Interoperability Architecture for Electric Mobility

Allard Brand, Maria-Eugenia Iacob, Marten Van Sinderen

Interoperability architecture for electric mobility

Allard Brand[1], Maria-Eugenia Iacob[2], Marten J. van Sinderen[2]

[1] Energie Data Services Nederland, Baarnsche Dijk 4D, 3741 LR Baarn, The Netherlands
[2]University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands
allard.brand@edsn.nl, {m.e.iacob, m.j.vansinderen}@utwente.nl

Abstract. The current architecture for electric mobility provides insufficient integration with the electricity system, since at this moment there is no possibility for influencing the charge process based on information from market parties such as the distribution system operator. Charging can neither be influenced by grid constraints nor by the amount of (renewable) energy supply available. Because of the potential threats and opportunities and the impact these could have on the business model, there is a need for further integration of the energy and electric mobility markets. The aim of the current research is to define a reference architecture based on the current developments and concepts from literature to help market players in making the right steps forward. As main objectives, the reference architecture should (1) optimally integrate with the electricity system, (2) accommodate the adoption of renewable energy sources, (3) be aligned with European standardization developments and (4) have a positive impact on the current business model. The main concept behind the reference architecture is the concept of 'smart charging'. Based on a literature study, a reference architecture is defined for electric mobility. To provide a path for implementation and migration, a migration architecture is proposed.

Keywords: Interoperability, electric mobility, electricity system, electric vehicles, smart charging.

1 Introduction[1]

The energy provisioning will change dramatically in the coming decades. The European Union has committed to reduce Europe's greenhouse gas emissions by 20% in 2020, and by 80-95% in 2050, compared to the level in 1990 [9]. In order to make this happen, non-renewable energy sources such as coal are expected to be replaced by renewable and sustainable energy sources. At the same time, the transition to (more) electric mobility is considered as a contributing factor. Car manufacturers, consumers and grid operators show a growing interest in electric mobility.

Up to now, attention has mainly focused on the development of electric vehicles and the realization of an accessible charging infrastructure. However, massive use of

[1] The current research has been conducted at Alliander, one of the main distribution system operators in the Netherlands.

electric mobility also introduces threats and opportunities in relation to the electricity system, which requires an increased degree of integration between the markets of electric mobility and the electricity system. The current architecture for electric mobility is inadequate, since there is a lack of integration between electric mobility and the electricity system. The main reason is that currently, there is no possibility for influencing the charging process based on information from market parties such as the operator of the distribution system or the energy supplier. Charging can neither be influenced by grid constraints nor by the amount of (renewable) energy sources available. In the current situation, charge points can only be controlled by the charge spot operator, which indicates a low amount of interoperability in the current architecture. Thus, the main goal of this research is to define *a reference architecture for electric mobility with the purpose of facilitating interoperability between involved parties from the markets of electric mobility and the electricity system*.

A *reference architecture* captures the essence of existing architectures for a class of problems (in our case that of designing an integration solution for the energy and electric mobility markets), and a vision of future needs and evolution to provide guidance to assist in developing new system architectures [5]. For the concept of *interoperability* we adopt the definition proposed by Chen et al. [4] stating that interoperability can be defined as the ability of two systems to understand one another and/or use one another's functionality.

We adhere to the 'Design Science Research Methodology' as defined by Peffers et al. [19]. The approach we take to develop our reference architecture is as follows. After we investigate the concept of electric mobility (Section 2), the objectives for the reference architecture will be defined on basis of the main problems and limitations in the current situation (Section 3). Given these objectives, we provide an elaboration of the smart charging concept (Section 4), and are able to derive a reference architecture for electric mobility (Section 5). For the design of the reference architecture, we apply the enterprise architecture approach as proposed by Iacob et al. [11]. This approach is based on open standards; using the 'Architecture Development Method' from TOGAF, and ArchiMate as the modeling language and framework. In line with this method we also formulate an implementation plan expressed as migration architecture (Section 5). The reference architecture is then evaluated by means of interviews with experts (Section 6).

We follow the approach depicted in **Fig. 1**. Based on the concepts defined in the ArchiMate core, architectures can be created that fill in the views related to phase B, C and D of the TOGAF ADM cycle; the phases concerned with creating the business, information systems and technology architectures. For describing the implementation and migration paths, a migration architecture will be established, providing an interim solution as a first step towards the reference architecture (phases E and F).

2 Energy Market Overview

In order to create a clear and comprehensive understanding of the concepts, services and structure in the current situation, we will review the markets of electric mobility and the electricity system.

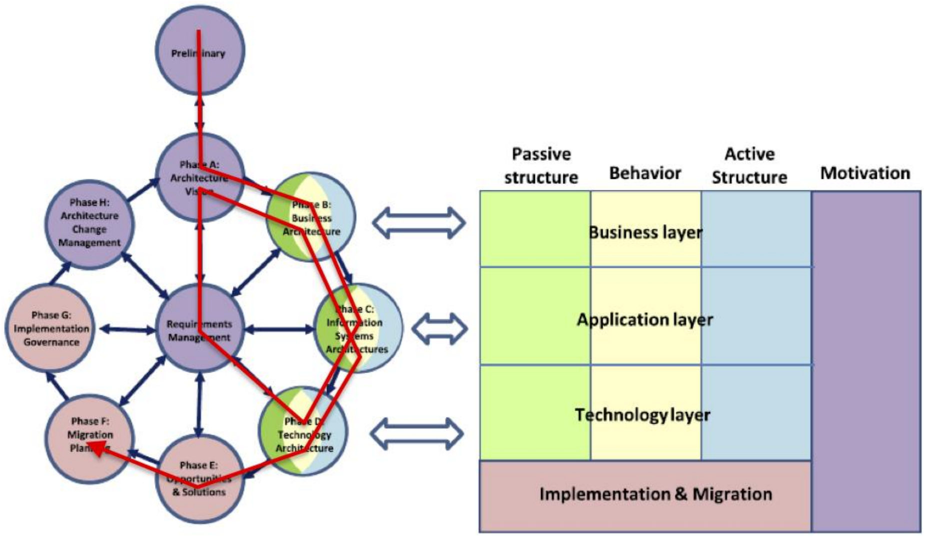

Fig. 1 Approach of the current research [10]

2.1 Electric mobility

Based on the definition by Gartner, we define *electric mobility* as the concept of using electric technologies, in-vehicle information, and communication technologies and connected infrastructures to enable the electric propulsion of vehicles and fleets [9].

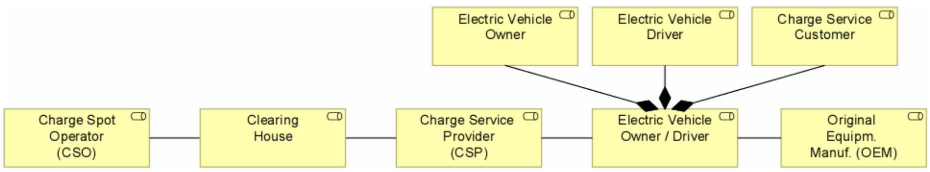

Fig. 2 Overview of the market roles within the market of electric mobility

In the current market for electric mobility, five main roles are evident. These roles are depicted in **Fig. 2**. The charge spot operator (CSO) is responsible for managing and operating several charge points. The e-mobility or charge service provider (CSP) is the central point of contact for the customer, providing them with the ability to charge at public charge points, irrespective of the responsible CSO. In order to realize this, the role of a clearing house exists, which unburdens both CSO and CSP, making it possible to provide roaming functionality to their customers. The original equipment manufacturer (OEM) is the producer of electric vehicles and/or charge points, and provides EV related services. The remaining role is the role of electric vehicle owner and/or driver. This role aggregates several sub roles: the owner of the electric vehicle, the driver of the electric vehicle that influences its charging needs, and the charge service customer, who owns the contract with the CSP.

For the charging of electric vehicles, charging infrastructure is needed. The current research is focused on the charging infrastructure in the public and semi-public space, concerning charge points for customers that cannot charge at home or need to charge during their travel. The main reason behind this decision is that most citizens do not have a private driveway and depend on public charging infrastructure.

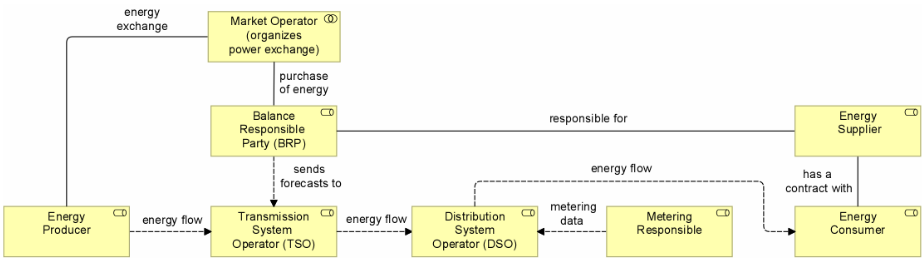

Fig. 3 Overview of the market roles within the electricity system

2.2 The electricity system

De Vries [6] defines the electricity system as the combination of systems that produce, transport and deliver power and provide related services, including the actors and institutions that control the physical components of the system. The electricity system consists of a technical and an economic subsystem. The technical subsystem is defined as the physical part of the electricity system, consisting of the hardware that physically produces and transports electric energy to customers, as well as the devices that use the electricity. The economic subsystem is defined as the actors that are involved in the production, trade or consumption of electricity, in supporting activities or their regulation, and their mutual relations [6] (see **Fig. 3**).

Energy producers feed their electricity directly into the transmission grid, based on contractual agreements with the transmission system operator (TSO). The electricity is then transported to the distribution system operator (DSO), from where it is distributed to (small) consumers. The metering responsible party is responsible for the metering processes. In the Netherlands, the DSO used to perform this role; however, since the introduction of the 'supplier model', the energy supplier has been given this responsibility [7]. For the sake of understandability, we identify the metering responsible as a separate role. On the market, organized by the market operator, electricity gets traded. Energy producers offer their electricity on this market. Balance responsible parties (BRP) buy commodity on the wholesale market in order to serve the customers of the energy supplier they represent. The energy supplier sells electricity to its customers. Very large electricity consumers can buy electricity directly on the wholesale market [6].

The liberalization of the energy market has led to the establishment of a separate balancing market in the Netherlands. This market is controlled by the TSO, who is the single buyer on this market. When there is imbalance in the network, the TSO corrects this by buying the lowest priced offer in the balancing market. Most of the offers come from large power producers. However, sometimes smaller energy producers or energy suppliers offer electricity as well. The TSO charges the balance responsible parties that caused the imbalance on basis of the price that it has paid on the balancing market. The mechanism works the other way as well: in case of a surplus of produced electricity, the TSO accepts and receives the highest bid in the balancing market for adjusting generating units downwards [6].

2.3 Changing nature of the electricity system

According to [14] two inter-related movements can be seen in electricity generation, impacting the way the electricity system will be managed in the future. The first movement is the increase of electricity generated from sustainable energy sources in order to reduce greenhouse gas emissions. The second movement entails the decentralization of electricity generation; instead of centralized power plants with high capacity, the number of smaller electricity generating units is growing and moving closer to the load centers.

Fossil fuel usage is one of the greatest contributors to greenhouse gas emissions, leading to a significant increase in the concentration of carbon dioxide in the atmosphere [14]. This introduces one of the greatest global challenges of our time: climate change [21]. Issues concerning climate change are high on the political agenda; as illustrated by the commitment of the European Union to reduce Europe's greenhouse gas emissions to 80-95% in 2050 [9]. Worldwide, energy provision is radically changing; under the influence of climate change a strong drive exists to reduce fossil fuels usage and make the transition to renewable sources instead [22].

The second movement described by [14] concerns the decentralization of electricity generation. Thus, electricity generation capacity is increasingly realized in the distribution part of the electricity system as small-scale generation units are directly connected into the distribution grid.

3 Objectives

The main objective of the current research is to improve interoperability between the involved parties from the markets of electric mobility and the electricity system. To serve as a basis and assessment for the reference architecture, various underlying objectives have been defined on basis of the problem description and analysis in the preceding sections.

3.1 Optimal integration of electric mobility and the electricity system

Verzijlbergh et al. [23] investigated the impact of electric vehicle charging on residential low-voltage networks. Their results, based on data from Enexis, show that the charging of electric vehicle has a significant potential impact on residential low-voltage networks. This impact can be reduced by influencing the charge process, shifting demand away from (household) peaks. This way, the number of overloaded transformers and cables can be reduced drastically. In an impact scenario, this reduction is approximately 25% and 8% for overloaded transformers and cables.

Therefore, the reference architecture should reflect and accommodate the ability to let distribution network operators influence the charge process, with the goal of using current assets as efficient as possible and avoiding unnecessary investments in assets.

3.2 Accommodation of the adoption of renewable energy sources

As mentioned in section 2.3, a movement is expected from centralized electricity generation based on fossil fuels towards electricity generated from sustainable energy sources. The main driver for this movement is the reduction of greenhouse gas emissions [14]. However, renewable energy sources and distributed generation are generally unpredictable and introduce fluctuation in supply [17]. Electric vehicles can improve the economics of distributed energy generation when integrated in an optimal manner [20], and offer an enormous ability to temporarily adjust demand. Therefore, the reference architecture should reflect and accommodate the advantage offered by electric vehicles to optimally integrate renewable energy sources.

3.3 Optimization of the business model for electric mobility

The business case for charge points has been a negative business case up to now [24]. The market model as originally proposed by [17] has been implemented, but does not seem to succeed very well. In addition, the current architecture implies a situation where customers have no choice of energy supplier, since the energy contract is established between the supplier and charge spot operator. For the reference architecture, various alternative solutions have to be compared to see whether other implementations could result in a better business model [14].

4 The Concept of 'Smart Charging'

In the current situation, no external control is involved in the charging process. This basic form of charging electric vehicles is called 'uncontrolled' or 'dumb' charging [2]. As stated in the problem analysis and objectives, integration is needed between the process of charging electric vehicles and external influences based on fluctuations in demand and supply. In an ideal situation, charging should be influenced based on grid constraints and the amount of (renewable) energy supply available. This concept is not new, and is widely regarded as 'smart charging'. The concept of smart charging is one of the central concepts that has been applied in the reference architecture.

The main idea of smart charging is that by taking control of the charging process, the use of the grid and available energy can be optimized to minimize additional investments and facilitate the integration and storage of renewable energy [2].

The concept of smart charging is positioned as an alternative to 'standard' or uncontrolled charging. Movares defines smart charging as a method for charging electric vehicles optimized according to the available grid capacity and/or fluctuations in the supply of (sustainable) energy [16].

Based on a use-case analysis by CEN, CENELEC & ETSI [2] four drivers can be identified, that are depicted in **Fig. 4**. The four drivers can be summarized as follows:

(1) Charging has to be performed within boundaries as specified by the customer. (2) The process of charging should be optimized to meet grid constraints. (3) Charging should be based on supply and availability of renewable energy sources. (4) Charging should be optimized to 'avoid' peaks and efficiently use production capacity.

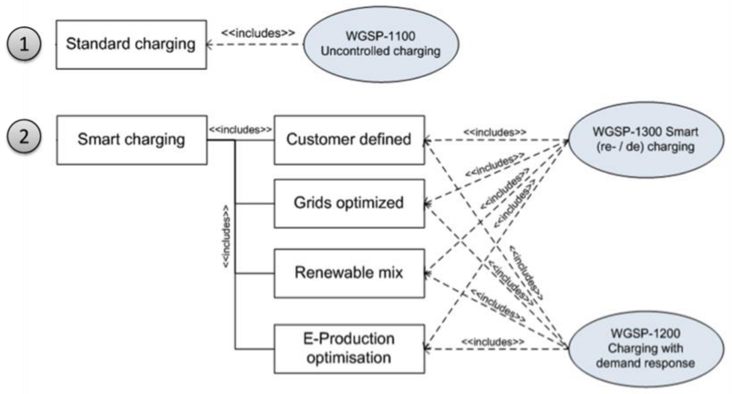

Fig. 4 Drivers for 'smart charging' [2]

As hinted in **Fig. 4**, there are essentially two ways to 'implement' the concept of smart charging. In the following sections we will present these two options.

4.1 Controlled charging

Controlled charging is a realization of smart charging based on flexible contracts and technical signals for load control [2]. Control signals can be sent to either the charging station or the electric vehicle. These control signals can range from simply switching between on and off, charging with a specific rate or can involve communication about sophisticated charge schedules. Controlled charging should be seen as a 'top-down' approach in demand-side management, where measures are taken by market actors in order to control the electricity demand [2]. In other words, market roles (such as utilities) decide to implement measures on the demand side to increase the efficiency of the energy system. This is the approach that has been used by the vast majority of the power industry over the last thirty years [8].

In the scenario of controlled charging, the role of the 'aggregator' (also referred to as 'flexibility operator') arises. This is a generic role that links the role customer and its possibility to provide flexibilities to the roles market and grid [2]. The aggregator is responsible for summing up flexibilities from several customers, and actively participates in energy market commercial transactions to market these flexibilities [1]. The aggregator coordinates the charging process on basis of based on control signals.

4.2 Demand-response charging

Demand-response charging involves extra communication that makes it possible to receive price signals or other incentives, providing the possibility for a customer to respond [2]. In contrary to the controlled charging approach, the concept of demand-response implies a 'bottom-up' approach, where customers become active in adapting their consumption patterns [8]. According to the International Energy Agency, demand response refers to a set of strategies which can be used in competitive electricity markets to increase the participation of the demand-side, or customers, in setting prices and clearing the market [13]. Demand response can be seen as a concept describing an incentivizing of customers in order to initiate a change in their consumption or feed-in pattern [2].

In a demand-response approach, customers are exposed to (near) real-time prices or other incentives, to which they may respond in two ways [13]: shifting their demand in time to an off-peak period, or reducing their total or peak demand (either by energy efficiency measures, or self-generation). Of course, customers are free to choose to not respond and pay the market price instead.

Demand-response can be implemented in two ways, based on the method in which customers can respond to the price signals. The first option is a manual implementation: customers get price information, for example on a display, and based on this information they decide whether or not to shift their consumption. The second option considers an automated implementation: customers shift their consumption automatically, based on technical signals and some kind of an energy management system. For instance, the system could set-up the system in such a way that (part of) their consumption is shifted when prices are at a certain level [8]. In contrast to the scenario of controlled charging, the external control of the charging process could be fully automated based on a demand-response energy management system (EMS). This EMS acts as a software agent that represents the customer. The EMS communicates about demand-response price signals over some sort of communications network, such as the internet [18]. Based on the price signals, the EMS can adjust the charging process automatically. The PowerMatcher technology [15] is an example of agent-based system for demand-response energy management.

4.3 Consequences for design choices

Adopting the concept of smart charging affects several other design decisions, ranging from consequences on the structure of the energy market to changes in the metering functionality. The main question to be answered is how to relate the relevant stakeholders to the charging process; how can the role specific objectives be translated into either price or control signals (such as start charging, stop charging, and charge at a specific level).

In the demand-response approach, price signals or other incentives are used to influence the charging process. In order to realize this approach, new kinds of energy markets need to emerge. In the 'European conceptual model of Smart Grids' [2], three markets are identified that are expected to emerge in the smart grid of the future: the energy market, the grid capacity market and the flexibility market. The grid capacity market gives distribution system operators the possibility to attach variable prices to grid capacity, in contrast to the fixed grip capacity prices as reflected in the current situation. In this way, the DSO can use a demand-response approach for congestion management. As identified in the previous section, automated demand-response requires some kind of energy management system (EMS). A logical location to implement this EMS would be inside the electric vehicle.

In the controlled charging scenario, control is performed by a secondary actor, outside the scope of the electric vehicle. The aggregator needs to be able to send control signals to the charge point management system of the charge spot operator, which translates these control signals into commands towards the charge point. The charge point reacts to these control signals by adjusting its charging process.

5 Reference and Migration Architecture

Based on [15], the automated demand-response approach using two-way communication is considered as the most favorable scenario. According to Kok, this scenario forms the hot spot in his ‘smart energy management matrix’ [15]. The main advantages of this approach when compared to controlled charging is that it mitigates privacy issues and enables distributed control with full power and responsibility at the customer. At the same time however, demand-response involves radical changes when compared to the current situation. Flexible energy and grid prices are needed and energy management systems need to be implemented within electric vehicles. Because of this radical change, we choose to establish two architectures: a reference architecture, based on the demand-response approach towards smart charging, and a migration architecture, providing an interim solution as a first step towards the reference architecture. The migration architecture focuses on the realization of the objectives as identified for the current research that are feasible on a shorter timescale, and implements the scenario of controlled charging.

For both the reference and migration architecture, a new ’type’ connection is introduced for charging stations, on which various energy suppliers are allowed to deliver energy. This introduces the ability to ‘switch’ between energy suppliers, and allows the customer to have their ‘own’ contract for the provision of energy. To distinguish between separate charging sessions, it is desirable to replace the currently separated meters of the DSO and CSO with a single certified meter per outlet, managed and controlled by a trusted third party. Based on a shared registry for the metering data of charge points, metering values can be exchanged between energy supplier, DSO and CSO. This situation would be in line with the current ‘meter values registry’ for regular connections, as mentioned in [7].

The reference architecture is shown in **Fig. 5**, Please note that for comprehensibility, some relationships have not been drawn [2]. The servers in the infrastructure layer realize the applications in the application layer, except for the on-board management system which runs on a local server inside the electric vehicle. However, these realization relationships have not been drawn. Although, both smart meters are related to the metering database; for simplicity, only one of the relationships has been drawn.

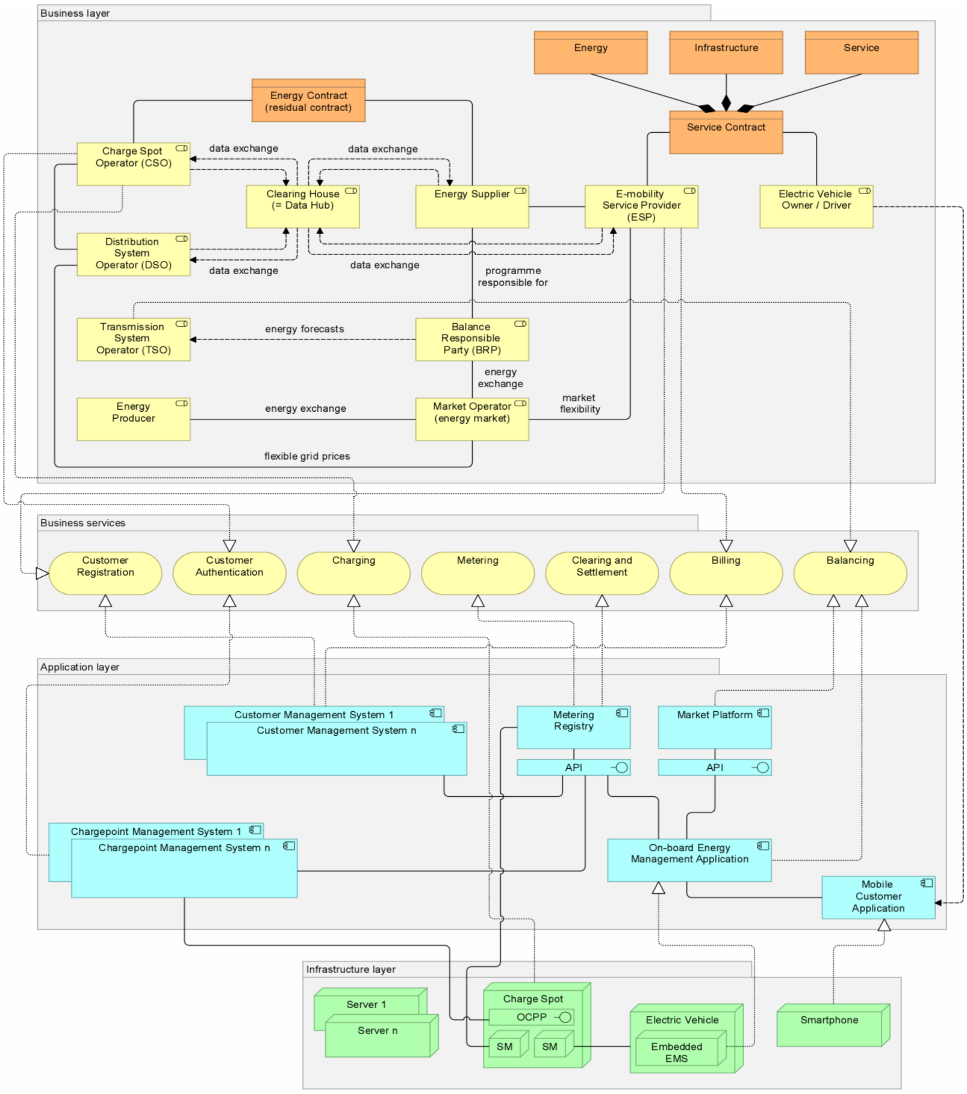

Fig. 5 Reference architecture for electric mobility

The migration architecture is shown in **Fig. 6**. In this architecture, the role of 'aggregator' is depicted, reflecting the controlled charging approach as described in section 4.1. The aggregator is the key mediator between the consumers on one side and the markets and the other power system participants on the other side [1]. By externally controlling the charge process, the aggregator combines flexibilities from several customers. In the migration architecture, the radical changes that are required to support an automated demand-response approach (that forms the basis of the reference architecture) are absent.

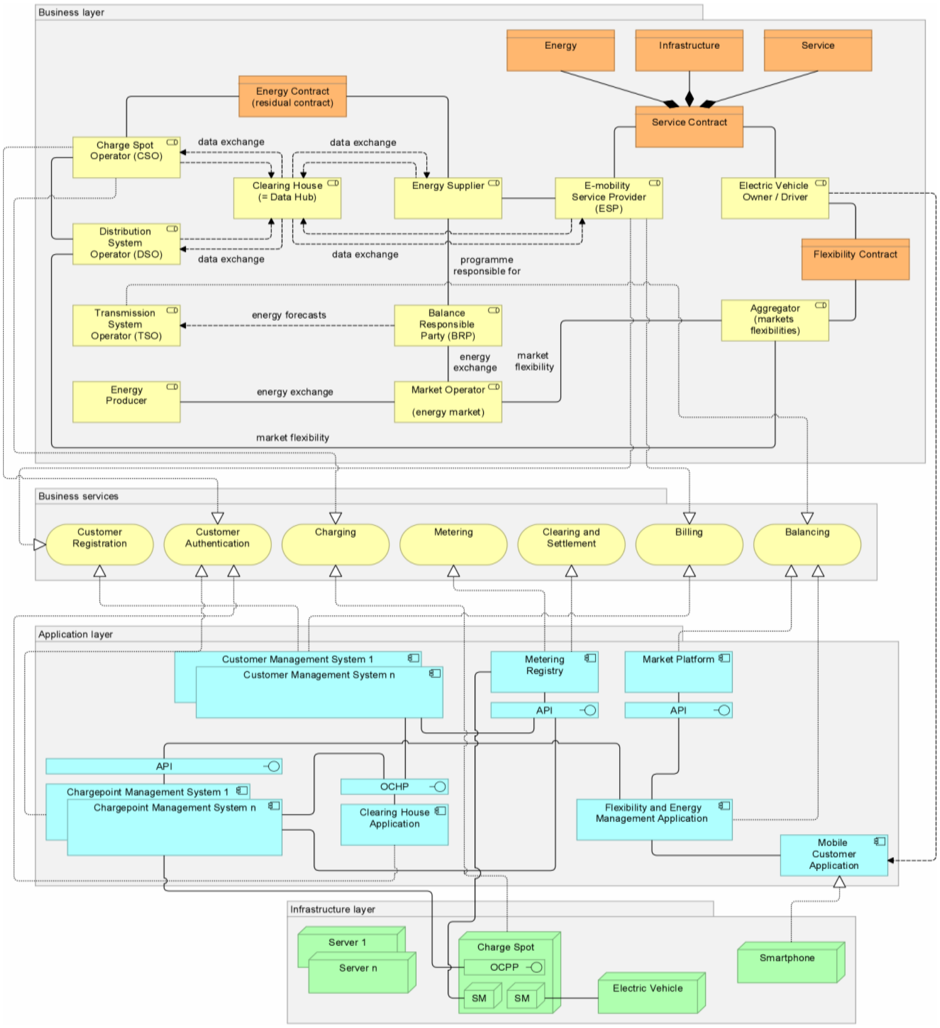

Fig. 6 Migration architecture for electric mobility

6 Validation

For the validation of the architectures, we used a qualitative approach. A series of structured interviews (of about 90 minutes) have been carried out with six experts in the fields of energy, electric mobility, and of (enterprise) architecture (in **Table 1** the experts that have been interviewed are listed, including their experience in years). The interview consisted of an initial presentation on the background, motivation and design choices as made for the reference architecture. Following on this presentation, the reference architecture has been presented to each of the interviewees.

Overall, the interviewees showed confidence in the model and outlined that in principle, it can greatly improve the identified problems. The results of the validation are graphically displayed in **Fig. 7**. All of the interviewees with experience in the energy sector agreed that the situation as modeled in the reference architecture would enhance the integration between electric mobility and the electricity system, and reduce the potential impact of electric mobility. One of the main reasons given was that smart charging results in a better utilization of the electricity net. By applying control and scheduling in charging, less of the electricity cables need to be replaced.

Table 1. Validation interviewees (including their years of experience)

Company	**Profession**	**Energy**	**Architecture**
E-laad	Manager R&D and innovation	12	n/a
Enexis	Manager smart grids	28	n/a
EDSN	Manager architecture and services	25	15
Eneco	Senior project manager	12,5	n/a
Univ. of Twente	Professor, Information Systems	n/a	10
Delft University, UCPartners	Senior researcher and CTO	15	15-20

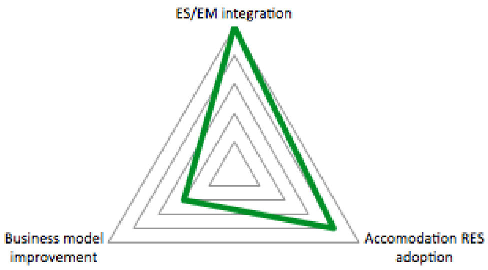

Fig. 7 Validation results (outermost contours represent highest scores)

The interviewees confirmed that the reference architecture depicts a situation that drives the adoption of renewable energy sources (RES) in the electricity system. When compared to household devices such as washing machines, electric vehicles have an enormous potential capacity. The idea of dynamic demand and supply can helps significantly in solving the intermittency problem of renewable energy, which concerns its stochastic behavior. Being able to 'follow' the availability of energy supply offers a more effective solution than the globally examined opportunity of storage, since the latter involves an energy loss. Some interviewees mentioned the importance of regulation for the success of RES adoption. The interviewees agreed that the current business model does not yield a profitable situation. Several of them pointed out that this is only the case for the realization of public charging infrastructure (the focus of the current research); for private and semi-public charging infrastructure positive business cases can be made. It was also pointed out that the main reason for the negative business case of the current business model is its narrow scope. The realization and commercialization of public charging infrastructure is not profitable when considering just the provisioning of uncontrolled charging. However, there is financial potential in the reduction of grid investments, the balancing of the electricity system and the storage of energy. In the discussion about the implementation of smart charging, various viewpoints have been mentioned. Overall, the interviewees agree that smart charging has to be based on incentives. However, the opinions concerning the implementation of these incentives vary. Real-time price signals (as in the demand-response approach) are desirable for the future, but are not feasible in a short timescale since they are radically different from the current organization of the energy market. The current energy market is based on forecasts and reconciliation, and involves financial risks. One of the interviewees mentions that for the distribution system operator (DSO), price signals are not an adequate instrument at all; he mentions that the component of the energy prices that a DSO can influence is insignificant (since it concerns only a few cents); prices need to be increased at least a tenfold before having a little effect. Even though it was confirmed that price signals offer the simplest mechanism and are preferred on long term, most interviewees mentioned that controlled charging is more feasible on a short term. This confirms the migration path as proposed in the current research.

7 Conclusions

To address the drawbacks of the current architecture for electric mobility, we proposed a reference architecture that facilitates interoperability between the involved parties from the markets of electric mobility and the electricity system. The main architectural choices that have been made involve the implementation of ‘smart charging’; the integration of flexibility and intelligence in the charging process, the location of control and the metering of the usage of electricity for individual charging sessions. The reference and migration architectures are depicted in **Fig. 5** and **Fig. 6**, and have been validated qualitatively, through a series of interviews with experts in the fields of energy, electric mobility, and (enterprise) architecture.

Reflecting on the main result of this research, we conclude that the proposed architecture forms a useful blueprint for the realization of an integrated solution for electric mobility and the electricity system. This is expected to drive the integration of RES, to have a positive impact on the business case for the charging infrastructure and to prevent potential threats towards the electricity system. In addition, the architecture provides a common vocabulary for further discussions, aggregating various concepts from literature. The current research can be used as a reference for helping market players make the right steps forward.

As any other research, the current research involves certain limitations. Even though the reference architecture seems to provide a promising solution, the level of abstraction is relatively high. The field of electric mobility is still immature, and therefore the main focus of our research has been on analyzing market roles, processes and high-level design choices to provide an integrated architecture for electric mobility and the electricity system. Especially the application layer needs further refinement in order to provide concrete guidelines for involved stakeholders.

Another limitation regards the validation of the reference architecture. Although the reference architecture has been discussed extensively with leading experts, the number of interviews that could be performed is relatively low. We believe that further validation research might result in improved feedback and uncover further issues in the reference architecture. Also, the development of one or more concrete business cases can help to open the discussion with the stakeholders.

Finally, we have not examined the concept of inductive charging. Further research is needed in this area and may have implications for the reference architecture.

References

1. ADDRESS. Technical and commercial conceptual architectures. 2009.
2. R. van Buuren, H. Jonkers, M.-E. Iacob, and P. Strating. Composition of relations in enterprise architecture models. Graph Transformations, LNCS 3256, pages 39–53, 2004.
3. CEN, CENELEC & ETSI. Smart Grid Coordination Group – Sustainable Processes. 2012.
4. D. Chen, G. Doumeingts, and F. Vernadat, Architectures for enterprise integration and interoperability: Past, present and future. Computers in Industry 59, pages 647–659, 2008.
5. R. Cloutier, G. Muller, D. Verma, R. Nilchiani,E. Hole, and M. Bone. The concept of reference architectures. Systems Engineering, pages 14–27, 2010.
6. L. J. De Vries. Securing the public interest in electricity generation markets: The myths of the invisible hand and the copper plate. Technical report, 2004.
7. EDSN. Stroomopwaarts: Gezamenlijk stapsgewijs naar een beter functionerend marktmodel voor kleinverbruik. 2013.
8. Eurelectric.Power Choices: Pathways to Carbon-Neutral Electricity in Eur. by 2050, 2011.
9. European Commission. What is the EU doing about climate change?, July 2013. Obtained online from: http://ec.europa.eu/clima/policies/brief/eu/ index_en.htm.
10. Gartner. IT Glossary: Electro Mobility, Apr. 2012. Obtained online from: http://www.gartner.com/it-glossary/ electro-mobility-e-mobility/.
11. M.E. Iacob, H. Jonkers, D. Quartel, H. Franken, and H. Van den Berg. Delivering Enterprise Architecture with TOGAF and ArchiMate, Van Haren, 2012.
12. M.E. Iacob, L.O. Meertens, H. Jonkers, D.A.C. Quartel, L.J.M. Nieuwenhuis, M.J. Van Sinderen, From enterprise architecture to business models and back, Software & Syst. Modeling 13(3), 1059-1083, 2013.
13. International Energy Agency. The Power To Choose: Demand Response in Liberalised Electricity Markets. 2003.
14. J. Kok, M. Scheepers, and I. Kamphuis. Intelligence in Electricity Networks for Embedding Renewables and Distributed Generation. 2009.
15. J. K. Kok. The PowerMatcher: Smart Coordination for the Smart Electricity Grid. 2013.
16. Movares. Laadstrategie Elektrisch Wegvervoer. 2013.
17. Netbeheer Nederland. Net voor de toekomst: een verkenning. 2011.
18. OpenADR. Openadr overview, June 2013. Obtained online from http://www.openadr.org.
19. K. Peffers, T. Tuunamen, M. Rothenberger, andS. Chatterjee. A design science research methodology for information systems research. Journal of Management Information Systems, pages 45–77, 2007.
20. D. B. Richardson. Electric vehicles and the electric grid: A review of modeling approaches, impacts, and renewable energy integration. Renewable and Sustainable Energy Reviews 19, pages 247–254, 2013.
21. Rijksoverheid. Nieuwe energie voor het klimaat: Werkprogramma schoon en zuinig. 2010.
22. TNO, UUtrecht, ECN. Naar een toekomstbestendig energiesysteem voor Nederland, 2013.
23. R. Verzijlbergh, Z. Lukszo, J. Slootweg, and M. Ilic.The impact of controlled electric vehicle charging on residential low voltage networks. pages 14–19, 2011.
24. VNO-NCW. Onoph Caron: ‘Hoe financieren we de aanleg van laadpalen?’.