E-MMM

A Market Maturity Model for Electric Mobility Grid Integration

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***Abstract*— One of the key elements for the success of the adoption of a new solution or service by customers is to analyse the target market in detail. Knowing the customer needs and the way an offer can release their pains will help defining the most promising marketing strategy to approach them. But performing a market analysis is a very complex task, especially if the market is not ready yet. This is the case of the EU-funded ELECTRIFIC project, aiming at providing innovative solutions for a seamless integration of eMobility into the electric grid. In order to facilitate the analysis of the potential market of the ELECTRIFIC solutions in different countries, a methodology called Maturity Models was applied and adapted to the characteristics of a general "EV grid integration market". This paper introduces this methodology, explains preliminary experiences within the project and provides examples of application.**

Keywords: EV grid integration, market maturity model.

I. INTRODUCTION

Maturity models have been used frequently to examine the maturity level of a product, system, technology or a process, especially in the field of IT management. The idea of a maturity model is to break down the overall maturity of a system into a handful of different domains or areas which are then analysed separately. For each of these areas various stages of maturity (so-called maturity levels) are defined by creating scenarios progressing with the maturity level. These are then evaluated via objective criteria, subjective expert opinions or a combination thereof. Due to their flexible framework, maturity models can be applied in many different settings; if used to assess the maturity of a market for a product they are called market maturity models. A market maturity model can help assess the market potential of a product, a product suite or a concept.

The quality of the result of such a market model depends on two key aspects:

- The correct mapping of the domains in which the market maturity is broken down with the requirements of the product or concept analyzed
- The quality of the data collected

The EU project ELECTRIFIC [1] aims at seamlessly integrating electric mobility into the electricity grid by enabling users to adjust their routing and charging behaviour to the requirements of grid-friendliness, eco-friendliness and battery-friendliness while respecting the personal constraints of the users – i.e. the drivers. One important feature to make electric mobility users adapt their plans is a set of incentive structures, consisting of an optimized combination of psychological and material/financial incentives targeted at a specific user group. A tool box offering various product bundles which can be used via a smart phone app or a different web-based interface is currently being developed.

In order to assess the chances for such a product suite on several European markets the maturity model methodology was an ELECTRIFIC Market Maturity Model (E-MMM) was developed. Overall, the application of the E-MMM will convey a comprehensive picture of how mature the market for the ELECTRIFIC toolbox is in the analysed region (Germany, Spain and the Czech Republic in the case of the ELECTRIFIC project) by facilitating and standardizing the assessment of e-mobility grid integration.

II. MARKET MATURITY MODELS

As already mentioned, maturity models reduce the complexity of a maturity phenomenon by breaking it down into areas and levels, thus creating a maturity matrix. The number of chosen areas and levels must both be adequate to reduce complexity and on the other hand grasp the most important features of the design object, e.g. a system or a market.

De Bruin, Freeze, Kaulkarni and Rosemann [1], emphasize that the purpose of a maturity model can be either descriptive, prescriptive or comparative in nature. A descriptive model is suitable for evaluating the status quo. A prescriptive model analyses the impact of the area descriptions on business performance implying how to approach maturity improvement in order to affect business value positively. If a model enables benchmarking across regions or industries, it is characterized as a comparative model [2], [1], [3]. Even though these types of maturity models can be identified as separate, it is argued that they primarily represent evolutionary phases related to the

[1] www.electrific.eu

lifecycle of a maturity model [RoBH04]. First, a maturity model is characterized as descriptive to develop a richer understanding of the status quo in the areas. After this, a maturity model can then be evolved into becoming prescriptive and then further be developed into being comparative. De Bruin, Freeze, Kaulkarni and Rosemann [1] have created a framework that forms a comprehensive basis to guide the development of a maturity model through these three iterations, dividing the overall process into a workflow that comprises 6 phases:

- Phase 1 – Scope: At the very beginning, the scope of the maturity model needs to be defined [2], [3], [4]. An essential part of this phase is to determine which focus the model should have as well as the intended audience, that aims at understanding the market.
- Phase 2 – Design: In the second phase the design or architecture for the maturity model is created that provides the basis for further development and application [1]. This should be done in a way to to meet the needs of the audience.
- Phase 3 – Populate: In phase three the general design needs to be spelt out into phenomena to be measured or evaluated and corresponding metrics. [2], [3], [4].
- Phase 4 – Test: After the maturity model is populated, it needs to be tested for consistency and relevance. Furthermore, it is vital to test both the construct of the maturity model as well as validity, reliability and generalizability [1].
- Phase 5 – Deploy: In this phase data need to be collected in accordance with these metrics and evaluation criteria. This means that the whole process needs to be organized and implemented; e.g determining sources for desktop research or organizing interviews. In doing this generalization of the maturity model should always be kept in mind [1].
- Phase 6 – Maintain: Finally, the model needs to be maintained and thus supported both in growth and usage [1].

III. ELECTRIFIC MARKET MATURITY MODEL: E-MMM

In ELECTRIFIC the methodology of maturity models is used to assess the market opportunities for EV grid integration software products. The main challenges preventing EU or country wide simulation-based or mathematical approaches are not only the complexity of overlapping markets but also a multitude of legislative restrictions and yet practically non-existent market features. Therefore a market application of maturity models as in [5] was chosen and created as "ELECTRIFIC Market Maturity Model" E-MMM. The E-MMM was developed as both a descriptive and comparative model in order to allow for the evaluation of the status quo in the trial regions of the project and comparing the market potential in these regions. The paper focuses on E-MMM's scope and intended audience (Phase1) as well as its design (Phase 2) and population (phase 3). Planned activities with regards to its testing (Phase 4) and the first deployment by application of the model for the ELECTRIFIC trial countries Spain, Germany and Czech Republic (Phase 5) are just briefly touched upon. Phase 6 is out of the scope of the project.

At the design phase, the team decided that four areas are sufficient to describe and compare the market complexity of ELECTRIFIC. They comprise "Electric Vehicles", "Energy Supply: Grid & Providers", "Charging Station Infrastructure" and "Consumers/Society". For each of those areas 5 maturity levels were defined taking into account technical and legal aspects. Evaluating these for Germany, Spain and the Czech Republic will lead to three different profiles of maturity and thus to different starting points for exploiting the target markets as depicted in Figure 1. The presented work will highlight the main challenges of this procedure and the results for the different regions.

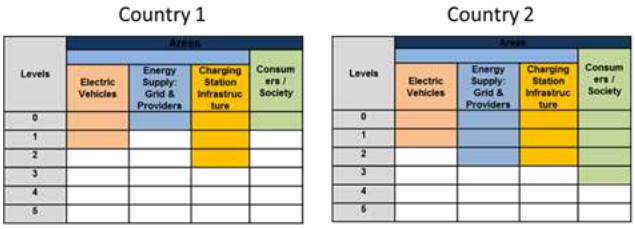

Figure 1: Example for different market maturity profiles

A. *Phase 1: Scope*

The goal of the E-MMM is to assess the maturity of a market for different software systems that help at integrating electric mobility into the electrical power grid taking into account both requirements from the electricity system side and users' requirements. It is intended to be used by stakeholders of this eco-system like EV fleet owners or charging station management companies that want to assess potential benefits of deploying business models based on ELECTRIFIC ideas and components. They will need the E-MMM design and/or specific results in order to determine their chances of marketing e.g. a smart-charging service in the ELECTRIFIC trial countries or to compare which region is the most promising starting point for their product.

B. *Phases 2&3: Design and Population*

The E-MMM consists of *four areas* comprising all aspects of electric mobility. The technological aspects of E-mobility are covered in the areas "Electric Vehicles", "Energy Supply: Grid & Providers" and "Charging Station Infrastructure". These three technology-based areas are complimented by the fourth area "Consumers/Society". The areas form the columns of the market maturity matrix and are each further split into a handful of subareas that deal with e.g. technological or legal aspects of the area. These are again differentiated into a small number of issues describing the phenomena that are to be directly measured or evaluated. For each of these issues either concrete metrics or evaluation criteria that can be answered via interviews or surveys are defined.

The area "Electric Vehicles" directly deals with vehicles: be it technological issues like battery size, EV market issues like differentiation into different makes or the variety of business models that involve E-Mobility and connected services including associated cost. Additionally, it identifies the political and regulatory actions taken in favor of EV development and the deployment of electric mobility solutions.

In the area "Energy Supply: Grid & Providers", the suitability of the electric grid and the preparedness of power grid operators for E-Mobility are examined. Especially, the grid operators' willingness or (legal or technical) ability to use decentralized intelligent control mechanism in the power grid is key for the introduction of ELECTRIFIC to the market. This is evaluated e.g. by the availability of GIS (geographical information system) data or the status of the smart meter rollout. Additionally, organizational aspects, legislation, incentives and goals of Government authorities are again taken into account.

"Charging Station Infrastructure" involves all aspects evolving around a charging station network that enables e-mobility and the use of EVs. It examines the level of convenient availability and geographical closeness of charging stations to EV users. To achieve high levels, the network has to be technologically advanced to enable fast charging and widely spread on one hand. Also standardization issues with regards to power connections and communication protocols play a great role in enabling grid integration via incentivizing users and or managing charging processes after the EV has been plugged into a socket. Finally, the consideration of governmental efforts to set industry quality-standards, subsidize charging infrastructure and guarantee trouble-free operation is taken into account.

The fourth area "Consumers/Society" focuses on the general societal and specific consumers' readiness to embrace e-mobility. Here barriers to adopting this new mobility are determined and evaluated for each level. Subareas in this context are for instance the attractiveness of EVs and awareness of environmental change necessity Additionally, the area examines how well the political and economic activity in favour of E-Mobility is received by society.

For each of those four areas, five maturity levels (level 0 to level 4) were defined to display the status of preparedness for electric mobility of a country or region in appropriate granularity. Level 0 is describing an environment in the analyzed region with hardly any e-mobility and related infrastructure and thus no pressure on the power grid from e-mobility related electricity demand. Consumers and the society in general as well as the government and regulatory authorities do not include e-mobility in their decision making. One reason for this is a comparably low environmental awareness. All in all, there is no demand for electric mobility. Consequently, there is no offer of EVs and related mobility services from business side.

Contrary to level 0, level 5 describes an environment where the link between environmental awareness and e-mobility has been made and is manifest in a mobility sector dominated by e-mobility. At this point, the infrastructure for e-mobility as well as the EV technology has reached its most advanced level. This means, for instance, that the availability and number of charging stations as well as the infrastructure of the electric grid supports a mass deployment of EVs. Consistently with this, EV technology is viewed as the most convenient way of traveling as, for example, battery range is adequate, charging technology simple and standardized. The electricity which is used for charging the batteries is generated using only renewable energy sources – a situation that cannot be realized without some planning and steering as suggested in the ELECTRIFIC approach. In this level, software solutions for trip planning, charging coordination or micro charging adaptation after the charging process has been started are sought for in a mature market.

In the E-MMM summary matrix, the levels form the rows. For each of the levels between level 0 (no electric mobility) and level 4 (optimal electric mobility grid integration) scenarios are created for the four different areas and are measured or evaluated using the corresponding metrics or evaluation criteria. The schematic picture of this E-MMM summary matrix is shown in Figure 2:

Levels	Areas			
	Technological Areas			Consumers / Society
	Electric Vehicles	Energy Supply: Grid & Providers	Charging Station Infrastructure	
Level 0	SUBAREAS: • EVs Offer/Supply • E-Mobility Business Models • E-Mobility Technology • E-Mobility cost • Standardization • Governmental Legislation • Governmental Incentives • Governmental Goals	SUBAREAS: • Technology • Grid situation in low voltage grids • Standardization • System Operator Legislation (Governmental/ BNetzA) • System Operator Incentives (Governmental/ BNetzA) • System Operator Goals (Governmental/ BNetzA)	SUBAREAS: • Network • Business • Standardization • Governmental Legislation • Governmental Incentives • Governmental Goals	SUBAREAS: • Demand for Electric Mobility • Usage of Incentives • Awareness of Sustainability & Environment • Information level of users • Approval of Electric Mobility • Social Desirability
Level 1				
Level 2				
Level 3				
Level 4				

Figure 2: E-MMM summ ary matrix: areas and levels

Obviously, a lot of information and data needs to be displayed in order to sort the evaluations gained into maturity levels for each area. In order to maintain both a good overview and present all necessary information, the summary matrix is split into four tables (one for each area) that contain the areas, subareas, issues, metrics/evaluation criteria and finally the data collected. One final challenge is to consistently aggregate and merge the different evaluations of subareas for each area in the region under scrutiny. This is done assigning different weights to the evaluation criteria and thus to the measured characteristics. Obviously, the final result of the E-MMM needs to undergo some sensitivity testing.

C. Phase 4-6: Testing, Deploying, Maintaining

Phases 4-6 cover testing, deploying, and maintaining a maturity model. In the course of the project, the model will be deployed in the trial countries of the ELECTRIFIC consortium (Germany, Spain, Czech Republic). This will also comprise determining the aggregation rules for aggregating subareas. Testing will be done in the form of the sensitivity analysis mentioned above, tuning at the weights for the various criteria. Generalizing (Phase 5) and maintaining (Phase 6) the E-MMM will not be covered within the project scope.

When deploying the E-MMM in the ELECTRIFIC trial regions, the generalization of the model will be kept in mind by carefully designing the process for data collection and gathering evaluation information. Generally, two complementary approaches are foreseen: On the one hand, some – factual - data can be elicited via desktop research, browsing statistics and other data sources. However, for some issues it is impossible to find meaningful metrics, like e.g. regarding the legal situation in a country and area. Counting laws leads nowhere. In these cases, the E-MMM depends on experts that can give their opinion either directly in surveys or personal interviews or indirectly in case there is some publication on the corresponding issue.

In order to give some more insight into the implementation of the modeling for the case of the E-MMM, the area "Electric Vehicles" is presented as an example.

IV. An Example: The Area Electric Vehicles

One of the areas that are being analyzed in order to evaluate the maturity of the market for smart grid integration of electric mobility is obviously the area "Electric Vehicles". As explained above, each area is represented in a separate set of tables, one table for each level. The example shows the subareas, issues connected with them, metrics that will be used for data collection and the manifestation of these metrics for the level considered. The subareas are maintained in all levels, whereas the issues may change. In the case of the EV area, subareas are "Offer/Supply of EVs", "EV Business Models", "E-Mobility Technology", "Cost of E-Mobility", "Standardization", "Governmental Legislation", "Governmental Goals". Regarding the E-mobility business models, in level 0 only public transport plays a minor role, whereas in level 4 business models connected to e-car-sharing and automated driving are widespread. Metrics can be the percentage of registered EVs in comparison to combustion vehicles.

It is not possible to find metrics for each of the issues that play an important role in evaluating the area. Therefore, additionally to metrics wherever possible, other criteria are used, e.g. with regards to standards or the legislative framework. This also means that in order to collect information, in these cases it is not feasible to work with desktop research, but it is necessary to ask the opinion of experts. In order to enable the partners working with the E-MMM to retrieve the optimal information from the experts, currently interview guidelines and surveys are being created.

Each section begins with a level summary in order to give the E-MMM audience an impression about the general ideas. In the case of the area EVs these are:

- Level 0: In this market EVs are just used by some innovators. There are not many different models at the market and the usability of those is quite restrictive due to lacking standardization for charging and paying processes. The battery capacity is lower than 150km. The government does not provide any special EV legislation at all.
- Level 1: In this market level EVs are only used from a small group of people. About 33% of the car manufacturers supply EV solutions and eCarsharing starts to attract people to EV solutions. The battery capacity reaches about 150km for an EV. The government does not punish the usage of CVs.
- Level 2: In this market level most suppliers of cars provide EV solutions which reach up 300km battery capacity. Every fifth registered vehicle is already an electric one. Standardization processes with charging plugs and the charging & payment processes help to promote emobility. Governmental legislation supports the usage of EVs.
- Level 3: In this market level EVs and combustion vehicles are at the same amount. The capacity of the batteries reached a critical point with 350km in average, which allows full independence for EV drivers. Governmental legislation starts to punish the usage of combustion vehicles with either extra fees or a max. amount of registered combustion vehicles.
- Level 4: In this market level EVs are the most common vehicles for private and public transportation. With new technologies like self-driving EVs and bi-directional charging permitted, EVs are most attractive. Industry standards and EV manufacturers are aligned with 100% emobility. The governmental legislation punishes the usage of combustion vehicles.

Find below the E-MMM matrix for the area EV for the levels 0 (hardly any electric mobility around) and 4 (the vision of an optimal electric mobility grid integration).

EV Level 0: No / Hardly any Electric Mobility

Subareas	Issues	Metrics/Evaluation Criteria	Description
Offer Supply of EVs	▪ Sufficient product range ▪ Availability of some EVs	▪ Less than 10-15 different EV models available; ▪ Delivery time for EVs is way higher than comparable combustion vehicles (>18 months)	▪ Some EVs are available but suffer a long delivery time
Electric Mobility Business Models	▪ Public transport offers	▪ Percentage of registered EVs in comparison to combustion vehicles (about <1%) ▪ Limited availability of (public) CS	▪ Public transport, taxi services, eCarsharing and ride offers help to increase the amount of available e-mobility solutions ▪ Hardly any operating public CS are available
Electric Mobility Technology	▪ Battery capacity	▪ Battery capacity should increase to average <150km for an EV;	▪ Battery capacity is lower than 150km in average;
Cost of Electric Mobility	▪ Attractive retail prices	▪ Retail price of an EV >50% higher than a comparable combustion vehicle;	▪ EVs are 50% more expansive due to the lack of mass production and the price of the batteries;
Standardization	▪ Charging sockets	▪ Only low power charging (<3,7kW) as standard charging socket;	▪ Only low power charging sockets (<3,7 kW) are the standard charging plugs at public CS
Governmental Legislation	▪ Definiton of an EV with regards to governmental incentives	▪ No governmental legislation of EVs;	▪ There is no governmental legislation of EVs at this stage;
Governmental Goals	▪ Reduction of CO2 to achieve (national) climate goals	▪ Reduction goals of greater than 25-30% of CO2 emissions compared to the year 2000;	▪ The CO2 emissions should be lowered in a small-scale dimension;

EV Level 4: Optimal Electric Mobility Grid Integration

Subareas	Issues	Metrics/Evaluation Criteria	Description
Offer Supply of EVs	▪ Sufficient product range ▪ Availability of EVs	▪ Number of available EV models ▪ Delivery time comparable to combustion vehicles (about 3 months)	▪ All manufacturers provide EVs and supply a sufficient range of different models in a short time period
Electric Mobility Business Models	▪ Self-driving EVs ▪ Public transport offers ▪ Taxi / ride services eCarsharing	▪ Registered amount of EVs (self-driving, E-Busses, E-Taxis etc.) ▪ Percentage of registered EVs in comparison to combustion vehicles (about 70%) ▪ Amount of eCarsharing Customers comparable to combustion carsharing at Maturity Model Level 0 ▪ eCarsharing stations in relation to inhabitants ▪ eRidesharing in relation to inhabitants ▪ Expert evaluation of diffusion of eCarsharing (high)	▪ Self-driving EVs solve the problem of availability of EVs and station-based eCarsharing offers ▪ Public transport, taxi services, eCarsharing, eRidesharing and ride offers help to increase the amount of available e-mobility solutions ▪ Experts help to evaluate the grade of diffusion of eCarsharing
Electric Mobility Technology	▪ Battery capacity ▪ New charging technology ▪ Self-driving EVs	▪ Battery capacity increased to average >400km for an EV ▪ Percentage of homes with smart-home equipment >40% ▪ Expert evaluation on amount of investments into new technologies (medium) ▪ Share of self-driving EVs at total EVs (~50%)	▪ High battery capacity allows a full acceptance of mobility needs ▪ Smart-home equipment allows home-charging and reduces the needs for too many public CS
Cost of Electric Mobility	▪ Attractive retail prices ▪ Incentivized charging options	▪ Retail price of EVs will be lower than combustion vehicles ▪ Expert evaluation of incentivized charging impact (high)	▪ EVs need to be cheaper than comparable combustion vehicles as they are the common vehicle at level 4 ▪ Experts help to evaluate the incentivized charging impact ▪ Incentivized charging helps to promote the popularity of emobility
Standardization	▪ Automatized charging & payment process ▪ Charging sockets ▪ Mobility app (not stuck to certain providers or vehicles)	▪ Expert evaluation of usage of the mobility app (high) ▪ 100% of the charging sockets should be matching to plugs of CS ▪ 100% of all charging and payment processes are standardized	▪ A mobility app, which includes all public transport, taxi and eCarsharing transport solutions will be a milestone along with the self-driving EVs ▪ The standardization of the charging sockets helps to utilize the public CS ▪ Standardized charging and payment processes help to promote emobility
Governmental Legislation	▪ Energy and electricity tax laws ▪ Definition of an EV with regards to governmental incentives ▪ Regulation of new registered cars ▪ Adaption of fuel taxation	▪ Tax laws supporting renewables reducing CO2-emissions expert evaluation (high) ▪ Bidirectional charging permitted ▪ Official definition of an EV with certain criteria (min. electric range) ▪ Regulation prescribes max. amount of combustion vehicles ▪ Extra fee for combustion vehicles ▪ Operating cost for combustion vehicles due to fees >200% of EVs	▪ The government strongly influences the acceptance of EVs with incentives, punishment and taxation possibilities; e.g. a max. amount of fuel-based vehicles could be possible ▪ To enable a mass-market with EVs certain legislation adaptions as the definition of an EV need to be performed
Governmental Goals	▪ Reduction of CO2 to achieve (national) climate goals ▪ Independence of fuel	▪ Reduction goals of greater than 80% of CO2 emissions compared to the year 2000; ▪ Amount of imported fuel negligible;	▪ By increasing the amount of EVs the overall CO2 emissions will be lowered as (public) transport is one of the biggest factors for those emissions ▪ Additionally a reduction of imported fuel helps to reach those goals

V. CONCLUSION

In this paper we provided an example of how the Maturity Model methodology was used within the market analysis framework for the ELECTRIFIC project. First, we introduced the general elements of the methodology and then we explained how ELECTRIFIC used it. In order to facilitate replication in other contexts, an easy-to-understand example based on "Electric Vehicles" market segment is presented.

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