Addressing the Challenges of a Cross-Industry Consortium Project for the Integration of Electric Vehicle in the Energy System

Elisabeth Springmann, Jakob Zahler and Kirstin Ganz

FfE Munich, Am Bluetenanger 71, Munich
espringmann@ffe.de

Abstract. Cross-industry collaboration is needed to meet the challenge of integrating electric vehicles into the electricity grid. The unIT-e² project meets this requirement with a consortium of partners covering the entire value chain - from electric vehicles to charging, IT and metering infrastructure to grid operators. At the same time, this special feature brings with it a number of challenges, such as the different backgrounds of the partners in terms of technical know-how. In order to meet these challenges, the project is set up by a consistent and uniform project structure. This includes on the one hand the division into subprojects and practice clusters and on the other hand the uniform approach applied across them. Another special feature of the collaboration between the energy and automotive industries is the different "markets" that they serve. While the energy industry is predominantly based on the German market and regulation, the automotive and component manufacturers aim to develop globally marketable products. unIT-e² addresses this issue by integrating a European perspective in the synthesis and a subsequent analysis regarding the applicability of the developed approaches to other European countries.

Keywords: electric vehicles, living lab, project methodology, grid and system integration, international comparison.

1 Motivation

The rising number of electric vehicles poses challenges for the power grid in the long term. The increase in load, in particular due to the simultaneity of different consumers in certain time frames, e.g., due to potential price incentives, can probably not be coped through the existing grid infrastructure. [1] The expansion and upgrading of the grids will hardly be able to keep up with the dynamics of the change to electric vehicles in the transportation sector. For this reason, a wide variety of approaches for grid-friendly and -serving charging of electric vehicles are being discussed. In the project "unIT-e² - Living Lab for integrated E-Mobility", concepts are developed in four different practical clusters that, among other things, enable the provision of grid and system services. The technical implementation is to take place in the corresponding field tests in the further course of the project. To depict the entire process chain arises the necessity of including a multitude of partners into the project. A project with such a size and diversity of the consortium brings many advantages and at the same time presents a challenge, especially in terms of efficient coordination and profitable exchange between the partners.

Furthermore, research projects in the automotive context involve special framework conditions, because product developments must also be observed from an international perspective if promising technologies are to be developed. Business models in the context of electromobility are particularly promising if they can be scaled beyond national and, if possible, European borders. In contrast, the energy industry has so far been able to limit itself predominantly to the German "market". Requirements for connecting plants to the electricity grid and for controlling them only have to meet German specifications, even if these are embedded in European legislation. This difference in approach between the automotive and energy industries, with nationally specific standards versus the need for internationally successful products and business models, thus plays an important role in the development of solutions for grid and system integration of electric vehicles. Relevant interfaces must be identified for which an international standard is required. In this way, globally attractive products can be developed that are at the same time compatible with the individual requirements on the part of the energy industry in the countries.

2 unIT-e² - Living Lab for integrated E-Mobility

The unIT-e² project has set itself the goal of integrating electromobility intelligently and securely into existing and future infrastructures in order to cope with the transformation of the energy system. To this end, stakeholders from different industries, from vehicle manufacturers to grid operators, are to enter into an exchange and jointly develop and test interoperable solutions. unIT-e² is thus making a significant contribution to the sustainable and socially accepted renewal of the transportation sector, while at the same time addressing the challenges of increasing sector coupling.

2.1 Project Idea and its Challenges

The composition of the unIT-e² partner consortium reflects the cross-sectoral project orientation. Four automobile manufacturers and seven grid operators are accompanied by 15 partners of both industrial and scientifical background to develop a holistic approach for the integration of electric vehicles into the energy system. Therefore, use cases were implemented, that intend to generate a beneficial impact on the grid while being potentially financially appealing and ecologically reasonable. The composition of the consortium emphasizes the importance of cross-sectoral cooperation and allows the partners to bilaterally discuss respective interfaces with the prospect of achieving contemporary and practicable solution strategies. The living lab design of unIT-e² ensures a purposeful realization of the scientific concepts through ongoing interaction between ideas, implementation and examination. The possibility of corresponding not only in a cross-sectoral context but also with organizations of similar structure can add further value for the participants. For example, unIT-e² allows grid operators to discuss and develop future options for their respective field of activity. Especially grid operators face challenges through the necessity of a contemporary and widespread transformation of the energy sector. This transformation is both cost-intensive and time-consuming. A living lab approach like the one exercised in unIT-e² allows for a discussion of probable solutions without prejudging the outcome and can hence help reducing barriers between the different stakeholders. The development of mutually agreeable and feasible solutions can thus be achieved.

Managing a project with such a number of partners from different sectors and regions inherently leads to several challenges. Firstly, the multitude of participants requires a significant coordination effort. The living lab design of unIT-e² and its holistic approach intensifies the coordination demands since every process step depends on the active collaboration of various partners. Additionally, the interdisciplinary background of the different partners gives risk to the occurrence of misunderstandings or can lead to an inhibited tone of discussion. The fact that some of the participants are competitors on the market and that there is a conflict of interests between some industrial sectors must also be considered. Another challenge is the difference in the markets that the partners are serving. While the energy sector, especially grid operators, are only focusing on the German framework conditions, component and car manufacturers want to develop products that can be sold beyond German and European boarders.

Another challenging aspect is the regulatory framework which is of a great importance especially for participants of the energy industry. The recently ongoing discussions surrounding adjustments of the current law and regulation structure are a constant uncertainty while managing a project like unIT-e². A challenge for the scientific participants of the living lab is displaying this dynamic process of regulatory, legal, and technological development in their respective analysis and scientific work. Therefore, the scientific partners rely on the practical participants to share their knowledge and thus come to feasible proposals for action. **Fig. 1** shows the characteristics of the unIT-e² project approach and the resulting challenges for the project management and work.

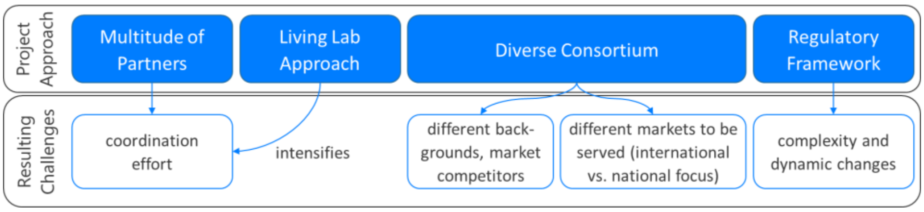

Fig. 1. Characteristics of the project approach and resulting challenges

2.2 Approaches to meet the challenges

The structure of unIT-e² is designed to cope with some of these challenges by taking into account the expertise as well as the constraints of each participant. Therefore, three approaches to solution are identified as key for the efficient performance of the living lab, which are subsequently presented.

Subprojects as (partially) autonomous ecosystems with well-defined interfaces

Having various automobile manufacturers participating in the living lab leads to the necessity of different subprojects from an antitrust point of view. By contrast, harmonizing concepts and scientific support for grid operators and energy suppliers is of great importance regarding future standardization in the transformation of the energy sector. Therefore, the unIT-e² project platform is divided into seven subprojects (see **Fig. 2**): three subprojects lay the conceptual foundations, while four subprojects are dedicated to implementation and testing as practical clusters. The various living laboratories have different regional and content-related focal points. This is intended to minimize the coordination effort between the partners and to develop solutions initially in a small environment before they are incorporated into the cross-cluster exchange.

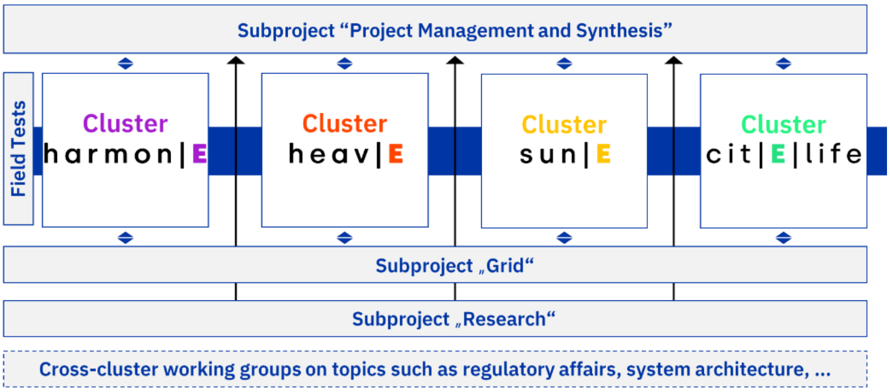

Fig. 2. Four field tests and three conceptual subprojects

The practical clusters are supplemented by three superordinate subprojects. These will answer questions about fundamental processes and framework conditions that are relevant to all clusters. In the subproject "Grid" for instance, grid operators as well as component manufacturers develop mechanisms and technologies for the integration of charging points in grid operation processes. One topic here is for example the smart meter infrastructure and its further development to meet requirements for the realization of use cases.

The subproject for "Project Management and Synthesis" is organizing exchange between the clusters and provides a common project methodology for the clusters. This allows a synthesis of the results of the clusters, as isolated studies and isolated solutions do not satisfy the enormous scope of the electromobility issue. Only a holistic utilization and processing of all work packages will enable the successful transfer of research results to politics, industry and education. The subproject "Research" is doing the accompanying research, i.e., through analyzing the use cases in energy system and grid modelling tools. But also, vice-versa, there is an exchange between the clusters and the research partners: through the investigation of the industrial partners, various input parameters for modeling and calculating scenarios were collected and thus build a common database for the analysis in the research subproject.

Additionally, the structure displayed in **Fig. 2** offers the advantage that a potential integration of further future clusters into the existing project or a possible follow-up project can be implemented without any problems. Beside this “official” project structure, working groups were established in order to have an option for cross-cluster discussions about topics that are relevant for all, as for example regulatory affairs or the system architecture.

Project methodology as enabler for harmonization and specification of field tests

Due to the variety of partners involved there are also numerous characteristics of the concrete implementation of the integration of electric vehicles into the energy system. Therefore, it is necessary to create a common standardized basis at the beginning of the project, which defines the approaches and applications to be developed for all. As established in previous projects a moderated process based on the use case methodology according to the IEC system approach (see DIN IEC/TS 62913-1 in [2]) was developed, which guided the partners in shaping their ideas up to implementation. In unIT-e², this methodology was further developed to reflect the transdisciplinary nature of the project. A detailed description of the adapted use case methodology, which provides a uniform format for the description and design of use cases, both on the economic and technical level, can be found in [3]. Using this specified methodology, the intended use cases were identified in a large number of workshops with the project partners of the clusters in the first half of the project, structured uniformly and then technically designed. This defines a basis for further research and development work and creates the possibility for comparison and exchange between the partners and clusters.

As outlined in **Fig. 3**, the precise process definition is set to take place as the basis for developing the necessary hardware and software to implement these use cases. The implementation in the field test, in turn, can provide valuable insights into the technical implementation and the interaction with customers. These are synthesized across all clusters at the end of the project and used for the subsequent further development of the use cases to the market-ready stage.

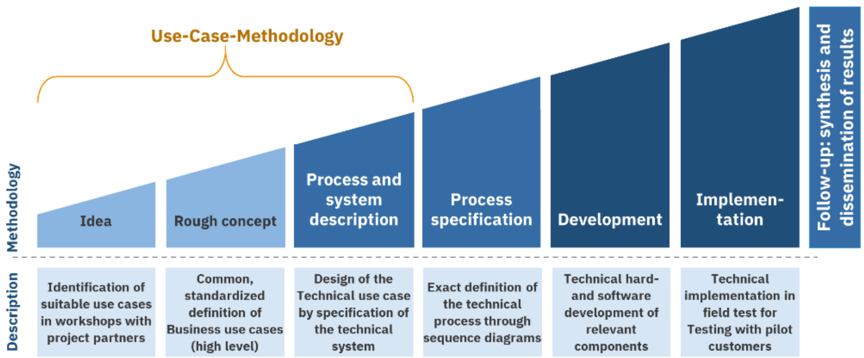

Fig. 3. Phases and Methodology of the Project

Cross-sectoral knowledge transfer and identification as a basic precondition

The interdisciplinarity of the project team is both a strength and a challenge. For efficient, goal-oriented collaboration it is important to speak the same language and use uniform terms to ensure that the team has a common understanding. For this purpose, proven tools such as a glossary describing more than 70 terms from the context of the energy and automotive industries were used to serve as a reference work for the team [4]. Furthermore, the transfer of knowledge between the partners in the project is explicitly promoted. A format has been established, the so-called universIT-e², in which a specialist topic is presented every two weeks and afterwards discussed in the panel. This gives the team the opportunity to build up interdisciplinary knowledge and discuss different perspectives and points of contact. There is a great deal of interest in professional exchange in the project and many topics have already been addressed: from Redispatch 2.0 to battery technologies and revenues of the marketing of capacity from electric vehicles.

The process for the identification of the unIT-e² mission statement is aimed at the understanding addressed here - both within the project and in external communication. Research projects such as unIT-e² with a strong technological-processual focus quickly become preoccupied with details. Thereby, the concrete implementations and the question of "why" are sometimes difficult to discern. Therefore, a common mission statement was developed according to Simon Sinek's Golden Circle methodology: Here, the "why" of the project was elaborated, the "how" was sharpened with the choice of methods, and thus the "what" could be placed in a larger context. The short, concise "unIT-e² story" created in this way serves to present the project to the outside world and to consolidate as well as create a common understanding of the project focus in internal collaboration.

In summary, through unIT-e², living laboratories are created that offer a neutral framework for stakeholders with sometimes competing interests to work together on solutions under scientific supervision without having to put their own business goals on hold.

3 Analysis of the Grid and System Integration of E-Mobility in international Context

The international perspective plays an important role in the unIT-e² project. As already mentioned as one of the challenges in the cooperation between the energy and automotive sectors, international products are to be developed that simultaneously meet the energy industry requirements, both technical and regulatory, in Germany. However, the strategies for charging the increasing number of electric vehicles in the individual countries play an essential role here. Thus, the steps for the grid and system integration of electric vehicles were defined before examining their implementation in European countries.

3.1 Grid and System Integration of Electric Vehicles

With the aim of investigating international strategies, different stages of grid and system integration of electric vehicles are considered (see **Fig. 4**), whereby the steps cannot be clearly separated from each other and therefore overlap. Digitization builds the basis, with the rollout of smart meters playing an essential role in maintaining high data availability and quality and for controlling generation and consumption units. The next step is grid-friendly charging, which has the goal of not hindering the ramp-up of electrical consumers due to limited and possibly insufficient grid capacity. The next step is grid- and system-friendly charging, in which electric vehicles provide grid and system services and thus contribute to stability. This step goes hand in hand with the market integration of electric vehicles, whereby their capacity is marketed on the energy markets to generate revenues.

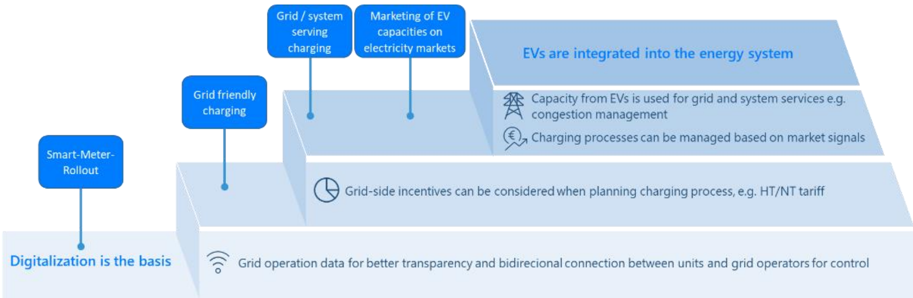

Fig. 4. Steps for the grid and system-integration of electric vehicles

Smart Meter Rollout

The smart meter rollout in Europe is based on the EU internal market package for energy 2009/72/EC from 2009, according to which all countries are obliged to carry out a rollout. The original plan was for an economic evaluation of the countries to be carried out by 2012 with regard to the design of the rollout. Based on a positive evaluation, around 80 % of consumers should then be equipped with a smart metering system by 2020. [5]

Grid friendly charging

In grid-friendly charging, grid-side incentives can be taken into account when planning the charging process. An example of this are time windows in which the grid fees are cheaper than in others, e. g. day & night tariff (deutsch: HT/NT Tarif). The specific time frame and the concrete financial structure of these tariffs are the responsibility of the grid operator. They are determined by contract. This concept thus differs from dynamic tariffs / market oriented charging. [6]

Grid and System serving Charging

When charging grid or system serving, the charge point operator has a contract with the grid operator. This allows the grid operator to use the capacity of electric vehicles connected to this charging point for a specific grid- or system-serving service. This can include, for example, control power, congestion management or redispatch measures. In return, the owner of the electric vehicle or the charge point operator is getting financial compensation for this.

Market oriented Charging

In contrast to the other two, the third concept is detached from grid requirements and is instead based on market signals. Here, the charging process is optimized so that charging takes place at times when electricity prices are low. By extending this concept for bidirectional vehicles, electricity can also be traded and fed into the grid at times when electricity prices are expensive. This concept is often discussed under the name of dynamic tariffs.

3.2 International Approaches

For a better understanding of international approaches, the described steps for the grid and system integration for electric vehicles are investigated for different countries. The results provide insights into the relevance of the use of electric vehicles for the provision of grid and system services as well as their market access in the countries considered.

Smart Meter Rollout in Europe

Most EU countries are currently carrying out a full rollout for all metering locations. In Bulgaria, Hungary and the Czech Republic there is currently no rollout [7], [8]. In Slovakia, Germany and Belgium, a selective rollout for specific user groups has been implemented so far. In Slovakia, there is a mandatory rollout for electricity consumers with consumption above 4,000 kWh per year [9]. In Germany, consumers above 6,000 kWh per year and systems with an installed capacity above 7 kW are affected by a mandatory rollout [10]. Within Belgium, there are different selective regulations for Flanders and Wallonia. In Flanders, rollout is mandatory for new equipment, renovations, and prosumers; in Wallonia, it is mandatory for consumers over 6,000 kWh, prosumers over 5 kW, and public charging points [8]. The functionalities covered by smart meters differ between countries, sometimes significantly (cf. **Fig. 5**). In particular, the remote control of generation and consumption plants is currently provided in only five EU countries.

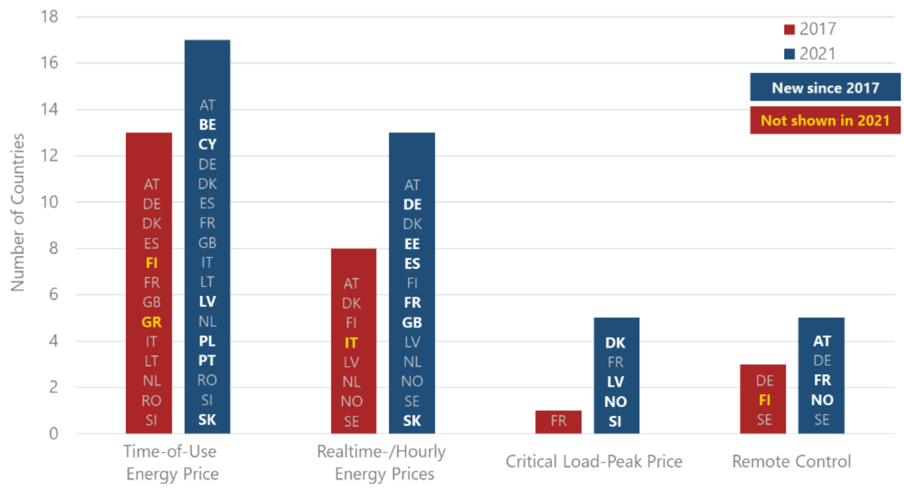

Fig. 5. Functionalities of smart meters in European countries [11] [12]

Concepts for grid-friendly charging in Europe

In Germany, there is an ongoing discussion on the amendment of §14a EnWG. Considering the approach of other European countries, a distinction can be made between capacity- or power-based grid charge designs and the application of time-variable grid charges to achieve a more even grid load (cf. **Fig. 6**).

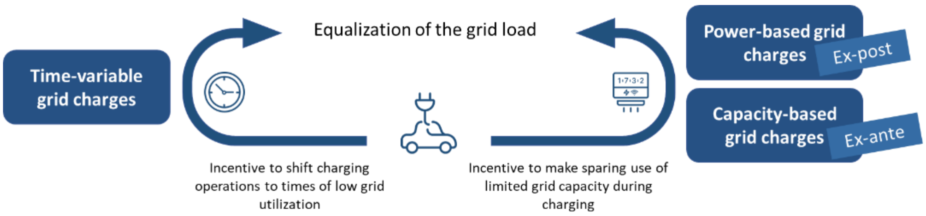

Fig. 6. Concepts for the equalization of grid load [13]

In both cases, there is a large number of different variants. Both ideas are conclusive and intend the following:

- the sparing use of limited grid capacity or
- the shift of power consumption to times of low grid utilization.

It can be stated that none of the approaches has yet gained acceptance in Europe. The analysis of the European countries shows that time-variable tariffs are already available in some countries (cf. **Fig. 7**) - partly for all household customers (yellow) and partly only for specific households (light blue). Capacity-based prices for residential customers are only available in Italy and the Netherlands. Only in Germany, Austria and Norway there are volume-based tariffs for households without any time differentiation. Sweden and Finland play a special role: here, the network operators can specify the tariff system themselves.

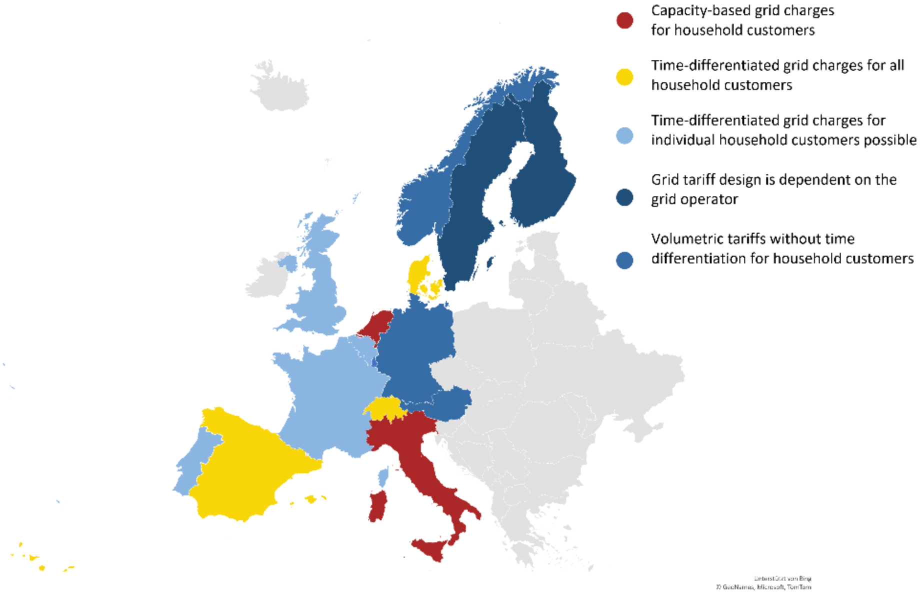

Fig. 7. Design of grid charges in European countries [13]

Relevance of Grid and System serving Charging in Europe

This analysis mainly focuses on congestion management and ancillary services [14]. Congestion management measures in European countries are currently implemented very individually and mainly depend on the available power plant fleet in the specific country. For the provision of ancillary services, in the countries considered also mainly large power plants are used. Germany seems to play a lone role in the implementation of Redispatch 2.0 and the associated inclusion of small units in congestion management measures. Norway, as a country with a high penetration of electromobility (16.9% of the passenger car stock are battery electric vehicles [15]), can hardly be considered a model for Germany with the predominant provision of electricity from hydropower plants and thus a base-load capable renewable energy resource. In this case, zonal pricing works well as a control instrument. The countries considered, which do not operate a zonal or nodal system, exclusively target the deployment of large capacities in the markets for redispatch or frequency: For example, in the Netherlands, the minimum bid size is 1 MW [16], and in the UK it is 3 MW [17][18].

It can be concluded that Germany is taking a special path, compared to the considered countries, due to the integration of small units and, in the future, also loads into ancillary services. For the actors involved, this may mean that the provision of ancillary services from small units could initially be a market limited to Germany. However, other countries could also integrate small flexible plants into their ancillary service processes in the future. In this case, players already involved in their implementation today would have an advantage and could contribute their experience from the German market.

	Action: Redispatch	Action: Operating reserve	Participation	Remuneration
Germany	System stability criteria for measure selection	Tender for pre-holding (merit order), automatic activation if required	RD: >100 kW mandatory FC: 1 MW (also pools)	RD: cost based FC: capacity charge (+energy charge (aFRR, mFRR))
Netherlands	passive flexibility provision + location-specific bids	Combination of cost-optimized activation and passive control	min. 1 MW + 60 min.> 60 MW mandatory	Pay-as-bid (capacity & energy charge)
France	Congestion management in combination with tertiary reserve, indication of possible schedule deviation		mandatory, mainly hydro & nuclear power plants	Pay-as-bid (capacity & energy charge)
Italy	DAM & IDM zonal, RD & FC: common market with nodal offers (nodal), cost-optimized procurement.		> 10 MW mandatory	Pay-as-bid
Norway	zonal system + redispatch + countertrading (merit order)		contracted players	Marginal price of the bidding zone
United Kingdom	"Balancing Market" (BM): Combined market for redispatch and operating reserve + Bilateral negotiations between grid operators & plant operators.		various products	BM participants: Pay-as-bid, otherwise auction capacity & energy charge
Spain	Trading, predominantly "MSRT market" (1st phase), merit order	MSRT (2nd phase) or positive reserve capacity market.	aFRR: min. +500 MW, -400 MW mFRR: mandatory	RD: Pay-as-bid aFRR/mFRR: marginal capacity charge
USA (PJM)	Nodal system	All participating stakeholders are called as needed (collective adjustment).	mandatory ("central dispatch")	RD: according to nodal prices FC: performance-dependent (response time)

Fig. 8. Overview of the provision of redispatch and operating reserve in various countries [14]

In addition to the potential provision of ancillary services by small units, the approach discussed in Germany also includes the advantage of tapping the flexibility potential for grid services in the distribution grid. In addition to establishing energy industry processes and regulations, the prerequisite for this is the connection of the plants via communication and telecontrol systems. Within the framework of the unIT-e² project, approaches for the design of such processes are being developed, and the technical integration of small-scale flexibility - especially from electric vehicles - -into the grid and ancillary service processes is being investigated and tested in practice.

Comparison of European Market Designs

For the third step of grid- and system-integration of electric vehicles, the trading of their capacity on the energy markets becomes relevant. The concrete market design varies between European countries. In the analysis, the geographical boundaries are based on the borders of the European Union, the membership of the power exchanges in the NEMO Committee and is extended by the countries United Kingdom and Switzerland due to their central location and political relevance. In addition, smaller countries are pooled, resulting in 26 regions. The study investigated five market mechanisms: spot markets, forward markets, balancing services, existence of capacity mechanism and number of bidding zones. Thus, there is an overlap between the system serving charging and the market integration of electric vehicles. [19]

The market mechanisms are specified using 19 different key parameters. The analysis is described in detail in [19]. As a result, the countries Italy, Ireland, Spain, the United Kingdom, and the Czech Republic show the highest deviations from the German market design (see **Fig. 9**). The high rating can be derived mainly from the large (e.g. Italy) or small (e.g. Czech Republic) variety of trading products on the respective markets. In particular, the characteristics of balancing energy are the most influential factors when comparing the countries.

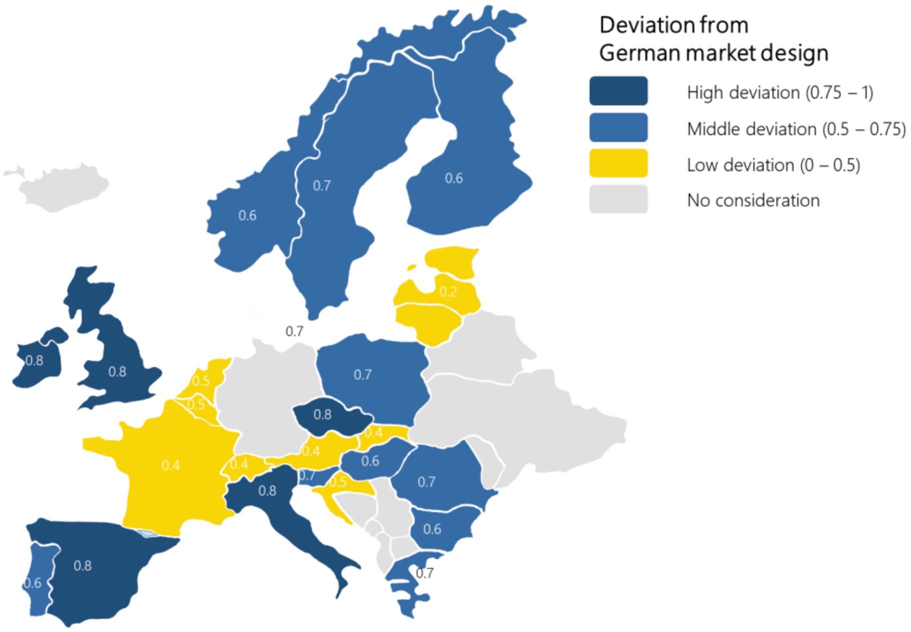

Fig. 9. Deviation of the market design in European countries in comparison to the German market design [19]

4 Conclusion

The successful ramp-up of electromobility requires cross-sector collaboration between the automotive and energy industries. Among other things, this entails a great deal of organizational effort, which is solved in the unIT-e² project by a consistent project structure and a project methodology that is applied across the subprojects. With its project structure and methodology, unIT-e² can serve as a blueprint and shows how interdisciplinary innovations can be developed and implemented. Furthermore, in interdisciplinary projects, the framework conditions vary between different partners. One example is the need for international products (automotive industry) versus national requirements (grid operators). This challenge is addressed in the project by focusing on national requirements in the first step of the development of solutions. This procedure is supplemented by accompanying scientific analyses regarding their transferability to other countries. The analyses so far have shown, that the approach to integrating electric vehicles into the electricity grid, energy system and market is currently very heterogeneous and depends heavily on the specific national framework conditions. Thus, in the near time, local use cases that are largely independent of the regulatory framework should be implementable beyond German and European borders and be marketable accordingly. For example, these include use cases for optimizing self-consumption or reducing peak loads. In order to be able to offer further use cases across national borders, international exchange and the establishment of technical standards are required. In this way, standards-based technologies can be marketed internationally and individual use cases can be implemented.

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