charging process, considering the balance in the grid, EVs can enter demand response programs. However, as EVs can also store electricity and disperse it at a later point in time, they also qualify as mobile storage capacities. Within the context of this thesis, V2G is defined as a bidirectional charging technology, using the intelligence of the smart grid. In the light of an increasing amount of intermittent energy sources, the main objective of V2G is to create a market for cheap security stock and to balance the grid more efficiently (Lund & Kempton, 2008).

3.1.2 Decentralized Electricity Storage

Decentralized electricity storage (DES) stands in a complementary relationship with decentralized renewable energy sources (DRES). An increasing proportion of energy from DRES calls for more DES, balancing intermittent energy generation. With DRES being an important independent variable of DES, the currently growing desire to invest in DRES affects the penetration of DES positively (Rydén, 2015). Pepermans et al. (2005) list the three main drivers stimulating investments in DRES: the electricity market liberalization, environmental concerns and regulations and technological innovation.

Once DRES, most importantly solar and wind power plants, surpass 10-30% of the total electricity production, compensation power in the range of 30 to 40 percent of the average vertical grid load will be required to balance fluctuations. Tackling intermittency, such security stock can generally be managed either by backup or storage (Kempton & Tomić, 2005; BCG, 2011). “Backup” refers to generators that can be turned on to provide power when the renewable source is insufficient. The only large-scale backup sources in Switzerland are nuclear power plants and hydropower. Since Switzerland, alike Germany, has agreed to tread the path of a nuclear phase-out and hydropower is already widely skimmed, energy storage systems are the only viable source of low carbon electricity during periods of energy deficits (BFE, 2014). “Storage” can also be turned on in times of low power supply but additionally has the advantage of being able to absorb excess power. However, giving back power from storage devices is duration-limited (Kempton & Tomić, 2005). In Switzerland, the main type of storage currently being used, is centrally installed pumped hydro. Because the potential of expanding pumped hydro in Switzerland is seen as very small and geographically confined, it is necessary to foster the diffusion of other storage technologies, such as (lithium-ion) batteries (BFE, 2014). Until recently batteries were very expensive, but due to recent developments of electric cars the technology is becoming the most economical storage capacity (BCG, 2011).

Battery storage solutions differ by system-use: central or distributed storage and mobile or location-bound storage. V2G supports a system of mobile and distributed storage, using an EV battery as a storage capacity. The unique advantage of using EVs as a mobile storage is that they follow where people go. People move to city centers in the day, where the big load is located, and to residential places in the evening, which also mirrors the demand on the electricity network. Facing the integration of a growing number of RES, a network of mobile DES has a high value for society. The following benefits would be distributed among various stakeholders (Rydén, 2015; Pepermans et al., 2005; Sovacool & Hirsh, 2009):

(1) Serving as a security stock, DES allow an ***efficient integration of intermittent RES***.

(2) Even if pumped hydro will continue to be the leading storage technology in terms of installed capacity, car batteries will become increasingly important because of their ***flexibility and mobility***, especially in smaller, decentralized applications.

(3) V2G empowers EV owners to act as prosumers and earn money with their EV, thus ***reducing the cost of ownership***.

(4) ***Less energy loss*** from electricity transmission over long distances and transformation losses from high to low voltage grids. Well chosen distributed generation locations (i.e. close to the consumption) reduce electricity losses. The IEA (2011) reports average grid losses of 6.8% in the OECD countries. According to Dondi et al. (2002), cost savings of 10–15% can be achieved in this way.

(5) Even greater savings are made with ***avoiding grid expansion***. Electricity demand forecasts predict increasing demands of 23%-46% between 2007 and 2050 and peak load increases of 13%-67%. Infrastructure investments are determined by the capacity of the transmission grid, which depend greatly on peak loads. Distributed energy storage relieves network bottlenecks by reducing peak loads on transmission lines. According to the IEA (2011), this could result in cost savings in transmission and distribution of about 30% of electricity costs.

3.1.3 Smart Grid as an Enabler

The rising number of local devices connected to the low voltage grid producing, consuming and storing electricity drives the need for integration and control (Giordano & Fulli, 2012). Especially, the complementary character of storage capacities and renewable energy supply calls for an intelligent integration as the benefits can only fully be realized if they are managed jointly within a network. This bears new challenges for the transmission system operator (TSO) and distribution system operators (DSO). Swissgrid is the TSO in Switzerland, owner of the high-voltage grid and responsible for the security of energy supply. The DSO varies from region to region; within Switzerland there are around 800 companies. DSOs are sometimes utilities and responsible for distributing the electricity where it is needed (Swissgrid, 2015a). Many scholars believe, that the future distribution system of the TSO and DSOs will need to become more active and flexible. EVs with the capability of charging bidirectional are not only energy storage units but also controllable energy consumers within a grid system. To activate this potential the grid needs to get smarter and include a power management system by incentivizing energy consumption and allocating energy reserves where they are needed most. The solution is to apply a dose of computer power (Economist, 2009). Adding advanced metering infrastructure (AMI) to the distribution system, such as digital sensors and remote controls, increases information exchange and thus transparency among all involved players. In sum, a smart grid allows a more efficient coordination between power generation and power consumption (Römer at el., 2015).

In Germany electric power companies are legally obliged to install smart meters in new buildings since 2010 (Zheng et al., 2013). The EU directive 2006/32/EG demands an 80% market penetration of private households by 2020 and 100% by 2022. To date, the diffusion of these future smart grids' core components in Switzerland are low. In contrast to the EU, there is no legal obligation or political objective targeting the diffusion of smart meters. Due to the currently low energy prices the financial incentive to seek energy savings through smart metering is not sufficient to cause a larger diffusion (VES, 2015). However, with the increasing market penetration of EVs as large energy consumers, this might change. 'Smart Charging' pursues a controlled charging process considering current production patterns connected to the 'smart grid'. Adapting the consumption to the supply of distributed generation sources has its merits for the DSO as transmission lines do not need to be expanded but can also pose a threat. Increasing the consumption share of self-generated solar power within a micro-grid leads people on the path of autarchy. A pilot project on V2G, in Utrecht, Netherlands, managed to decrease demand peaks by 27–67% and increase RES self-consumption from 49% to 62–87% (van der Kam & van Sark, 2015). To sum up, an important advantage of EVs in smart grids is that they can be used both as a flexible demand source and as a storage option, enabled through smart uni-/bidirectional charging.

As the proportion of intermittent DRES increases, the fluctuations in the total supply also rise. The ability to accurately forecast the generation capacity – along with loads – would improve the efficiency. However, forecasting the state of such a complex system, with the vast number of dependencies and interdependencies, from weather to energy prices, calls for new levels of intelligence. Combining real-time information with predictive information further increases the value of the energy storage system (ABB, 2012).

3.2 Technical Characteristics and Socio-Technical Obstacles

From a technical perspective, the V2G technology is the centerpiece of a two-way charging system. Four elements are required: a connection to the grid, a communication synapsis with the service operator, a bidirectional charger and a precision on-board metering.

The communication synapsis allows the service operator to receive charging constraints and on-board data, such as lead-time and state of charge (SOC) from the vehicle. Further the logical connection requests the execution of ancillary services or other energy services and meters the results. Subject to external incentives, the service operator orders to charge, discharge or wait. (Palizban et al, 2015; Letendre & Kempton, 2002). After Guille (2009) the economic value of V2G lies in the flexibility provided to the client, which mirrors in the energy capacity and time. Statistics show that the normal driving time of a passenger vehicle is about 2 to 4 hours per day. This leaves 20 to 22 hours per day during which EVs can act as a distributed mobile storage units. However, it must be noted that this is an average and does not apply for rush hour where more than 10% of the cars are on the road. Operating under these rules, if each vehicle provided 15 kW, supplying 1 MW would require 67 vehicles available. To allow some vehicles being low on fuel or charge, being maintained, or being in use off hours, a rough multiplier of 1.5 can be used. Thus, a fleet of 100 vehicles, 15 kW each, should be able to bid 1 MW contracts during non-driving hours (Guille, 2009).

For charging, generally two options exist: AC- and DC-charging. All EV batteries operate with direct current (DC) whereas the electricity flowing through the grid is alternating current (AC). Consequently, a conversion has to take place when power is transferred between the grid and battery and vice versa. With DC charging stations, the AC-DC conversion takes place in the station itself, transmitting DC to the car. AC charging stations rely on the electric vehicle's on-board converter to convert the current. This has repercussions on the charging station's cost, weight and complexity of the communication protocol. AC Charging is generally used for slow and semi-fast charging at homes and offices and the majority of public recharging stations. DC charging supports higher power levels and is used for fast charging. There are charging stations of both types supporting bidirectional charging, with different advantages and disadvantages. Scholars still disagree on the best solution for V2G (Yilmaz & Krein, 2013).

The history of renewable energy technologies implies that socio-technical barriers may be just as important to the diffusion of V2G as technical barriers. The term 'socio-technical' refers to the more subtle impediments, relating to customer behavior in the light of economic uncertainties, cultural and social values, business practices and resistance to infrastructural changes (Sovacool & Hirsh, 2009). EVs in general face a significant first-cost hurdle and require a change of behavior, which serves as a disincentive. Customers sensitive to the economic value of electric vehicles may be discouraged by the number of variables they need to consider, such as the present value of fuel savings. The same holds true for uncertainties complicating the cost of ownership calculation, for example the income from V2G services to the grid. However, travel behavior indicates that within consumer choice 'hard' components such as costs or range can be overcompensated by deeper values such as comfort and mobility or product styling (Sherman, 1980). The change from an internal combusting vehicle to an EV poses a challenge as a majority of owners prefer to maintain their habits and any inconvenience regarding comfort, flexibility and mobility would need compensation:

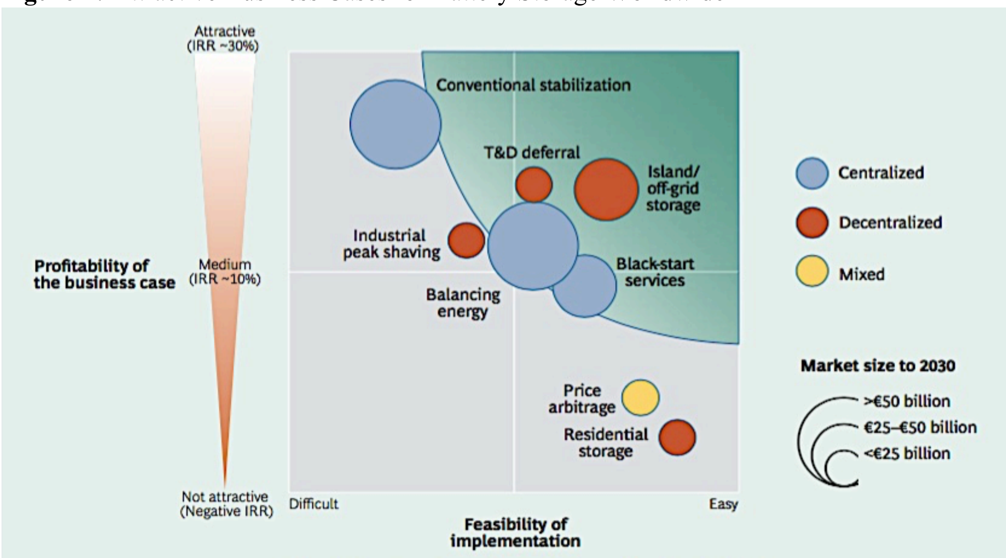
> *„A majority of owners preferred to recharge their cars during the day rather than at night. Also many drivers found it embarrassing to ask property managers for permission to recharge when needed. Several felt that interfaces were too complex, in some cases causing drivers to ignore fuel economy displays“ (*Sovacool & Hirsh, 2009, p. 1100)

The history and sociology of energy consumption suggests that while a few early adopters may assert their individualism, most consumers often remain impatient and close-minded about new energy technologies. While the potential benefits of a V2G transition remain significant, they may not accrue without bridging the social conflict (Kirsch, 2000). Measures that increase convenience, comfort and flexibility could help to overcompensate the renunciation of current habits. So, to win the acceptance of users, V2G needs to maintain the current behavior patterns or bring an improvement to them. All aspects of their operation must be transparent and simple - a goal that requires not only good engineering but also good knowledge of customer behavior and psychology (Sovacool & Hirsh, 2009). Subsumed, a successful integration of EVs into the energy system is directly influenced by the necessary mobility behavior for its adoption. The charging routines defined by the charging infrastructure and V2G charging software is therefore a relevant success factor.

3.3 Commercial Value of V2G Services in Switzerland

Energy storage business models that deliver multiple, stacked services provide system wide benefits. EVs with the capability of bidirectional charging are able to cover several application fields. Services from batteries reach from storage of self-generated solar energy over price arbitrage and peak power generation to ancillary services. However, not all services are profitable. Electricity from V2G, sold to the grid, is expensive when compared to bulk electricity from large power plants and therefore needs to find a well-compensated and suitable service. A preliminary evaluation of interesting markets for battery storage shows that A/S (conventional stabilization and balancing energy) shows the most profitable business cases (BCG, 2011; Kempton et al. 2008). An experimental run of price arbitrage, trading electricity on the spot market, resulted in a negative return on investment (Fournier et al., 2013). Thus, the following chapters focus on A/S.

Figure 1: Attractive Business Cases for Battery Storage Worldwide



Source: Bosten Consulting Group, 2011

3.3.1 Market Volume A/S

The client for ancillary services (A/S) in Switzerland is the Swiss TSO, Swissgrid. Due to low number of A/S providers in Switzerland, supply deals are contracted out in an open competitive bidding. A/S help Swissgrid to fulfill their main objective of national security of energy supply. Most people take constant availability of electricity for granted, but this must be designed in at an additional cost. For a stable system frequency of 50 Hz, the TSO needs to match generation and load on a constant basis. If the power plants from utilities fail to keep the electric tension of 50 Hz, ancillary services are called to action. A/S are in fact withheld power capacities from utilities, which are activated upon request and restore the balance in the grid. In Switzerland, ancillary services are roughly separated into primary, secondary and tertiary regulation (PRL, SRL and TRL). Each category has a different market volume (BFE, 2007; Fournier et al., 2013).

The A/S market consists of two elements – capacity withholding and regulation energy. Swissgrid pays each provider a price for withholding a power capacity to alter the balance of the grid, when needed (Fournier et al., 2013). For withholding capacity each MW is compensated with 3000 to 7000 CHF per week as illustrated in *Table 1*. However, this requires the capability of delivering 1 MW more and 1 MW less to the grid at all times upon request. With a total volume of around 950MW of positive and negative capacity, Swissgrid pays around 210 million CHF per year for regulation capacity (BFE, 2015). To date, hydro power plants provide A/S and the pricing for their capacity provision is based on opportunity cost (Swissgrid, 2016).

Table 1: Ancillary Services Prices

	Primary Reserves (only capacity)	Secondary Reserve (capacity & power)	Tertiary Reserve (capacity & power)
Prequalification	Minimum ±5 MW	Minimum ±5 MW	Minimum ±5 MW
Capactiy Demand (2016)	±71MW	±400 MW	+ 450MW, -300MW
Capacity Price	Pay-as-bid 156'000 - 364'000 CHF per MW (2016)	Pay-as-bid 156'000 - 364'000 CHF per MW (2016)	Pay-as-bid 156'000 - 364'000 CHF per MW (2016)
Positive Balancing Demand	-	192’000 MWh (2016)	111'000 MWh (2016)
Ø Positive Balancing Price	-	Spotprice + 20% 47,2 €/MWh (2016)	Pay-as-bid 66,3 €/MWh (2016)
Negative Balancing Demand	-	-139'000 MWh	- 83'000 MWh
Ø Negative Balancing Price	-	Spotprice - 20% 29,9 €/MWh (2016)	Pay-as-bid -41,8 €/MWh (2016)

Source: Own illustration of A/S prices based on Chacko, 2017 and Fournier et al., 2013

Regulation energy is the second source of income, generated through the lucrative sales/purchase of energy, when capacities are activated. Swissgrid differs between positive and negative balancing energy. If load exceeds generation the frequency and voltage in the grid will drop. The TSO will then execute a signal to providers of A/S requesting to put more energy on the grid (*positive regulation*). When generation exceeds load and frequency increases, the TSO requests to reduce generation or absorb electricity (*negative regulation*). For secondary regulation, energy is sold 20% above, and bought 20% below the current spot price. Tertiary reserves energy is compensated as bided (pay-as-bid). Total energy sold to the

TSO was estimated at 10 million CHF in 2016. The total market for secondary and tertiary reserves is estimated at 221 million CHF (Fournier et al., 2013; Swissgrid, 2016).

As shown in *Table 1*, to participate in the A/S market, a prequalification size of 5MW capacity needs to be guaranteed towards the TSO. It is a challenge to define the necessary number of cars to meet this requirement. Assuming that 50% of a car pool and each with an 11kW power connection are available, at least 450 cars would be necessary. However, not all cars qualify to charge/discharge at this rate, as *Table 2* shows. Every car manufacturer follows a different charging station strategy. While the Japanese car brands built in on-board chargers with a low power conversion, European and American cars tend to have more powerful on-board chargers (Pan & Zhang, 2016).

Table 2: Some EVs, their Range and Charging Options

Model	AC charger (phases/kW)	Energy storage (kWh)	Approximate Range (km)	Off-board charging option
Renault ZOE	3/43	41	400 (NEFZ)	No
VW Golf-e	1/7,2	35	300 (NEFZ)	Yes (CCS)
Opel Ampera-e	1/7,2	60	520 (NEFZ)	Yes (CCS)
Tesla Model S	3/22	85	480 (Tesla)	Yes (Tesla)
BMW i3	1/11	30	300 (NEFZ)	Yes (CCS)
Nissan Leaf 2013	1/6,6	30	250 (NEFZ)	Yes (CHAdeMO)
Mitsubishi i-MiEV	1/3,3	16	100 (EPA)	Yes (CHAdeMO)

Source: Own illustration according to Pan & Zhang (2016)

3.3.2 Cost Structure A/S

The reason why car batteries have the potential for being a cheap energy storage unit lies in the cost structure. The cost structure can generally be divided into three subgroups: capital costs, infrastructure costs, and operating costs. The cost structure of a utility operating a hydropower plant and consists essentially of the capital costs bound to the construction of the site. Operational costs are relatively low. (NZZ, 2016) With this cost structure a hydro power plant always strives for the highest degree of capacity utilization possible. Every production capacity withheld, equals lost earnings because marginal costs of every unit produced are close to zero. Hydropower plants need to be in operation at all times in order to deliver positive or negative regulation energy. In order to rise or lower the energy level in the grid upon request, they mustn’t reach their full capacity or their minimum capacity. This implies opportunity costs to the amount of the withheld generation capacity times the price for the electricity. Thus, the withheld capacity equals the cost of opportunity.

The cost structure of a system of EV batteries and bidirectional chargers differs greatly. Because the car battery serves primarily mobility needs and secondarily to store energy, capital costs are low as no investment into a battery needs to be made. With the battery as a storage capacity and not a production unit, the costs of opportunity are zero, as the battery would be unproductive if not used for A/S. Thus, the proportion of capital costs is much smaller, implying a smaller urge for capacity utilization. Infrastructure costs for bidirectional charging units, telematics and measuring instruments are hard to estimate as they vary and only few suppliers exist, as this is a young market (Fournier et al., 2013). The investment sum into the infrastructure can decide about the feasibility of the business case. Operational costs consist of reimbursement of the EV owner for providing capacity and compensation of all costs using V2G. Battery degradation is the largest variable cost driver controversially discussed among scholars. The depth of discharge (DoD) and frequent switching of the state of charge (SOC) both cause a decrease in battery storage capacity. However, the battery degradation through V2G is much lower than through driving support. The percent capacity lost per normalized Wh is $-6.0x10^{-3}$ % for driving support and $-2.70x10^{-3}$ % for V2G support. These values show that several thousand driving/V2G driving cycles incur substantially less than 10% capacity loss regardless of the amount of V2G support used. More important for the battery degradation is the DoD. With a DoD of 80% instead of 100%, EV batteries triple their lifetime (Peterson, 2010; Briones et al., 2012). While short discharging has little effect on battery life, deeper cycles of charge and discharge have an over-proportional effect. Hence, V2G does influence battery degradation, but there are ways to manage the costs related to it. Stopping drawing current when the SOC reaches 85%-90% can optimize battery life (Guille, 2007). It must be noted that battery degradation costs incur only when feed energy back into the grid.

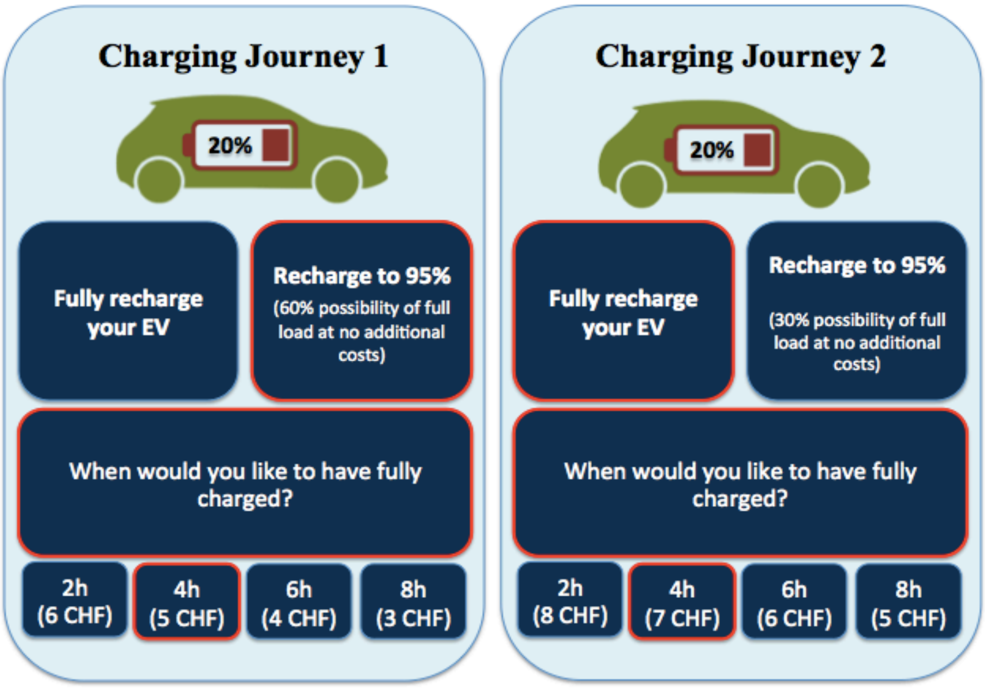
3.3.3 Value Proposition A/S

Central to the viability of a V2G business case focusing on A/S, is the management of needs of the two parties - the driver and the service operator/grid operator. The driver needs enough stored electricity in the battery for driving support and wants a convenient charging solution. Any loss of driving range, freedom and flexibility or inconvenience regarding comfort would need compensation. However, any improvement to the current charging situation could be sold for a price premium (Sovacool & Hirsh, 2009). The service operator wants to maximize the flexibility value of the available battery capacity to feed in energy or draw out energy at all times. For this purpose batteries are best suited for grid services, when not fully charged or empty. The longer the battery is connected to the grid the larger, the value per customer. With these restrictions, different charging strategies are possible to align the needs of the two parties (Kempton & Tomic, 2005). In general, the solution can include a monetary incentive or it can be of another nature (Fournier et al., 2013):

Approach Charging Discount (Hill et al., 2012; Letendre & Kempton, 2002)

This approach combines the V2G application with a conventional charging station and steers the EV charging behavior with a monetary incentive. Two factors stimulated by remuneration could be the charging duration and the capacity withheld for positive regulation energy: the longer the charging period for completing the charging objective, the cheaper the electricity per kWh; the closer the charging objective is to 95%, the cheaper the electricity per kWh. To avoid consumer confusion, the customer should only be confronted with as few input factors as possible. *Figure 2* shows an example how a charging journey could look like using V2G.

Figure 2: Generic Charging Journeys



Source: Own illustration based on Letendre and Kempton (2002)

The customer can simply choose the load objective he wishes and the time he wishes the battery to have completed that load objective. The sooner the objective needs to be accomplished, the lower the flexibility value and subsequently the higher the price. Putting a penalty on full charges but giving the customer the possibility of a free top up from 95% to 100%, is an attempt to reimburse for the lost range capacity. These monetary incentives motivate the EV owner to connect the battery for a longer period to the grid and channel the decisions of the EV users to choose a 95% recharge, leaving capacity for negative reserve energy. The price includes a discount, accounting for the costs of battery degradation.

Approach Infrastructure (Briones et al. 2012; McKinsey, 2014; BFE, 2007)
As a EVs needs to be connected to the grid to deliver V2G services, it is seems likely to integrate a V2G solution into an existing charging infrastructure. Apart from monetary incentives, an adequate charging infrastructure can tackle obstacles to the diffusion of V2G services. Intelligent charging strategies can only be offered if a car can be parked for a longer period. Offering value-adding infrastructure to support longer charging periods at the right locations is a way to enable V2G. There are three technical differences between charging electric cars and refueling internal combusting (IC) cars that change behavior significantly;

the charging speed, the ubiquity of electricity and the charging frequency. Especially the time a customer needs to wait to regain full capacity pressures charging infrastructure operators to search for new concepts where the customer doesn't perceive longer charging periods as lost time. The following infrastructure solutions are examined for their suitability for V2G services:

Residential charging is to-date the charging preference number one of the EV drivers. No waiting period is necessary, as EV owners usually charge their vehicle overnight (Smart et al. 2010). Thus, the vast majority of the charging takes place from approximately 6 p.m. to 6 a.m.

Superchargers represent the analog of the petrol filling station. Fast charging offers the possibility of recharging the battery in less than ½ hour and is located at main road intersections and highways. With level 3 charging, feeding power back into the grid conflicts with the basic premise of minimizing connection time and absorbing substantial amount of energy as quickly as possible. Thus, superchargers are not suitable for V2G.

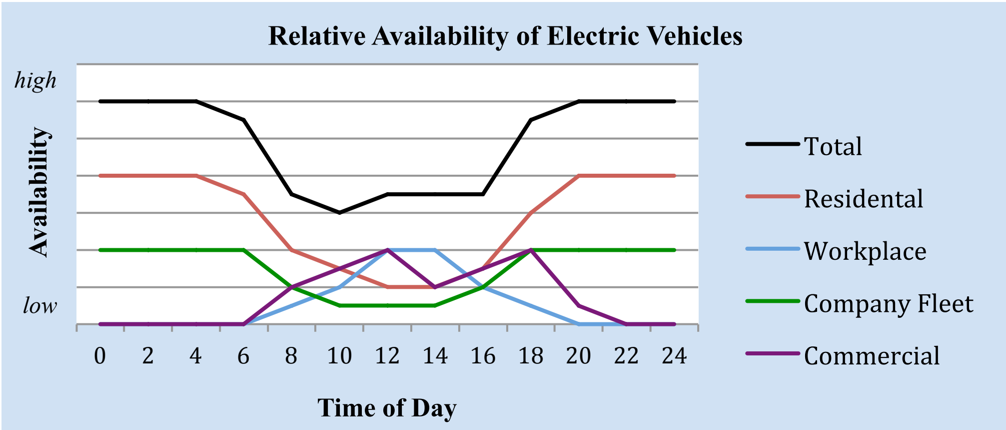
Workplace charging is a means for employers to provide amenities for employees to encourage loyalty. Because the average distance traveled to work by car in Switzerland is only just over 25 km, the vehicle battery is likely to still be at a high SOC when arriving at work and could be restored to full charge quickly (BFS, 2014). Thus, workplace charging is likely to only recharge small amounts of energy with the car connected for a long period. This would allow offering the batteries for energy service during a long period before the users return home.

Company fleet charging is similar to workplace charging in that it occurs at the place of work. However, the charging stations are owned by the company and are considered supporting systems that enable their business processes. It is not likely that a fleet owner would leave a substantial quantity of fleet vehicles connected during the work day. However, it is very likely that these parked vehicles would be available for V2G services on the non-business hours and weekends. When looking at fleets, *car-sharing* operators are also particularly interesting option for V2G. With the fleet connected to the grid, car-sharing operators could generate revenue at all times, when the cars are used and when they are parked. This increases profitability and decreases the importance of capacity utilization of their cars.

Commercial charging will be installed in locations where EV users will stay long enough to allow their vehicles to complete a significant portion of the charge. These venues may include restaurants, theaters, shopping malls, airports, doctor/lawyer/dental offices, and so forth.

To sum up, V2G charging infrastructure of the future will focus on level 2 charging infrastructure in private and public facilities of residential areas and working places (Yilmaz & Krein, 2013). But also fleet charging and commercial charging have their benefits. Each segment shows different periods of availability to the V2G use. To provide a smoothed level of battery power for grid services, residential charging and company fleet charging can be combined. Other combinations are workplace charging and commercial charging or work-place charging and company fleet charging.

Figure 3: Relative Availability of Electric Cars



Source: Own illustration based on BFE (2007)

3.4 Interested Stakeholders

Load management and storage are opportunities frequently mentioned in the renewable energy sector. V2G combines a mobile storage system with a smart grid solution, two applications unlikely to successfully commercialize without cooperation. Because challenges of energy solutions enabled through V2G are distributed among various industries, a business model may only be realized when offered jointly by cooperating partners (Engelken et al., 2016). The grid integration of EVs could offer interesting opportunities for automobile manufacturers, utilities, charging station manufacturers, individual EV owners, EV fleet owners, service providers such as car sharing operators, and new market entrants, possibly from the IT-sector (Fournier et al., 2013).

3.4.1 Utility

The electric utility has two primary objectives: to reliably supply electricity to its customers and to operate profitable for its stockholders. Facing climate change, utilities are also called on to provide "cleaner" power through production of renewable energy. These goals intersect with the need for a cost effective management of loads and energy storage. Participating in a V2G business model the advantages would be threefold (Briones et al, 2012):

(1) *Renewable Energy Storage*: The lack of cost-effective storage capacities is seen as one of the obstacles to the wider diffusion of renewable energy. Because the energy supply of intermittent RES might not coincide with the daily peak usage, this would lead to low wholesale prices for renewables in times of excess generation. This jeopardizes the investment return on energy from RES. Using EV batteries for bidirectional smart

charging helps utilities to optimize sales from electricity production, preventing the selling of electricity to low prices due to overloaded markets.

(2) *Complementing A/S portfolio*: V2G is an alternative to capital-intensive revenue sources fulfilling ancillary services. The ability to activate distributed storage, along with demand response (DR) mechanisms, provides a cost-effective alternative to expensive and capital-intensive spinning generators. The very need to build peaking plants could potentially be avoided, thereby saving millions of dollars in deferred infrastructure spending.

(3) *Customer Loyalty*: Utilities typically respond with innovation when driven by economic impacts or regulatory mandates. The increasingly decentralized energy generation of prosumers affects the revenue negatively. Using EVs for energy services and sharing the profits could increase customer loyalty in a soon to be liberalized market.

3.4.2 DSO

DSOs are responsible for distributing the energy within a local grid. The increasing volatility of the electricity demand due to a growing number of gadgets consuming electricity, calls for more balancing mechanisms. The intermittent nature of RES might not coincide with the daily peak usage, might destabilize the electrical grid. To avoid costly grid expansions DSOs need a load management system with an intelligent distribution mechanism (Briones et al, 2012).

3.4.3 Aggregator Service Provider

Utilities and DSOs have naturally a great interest in the V2G solution but may not wish to do business with thousands of small providers of battery storage. In this case, it will be the task of an independent third party with expertise in communication networks and customer application deployment to aggregate small storage capacities into MW blocks and steer the charging process of each EV within this virtual power plant. The consideration of multiple factors is necessary to maximize the flexibility value but at the same time guarantee individual mobility needs: a minimum available storage capacity, the scheduled departure time, SOC of the vehicles, electricity rates and market signals. Possible clients could be the utility, the regional DSO, the TSO or the end-customer of electricity. Given the tasks, the aggregator is most probably a player from the IT sector. The core value of the aggregator is a system with sophisticated communication, an algorithm and a messaging protocol. AMI would allow the aggregator to control the electricity flow automatically or manually in harmony with generation and demand. It ensures that the energy transfer to and from the EV batteries can be programmatically controlled and optimized by both the vehicle owner and the grid operator. The SOC and owner preferences for timing and level of minimum SOC are communicated to the aggregator for control strategy decisions for all vehicles participating in the V2G system. The aggregator provides a single point of contact not only for the client but also for cooperating partners (Briones et al, 2012; Letendre & Kempton, 2002).

3.4.4 Vehicle Manufacturer

Vehicle manufacturers participate in a highly competitive market. The electrification of the automobile has begun to negatively affect the after sales revenues of automobile manufacturers. Entering the energy industry could be a way to compensate for lost revenue. A bidirectional port enabling V2G services can become an attractive quality of an EV contributing to the value of the car. On the contrary, additional charge and discharge cycles caused by V2G reduce the battery lifetime and could increase automotive warranty costs, conflicting with the interest of a vehicle manufacturer (Briones et al, 2012).

3.4.5 Individual EV Owner

In a V2G system, the vehicle owner or fleet manager becomes both a consumer and seller of electrical energy and capacity. Because the vehicle owner controls the source of the V2G capability, he is in a position to demand benefits from it. EV owners will be motivated by a combination of benefits. For the general, consumer monetary benefits and other superior charging conditions would trigger the interest of EV owner. Together with increased convenience due to superior charging conditions, they must be weighted against negative effects on battery longevity and warranty, impact on vehicle availability and user-friendliness. Assuming a 10kW bidirectional charger, and a EV available for V2G services 12 hours a day on average, the revenue r accumulated over one month is 10kW x (12hr x 30days) x 0.029CHF/kWh = 104 CHF as a capacity price only. Over the course of an year, this vehicle would generate a revenue of 1'248 CHF. This is a considerable amount of money generated just by having a car parked and plugged in (Briones et al, 2012).

3.4.6 EV Fleet Owner

Vehicle-to-grid (V2G) opportunities may present additional revenue for fleets by providing ancillary services, analog to individual EV owner. A fleet owner could consider V2G as an additional revenue source, but would need to understand the risk of the investment and how it would affect the core business. The fleet vehicles are in use mostly during the day and are parked after working hours (Briones et al, 2012).

3.4.7 EVSE Supplier

The electric vehicle support equipment (EVSE) supplier provides the hardware for the connection between the vehicle's battery and the grid. The EVSE and vehicle must be designed for this bi-directional flow and provide for the communications flow paths to allow the access and control of both the charge and discharge of the vehicle battery. With this charging equipment being more expensive than unidirectional equipment, V2G can be seen as an upselling of their products (Briones et al, 2012).

4. Business Cases

Now that the key components of a business model have been explained, the technical characteristics and socio-technical obstacles have been identified and the commercial value and stakeholders have been presented, it is essential to develop a conceptual framework to bring the V2G vision to reality. To benefit from the potential identified, players from different industries need to identify a self-sustaining business model embedding the V2G technology. This chapter is devoted to proposing three different frameworks by means of three case studies. While doing this, it is a necessity to define rights and duties of each player in a value network, as widely distributed benefits cause situations of positive externalities and lead to the omission of a socially desirable deployment of the examined technologies (Römer et al., 2012). After describing the business model, each case scenario explains the exchange of values and challanges. Finally, the business case is examined from an economic viewpoint. The cost and revenue structure is analyzed for room of improvement. Value exchanges between different actors are viewed as financial flows and subsequently summarized and analyzed by means of spreadsheet techniques. The financial analysis focuses on the question, whether a chosen business scenario is profitable for each individual actor involved.

4.1 Case Study A: We Drive Solar

The current mobility paradigm, based on individual and fossil fueled mobility, is challenged by a variety of drivers. Social drivers like "collaborative consumption" where participants share access to product or services, create the need for innovative mobility solutions (Fournier et al., 2013). When used for car sharing, EVs are regularly stationed at the charging station, making them suitable for grid services (van der Kam & van Sark, 2015). Combining an electric car-sharing concept with V2G creates synergies, as they are mutually beneficial.

4.1.1 Case Introduction

'We Drive Solar' is an electric car-sharing company in the district of Lombok, a neighborhood in Utrecht, the Netherlands. The main business idea is to offer electric car sharing powered with energy from locally installed photovoltaic (PV) modules. As a means of storage, the EVs are used as a way to increase the amount of self-generated energy in the region and optimize the stress on the low voltage grid and national grid. Charging their vehicles intelligently according the stress on the grid, We Drive Solar generates additional sources of income. Trading energy loads on local and national energy markets, the business model enables to postpone charging according to the need of the local and national grid needs. The DSO and TSO compensate these services accordingly. However, it must be noted that We Drive Solar does not yet feed electricity back into the grid, as the EV fleet is not yet capable due to technical limitations (Renault ZOE). Nevertheless, the business case shows how the existing business model can be extended to offering bidirectional charging and highlights what additional benefits and challenges bidirectional charging offers. As the smart charging processes are embedded into an existing business model, one premise is key to the business model. The main priority lies in the service to the customer's mobility preferences and the smart charging processes should interfere with these priorities as little as possible. Thus, the fleet owner needs to understand the risk of the investment financially and how it will affect the core of the business.

Value Proposition

'We Drive Solar' offers electric car sharing powered by solar energy produced in the region of Utrecht. The main objective of embedding a smart charging network into an electric car sharing business model is to increase its profitability without compromising the value of the core business. Offering energy services when the car is connected to the grid, car-sharing operators can generate revenue at all times, when the cars are used and when they are parked. This increases profitability and decreases the importance of capacity utilization of their cars. The core business model focuses on customers described as heavy user in the car-sharing industry. There is a limit of 6 persons with access to a particular car, which guarantees higher availability of cars to all members living in the region. As the 6 users are mutually responsible for cleaning and regular upkeep of the vehicle they share a closer relationship. Accordingly the price range of 99€/max.2500km to 196€/max.5000km per month is more expensive than fellow companies offer their service.

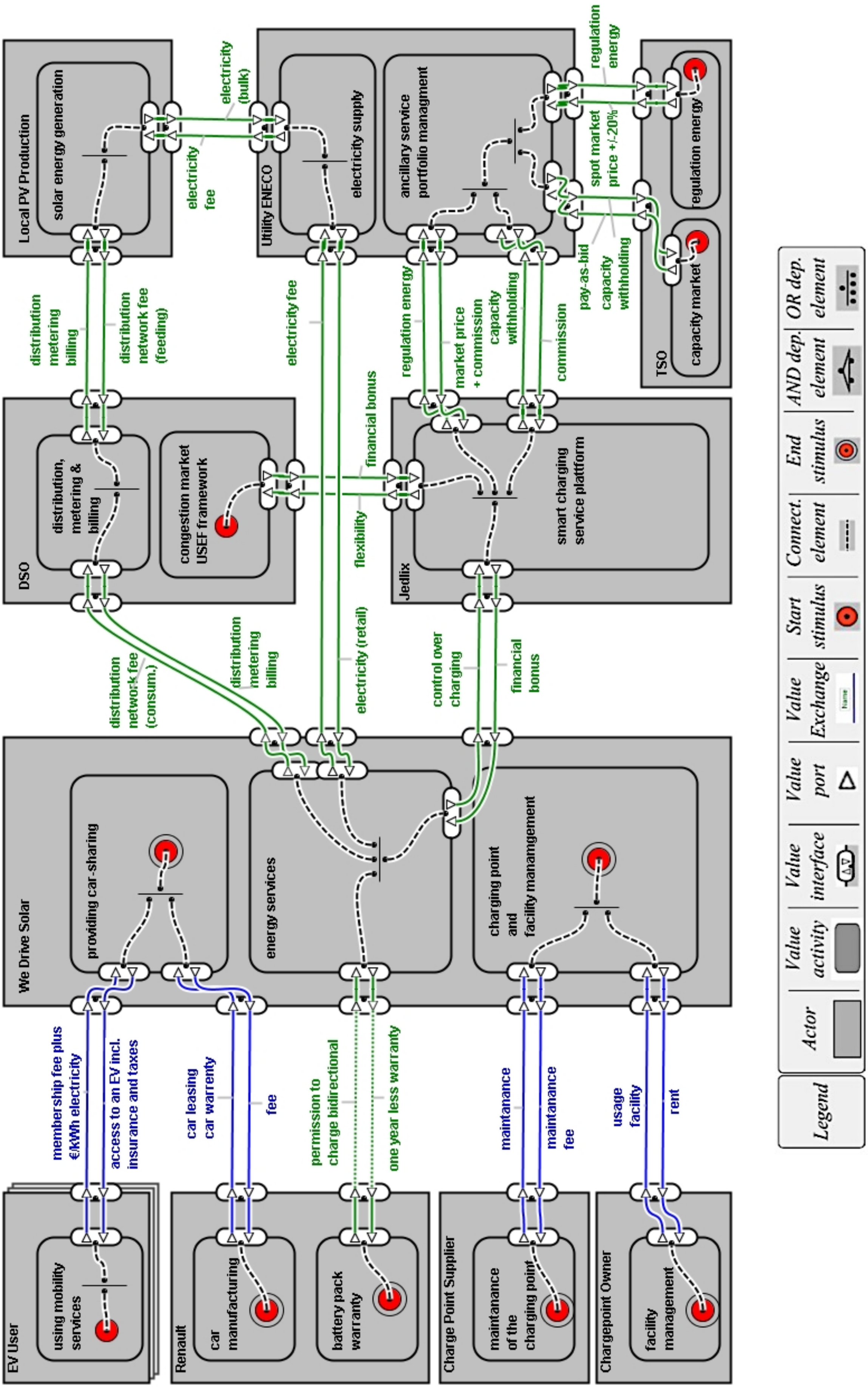
Value Network

The core business of car-sharing requires partnerships with car manufacturers, facility owners, and charge point suppliers. To guarantee solar power supply, a cooperation with a local solar energy producer and utility is required. The second part of the business model, consists of the smart charging value network. An aggregator/service provider is contracted for the purpose of coordinating the charging processes. To offer the best possible terms for recharging the car fleet, the service provider trades flexibility on different energy market. He bids flexibility into an experimental DSO congestion market, balancing the local grid. On a national level the service provider sells flexibility to utilities holding an A/S portfolio, themselves selling to the TSO.

Cost/Revenue Structure

Acting as a unidirectional charging system of load control, the cost structure of We Drive Solar consists of no additional costs. However, this changes when expanding the business model to bidirectional charging with fixed and variable costs. The cost structure of the service provider consists of the R&D of the smart charging software and all licenses to accesses the energy markets. The charge point owner needs to invest into additional EVSE hardware capable of bidirectional charging. In return both parties participates on the compensation received for the flexibility provided to the markets.

Figure 4: Networked Business Model - 'We Drive Solar'



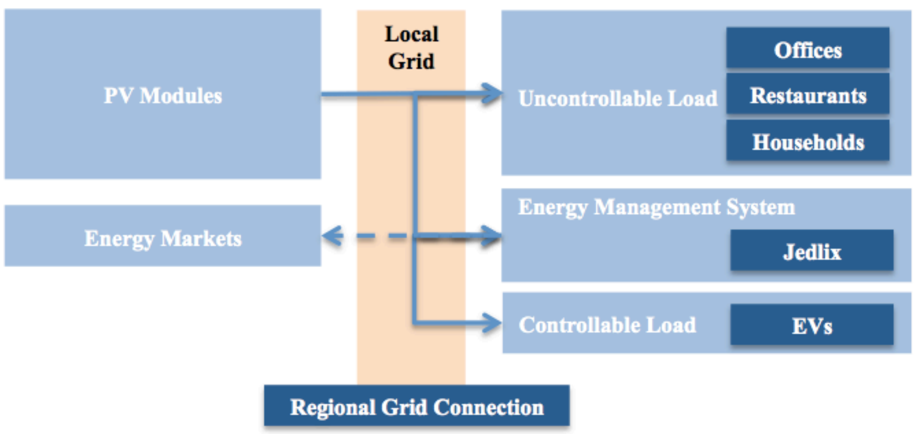
Source: Own illustration based on van Heesbeen (Interview, 2017) and van der Woude (Interview, 2017)

4.1.2 Business Scenario

The business idea involves an electric car-sharing platform and a simultaneously running 'virtual power plant' containing the aggregate of all EVs in stand-by mode. While We Drive Solar focuses on the service quality of the car-sharing platform, Jedlix, a smart charging provider, coordinates the virtual power plant. The conceptual idea of the virtual power plant is embodied in the creation of a package deal. This package deal has two parts: (1) it guarantees the recharging of all EVs. 'We Drive Solar' communicates charging conditions, such as minimum SOC to ensure satisfied customers at the beginning of a journey. These represent the boundaries for the smart charging provider he must never breach when trading flexibility in the energy markets. (2) Apart from these charging conditions, Jedlix has the flexibility to offer the battery packs for grid services as he pleases. The flexibility increases with the time and size of the energy capacities available for trade. "We Drive Solar" and Jedlix participate in form of a financial bonus for providing flexibility to the grid.

The local grid environment, in which Jedlix trades flexibility, has six main components: the PV modules, the uncontrollable load, the controllable load, the energy management system, the local grid and the connection to the energy markets. The demand from the uncontrollable load needs to be met at all times and can fluctuate during day and night. The solar power from PV units covers both, the uncontrollable and the controllable load. If no solar power is generated at night, the electricity comes from an external source via the regional grid connection. The way the local grids are built and buried into the ground, they can only transmit a certain load of energy. During a period of high power demand from the uncontrollable load, EV charging can be postponed to avoid local grid congestion. During a period of excess solar energy production the EVs can absorb the electricity to avoid an overload. The flexibility of the charging function relieves the grid from stress and avoids a collapse. A collapse is expensive for the local DSO to repair.

Figure 5: Local Grid Environment



Source: Own illustration based on van Heesbeen (Interview, 2017)

Jedlix trades flexibility in two energy markets simultaneously: an experimental DSO congestion market and the energy imbalance market connected to the A/S market. The DSO congestion market overlooks the local grid capacity utilization and sends a request towards all market players. Players like Jedlix can then bid in flexibility towards the DSO and are rewarded accordingly. The steering is done through a universal smart energy framework (USEF, www.usef.energy). Simultaneously, the energy is sold on the energy wholesale market. The balancing responsible party, in this case Eneco Energy Trade, offers a gateway to trade energy on the intraday market and the imbalance market, which is related to the A/S market. On the imbalance market, utilities can buy regulation energy to complement their A/S portfolio. Thus, Jedlix does not have a direct connection to the TSO but the way they steer the power in the EVs, indeed helps the portfolio owner to lower costs providing A/S. The reason for not being connected to the TSO directly is not about the minimum power threshold but more about efficiency. The balancing responsible party has usually already met all TSO preconditions, such as a 24/7 help service, to a considarable cost. So it's more efficient to build upon parties already providing A/S.
When the EV is reconnected to the charging station after a journey, the car is blocked for recharging ½ hour before the next user can use it. This measure aims at guaranteeing a SOC minimum of 33% (100km) as a fair play rule and to ensure customer satisfaction at the beginning of a trip. According to van Heesbeen (2017), chief business developer at Jedlix, this is would ensure that at least 90% of all customers could drive the vehicle without recharging at a public charging station. Thus, the charging restrictions implies no flexibility untill 33% of the battery capacity is reached. Jedlix cannot arrage for superior charging conditions and no financial bonus is paid out. As illustrated with this example maximizing value for the users and energy markets at the same time can conflict. Once the battery reach a load of 33%, Jedlix has full flexiblity over the EV's battery packs and can sell charging flexibility on the DSO congestion market and imbalance market. We Drive Solar receives a bonus payment for providing the EVs holding the capacity. The balancing responsible party sells the aggregate of EV battery flexibility bought from Jedlix as a part of a larger A/S portfolio to the TSO. Now two scenarios are possible: (1) The TSO does not request any regulation energy. Jedlix shares the bonus payment for withholding negative capacity with We Drive Solar. (2) In the case of excess energy production, an additional bonus payment is paid. All bonus payments are apart from the electricity bill. Therefore We Drive Solar pays the utility according to their tariff model. In the near future, the Renault ZOE will be able to feed back energy to the grid and offer the possibility of positive regulation. The bidirectional port is already in development and and will be introduced within the next 1 – 3 years.
The electricity to recharge the cars is generated from 4000 locally installed PV modules owned by LomboXnet. In cooperation with the utility Eneco the electricity is used to charge the EVs. This is understood virtually, as electricity always takes the shortest exit and the solar panels are not directly connected to the charging stations but to the local grid. In the

Netherlands the utility can be chosen freely since the energy retail market has been liberalized for individuals as well as for companies. The local DSO is paid a metering, a billing and a network distribution fee for all electricity running through a public grid.

Renault-Nissan enterprise provides We Drive Solar with electric cars. The leasing contract involves the possibility of obtaining the Renault ZOE with a NEFZ range of 400km (realistic range: 300 km). A leasing fee is paid for the car as well as for the battery pack. The warranty for the battery packs is set at 8 years. According to the Nissan-Renault enterprise the warranty period for bidirectional charging is 1 year less as the battery degrades faster.

With a Renault ZOE fleet, Jedlix has only been able to trade with negative flexibility in the grid so far. However, the transition to bidirectional charging can be done smoothly as Renault is developing the next ZOE generation with V2G technology. All currently installed AC charging stations are yet capable to process bidirectional charging. All value exchanges in drawn in blue in *Figure 4* are part of the core business model and not taken into account for the calculations of the V2G business model, as they need to be self-sustainable.

4.1.3 Business Analysis

The following section analyses the added value of the smart charging network within the concept of electric car-sharing. Thus, the car-sharing platform offering mobility services is not part of the analysis.

Table 3: Pros and Cons of the Business Model – We Drive Solar

Car-Sharing Provider	**(1) Additional income stream** with cars in stand-by mode increases profitability and takes pressure off the main KPI; capacity utilitzation of cars.
DSO & Smart Charging Provider	**(2) DSOs with a balanced grid** – at a lower cost than putting new cables into the ground. The smart charging provider has an **additional income stream next to providing A/S.**
Smart Charging Provider & A/S Portfolio Manager	**(3) Third party model for accessing A/S market is a win-win situation for both parties;** cooperation allows Jedlix to offer flexibility at low fixed costs and the A/S portfolio owner has a new source of flexibility at low marginal costs.
Smart Charging Provider & EVSE provider	**(4)** AC charging stations enable **three step approach**: a smooth transition to bidirectional charging in the future.
Users	**(5) User-friendly solution** as users are not confronted with the complexity of the charging process and do not need to deal with a utility.
Smart Charging Provider	**(6) Limited scalability of the business model –** Limited number of car-sharing fleets limits potential of scaling and breaking-even.
Car Sharing Provider	**(7) We Drive Solar pays network distribution tariffs** when drawing and feeding energy into the grid. This marginalizes the profit on grid services.

Source: Case study analysis

Unidirectional smart charging allows We Drive Solar to generate additional sources of revenue when the EV is not used for mobility services. This increases the overall profitability of the business model. To which extend V2G can contribute to a successful income statement depends on how the conflict of battery capacity is handled. A compromise needs to be found between maximizing the profits from deploying the battery for energy services and maximizing range capacity to serve the mobility needs of the users best. The following trade-off applies: the higher the target SOC for the customer at the beginning of the journey, the larger the range freedom for the customer but the lower the flexibility provided in the DSO congestion market and imbalance market.

DSOs have a more balanced grid, getting rid of all the solar energy during the day they could not manage otherwise. During the night, they have less stress because the majority of the EVs have already charged.

Only providing negative regulation through unidirectional smart charging and not reaching the minimum threshold of 5MW supply power, Jedlix does not meet the requirements to bid in flexibility towards the TSO directly. To partner with an existing utility with an existing A/S portfolio brings a win-win deal. Jedlix shares the profit with the utility and the utility comes up for the costs meeting the preconditions set by the TSO. This increases the efficiency of both partners.

In the case of bidirectional charging the business case is even more interesting for the utility as he no longer needs to withhold production capacity, as he can take over the part of negative regulation and putting in charge Jedlix of the positive regulation. Running a power plant at full capacity the opportunity costs are significantly lower. The main cost would then be the infrastructure and manpower to meet the preconditions of the TSO.

Operating a centrally managed fleet a car-sharing company needs to bear the cost of maintenance and fuel usage. Since it has been observed that users tend to have a 'low value' relationship with electricity and utilities, it would require a culture shift and an increase in perceived value of the utility–consumer relationship for users to actively interact with the utility (Hill et al., 2012). This can be completely avoided in this business case as only the fleet manager is confronted with such players. In addition, there are questions about the amortization of the additional infrastructure costs. Individual car owners are unlikely to tolerate added risk, whereas fleet managers may be able to tolerate this additional risk in exchange for a higher profitability.

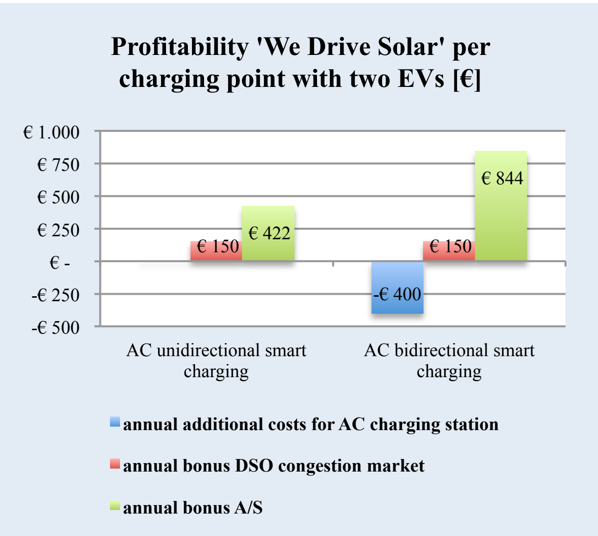
A weak point in this business case concerns the network distribution tariff. Every time an EV draws or releases energy into the grid, a network distribution fee needs to be paid. Jedlix and We Drive Solar, both trying to benefit from providing flexibility to the grid basically get penalized for doing so. This marginalizes the profitability of the business case for both parties. The DSO however only sees benefits. He saves money as he avoids putting more cables into the ground and on top of that increases the revenue from network distribution fees.

Base-case

Business actors can assign values to all relevant variables (price, information, cost reduction etc.). The following profitability assessment of the so-called 'base-case' business scenario is based on the assumptions listed below. Most of the assumptions are based on statements made from company representatives involved in the business case. Transcripts can be review in the Appendix. If the interview partner did not reveal information needed for calculations, literature and Internet research are sources were sources of inspiration.

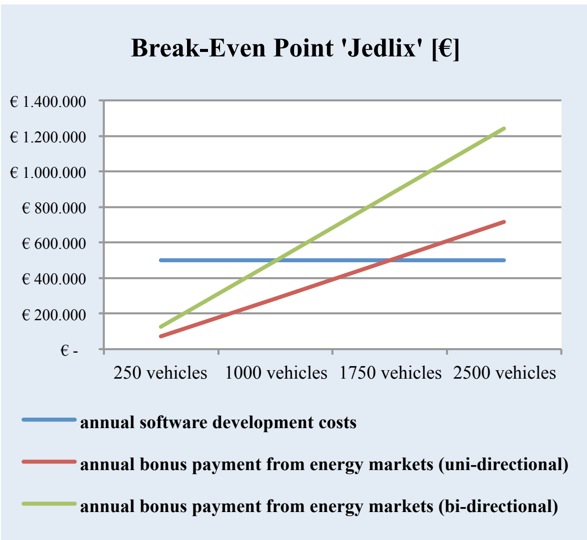
- An AC charging station with a 20 kW power delivery and two outputs (each 10 kW) including installation costs 6'000€. To be able to charge bidirectional the AC charging station has an additional cost of 4'000€.
- The car average capacity utilization is 5h a day (21%) and an average 150km is driven per day. Jedlix is free to trade flexibility during 18 hours an amount of 120km equaling 12 kWh. 30km are charged directly with no flexibility (3 kWh).
- The bonus payment on the DSO congestion market for smart charging 120km a day, equals 20% of the total electricity bill. This bonus payment is shared at equal shares with We Drive Solar.
- The bonus payment for selling A/S services to the TSO is 2250€ for 10kW during 24 hours and 356 days. Positive and negative regulation account for 50% each. The A/S portfolio manager keeps half the compensation as a gateway opener and the remaining half is shared at equal shares between Jedlix and We Drive Solar.
- The energy price is 0,15€ per kWh, including the network distribution tariff.
- Software development costs are estimated at 2.5 million €, amortized over 5 years.

Figure 6: Annual profit – We Drive Solar



Source: Case study analysis

Figure 7: Annual Profit - Jedlix



Source: Case study analysis

The base case shows that the value per user per year is relatively small offering uni- (211€) and bidirectional charging (422€). From the point of view of Jedlix the business model makes only sense if the business can be scaled to reach at least over 1500 EVs. As the number of cars in a car-sharing fleet is limited, Jedlix needs to find other sources of income to cover the costs of the software development.

This business case underpins the importance of the distribution key to align interests. The distribution key used in the base case of 1:1:2 among car-sharing provider, service provider and portfolio owner bears no financial incentive for the car-sharing provider to switch to bidirectional charging. However, the service provider reached break-even with fewer clients and has great interest of switching to bidirectional charging. Therefore the distribution key needs to be altered to align interests for bidirectional charging.

This business case nicely illustrates a three-step approach towards applying the V2G technology to offer A/S. The fist step includes offering flexibility at very low risk with no additional investment for the car-sharing provider. In a second step, an investment into bi-directional EVSE is needed and Jedlix would need to compensate for battery degradation, however also increasing the value per user. In a third step and with a minimum power supply of 5 MW (6700 EVs), Jedlix could pledge for a direct connection to the TSO, if more economical.

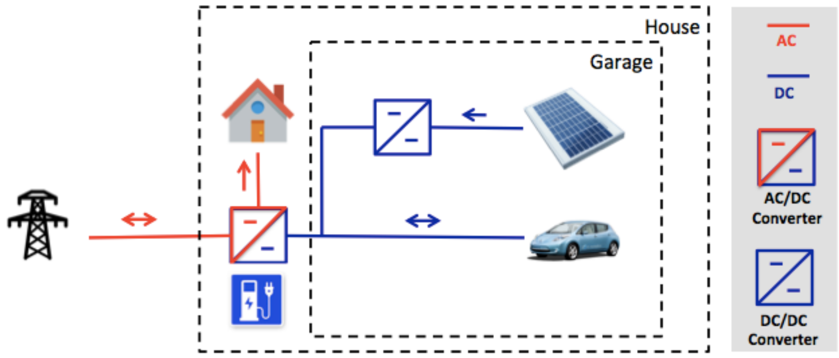
4.2 Case Study B: V2X Pilot Project – by Nissan & Enel

The pilot project under the lead of Nissan and Enel focuses on individuals, more precisely on private EV and homeowners. Together with Mitsubishi, Nissan is commonly known as the pioneer of bidirectional charging. Nissan has commercialized V2G capabilities for cars and integrated the technology into the Nissan Leaf and the e-NV200. The discharging fuctionality works with the CHAdeMO protocol only, a simple campus-system. To charge bidirectional, it must be connected to a DC charging station. Enel is a multinational energy player and also develops charging stations technologies under the name of subsidiary Endesa. In cooperation with Nissan, Enel developed a V2X charging station that charges and discharges at 10kW. It is designed to provide energy to the vehicle, to the grid or to the house. A limited number of customers were selected for this pilot project to test this product. Participants are homeowners with installed PV modules on their roofs.

4.2.1 Case Introduction

The goal of this business case is to use the synergies between the electrical system of the building and the electric vehicle. Increasing the consumption share of self-generated electricity the homeowner saves on distribution network fees paid towards to DSO. The following elements are needed for the system to work: photovoltaic modules, a DC charging unit, a EV capable of charging bidirectional and connection to the house and grid for delivering electricity.

Figure 8: Home Environment – Nissan/Enel



Source: Own illustration based on Carranza (Interview, 2017)

The system runs on two premises. (1) No electricity expense in a household is as high as the electricity paid for mobility. The costs of electric gadgets in the house are small compared to bills paid for running a car. This is why the PV primarily charges the EV if connected. With the EV at the charge point, the car always has priority over other gadgets up to the SOC where the drivers kilometer needs are covered. (2) Without any storage unit such as an EV battery, solar energy is sold cheap to the grid during the day and bought for charging or home use at a higher rate. This is partly due to low repurchase tariff per kWh, which vary from utility to utility, and can be lower than the standard energy price paid for consumption. Constantly sinking repurchase tariffs also mirror the market situation in Switzerland. The main reason to increase the consumption share of self-generated PV electricity lies in the because network distribution fees and taxes paid on top of the electricity price per kWh for consumption.

The scope of this pilot project includes the installation of 100 DC charging stations with the CHAdeMO protocol and a 10kW power supply. Target locations are the homes of private EV owners (Nissan Lead & e-NV200) also acting as renewable electricity producers. The maximum total power to be provided to the National Grid is 1 MW, which is reached at times during the night, when all EVs are connected to the grid.

Value Proposition

This business model provides individual Nissan Leaf or e-NV200 owners with an alternative income stream through grid services and increases self-consumption of their solar energy saving on network tariff fees. This reduces the cost of ownership of the EV and shortens the payback time of the PV modules. The target group is EV and homeowners with a parking facility in a garage or an outdoor space next to the production unit.

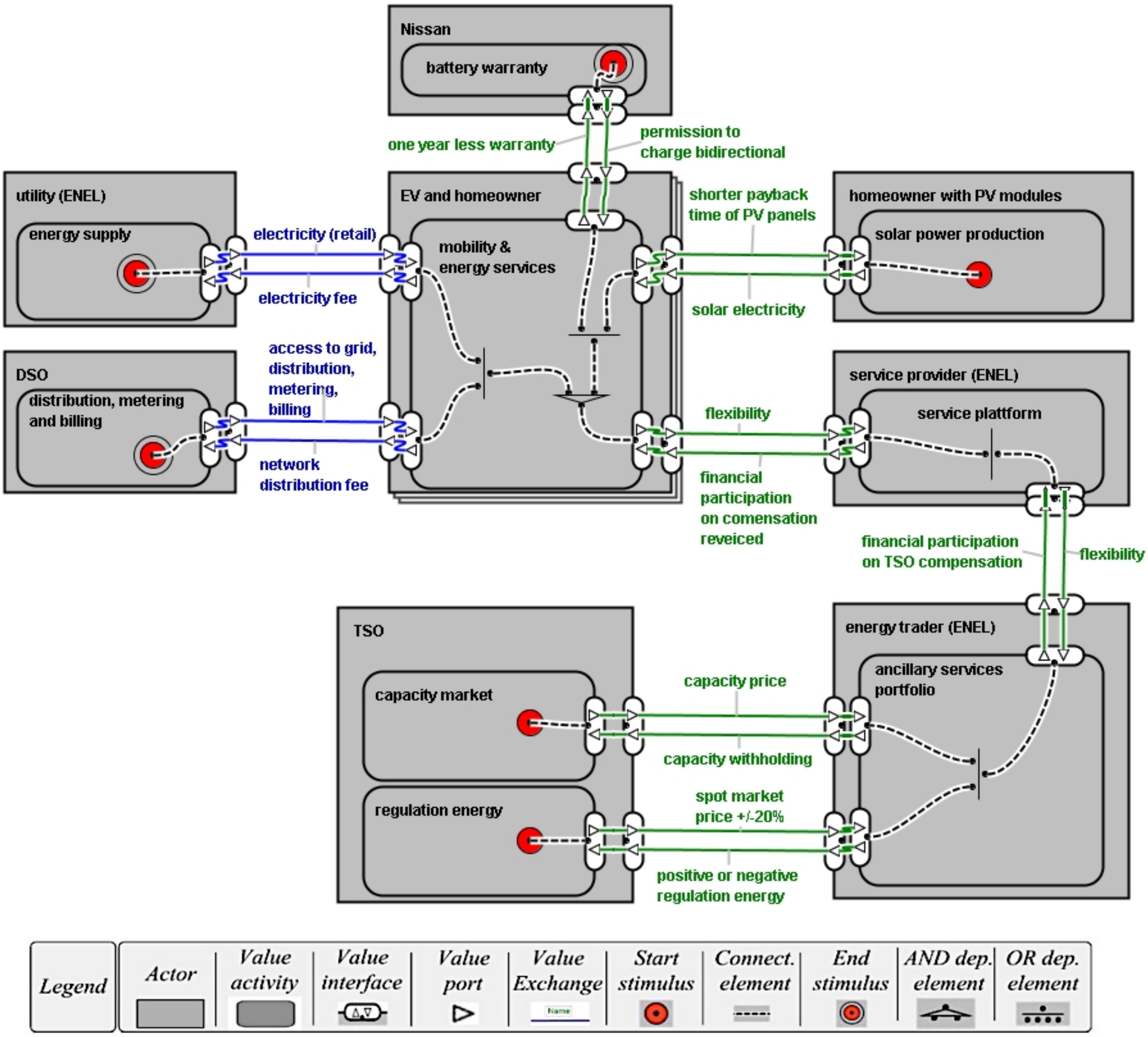
Value Network

The value network consists of similar players as the first business model. However, the utility is not only supplying electricity but also acting as the provider of the charging software. Further players are the National Grid (TSO), the DSO and the private EV user and homeowner with PV modules on the roof.

Cost/Revenue Structure

The amortization of the DC-charging unit and the battery degradation are the only cost blocks in the income statement of the EV and homeowner. Revenue streams are twofold: Revenue generated through ancillary services and savings on distribution tariff fees. For the Nissan-Enel cooperation, a large research and development cost for the steering and control software as well as for the charging station needs to be amortized by selling a large number of gadgets and acquiring a large number of clients using the gadget.

Figure 9: Networked Business Model – Nissan/Enel



Source: Own illustration based on Carranza (Interview, 2017) and Enel (2016b)

4.2.2 Business Scenario

The business model intends for Nissan to approach the customer after purchasing or leasing a Nissan Leaf or an e-NV200. The DC charging station offered from Enel also acts as a control and distribution center. The V2X system determines when and how much to charge the EV batteries based on the current SOC and ensures that the kilometer needs of the vehicle owner are always met. As soon as the minimum kilometer needs of the driver are met, the battery is also used to balance the national grid as an additional income stream. This ensures that the battery capacity desired by the driver is available when beginning the journey and sets the rules for providing the grid with power.

At night or in the early morning, at times with no solar power production, electricity is redirected from the vehicle to the house, if the car battery has electricity to spare exceeding the kilometer needs. No public grid is used for this energy exchange, which means that no network distribution fees are paid for the electricity transfer between the house, PV units and the car. There is one exception to the theory. As the CHAdeMO protocol is not able of dosing energy but can only be turned on and off, energy is sold to the grid when redirected to the house, if the house does not absorb the amount of 10kW.

The electricity stored in the vehicle battery is also controlled and aggregated by a centralized server of Enel. Similar to the previous case, the aggregate of batteries stands for a 'virtual power plant' sold as A/S. However, as nobody can control the operating schedules of individual vehicles, the power availability to the portfolio is only offered in the statistical aggregate. This impedes from offering the aggregate of power to the TSO directly and requires a third party taking responsibility for matching the agreed power capacity. When offered to the National Grid (TSO), all EVs are part of a larger ancillary services portfolio of Enel completed by hydraulic power. Enel shares the financial compensation with the homeowner for providing a service to the national grid.

Enel charges and draws from vehicle batteries within an existing business relationship. It expands the business from selling retail electricity to also purchasing V2G power. To increase the service availability to the grid, Enel provides financial incentives to stay plugged in when possible. This financial incentive is given through higher self-consumption rate of solar energy and bonus payments from grid services only when pluggd in. Enel includes payments for V2G services into the existing electricity billing, resulting in lower net payments from customers. However, only a liberalized market allows individuals to choose their utility.

Enel has spent millions in the research and development of a cheap DC home charging station and is interested in selling it in bulk to customers. The same holds for the software developed for controlling the V2X system, ensuring the drivers' kilometer needs and drawing energy from or feeding the energy back into the grid if the national grid requests it.

4.2.3 Business Analysis

Table 4: Pros and Cons of Business Model – Nissan & Enel

EV and homeowner	**(1)** Saving network distribution fees and taxes **due to an increased self-consumption rate of locally produced solar energy.**
DSO	**(2)** Liberated from the task to redirect large amounts of solar energy **during the day, followed by less stress on the local grid in the evenings. However, DSOs also loose income from network distribution fees.**

Utility	(3) Create customer loyalty **in an increasingly free and independent market**
Smart charging provider	(4) No fixed costs of offering ancillary services **to a A/S portfolio imply low entry barrier to the A/S market**
Charging station manufacturer & smart charging provider	(5) **Small pool of potential customers** (EVs need communication protocol CHAdeMO and homeowner an own energy generation unit). On the contrary, Enel needs to sell a large amount of DC chargers to break-even.
Smart charging provider & homeowner	(6) **Distribution network fee is charged for any type of regulation energy**, marginalizing the profits
EV and homeowner	(7) With a solar panel installed on the rooftop of a facility, the EVs need to be connected during the day to increase the value of the business model. **Not user-friendly and unlikely business case for commuters**.
EV and homeowner	(8) Limitations of the CHAdeMO protocol does not allow to dose energy, **loosing energy to the grid** when actually intended to feed back to the house.
EV and homeowner	(9) **High costs of a DC charging station corrupts the business case** for the homeowner

Source: Case study analysis

The objective to increase the consumption share of self-generated energy, produced by the PV pannels, deceases the amout of distribution network fees and taxes paid for consumption. However, to minimize the amount of electricity feed back to the grid during the day, the cars need to be connected to the charging station of the facility during the day. This constraint limits the users mobility behaviour and is unlikely to be followed, especially if the car is used for commuting to and from work. Additionally when the battery is charged and discharged for ancillary services, a fee to the DSO must be paid in both cases, marginalizing the profit from grid services.

EVs absorbing the large amount of PV energy produced during the day has a positive and a negative effect from the perspective of a DSO. On the one side, it liberates the DSO from the task to redirect the large amount of solar energy generated, causing the local grids to overload. Because a great share of electric vehicles have already recharged during the day, the stress on the local grid in the evenings when all people return home from work is also smaller. Thus, this business case saves the DSO from balancing the grid at no additional costs. On the other side and more importantly, the increased share of self-consumed solar energy decreases the total revenue generated from network distribution fees for electricity consumption.

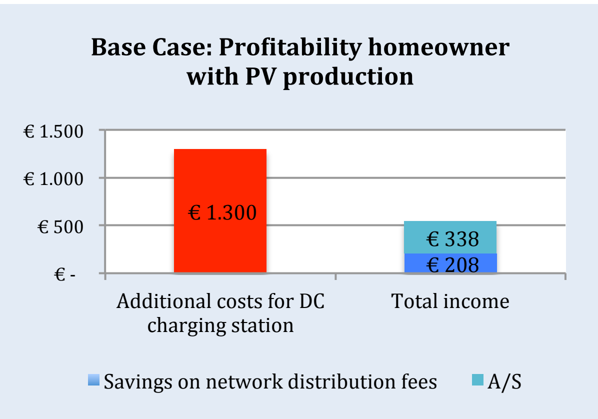
The simplicity of the CHAdeMO protocol shows its weakness when redirecting the energy to the house. Only capable of turning on and off the energy supply to the house at two rates (10kW and 1 kW) the energy not used by the house get redirected to the grid. This corrupts the idea of an increased share of self-consumpted PV energy produced. Offering the DC charging station in combination with a energy delivery contract creates customer loyality in an increasingly free and independent market.

Base case

Most of the assumptions are based on statements made from company representatives involved in the business case. If the interview partner did not reveal information needed for calculations, literature and Internet research are sources were sources of inspiration. To calculate the financial feasibility of this case, the following assumtions were made:

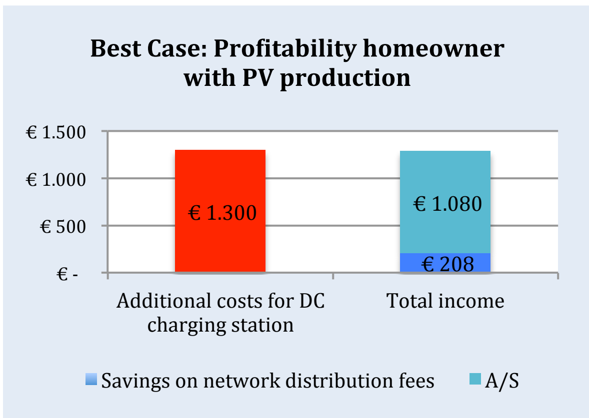
- An AC charging station sufficient for home-charging costs 1'000€. The DC charging station is sold at the price of 14'000€. The life-span is set at 10 years.
- Electricity price is 0,07€/kWh. The network distribution fee is 0,08€/kWh.
- The total energy consumption per homeowner is 6500kWh annually. The share of self-consumption rises from 40% to 80% by using the V2X system.
- The financial bonus for providing 10kW for 24h of positive and negative power capacity is estimated at 2250€ annually. The cars are available for grid services 14,4 hours (60%). The rest of the time the EV is unplugged or unavailable for grid services.
- *Base case scenario*: The portfolio manager takes half of the bonus payment for being the gateway to the A/S market. From the 50% remaining, Enel shares bonus payment with the homeowner at equal shares. In the *best case scenario:* the customer is left with 80% of the bonus payment instead of 25%.
- Software development costs are estimated at 2,5 million €. Charging station R&D costs are estimated at 3 million €. Lifespan is estimated at 10 years. The gross profit on the DC charging station is 10%.
- Manpower assigned to the maintenance and steering of the platform is estimated at 180'000 € per year. This includes communication with the TSO in the case of need for problem solving.
- The Internet connection and continuous sending on live data on the availability of the power supply, requested by the TSO, is estimated at 10'000€ annually.
- The aggregate of EVs is part of a 10MW portfolio sold to the TSO.

Figure 10: Annual Profit – Homeowner (base case)



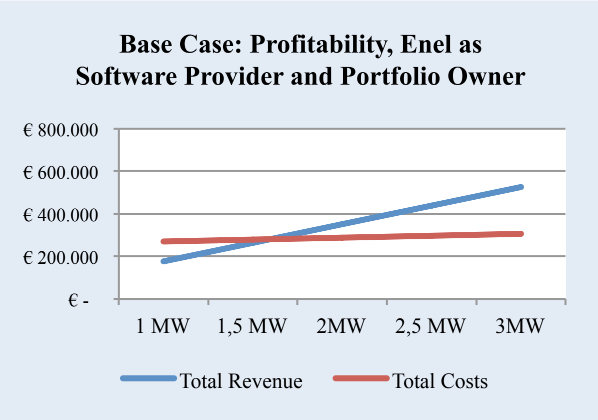
Source: Case study analysis

Figure 11: Annual Profit – Homeowner (best case)



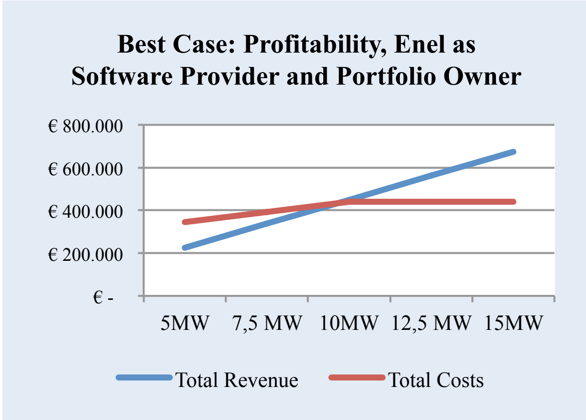
Source: Case study analysis

Figure 12: Annual Profit – Utility (base case)



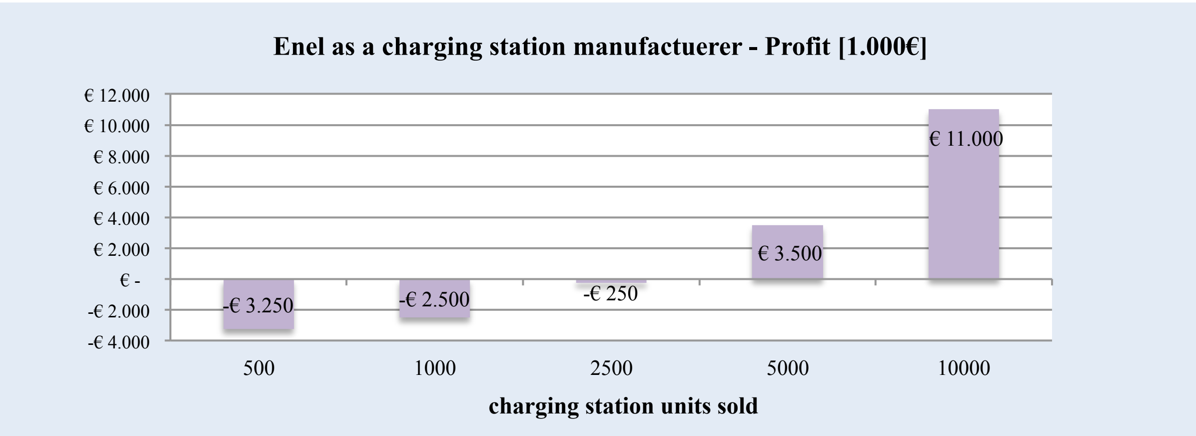
Source: Case study analysis

Figure 13: Annual Profit – Utility (best case)



Source: Case study analysis

Figure 14: Annual Profit – Charging Station Manufacturer



Source: Case study analysis

The base case shows an ambiguous situation for different stakeholder in the value network. While the business case is highly unattractive for the homeowner and the charging station manufacturer would need a large sales volume to break even, the software provider and portfolio owner could make money with providing only 2,5MW flexibility.

The price of a single DC charging station is far too high for a single household. Even with a participation share of 80% (best case) instead of 25% (base case) of all bonus payments, the homeowner would only hit break-even after 10 years. The value per user from increasing the self-consumption and grid services is too low to return the investment of 13'000€. This business case also requests the EV to be connected during the daytime to absorb all excess energy and feed it back into the house during the evenings and early mornings. This is highly unattractive for the user, as a EVs first purpose is mobility. Only for Enel as a software provider and A/S portfolio owner, the base case is highly attractive, crossing the break-even point at providing 2,5MW (416 customers). The best case scenario with a distribution key in favor of the charging station operator (*Figure 13*), would force Enel to acquire a much larger customer basis for themselves to hit break-even. A constant power supply of 10MW is necessary, requiring a car pool of 1700 EVs.

For Enel as a manufacturer of charging stations, none of these client bases would be enough to make the business case worthwhile. Over 3000 DC charging stations need to be sold to enter the profit zone. However it is doubtful if such a customer basis can be reached in Switzerland, as there are limitations to the business model. The DC charging station functions only with the CHAdeMO protocol, mainly supported by Asian car brands. Further, the system is more valuable for homeowners with solar panels on their roofs. These two restrictions limit the market of potential customers.

4.3 Case Study C: Nissan-Nuvve-Enel Project Denmark

This case focuses on embedding the V2G technology into a workplace environment. It is the first pilot project including a V2G hub operating in Europe. The main goal is to test the use of an EV battery for ancillary services, connecting the EVs directly to the TSO. 10 V2G hubs were installed on the site of the Danish utility Frederiksberg Forsyning. Being a fleet used for maintenance work and the observation of operation sites, EVs are used during the day while the electricity trade happens off working hours. Many players involved in the second business case are also involved this third business case. The project lead is assigned to Nissan and Enel, complemented by Nuvve.

4.3.1 Case Introduction

Unlike in the second business case, Nuvve takes the place of Enel as the provider of smart charging services. With a platform called GIV, Nuvve controls the power flow to and from the cars. Initially developed by the University of Delaware, it is now licensed, supported and commercialized by Nuvve. The goal of this business case is to establish a direct connection to the TSO. The advantage of the direct connection is the full recovery of the compensation paid by the TSO. As Nuvve is not selling their energy capacity on the energy imbalance market, the financial bonus is not marginalized by a utility offering to enter the ancillary service market at a fraction of the compensation. The downside however is that Nuvve needs to meet all the preconditions for beginning business with the TSO, which is expensive and technically challenging.

Value Proposition

The added value lies in the reduction of the cost of ownership of the electric fleet. As no own production unit is connected to the V2G system, revenue generated by ancillary services need to cover all the costs. The target group is fleet managers with a consistent usage pattern, who are able to plan the availability of their fleet. Unlikely to be customers are police or hospital vehicles. More likely to be customers are EV fleets of mail-delivery vehicles, craftsmen or salesmen.

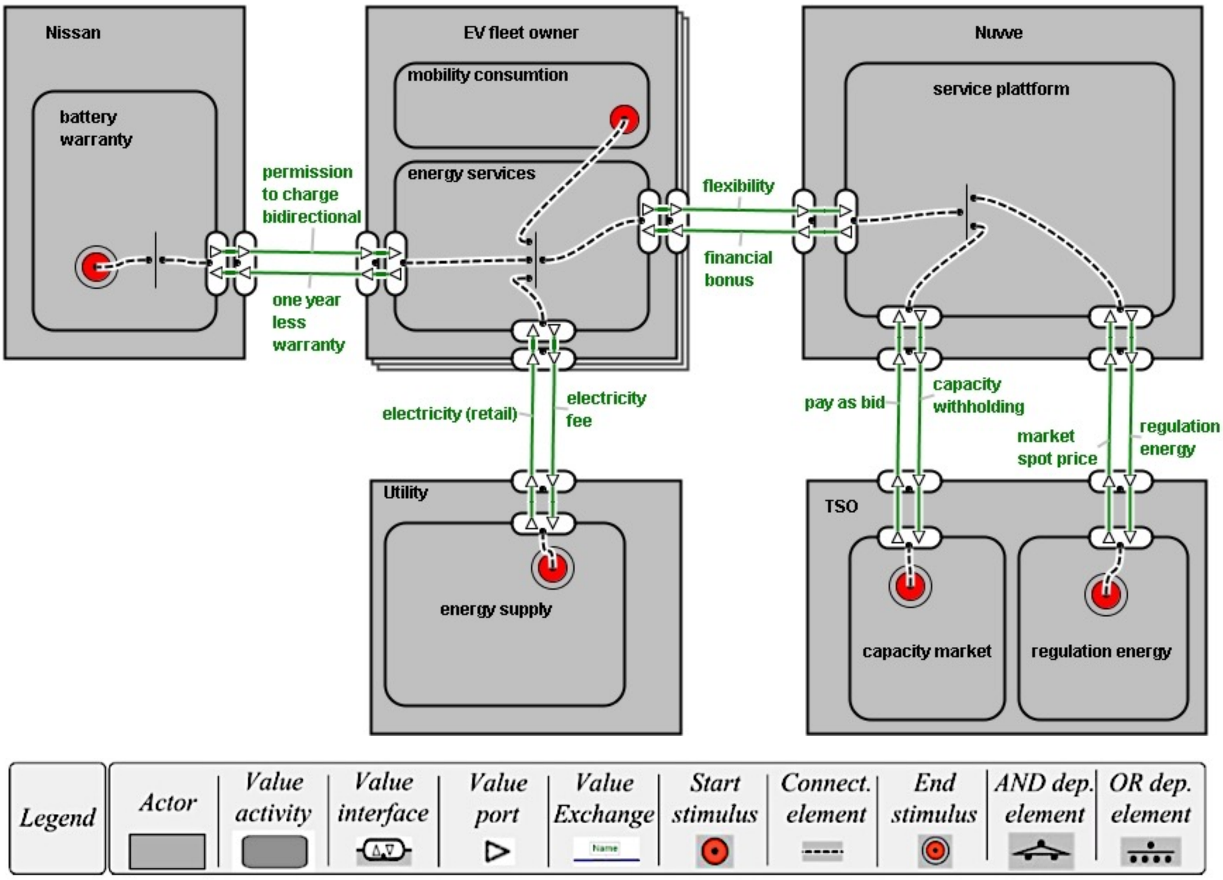
Value Network

The project is a collaborative effort between Nuvve, Nissan, Enel, Frederiksberg Forsyning and the Danish grid operator, Energinet.dk. Nissan is providing the cars (all e-NV200), Enel is the manufacturer and distributor of the DC charging stations and Frederiksberg Forsyning is the local fleet operator.

Cost/Revenue Strucutre

The fleet operator has an initial investment of the DC charging station, battery degradation costs and an annual income from providing A/S to the grid operator. Nuvve has invested a considerable amount of money in the development and operationalization of the V2G aggregation platform. Further incur operational costs attributed the services necessary to meet the precondition of the TSO. Enel's cost structure consists of the research and development costs attributed to the 10kW bidirectional DC charger and intends to enter the profit zone by selling the gadgets in bulk.

Figure 15: Networked Business Model – Nissan/Enel/Nuvve



Source: Own illustration based on Carranza (Interview, 2017) and Enel (2016a)

4.3.2 Business Scenario

10 V2G chargers were installed on the company ground of Frederiksberg Forsyning. However to meet with the minimum power supply of 3 MW positive and negative regulation energy

requested by the Danish TSO, this business scenario is scaled to 300 EVs, using 150 two-output charging stations from Enel. After all, the value proposition claims to establish a direct connection to the TSO. Surpassing that threshold means that Nuvve no longer has to share profits with a utility offering a gateways to the ancillary services market. The vehicle fleet of Frederiksberg Forsyning is coordinated by the fleet manager. He plans the availability and ensures that a certain number of EVs is connected to the grid during a period, both terms agreed on with Nuvve. With 12 e-NV200, the company fleet manager can always guarantee 10 cars to be connected from 8pm to 6am, providing a total of 100kW power to the TSO. On Sundays the cars are available 24 hours. On average the cars are connected to the grid 15 hours but are available for grid services for only 12 hours due to charging restrictions. The main restriction given to the GIV platform is to have fully charged the cars in the morning when used for driving. Thus, the battery is used for ancillary services in the evenings and during the night on weekdays and Saturdays and during the whole day on Sundays. The electricity stored in the vehicles' batteries is controlled and aggregated by a centralized server. The computer software links multiple vehicles together, allowing them collectively to be viewed as a single power plant. Similar to the business case two, the DC charging stations are produced by Enel and sold to the user.

4.3.3 Business Analysis

Table 5: Pros and Cons of the Business Model – Nissan/Enel/Nuvve

Smart Charging Provider & Company Fleet	**(1)** Backwards integration of Nuvve allows **full recovery of the compensation for ancillary services,** received from the TSO
Smart Charging Provider	**(2)** Static mobility pattern of cars allows a **smaller car pool for reaching the same power capacity**
Company Fleet	**(3) Sharing charging station among 2 vehicles shortens pay-back time**
Company Fleet	**(4) High lock-in costs** through charging station only operating with CHAdeMO
Company Fleet	**(5) DC charging station to expensive and corrupts the business case for the company fleet.** Puchase price needs to be below 15'000€.
Charging station manufacturer	**(6)** Enel as a charing station manufacturer needs to **sell a large amount of DC charger to break-even**.

Source: Business case analysis

Compared to the unpredictable operation of privatly owned EVs, a company fleet can be managed and the number of available cars to the grid can be planned reliably. Compared to the business case two the power capacity provided to the TSO is not a statistical aggregate. For the smart charging provider Nuvve a smaller client pool is necessary for reaching the break-even point.

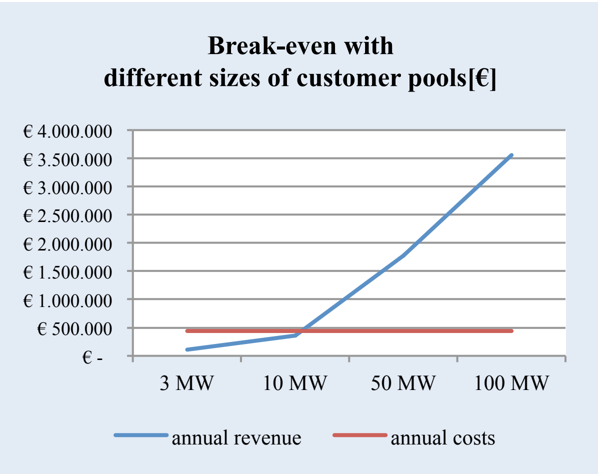
This business case requires a EV operating with the CHAdeMO communication protocol. This impies high lock-in costs as only a small nummber of Asian car manufacturers use this communication protocol. After puchasing the charging station, the EV and DC station owner needs to remain with a Nissan car untill the investment has payed off.

Base Case

To calculate the financial feasibility of this case, the following assumtions were taken:

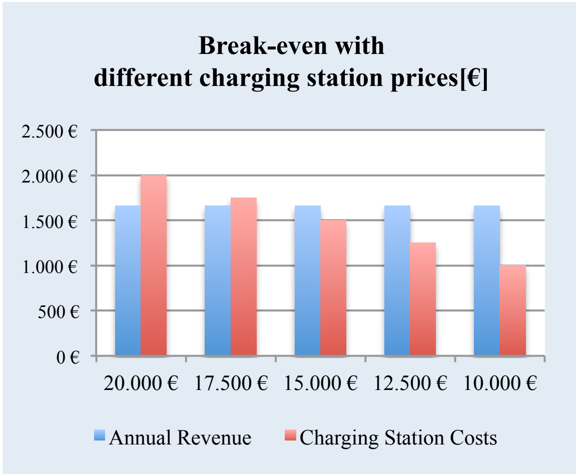
- The R&D costs of the GIV platform designed by the University of Delaware and licensed by Nuvve is estimated at 2.5 million €, license fee is 250’000€ per year.
- Manpower assigned to the management of the platform is 180’000 € per year.
- The internet connection and continuous sending on live data on the availability of the power supply, requested by the TSO, is estimated at 10’000€ annually.
- Capacity withholding is estimated 225’000 per MW on the base-case scenario for a 24 hour availability. The base case assumes an average availability of 12 hours.
- At a 3 MW ‘power plant’ available 24h, 1400 MWh positive energy and 1000 MWh negative energy is sold during a year. Energy is always sold with a 10% markup/discount on the energy price which is 0,15€ per kWh. The network distribution fee is already deducted.
- The customer participates with 70% from the financial bonus received by the TSO. The remaining 30% goes to Nuvve.
- Amortization period of the two output DC charger is set at 10 years and costs 17’000€.

Figure 16: Annual Profit – Nuvve



Source: Case Study Analysis

Figure 17: Annual Profit – Frederiksberg F.



Source: Case Study Analysis

As can be seen in *Figure 16*, Nuvve needs a client basis of at least 10MW to operate within this business model on a long-term basis. This equals a pool of 1’000 EVs connected to the grid. The backwards integration of Nuvve connecting directly to the TSO allows for sharing a larger share of the financial compensation and still reaching beak-even at 10MW. Analyzing the business case from the point of view of Frederiksberg Forsyning is quite simple. As long as the price of the charging station does not fall below 15’000€ the business case is not attractive.

4.4 Main Findings

The analysis of the three preceding business models resulted in the main findings summarized in *Table 6*. These guidelines help to construct a prototype business model for the Swiss market. They take into account the economic benefit for each stakeholder, the current state of technology but also apply a long-term view offering opportunities, which might be seized in the near future.

Table 6: Main Findings – Business Cases

- **(1)** The value per user is small. Comparatively, the additional capability of bidirectional charging comes at a high cost. To cover the costs, **revenue streams in addition to ancillary services need to be found.**
- **(2)** As the cost of a charging station is high, sharing a **two output charging station** among two EVs serves as a means of cut cutting.
- **(3)** To scale the business, the V2G system needs to operate with **AC charging** and a **widely accepted communication standard** for bidirectional charging, unlike CHAdeMO.
- **(4)** The distribution of the income sources from providing flexibility among EV owner, charging station operator and aggregator determines the break-even point of their investment. Thus, **the distribution key needs to be fair and determines if a stakeholder participates or not**. Therefore an attractive solution for all parties needs to be found.
- **(5)** Switching from DC to AC charging stations not only decreases costs but also allows for a **three-step approach, approaching the V2G technology with a long-term view**.
- **(6)** As the value per user is small, the aggregator's success depends on a **scalable business model** and a **broad basis of potential customers**.
- **(7)** Offering a statistical aggregate of flexibility**, it is more efficient to access the A/S via an imbalance market selling flexibility to a utility holding a A/S portfolio.**

Source: Case study analysis

(1) The additional investment into a charging station with the capability of charging bidirectional is very high compared to the value generated through a single grid service. Even with an estimated amortization period of 10 years it is not feasible for a single output charging station to generate enough revenue through ancillary services for a positive return on investment. The three business cases revealed two approaches to solve this issue. On the revenue side, various income streams from different market need to be combined. The *We Drive Solar* business case nicely illustrates two different markets are targeted simultaneously; an experimental DSO congestion market and the ancillary services market. A possibly third income stream is generated from saved network distribution fees, if the charging station is connected directly to a proprietary energy production unit, for example a PV unit. This is however tied to the condition, that the EV(s) is connected to the PV units during the day to avoid feeding solar energy back into the grid. The challenge is to find a user-friendly solution. As a positive side effect, the financial bonus received on the DSO congestion market increases because the electric vehicles absorbs solar energy during the day, the DSO would

otherwise need to distribute at cost. Another method to increase the revenue from V2G services is to target various customer segments to maximize capacity utilization without interfering with the mobility preferences of individuals. To force an EV and homeowner to park his car next to his PV unit during the day even though he would prefer to drive the car to work is not user-friendly, as it does not coincide with his desired mobility pattern. *Figure 3* shows different types of mobility patterns.

(2) On the cost side, the charging station can be shared between two cars. While the purchase price for a charging station with two outputs and the stronger power connection would only increase slightly, the revenue would double.

(3) The business cases proposed two different communication protocols between car and charging station, incompatible among each other. This splits the market and has a negative impact on the attractiveness of running a public charging station. Choosing one side of the market, the charge point owner will never be able to serve the client basis operating with the other communication standard. The bidirectional charging port of the car reveals the communicant standard used. The only car manufacturers currently offering a car with a bidirectional port are Nissan and Mitsubishi and they require (a) the CHAdeMO communication protocol, which works only with (b) a DC charging station. The prototype business model should not support this technology for the following two considerations. Firstly, a DC charging station, charging at 10kW costs almost two times of what an AC charging station costs. Secondly, the technical limitation of the CHAdeMO protocol and the lack of support within the automobile industry is small, as seen later in *Chapter 6*. European and American car manufacturers, unlike the Asian car manufacturers Nissan and Mitsubishi prefer the communication standard ISO 15118. Once the European and American car manufacturers start to offer a bidirectional charging port, a much larger client pool can be targeted. A further advantage is that the ISO 15118 communication standard is compatible with AC and DC charging for unidirectional and (soon) bidirectional charging. This lowers the initial investment risk and shortens the payback time of the charging station significantly.

(5) Settling for AC charging stations also gives the opportunity to enter a three-step path towards a V2G business model. The first step implies a focus on unidirectional smart charging as even users without a bidirectional port in their cars can use the service. In a second step, and as soon as enough car manufacturers have integrated a bidirectional port using ISO 15118, the smart charging provider can switch to offering V2G. In a third step the service provider could even offer A/S directly to the TSO, fully recuperating the TSO compensation.

(6) A further reason for choosing a widely accepted standard in combination with an AC charging station is that the scalability of the business is important to the service provider. The value per user is low and to break-even a large customer basis is needed.

5. Research Methodology

5.1 Research Design

Yin (2009) implies that the research design must guide the researcher throughout the process of his research study. He defines the research design as:

> *"[...] the logic that links the data to be collected to the initial questions of the study" (Yin, 2009, p. 24).*

The most important connection is the research question with the research method. If the method won't provide the data to answer the question, either the method or the research question needs to be changed. The selection of the appropriate research method can be determined by three important conditions:

a. the extent of control over behavioral events
b. the focus on contemporary events instead of historical events, and
c. the form of the research question

The main purpose of this thesis is to find out *what* an appropriate V2G business model would be to enter the Swiss energy market and *how* the roadmap to such a business model could look like. Manipulation of the participants' behavior is not possible and not necessary. So the answer to criteria a) is: no control. The study clearly deals with a contemporary if not future set of events, so b) is a yes. For this combination of the two conditions, both a case study approach and a interview/survey approach seem appropriate (Yin, 2009; Maxwell, 2013). This leaves the last condition: form of the research question. To answer the "what" and "how" questions in this thesis and to find about the underlying success factors and challenges of implementing a business model, a *grounded theory* approach seems most appropriate (Yin, 2009; Maxwell, 2013). A case study approach would be more suitable for research questions like "why" and "how".
The 'grounded theory' is designed to identify unanticipated phenomena and open up a space for the development of new theories. It is a qualitative research design of inquiry from sociology, in which the researcher derives a general theory grounded on the views of the participants. This research design requires conducting multiple interviews to gather multiple views as a means of triangulation and subsequent refinement of the information received. This strategy reduces the risk that the conclusion will reflect only the biases of a single interviewee. Exploring and understanding the meaning individuals ascribe to a problem, the grounded theory is especially useful when; the topic is new, the subject has never been addressed under study and the important variables are unknown (Maxwell, 2013).

5.2 Research Process

Unlike most other research methods, grounded theory merges the processes of data collection and analysis. Moving back and forth between data collection and analysis, the researcher attempts to 'ground' the analysis in the data. The aim of this movement is theoretical saturation. As a result, grounded theory does not provide the researcher with a series of steps, which, if followed correctly, will take him or her from the formulation of the research question through data collection to analysis and, finally, to the production of a research report. Instead, grounded theory encourages the researcher to continuously review earlier stages of the research and, if necessary, to change direction. Thus the grounded theory has an integrated and cyclical nature (Maxwell, 2013).

5.2.1 Data Selection

The most important decisions taken in the data selection phase are twofold: what number of interviewees and which organizations to examine. Eisenhardt (1989) stresses the importance of this phase since finding an adequate population "helps to define the limits for generalizing the findings" (p. 537).

Regarding the number of cases, it depends on the complexity of the case and certainty of results one wants to have. There is no ideal number of cases. A number between 4 and 10 is usually the target. With fewer than 4 cases it is often difficult to generate theory with much complexity and the empirical grounding is unlikely to be convincing (Eisenhardt, 1989).

Since the aim of the study is to learn about the structure and content of the main components of a V2G business model and a roadmap leading there, the selection of the interviewees is straightforward. To find out about the views and interests of potentially involved players in Switzerland, particular stakeholders need to be questioned. *Table 7* reflects the business cases and gives a nice overview of potentially affected enterprises.

Table 7: Potential Interview Partners

Stakeholder	Motivation	Possible Companies in Switzerland
TSO	Customer of A/S	Swissgrid
DSO	Participation in a DSO congestion market	EWZ, Groupe E, EKZ, BKW, CWS etc.
Utility	Energy trading	EWZ, Groupe E, EKZ, BKW, CWS etc.
Charge Point Manufacturer	Asset sales of charge points	EVIT, Innogy etc.
Charge Point Owner	Rent for facility	Swisscharge, Alpiq, EWZ, Groupe E etc.
Service Provider Software	Steering of smart charging	Jedlix ect.
OEM Car	Bidirectional Port on EV	BRUSA Electonics etc.
Car Brands	Car compatibility to V2G	Nissan, BMW, Opel etc.
Car-Sharing Provider	Electric fleet	Mobility

Source: Case study analysis

5.2.2 Data Collection

Data Collection Principles

The grounded theory approach requires the researcher to collect some data, explore the data through initial open coding, establish linkages between categories, and then return to the field to collect further data. To ensure a high quality of the data collected by interviews, the research follows the three essential data collection principles described by Yin (2009): using multiple sources of evidence, creating a database, and maintaining a clear-cut chain of evidence.

First, triangulation is essential (Eisenhardt, 1989; Maxwell, 2013; Yin, 2009). Eisenhardt (1989) emphasizes that triangulation through multiple data sources or methods of data collection (such as primary and secondary data from interviews, observations, archival records, etc.) lead to synergies as well as more robust results. Thus, primary as well as secondary data of both quantitative and qualitative nature was collected for the study. Interviews and corporate information (such as annual reports and web-sites) but also press articles and other publications were considered as multiple sources of evidence, all addressing the same research questions. Second, a case study database increases the reliability of the results. Therefore, all notes, transcripts, reports and other data used for the study were organized and centrally stored in electronic form so that it would be available for other researchers for an independent review of the data. Third, a chain of evidence was maintained. This means that all the parts of the case study process are consistent and that the research questions, collected data, database, and case study report are all logically connected.

Interviews

Grounded theory is compatible with a wide range of data collection techniques. Semi-structured interviewing, surveys, focus groups, even diaries can generate data for grounded theory. For this study mainly interviews were considered, where the choice is between structured and semi-structured. Semi-structured interviews allow for more flexibility. The interviewer can bring in new themes during the interview and explore unexpectedly relevant topics. This study follows the *problem-centered interview* based on Witzel (2000). Four instruments support the carrying out: a short questionnaire, interviewing guidelines, tape recordings of the discussion and a postscript.

First, a *short questionnaire at the beginning* serves to collect data on social characteristics, such as position within the company. However, the question should be followed by an open question as a strategy to trigger storytelling.

Second, *Guidelines* are a supportive device to remind the interviewer on the topic of research and provide a framework of orientation to ensure a certain comparability of interviews. The framework of the guidelines contain of several general topics. The broad thematic categories guiding the interviews were (1) Motivation towards smart charging and V2G, (2) V2G: content of business model components, (3) success factors and obstacles, and (4) a future outlook. These four blocks were determined to help structure the data collection process and focus on the research question. Because each stakeholder has a different approach to the topic, the questions were altered. To keep a certain focus and comparability of the interviews, the framework was kept. However, during the interviews, the guidelines were not strictly followed and the conversation was adapted to the interviewee's line of thought. Yet, the interview guidelines were helpful as an orientation to make sure the main topics were covered.

Third, *electronic recording* of the interview allows the researcher to fully concentrate on the interview. All the interviews for this thesis were electronically recorded with the permission of the interviewees and transcribed. The transcripts are available in the Annex.

Table 8: Overview of Interviews

Stakeholder	Company	Interview Partner	Duration
TSO	Swissgrid	**Aby Chacko** Specialist TSO Markets	30 minutes
DSO	Groupe E	**Felix Rug, Groupe E** Product Manager e-Mobility	40 min
Utility	Groupe E		
Charge Point Owner	Groupe E		
Charge Point Manufacturer	EVTEC Last Miles Solution	**Alexander Jochum, EVTEC** Head of Sales	30 min
Service Provider Software	Jedlix	**Jorg van Heesbeen** Head of Business Development	45 min
OEM Car	BRUSA Electonics	**Arthur Buechel** Senior Key Account Manager	20 min
Car Brands	Renault-Nissan Europe	**Francisco Carranza** Director of Battery and Energy Services	30 min
	BMW (Schweiz) AG	**Luzius Wyrsch** Project Manager BMW i & Enabler Electromobility	30 min
Car-Sharing Provider	Mobility	**Christoph Zeier** Head of Strategic Planning	30 min
Task Forces	V2G Clarity	**Dr. Marc Mültin,** Managing Director	30 min
	Utrecht Sustainability Institute	**Martine van der Woude** Project Leader Smart Charging Consortium Utrecht	20min

Source: Interview Partners

All personal interviews took place within a period of two weeks in March 2017. The interview partners were selected for their interest and knowledge of smart charging practices and therefore were the persons overseeing a product or products of the company related to mobility, EVs, charging infrastructure or energy services. All the interviews were conducted in person at the company's premises or by phone and lasted between 20 and 45 minutes. The interviews were conducted and also transcribed in German or English. The reason for this was that the interviewees had the choice to talk in the language they feel more comfortable in. *Table 9* offers an overview of the interviews, including the function of the interviewees within their companies and the interview duration.

5.2.3 Data Analysis

The data analysis phase is crucial for the study results, but at the same time the most difficult part of the study (Eisenhardt, 1989). *Coding* constitutes the most basic as well as the most fundamental process in grounded theory. Coding can be conducted line-by-line, sentence-by-sentence, paragraph-by-paragraph, page-by-page, and so on. The smaller the unit of analysis, the more categories arise from combining expert declarations. Later stages of analysis will integrate a lot of these into higher-level analytic categories (Eisenhardt, 1989; Miles & Huberman 2005; Patton, 2002; Strauss & Corbin, 2008).

The documents with the fully transcribed interviews are the basis for the coding. The analysis was done in Microsoft Excel without specific coding software. As Glaser (1978) suggested, open coding was applied to structure and analyze the text from the interview transcripts. Generally a rather broad view was adopted as not to miss any important aspects and have a good overview of the results. These first-order codes were typically summarizing larger parts of the transcripts and categorized them. The dimensions can be suggested by the research problem. However, the interview guidelines were already divided in several different thematic categories. Codes that shared a similar view on the topic were grouped into overarching sub-categories.

The procedure was done for every single case. Finally, after each case transcript was systematically analyzed, the codes were compared and integrated to lay the foundation for the final theory. Eisenhardt (1989) indicates that the main focus should lay on the cross-interview comparison. The presentation of the results is enriched with numerous quotes from the interview partners to provide a more vivid picture and highlight the key take-aways.

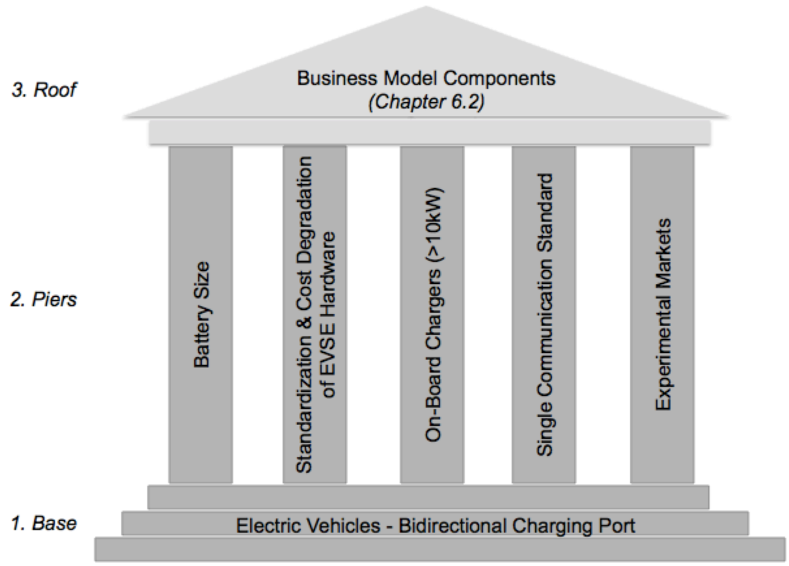
6. Results

This chapter presents the results of the qualitative research. An in-depth analysis of 10 conducted interviews with companies of the energy industry, automobile industry, charging infrastructure sector, service providers and others build the core of this thesis. The experiences and opinions of the representatives fall into three categories. First, *major challenges and the key success factors* for the commercialization of the V2G technology within a business model are subsumed in a success factor framework. Then, the *content of the business model components* are visualized. The last part illustrates a *future outlook* on the roadmap towards a prototype V2G business model. Given all the results, the business model prototype represents a recommendation from the author on how to design a V2G business model.

6.1 Major Challenges and Key Success Factors

This block presents six major challenges and key success factors, which were derived from conversations with the practitioners. Before explaining every success factor in detail, an overview is provided in *Figure 18*.

Figure 18: Success Factor Framework - Major Challenges and Key Success Factors



Source: Own illustration based on cross-interview analysis

Electric Vehicles - Bidirectional Charging Port

Electric vehicles that are able to charge bidirectional, lay the foundation to a functioning V2G business model. Currently only a few cars have a bidirectional charging port with V2G capability, which already kills a great deal of business cases.

> *"[...] If the charging point operator invested in additional hardware he should also be able to profit from the potential. But as an operator of a public station it is hard to control who comes and who not. The Tesla is not able to perform V2G and then you are already missing half of the opportunity" (van Heesbeen, Jedlix, Interview)*

So far two car brands (Mitsubishi and Nissan) sell cars with bidirectional charging ports. Renault, subsidiary of the Nissan-Renault enterprise, is planning to release the next generation of Renault ZOE with an integrated bidirectional port. However, most players in the car industry are hesitant to invest large sums of money in the development of a bidirectional port as they are still preoccupied with keeping the weight and cost of their EVs to a minimum. Additional weight reduces the range, which would sabotage the primary target of electric car manufacturers. However, instead of seeing a bidirectional charging as an extra weight, car manufacturers should see V2G as a component giving them a strategic edge over other car brands, as Carranza points out:

> *"[...] Most car manufacturers are trying to keep weight and costs to a minimum. They see the benefit for the grid and the energy system but not for the car as a feature to increase sales. We think of V2G as strategic project and we are thinking of a lot of options at the moment for the best user case of our electric cars apart from mobility. [...] The customer needs to value this car characteristic as for example an additional feature in a car such as faster acceleration or a larger range capacity. They can even make money with it" (Carranza, Nissan, Interview).*

Battery Size

If the EV is capable of feeding back energy into the grid, the car owner also needs to be willing to sell battery capacity to the grid, leaving him or her with less kilometer range. As the primary purpose of the battery is to satisfy mobility needs, the user might be hesitant to share the battery if he is unsure that the SOC left will take him to his destination. Thus, the likelihood of a successful V2G use case increases with the size of the battery.

Standardization & Cost Degradation of EVSE hardware

Another important issue, limiting the number of viable business models, is the lack of clarity within the industry on the charging station type used for bidirectional charging. While Nissan and Mitsubishi use a DC charging station, Renault is developing a bidirectional port for an AC charging station. There is an informal dispute forming a borderline between the Japanese car manufacturers and European/American car manufacturers on the advantages and disadvantages of each method. Enel, a multinational power company, has developed a DC charging station capable of V2G in cooperation with Nissan and Mitsubishi, while the Durastation from General Electrics enables bidirectional AC charging. This puts a public charging station operator in a difficult position, as he needs to decide between two markets. Choosing DC, he would need to pass on all Renault clients and settling with AC would he would pass on all Nissan and Mitsubishi clients.

However, there is a consensus among most of the representatives in Switzerland and Europe that the industry should focus on AC charging for V2G services. The main reason is the strategic mismatch of a DC charging station with bidirectional charging. Moreover, the a DC charging station is significantly more expensive than a AC charging station at no additional benefit for bidirectional charging. Compared to an AC station, a DC station contains an AC/DC converter. Therefore a DC station is also significantly more expensive and mainly used for fast-charging. High power loads try to minimize the recharging period and decrease the waiting period of the customer. Thus, discharging a car at a fast charging DC station would conflict with the initial purpose of fast-charging. Bidirectional charging makes more sense at places where cars are parked for a longer time, equipped with AC chargers.
The bidirectional chargign capability always comes at an additional cost. Therefore, the charging station operator needs to understand the risk of his investment. Switching back to unidirectional charging has severe repercussion on the ROI.

> *"Investing in costly hardware is risky because if the customer is not fond of the service anymore, this can have big implications on the potential flexibility value" (van Heesbeen, Jedlix, Interview).*

An AC charging station, capable of bidirectional charging, costs 2000-4000 Euros more than a conventional charging station. As the value per user generated from V2G services is small the charging station operator also has a limited budget for investing in a charging station. Several representatives are waiting for the production costs to drop before investing in bidirectional chargers.

> *"[...]V2G requires specific hardware to withdraw energy form the car. This is a challenge because the investment costs in specific hardware, which enables such a service might already kill the business case. We are waiting for this solution to scale up a little. We are waiting for Moore's law to apply. The difference could be as little as 1000 Euros in the future." (van Heesbeen, Jedlix, Interview).*

On-Board Chargers (>10kW)

With AC stations capable of charging bidirectional, the AC/DC conversion is accomplished by the on-board charger. Car brands follow different strategies when it comes to the conversion power of the on-board charger.

> *"[...] There are different philosophies, which differ among car manufacturers. The Japanese manufacturers stay at 3.6kW/6.4kW and want to maintain this level because they want to support their CHAdeMO fast-charger. The European are targeting for more powerful on-board chargers. The BMW i3 can charge at 11*

kW, the Renault ZOE at 43 kW. The new Opel Ampère is at 7,2 kW, if charged at one phase" (Rug, Groupe E, Interview).

With low performing on-board chargers of 3.6kW or 6.4kW, bidirectional AC charging is unattractive. Lower charging and discharging rates decrease the already small value per user Thus, investments into a charging station longer pay off, possibly killing the business case. This is why Nissan and Misubishi rely on the CHAdeMO protocol for discharging, as it allows to charge and discharge at higher rates.

"[...] A lot depends on the car manufacturers. Whether they are willing to invest into an on-board bi-directional charger depends on finding a valuable business case. Or they might think that this will give them an advantage over other car brands" (Rug, Groupe E, Interveiw).

Single Communication Standard

Concerns on the standardization of the EVSE also apply to the communication software. Without standardization, each car series would need to adopt the communication protocol to interact with the charging point and the smart grid at a high cost. There are two major communication protocols currently on the market. Nissan and Mitsubishi, both Japanese car brands, developed their proprietary communication protocol, CHAdeMO, for bidirectional charging. The ISO 15118 is the second communication protocol and supported by a task force with members of various car manufacturers and charging station operators. It intends to standardize the communication between the car and the smart grid worldwide. The two protocols are incompatible among each other, which propagates island solutions, an obstacle to the wide diffusion of the V2G technology.

"[...] Island solutions are in my opinion none-sense. Companies are trying to lock-in customers with their proprietary solution, but it brings inconvenience to the customer and cost explosion to the charging operator. This is why standardization is an important topic to help e-mobility succeed by lowering costs and increasing user friendliness" (Rug, Groupe E, Interview).

Most interviewees supported the view that the ISO standard is superior to the CHAdeMO protocol in many ways. The Japanese communication protocol is based on a simple campus-system not able to process a lot of information, such as pricing signals from the smart grid, thus limiting the user friendliness. The DC station steers the charging process connected to an external device controlled by the user. Moreover the CHAdeMO cannot dose energy flows. When feeding back energy into a household, this becomes a major issue, as it cannot adopt the energy flow to the consumption needs of the house.

Experimental Markets

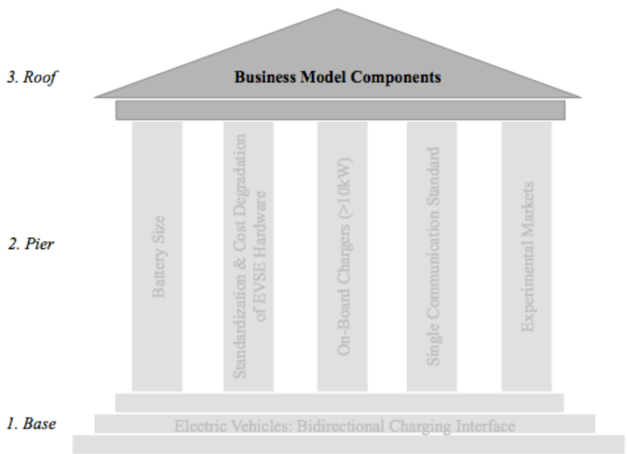
Many representatives identified an experimental space, excluded from the force of law, as an important factor to learn about local characteristics and propose sensible legislature, enabling future business models. With a focus on leveling the stress on the local grid, DSOs are seen as the main target of such testing and have a lot to win or loose. With a proactive attitude, local grid operators could profit from experimental market designs. The Netherlands is a positive example of an environment supportive of granting companies experimental space. On this basis a local smart charging provider and a local grid operator created a "DSO congestion market", a load management system for electricity in the local grid. A legislature not in accordance with the needs of the industry players could have severe repercussion on the business as van Heesbeen mentions:

> *"[...] An additional barrier is that the regulation of the energy sector is progressing quite slowly, although a vast share of people like the idea of smart charging. And that is killing for a company because we cannot wait for too long to make everything work" (van Heesbeen, Jedlix, Interview).*

A possible reason is that in many countries, incumbents have interest somewhat different from emerging companies. To maintain their position they slow down the changes in the legislature, which might shift power to new actors. Within this environment of harassment the lack of planning reliability can result in budgetary problems and limit firms' growth. Especially business models helping people, who desire independency from utilities and DSOs, enter political grounds when requesting experimental spaces.

6.2 Guidelines for Business Model Components

Figure 19: Success Factor Framework **-** Guidelines for Business Model Components



#1: Access A/S Market through Third Party Model
#2: Combining Various Revenue Streams
#3: Scalable Business Model
#4: Support Existing Mobility Patterns
#5: Flexible Business Structure
#6: Target Users with Stable Charging Patterns
#7: Adequate Distribution Key for Bonus Payments
#8: Cooperation
#9: Quick go-to Market Strategy
#10: Attractive Business Model with Perspective for Car Manufacturers

Source: Own illustration based on cross-interview analysis

#1: Access A/S Market through Third Party Model

The ancillary market is an important source of income in the V2G business model. There are basically two approaches to enter the market, both with a different risk and reward structure. One approach pursues the direct connection to the TSO, Swissgrid. The second approach, sells flexibility to a third party, herself with a direct connection to Swissgrid. Interviewees recommended the prototype business model accessing the A/S market through a third party model for different reasons.

(1) Firstly, the aggregator takes less risk and increases the efficiency of an existing provider. As the third party with an A/S portfolio has already invested into the mandatory infrastructure, the aggregator pays him with a share of the A/S compensation as a commission. This leaves the aggregator without fixed costs and enables flexible operation of the business. Especially in early stages of the business model with low levels of provided flexibility, this cost structure is superior to connecting directly to the TSO.

(2) Secondly, Swissgrid demands a minimum capacity of 5MW to connect directly. As security of energy supply is Swissgrid's priority number one, no exceptions to the rules are made for new technologies enabling the diffusion of RES. The aggregator would need to supply the promised power capacity reliably and to 100% of the agreed capacity upon request. However, with a car pool of individual EVs without a scheduled operation time or consistent charging pattern, the aggregator offers a statistical aggregate. To guarantee 5MW of power capacity, especially the last few percentages of security would be highly inefficient. Instead, the last few percentages can be supplied with hydraulic power within an imbalance portfolio.

(3) Lastly, acting through a third party leaves a lot of options open on how to deal with flexibility. It is possible to start with unidirectional smart charging, just providing for negative regulation energy waiting on the 'window of opportunity' to change to bidirectional charging.

#2: Combining Various Revenue Streams

The value per user is small when compared to the infrastructure investment necessary for enabling V2G services. In *Chapter 3*, the ancillary service market was considered as the only profitable market for V2G services. The interviewees however proposed three more sources of revenue, a car battery can be used for simultaneously. (1) The increasing number of DRES and EVs connected to the lowest grid level evoke the need for a local grid management. The success of a DSO congestion market model based on a USEF framework in the Netherlands could also be transferred to Switzerland. EVs balancing the local grid are compensated for charging the battery when the stress on the grid is low or excess solar energy is produced locally. (2) The integration of the car into the energy system of a house is the third revenue stream frequently brought up by the interviewees. It is a topic especially popular among utilities and car manufacturers. Especially with an own PV unit installed, smart charging increases the consumption rate of self-produced energy. Constantly sinking payback tariffs for feeding electricity back into the grid, raise the attractiveness of such business cases in Switzerland. With EVs charging at midday and absorbing all the excess solar energy, the homeowner might even be able to negotiate a bonus payment on the DSO congestion market. Not absorbing the solar energy during the day, the DSO would need to manage the excess power in the grid. Mainly distribution network fees and taxes are to be blamed for the higher repurchase price of electricity. (3) For businesses with large consumption peaks, bidirectional charging could be a gateway to industrial peak shaving. Extreme peaks can cause the electricity bill to skyrocket. Bidirectional charging can help to save money by only supplying a larger amount of electricity for a short time.

#3: Scalable Business Model

The value per user with (bidirectional) smart charging is low. For players with high R&D investments such as the aggregator and the charging equipment supplier, business models targeting niches are unlikely to be profitable. For those players to engage in a value network, the business model needs to address a large basis of potential clients/users.

#4: Support Existing Mobility Patterns

The value proposition of a V2G business model must ensure mobility needs at all times. Especially for a car/fleet owner V2G is only a means to an end. The main objective is a reduction of the cost of ownership of the electric vehicle, shortening the payback period of the PV unit or increasing the level of independency from the local grid. Therefore the V2G customer journey should always work around existing mobility patters or create an improvement to them. This increases user-friendliness. Especially if the business model is embedded into an existing business model, the core business needs to stay untouched. If anything, smart charging should increase the convenience in the user journey of charging the car.

#5: Flexible Business Structure

Closed charging environments limit the scalability of a business model as it only allows for a predefined group of users to access the infrastructure. The advantage is that all elements (EVSE, communication standard & EV) are elaborately chosen to match. Thus, standardization is not an issue anymore. A company fleet or a car-sharing fleet are two examples of a centrally managed fleets within a closed environment as their own charging stations are not for public use.

While the process of standardization in the industry is still ongoing and only few cars on the market have a bidirectional charging port, it might be difficult to find a large customer basis in public for V2G services. With the models of Nissan and Mitsubishi using the CHAdeMO protocol and new generations of cars using the ISO 15118 as a communication protocol, this splits the market and complicate to target a larger customer group. However, as one technology become dominant and the pool of users grows, the business structure needs to adapt to offer in a semi-open or public charging environment. A flexible business structure allows for a smooth transition from a closed environment with a small customer basis to an open charging environment with a large customer basis. It aligns the cost structure to the revenue and secures profitability.

#6: Target Users with Stable Charging Patterns

Capacity utilization is an important KPI to measure the profitability of a charging station. Targeting uses with a stable charging pattern allows for establishing virtual time slots and attend multiple user groups at different times. A complementing pattern combination is associated with workplace charging and company fleet. Workplace charging takes place during working hours and has a constant client basis consistent of commuters. Company fleets charge past working hours.

#7: Adequate Distribution Key of Bonus Payments

As already concluded in the main findings of the business cases, a fair distribution key of the bonus payments received from V2G services is crucial to the viability of a business model. It serves as the financial incentive of the EV owner, charging station owner, aggregator and portfolio owner to engage or disengage in a V2G business model.

#8: Cooperation

All interviewed representatives agree that a successful business case requires the collaboration among various players. A strong consortium is more likely to find a user-friendly solution when all heads are put together. A second reason to partner up is to share costs. The past has shown that if players act on their own initiative, is not in the interest of the business model's success.

Some positions in the consortium are contested and might be an obstacle to cooperation. Utilities and IT based startups are both interested in providing a software service accessing the energy markets and controlling the energy flow from and to the cars. Utilities are usually interested in developing a smart charging solution themselves and not cooperating with a third party. A scattered Swiss utility market could complicate the situation for a new entrant to find a partner utility.

Representatives see a high value in a network composed of companies with different competences. As commonly agreed, the leading position in the consortium should be held by a company of the energy sector, as the commercialization of V2G requires a fair share of knowledge in energy solutions. Other partner, such as Mobility, with a focus on mobility services, would only want to accompany the project as a consulting partner, ready to contribute with their knowledge and to invest their fleet for the business model.

#9: Quick go-to-Market Strategy

The Swiss ancillary market volume is limited, in prospect growing but still limited. With secondary regulation as the main market for V2G services, the aggregator needs to bid services to a lower price as fellow power plant operators to get the supply contract. First mover advantages in the ancillary service market often include higher a lower cost structure and a more reliable energy supply.

Moreover, with more and more V2G service providers entering the market, this could trigger a price race to the bottom. Therefore it is highly recommended to diversify the sources of revenue. This refers back to #2.

#10: Attractive Business Model with Perspective for Car Manufacturers

Car manufacturers lay the basis of the business model. They need to supply cars with bidirectional ports. However, to win the cooperation of car manufacturers needs an attractive business model constellation in their favor as Rug points out:

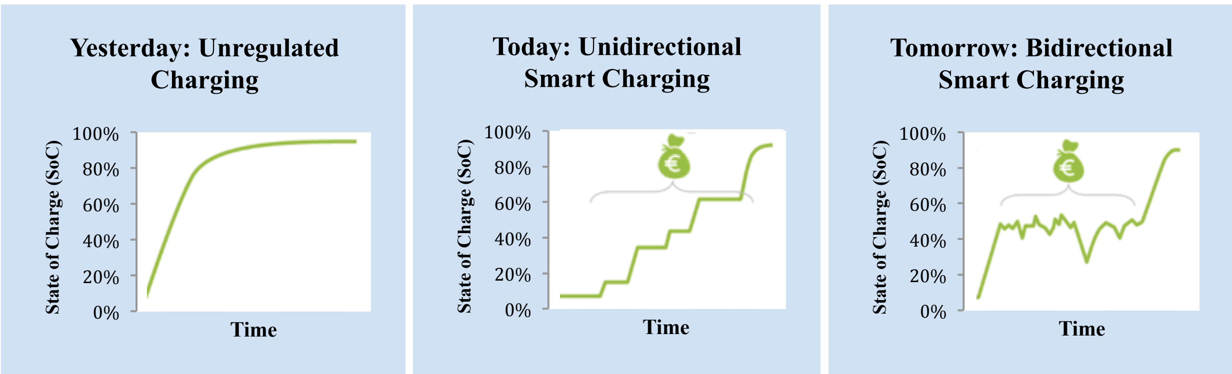
To develop a bidirectional port implies large costs for a car manufacturer and needs to pay off. Further, the additional charging and discharging cycles accelerate the battery degradation. Due to the additional wearing of the battery, most car manufacturers are unlikely to warrant for the additional risk. The prototype business model needs to consider this fact and at least compensate the car manufacturer accordingly. An attractive model could share the profits and risks of the business. Thus, the car manufacturer also participates in form of a financial bonus.

6.3 'Prototype' Business Model

The introduction of a V2G business model in Switzerland still has a lot of obstacles to overcome. Within the drawn limitations, it is important for a prototype business model to seize the current potentials but also to apply perspective. It is particularly important to have a long-term perspective and not to invest in the wrong technology as a process of standardization has just begun. The success factor framework in *Chapter 6.1* reveals in which hardware and software to invest and highlights some barriers of V2G still preventing a large-scale project. EVs and EVSE are not yet available to offer a large client basis for bidirectional smart charging at a reasonable costs. The solution to this issue is to establish a semi-open infrastructure to seize the current potential and feel the pulse of the market when the time has come for a large-scale project.

The roadmap towards applying V2G is not plain sailing. The risk of offering the V2G technology comes with a large initial investment. As it will take time for industry players to introduce standardized technical equipment and production costs to decrease, a full commitment comes with a considerable amount of risk. It would be smarter to seize the available potential of V2G by taking an intermediate step towards V2G. Unidirectional smart charging is an opportunity to test the waters and would encourage utilities and DSOs to establish a local grid management and cooperate with a service provider. It would also give time energy sector regulation to become acquainted with the local characteristics of the energy and automobile industry and propose legislature supporting future V2G business models. Thus, the prototype business model needs to be flexible. It needs to incorporate the functionalities of unidirectional smart charging and be easily extended to a V2G business model.

Figure 20: Roadmap to V2G



Source: Own illustration based on cross-interview analysis

The prototype business model

Many different business models would be possible, following the results from the business case studies and the interviews. However, only one business model is proposed. The idea of the prototype business model is to combine workplace charging for employees and company fleet charging with an own energy production unit. The two target groups naturally complement each other. During the day the employees charge their private EVs. Meanwhile the company fleet is on the roads. In the evening, when the employees commute back to their private homes and on weekends, the company fleet charges. This enables a high capacity utilization of the semi-public charging environment. The company fleet offers a certain security as they are constantly recurring customers, running on a technology compatible with the installed EVSE. The employees do not naturally own a car that is compatible with the EVSE offered at work but would use the infrastructure at work if it happens to fit.

The cars on the company facilitates, the employee cars and the company fleet, are parked close to each other. This permits for two cars to share a charging station with two outputs.

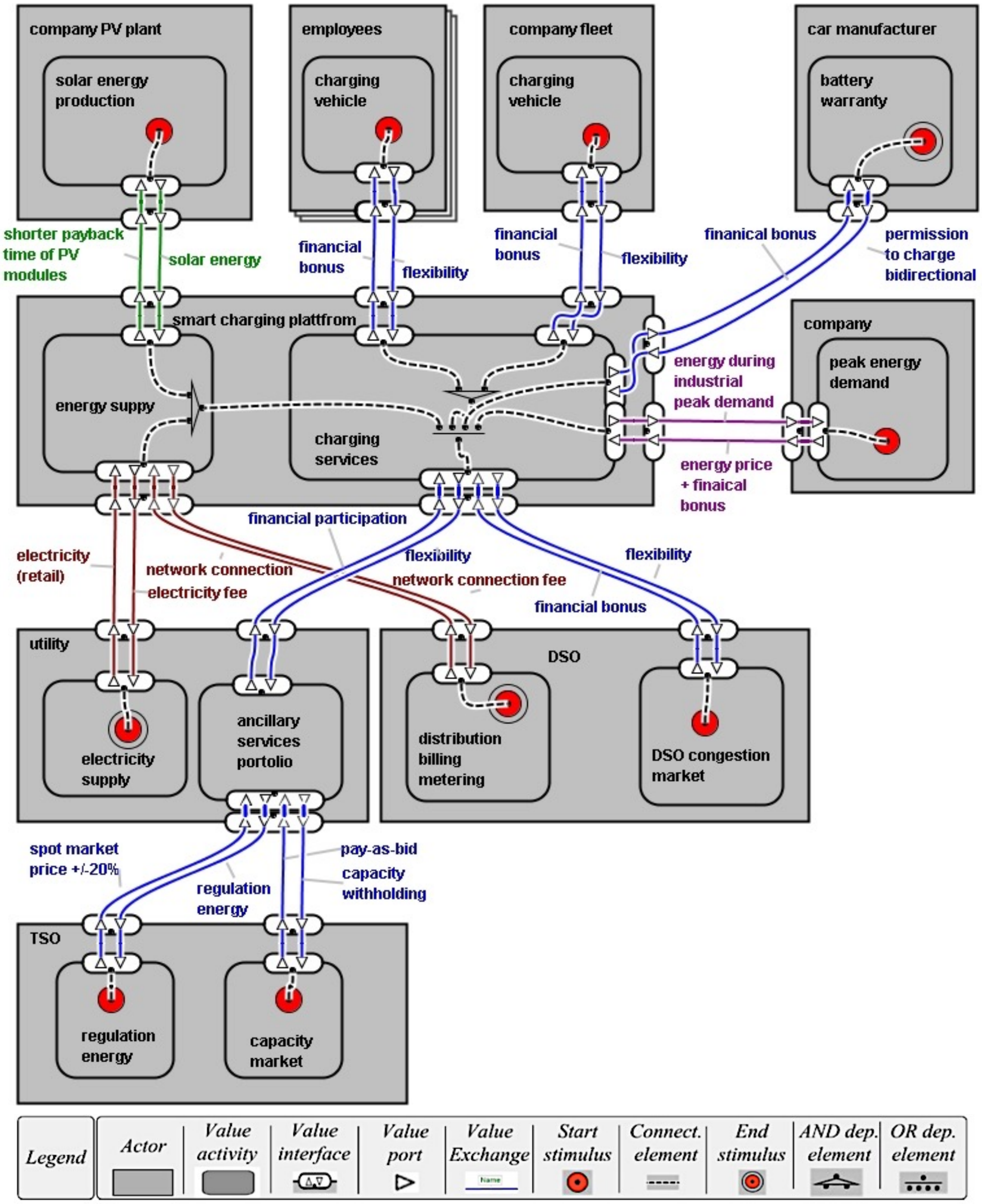
The business model generates revenue from four sources as seen in *Figure 21 & 23*: Savings from decreased distribution network fees and industrial peak shaving, a financial bonus from the DSO congestion market and a financial bonus from A/S. Employee charging during the day for a longer period with solar power increases the share of consumption of self-generated energy and saves on network distribution fees. Saving on peak power delivery generates the second source of income. The third revenue stream is generated form the DSO congestion market. If the cars would not absorb the solar power during the day, the DSO would need to handle a large amount of excess power in the grid. This is of benefit to the grid operator and has an economic value, which is calculated and compensated. If not enough solar power is available, the cars offer flexibility to the grid, as they are charged for a longer time. This applies to the company fleet recharging during the night. The third income stream comes from A/S sold to a utility portfolio.

The business model follows a three-step strategy to V2G. AC charging stations are installed on the company grounds with the capability of bidirectional smart charging. This lays the basis for the three-step strategy as it enables a smooth transition to bidirectional charging anytime, without loosing any customers and at no additional investment. The charging station runs on the ISO 15118 communication protocol, supported by European and American car brands at this time for unidirectional charging and for bidirectional charging in the future. In a first step, only unidirectional smart charging is possible. The revenue stream consists of bonuses from the DSO congestion market and savings from increased consumption of self-generated energy. Once standardization has progressed and cars with a bidirectional AC ports are available, also V2G services can be offered. A/S are sold via a third party on a imbalance market. Finally, when the service provider has a larger customer basis, a direct connection to the TSO is possible as shown in business case 3.

When docking on to the charging station, the private EV owner chooses a scenario communicating his departure time and the desired SOC. Assigning different prices to the scenarios, the smart charging provider incentivizes the charging behavior of the private EV owner. The higher the flexibility given by the EV owner, the cheaper the charging price. A simple incentive, effective to steer behavior, avoids consumer confusion and ensures user-

friendliness. Further this business model doesn't require the EV owner to enter a long-term relationship with a utility but only needs to make decisions for one charging cycle.
The profit generated with selling negative regulation energy to the grid (originally +20% of the energy spot price) is completely given to the car manufacturer. This mirrors the real degradation of the battery and shares the profits but also the risks of the business model. If the profits made on V2G services are higher, the car manufacturer also profits from this development.

Figure 21: Networked Business Model - Prototype



Source: Own illustration based on results

Value Proposition

This prototype business model enables high capacity utilization of a charging network for employees and a company fleet on enterprise facilities. All users receive a financial bonus for providing flexibility and reduce the cost of ownership. The charging process offers high convenience to the EV owner as the whole charging process is owned by the smart charging provider and he does not need to worry about electricity supply and the amortization of a PV module. The long parking periods of the private cars and company fleet offer high flexibility to the service provider. For the enterprise, a charging infrastructure with a high capacity utilization and supplied with electricity from an own production unit shortens the pay-back time of the entire infrastructure.

Value Network

The centerpiece of the value network is the aggregator. She coordinates the power flows from and to the grid and from the solar panels and is the party responsible for negotiating the terms of the three revenue streams. The enterprise also burdens a high risk with largest investment in charging units and the solar energy production unit. Other network players are the DSO, TSO, employees, company fleet manager and utility.

Revenue & Cost Structure

Similar to the previous business cases, the largest cost blocks of this business model is the amortization of the charging stations and the software development costs of the smart charging software.

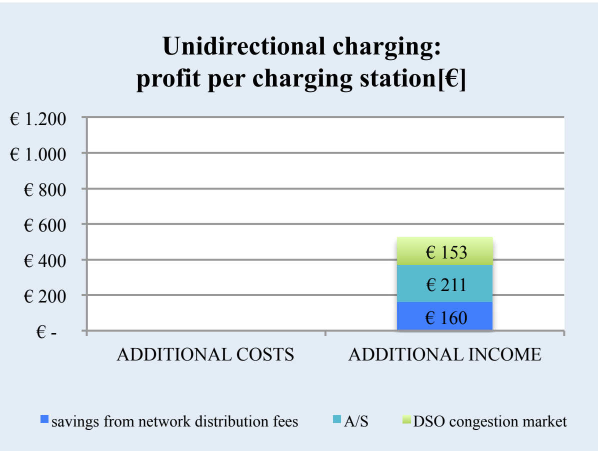
Base Case

To verify the profitability of the prototype business model the following assumptions were made:

- An AC charging station with a 22 kW power delivery and two outputs (each 11 kW) connected to two EVs costs 6’000€. To be able to charge bidirectional the AC charging station has an additional cost of 4’000€. Life-span is estimated at 10 years.
- The smart service provider is free to trade flexibility during 18h a day (75%) and an average 80km is recharged per car, equaling 7 kWh.
- The bonus payment for A/S is 2250€ for 10kW annually, positive and negative capacity. In case of unidirectional charging the bonus payment equals 50% of the original amount. The average bonus from the DSO equals 20% of the electricity bill.
- The bonus payment from the DSO congestion market and A/S market is shared at equal shares with the enterprise.
- The saved network distribution costs is absorbed entirely by the company.
- The charging station owner (employer) shares the bonus payments at equal shares with the car owner (employee/company fleet).
- The energy price is 0,07€ per kWh, the network distribution tariff is 0,8 per kWh.
- Software development costs are estimated at 2.5 million €, amortized over 10 years

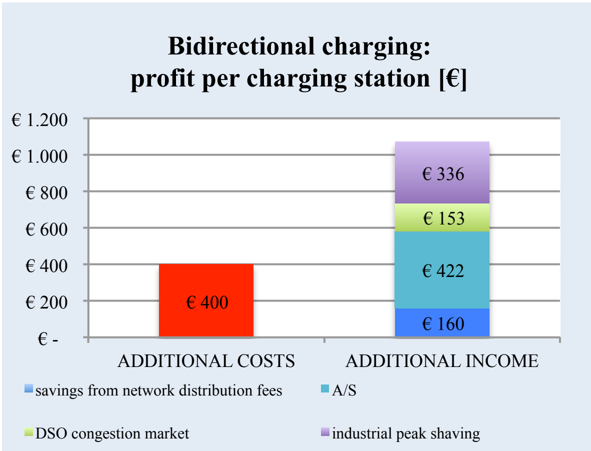
- The total energy production of the solar panels is 50’000 kWh annually and covers the electricity consumption of the company. The self-consumption rate of energy rises from 50% to 70% through smart charging.
- 5 charging stations with 10 charging outputs are installed.
- When discharging, battery degradation costs equal the 5% profit margin made on the sales of positive regulation. Battery warrantor receives the compensation.
- 20kW industrial peak shaving at 7€ per kW per month. Savings are entirely absorbed by the company

Figure 22: Annual Profit - Company (1)



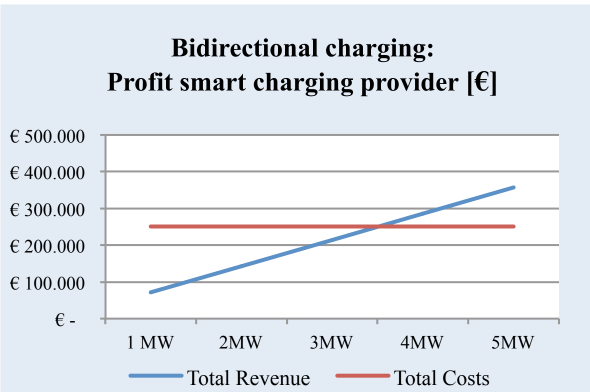
Source: Case study analysis

Figure 23: Annual Profit – Company (2)



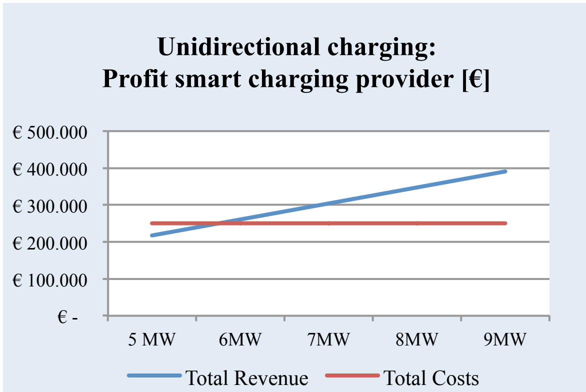
Source: Case study analysis

Figure 24: Annual Profit – Charging Provider (1)



Source: Case study analysis

Figure 25: Annual Profit – Charging Provider (2)



Source: Case study analysis

As illustrated in *Figure 22 & 23,* the profit from bidirectional charging is higher than the profits gained from V2G. Also from the point of view of the smart charging provider the break-even is sooner reached with bidirectional charging than with unidirectional smart charging. The compensation of each employee and car from the company fleet is attractive as he or she profits with 182€ resp. 287€ annually for charging on company ground. The distribution key, earlier mentioned as an important tool to align the interests of all parties involved in the business model, therefore needn’t be adapted and incentivizes all parties to participate in the business model proposed.

7. Discussion and Conclusion

7.1 Contribution and Implication

The objective of this Master's thesis is to research on guidelines for a suitable business model implementing the V2G technology in Switzerland. Three case studies and ten qualitative interviews with representatives of leading companies in the automobile sector, the charging infrastructure sector, the energy sector and others led to contributions that can be structured in three different fields: (1) *challenges and key success factors*, (2) *content of business model components* and (3) *future outlook*.

Presenting a snapshot in time, the results revealed that the different hardware and software solutions enabling grid services are still premature and non-standardized. However, a consensus among most automobile manufacturers is about to bring change. Nevertheless, at this point in time it complicates the integration of EV batteries into the power grid, although markets with clients exist, who are willing to pay for V2G services. Multiple, non-standardized technologies support island solutions, limiting the scalability of the business model and frequently lead to non-user-friendly applications. Assuming the risk in the form of large investment sums into the development of a software solution and bidirectional EVSE, it takes a large user pool to break-even. This is more realistic with a dominant and standardized solution increasing the basis of potential users. But as a V2G business model is always a collective effort, the process of designing a standardized solution is slow. There is still an informal dispute drawing a borderline between Asian and Europen/American car manufacturers. Therefore the risk of two island solutions incompatible among each other is still significant at this point in time. This is a factor preventing a lot of players to engage in a V2G business model. Nevertheless, following the guidelines from this thesis might be a way to convince the necessary players to engage in a V2G business model and operate profitable in Switzerland.

Firstly, the basis to the feasibility of a large-scale V2G business model is the number of EV models with a bidirectional port. According to the representatives of car manufacturers, investments into the development of a bidirectional EV port depend heavily on the attractiveness of a given business case. Among other conditions, the users need to be willing to offer their battery for grid services and the warrantor of the battery needs to be compensated for the additional charging cycles.

Secondly, the lack of standardization of the bidirectional charging hardware and software prevent positive diffusion effects. This forces a business model operator at this point in time to operate the V2G system in a closed environment with a fixed number of recurring users. For now, it seems the only way to keep the capacity utilization level of the charging point on a reasonable level. Examples of such users would be a company fleet or a car-sharing fleet with an own charging infrastructure. The challenge lies in finding flexible business structure aligning the risk/reward structure to the market. It must be able to smoothly transit from smart unidirectional charging to bidirectional charging. As more cars have a bidirectional port and standardization of the EVSE has progressed the business model can slowly open for public use. This approach is illustrated in a three-step roadmap. Starting with a low risk/low return model in a private charging environment with limited scalability the roadmap treads a path of continuously increasing the investment risk and expected return simultaneously. The first step includes mainly demand response activities performing unidirectional smart charging. Selling flexibility to different energy markets (DSO congestion market and imbalance market) the actors of the value network can make first experiences and develop experimental markets crucial to the profitability of a V2G business model. The second step intends to introduce bidirectional smart charging still selling the flexibility on the imbalance market. The final step proposes selling the energy on it's own initiative on the energy markets.

Thirdly, supporting the three-step plan, the right focus needs to be set on EVSE hardware and communication protocol. It is essential to install AC charging station, supporting the ISO 15118 communication standard. AC charging stations are designed for longer charging periods and support a smooth transition from uni- to bidirectional charging. They are significantly cheaper and are expected to be the future standard in bidirectional charging, opening the possibility to large-scale projects.

Further, the small value per user per MW for A/S forces the service provider to search for revenue sources apart from the TSO market to break-even and stay profitable in the future. The business cases disclose three revenue streams complementing the income from A/S, originally mentioned by scholars as the only market for a V2G services. The identification of the additional income streams originates from the realization that an EV battery is not only a storage capacity but also a large energy consumer. The increasing number of DRES and EVs connected to the lowest grid level evoke the need for a local management of energy. The success of a DSO congestion market built for this purpose and introduced in the Netherlands can be transferred to Switzerland. EVs balancing the local grid are compensated for charging the battery when the stress on the grid is low or excess solar energy is produced locally. The third revenue stream comes from increasing the consumption share of self-generated energy and saving the PV owner from repurchasing electricity to a higher price than sold to the grid. The constantly sinking payback tariffs for feeding back electricity into the grid, raise the attractiveness of this solution. The fourth revenue stream comes from industrial peak shaving. Using the EV batteries to provide for extreme peak demands of a company saves money. For all parties to engage it is important that the distribution key of all revenue streams is fair and somehow values the investment.

The presented business cases illustrate that V2G business models need to provide multiple, stacked services in order to be profitable. The user-friendliest way to seize the potential of all four revenue streams, is to install the charging infrastructure on a company ground. The business model prototype illustrates how two user groups, a customer fleet and employees can efficiently share a charging point without conflicts. Informally defined time slots intend for the employees to charge during the day and the company fleet during the night. This measure increases the capacity utilization of the charging stations and secures constant battery availability for industrial peak shaving. Moreover it corresponds with the actual mobility behavior, as most of the commuters park their car during the day on or close to the company grounds.

7.2 Recommendation for Future Research and Concluding Remarks

This Master thesis covers the specific topic of the implementation of V2G technology into a business model for the Swiss energy market and reveals interesting findings for theory and practice. The results can provide helpful orientation to a wide range of players in the Swiss energy market environment. Nevertheless, there are still knowledge gaps in different areas related to V2G, which would need to be closed by additional research.

Apart from vehicle batteries there are also other battery storage systems discussed among representatives of industry players. With EV drivers already heading towards second generation models, a lot of disused battery packs are available with enough capacity left for storing energy. Alone over 200’000 Nissan Leafs have been sold, meaning that in the coming years a lot of battery packs will be available. So-called second-life batteries, usually installed at homes, are an alternative to V2G. This thesis did not compare the profitability of different battery storage business models aiding the integration of renewable energy sources. This could be the objective of future research.

To conclude, I would like to come back to the quote from Al Gore (2016), which was already mentioned as a guiding thought on the first page of this thesis:

> *“Crossing the grid parity will be a breaking point in our economy. This threshold is like 0 and 1 degree Celsius on the temperature scale, it’s the difference between ice and water. In markets it is the difference between frozen up markets and liquid flows of capital into new opportunities of investments. […] Things take longer than you think they will and then they happen much faster than you thought they could” (Al Gore, TED-Speech, September 2016).*

V2G business models support the energy landscape to increase the share of renewable energy sources and integrate them more efficiently. It could change the rules of the game and make renewable energy cheaper for everyone, thus steering towards grid parity. However, there are more business models using other promising battery storage options, facilitating the integration of more renewable energy sources. Only a process of experimentation will reveal the most efficient technology and business model. Becoming the dominant solution, it will make renewables cheaper and contribute towards a more sustainable development of our society.

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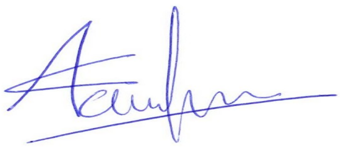

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