Hyper-Network for electroMobility

D6.3 NeMo Hyper-Network Validation

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Revision and history chart

Version	Date	Main author	Summary of changes
0.1	01/07/2019	S. Hadjidimitriou	Draft outline
0.2	18/07/2019	R. Tola	CRF contribution: description of the Italian pilot
0.3	24/07/2019	E. Caumont	Description of the French pilot
0.4	31/07/2019	C. Hartl	Description of the Austrian pilot and KPIs
0.5	2/08/2019	L. Müller	Description of the Interroaming service validation
0.6	16/08/2019	I. Chausse	Description of Spanish test site
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0.9	09/09/2019	S. Hadjidimitriou	Evaluation of the test drive and evaluation of the services tested in the pilot sites
1.0	16/09/2019	S. Hadjidimitriou	Final draft
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1.3	14/10/2019	E. Portouli / C. Anagnostopoulou	Final version after peer review
1.4	26/11/2019	C. Anagnostopoulou	Adding information per PO's requests during the project review

Table of contents

Index of Figures

Index of Tables

List of abbreviations and acronyms

Abbreviation	Meaning
ACEA	European Automobile Manufacturers Association
API	Application Program Interface
BESS	Battery Energy Storage Systems
BMS	Battery Management System
B2B	Business to Business
B2C	Business to Customer
CAPEX	Capital Expenditures
CDR	Charge Detail Record
CIM	Common Information Model
CP	Charge Point
CPMS	Charge Point Management System
CPO	Charge Point Operator
CPO2PP	Charge Point Operator to Power Provider
EC	European Commission
eM(S)P or EM(S)P	Electro Mobility (service) Provider
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FOT	Field Operational Test
IOPs	Input/Output Operations
JSON	JavaScript Object Notation
MGMS	Micro-Grid Management System
MSPs	Managed Service Provider
OPEX	Operational Expenses
RAM	Random-Access Memory
REST	REST Representational State Transfer
RFID	Radio-frequency identification
SLAs	Service-Level Agreement
SOC	State of Charge

Abbreviation	Meaning
TSO	Transmission System Operator
UI	User Interface
UX	User Experience
VCPU	Virtual Ventral Processing Unit
VM	Virtual Machine

Executive Summary

This deliverable presents the results of the validation activities related to the NeMo outputs. The validation methodology had a two-fold aim, i) to validate the usability of the core Hyper-Network functionalities (i.e. service creation, registration and execution) by service developers and providers and their acceptance and willingness to use them in the future and ii) to validate the electromobility actors' perceptions, opinions and overall acceptance as regards the added value of NeMo compared to stand-alone services. Finally, the drivers' perceptions were studied as regards the smart itinerary planning and the pan-European eRoaming offered via the NeMo Hyper-Network.

The Hyper-Network was perceived by service developers as very useful to create added-value electromobility services and to collect existing services and data in a single environment, interoperable and accessible by all connected actors. In the future, the operators of the Hyper-Network should create instructions and guidelines to facilitate its learning and use.

Overall, the NeMo services validated in the test sites were positively evaluated by electromobility actors and several comments have been provided to further improve them.

The cross-country drive, on the other hand, has demonstrated that range anxiety still remains an issue for EV drivers today, and there is a clear need for electromobility services provision for long distance travels. Indeed, drivers were much less anxious when planning to charge at a charging station that was interconnected via NeMo, and this is an indicator about NeMo's impact on drivers' experience as well as EVs market acceptance.

In conclusion, the results of the validation activities in NeMo are encouraging about its future. Electromobility actors and EV drivers were satisfied with the Hyper-Network functionalities and there is an interest by stakeholders to continue the work in this direction and establish an association that will manage the operation of the Hyper-Network after the project end.

1 Introduction

The present deliverable presents the results of the validation activities related to the NeMo project outputs. The results out of three years of project activities were validated based on the proposed methodology of D6.2 *"Validation methodology, tests sites set up and adaptation activities".*

The main output of the project is the NeMo Hyper-Network that enables the interoperable and seamless electromobility service provision across countries and across service providers. It entails an Open Cloud Marketplace for electromobility actors that allows for finding services, creating composite services, trading and executing electromobility related IT services in a business-to-business setting.

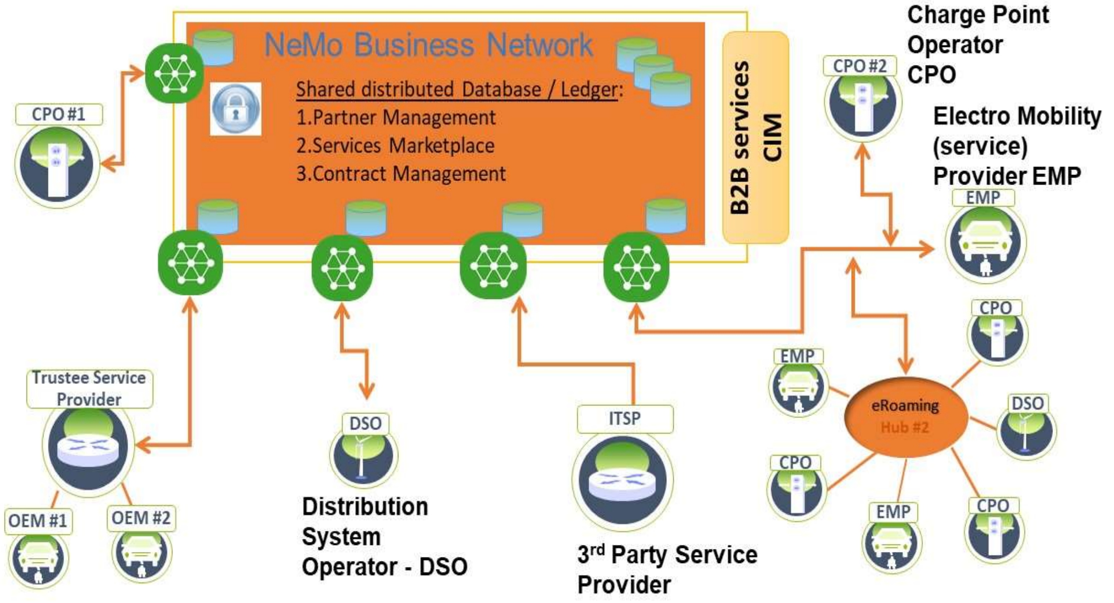


Figure 1: The NeMo Hyper-Network

NeMo has developed and made available in the Hyper-Network a set of horizontal smart services, i.e. electromobility actors' monitoring and profiling, service finder and optimiser, service brokerage that can be used by service providers to add intelligence to their own electromobility services. NeMo has also designed and implemented the Open Inter-roaming Protocol, which enables the direct communication between eRoaming platforms and the publication of their services in the NeMo Hyper-Network, specifically to enable a pan-European eRoaming Framework, namely the possibility to "charge everywhere with only one contract" in all regions and countries. Finally, a set of new and existing electromobility services have been integrated into the NeMo Hyper-Network, to validate the added-value of interoperable services provision accessing data from multiple actors. These include smart itinerary planning, grid load management, adaptive battery status calculation, and a service providing secure access to dynamic vehicle data.

The aim of the work presented in this Deliverable was to analyse the data gathered based upon the agreed methodology in order to validate the project results via the testing activities in the project test sites in Italy, Austria, Germany, France, Spain addressing end users of the services, and via training events and a Hackathon addressing service developers. Another part of the scope was to present the preparatory activities in the test sites, in order to conduct the tests.

The Hyper-Network direct users are service developers and electromobility actors, so the main focus of the validation activities aimed to capture their experience and opinions about its functionalities and expected impact. Still, some activities involved drivers of electric vehicles, who will indirectly benefit from the Hyper-Network, as it is expected to improve their charging and driving experience in general.

The validation methodology is described in NeMo Deliverable 6.2 *"Validation methodology, tests sites set up and adaptation activities"*, and had a two-fold aim, i) to validate the usability of the core Hyper-Network functionalities (i.e. service creation, registration and execution) by service developers and providers and their acceptance and willingness to use them in the future and ii) to validate the electromobility actors' perceptions and opinions as regards the added value of NeMo compared to stand-alone services. Finally, the cross country pilot drivers' perceptions were studied as regards the smart itinerary planning and the pan-European eRoaming offered via the NeMo Hyper-Network.

The Deliverable is structured as follows:

- Chapter 2 presents the validation of the NeMo Hyper-Network core functionalities by the Hackathon participants and other service developers.
- Chapter 3 presents the validation activities of services offered in the Hyper-Network by electromobility actors and drivers in the project test sites.
- Chapter 4 presents the validation activities related to the cross-country test drive and a comparison of drivers' experiences with those during the first test drive carried out early in the project.
- Chapter 5 concludes the deliverable.

2 Validation of the Hyper-Network core functionalities

The validation of the Hyper-Network core functionalities was done via a structured form that can be found in Annex 1 of Deliverable 6.2. This validation is relevant to Business Scenario 4 of NeMo Deliverable 1.1 *“Consolidated Version of the Use Cases and Actors’ Requirements”*, and describes the NeMo Service Development Environment with its components that provide the functionalities to develop and offer IT services via the Open Cloud Marketplace to all the business partners of the NeMo Hyper-Network. The structure form was completed by participants to the NeMo Hackathon and by all service developers who used the Hyper-Network functionalities during the project course.

2.1 The NeMo Hackathon

The Hackathon organisation and methodology is described in Deliverable 6.2. A dedicated page in the NeMo website was created to openly call for participants and inform the targeted audience for the objectives of the Hackathon as well as the guidelines for their participation and expected submissions (nemo-emobility.eu/hackathon/). More specifically, the objectives of the Hackathon were the following:

- Evaluation of the effectiveness of the Hyper-Network open tools for services creation
- Validation of the NeMo APIs
- Verification of the added value of horizontal services
- Validation of the easiness of data integration
- Engagement of external organizations, especially external service developers

Two proposals were selected. Both proposers were given the possibility to present their proposed service during the ITS European congress in Eindhoven, on 3-6 June 2019. The two services selected by the Jury that was formed by the project’s Steering Committee members, were the Pick&Pack, which is a car share & luggage service proposed by Pooja Rangarajan, and the ChargeSharing, proposed by e3Charge.

First Proposal:

The **Pick&Pack** works as follows:

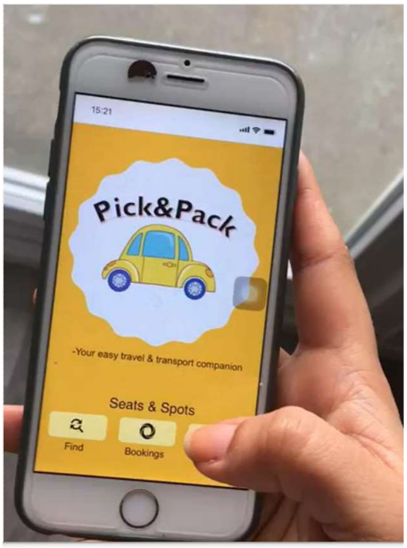


Figure 2: Pick&Pack

1. A commuter offers seats and luggage slots.
2. A user of the app registers with the commuter and books a seat or a luggage slot with one click on the App.
3. The user receives a GPS enabled QR code which the commuter scans at the meeting point.
4. The commuter drops off the user or the luggage at the drop off point offered by the commuter.
5. The luggage is tracked though the GPS enabled QR code to prevent loss.
6. The user receives a notification once the commuter has completed the ride and the user or the luggage has been dropped off.
7. Part of the payment sent by the user goes though on completion of the ride.

The Pick&Pack solution integration in NeMo was proposed to deploy three NeMo services combining the use of the app by EV drivers: get authenticated driver service (getEVDriverUser), which provides the driver profile – preferences recurrent places and trips, history, etc. - driver monitoring service, for tracking the driver and the parcel location and drop off, and charge point monitoring service (getEVSEdata) for information on the available charge points.

Second Proposal:

The **ChargeSharing** aims to improve the charging infrastructure thanks to the introduction of a community-based network consisting of private charging station providers. The service is based on the concept that the offering (price and opening hours) of private charging stations (charge point) must be simple for parties (private or commercial). On the other hand, EV drivers must be able to find the private charge point and use standard well known payment providers, such as “PayPal”, Apple or Google Pay for ad-hoc payment. In order to find the private charge point (EVSE) the technical solution needs to be able to publish the EVSE-data in various charging station directories, such as Google/Apple Maps, Opencharge Map and various others. In addition, the EVSE-data of private charge points must be published in vehicle manufacturers build-in navigation systems based on HERE, TomTom and other Electromobility Providers (EMP).

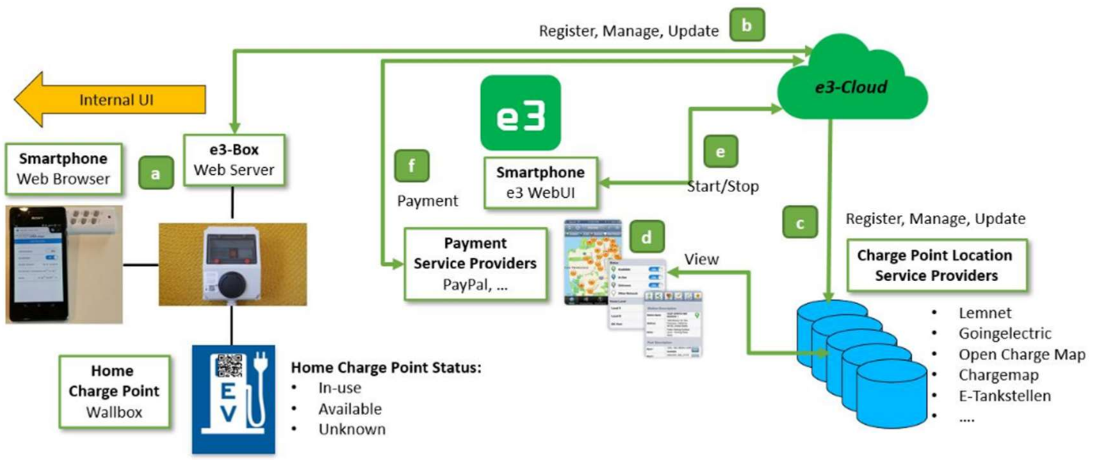


Figure 3: ChargeSharing system overview

The outline of the system is shown in Figure 3. This new community-based network of private charge points expands the public charge point network in areas where public charging could not be profitable. The solution of expanding the charging network by private charging stations for public use will increase the possibility to charge in rural areas, where there are very limited possibilities today for re-charging when traveling abroad. By providing an API for ChargeSharing, any electromobility provider could also integrate private charge points into available charge points along the route for his customer, in order to increase the charging network also in areas where public charging stations will never be commercially attractive.

ChargeSharing solution of e3charge can be used and integrated by other Electromobility Providers to expand the public charging network. In addition, local payment providers, who may be also part of the network, can be integrated to enhance the payment solutions. Subscription-based payment by EMP providers using roaming might be another possibility for payment for both parties.

Within the NeMo Hackathon, the solution proposed to be integrated in the Hyper-Network, required a composition of NeMo services, using the charge point information (getEVSEdata), input for the charging stations along the route (EVSEGetFullList), as well as the electromobility service provider proposal for charging (empChargeProposal). The registered NeMo service out of the ChargeSharing proposal provides added functionality to EMSPs connected to NeMo by enabling sharing of private charging points.

Table 1: Hackathon evaluation criteria and scores

Description of criteria	Failed (Score 0)	Well (Score 1)	Excellent (Score 2)
Level of usage of NeMo open Service creation tools	No use at all	Partial Use	Full Use
Number of atomic services used	No atomic service was used.	One atomic service was used.	More than one atomic service was combined.

Relevance criteria: **The proposed idea will be examined about its relevance to Electromobility and the NeMo high-level objectives.**	The idea is not relevant to electromobility or the NeMo objectives.	The idea is relevant to electromobility and meets most of the NeMo objectives.	The idea is relevant to electromobility and meets all NeMo objectives.
Innovation criteria **The idea is not already available in market at a large scale.**	The idea is not innovative (already available in the market in large scale).	The idea is innovative but already available in the market.	The idea is innovative and availability in the market is limited.
Interoperability criteria: **The service meets the relevant standards**	The idea does not contribute to interoperability.	The idea is promoting structured data exchange and seamless information sharing with limitations.	The idea is promoting structured data exchange and seamless information sharing on a cross-wide level.
Economic criteria: **The expected market value will be evaluated based on the perceived economic usefulness of the service**	The idea has low commercial potential.	The idea has some revenue potential via specific exploitation model clearly visible, while the targeted market may be small.	The idea has high commercial potential, clearly presenting a business model that targets a big market share.

The two services have been evaluated according to the criteria reported in **Error! Reference source not found.**.

According to the Jury's votes, the winner was the e3charge solution as having addressed most of the objectives set, and achieved the final integration to the Hyper-Network. The final scores were: e3charge: 9/12 and Pick&Pack: 6.25/12.

2.2 Service developers' feedback

Twenty-five (25) service developers completed the feedback form of Deliverable 6.2, which consisted of 10 closed questions (where the respondents could choose among five possible answers: Definitively no, Rather no, Rather yes and Definitively yes) and 4 open questions related to the willingness to use the NeMo Hyper-Network and the easiness of use. The majority of respondents were software engineers.

The features of the NeMo Hyper-Network that were mostly appreciated were the possibility to work on collaborative projects and share a service on the marketplace. In general, the idea of the Hyper-Network was considered as a good solution to collect different types of data into a single marketplace.

For what concerns the service creation, the NeMo Hyper-Network was considered to offer a useful tool to facilitate the semantic description of the electromobility services.

The majority of respondents (88%) claimed that they would need support to use the system and the 50% affirmed that the system was too cumbersome. The open answers confirmed the system was too complex for the users, even for creating small and straightforward services. One of the users claimed that he had the impression of using different systems rather than a unified framework for a single purpose.

The developers pointed out that the documentation was too long but also very complex. In general, it was difficult to have end-to-end guidelines on how to use the system. In the current status, the NeMo Hyper-Network tools can only be deployed by experts.

One of the respondents pointed out that the benefits of "standardization" (such as the intent of the CIM) might be overestimated. More specifically, the idea to model all actors, objects and interfaces is in principle very interesting, but it might be very difficult to establish such a "unified model" as a "standard" in the very dynamic electromobility sector. When it comes to interfacing business applications, the biggest problems might not arise from a lack of standardization in the format of the data (not even in the protocol of the data exchange). In this respect, software development is normally flexible. A bigger problem might be the lack of services and data themselves, or the sourcing, aggregation, or processing of specific data at their respective sources in existing business processes.

The responses to the closed questions are given in the figures below.

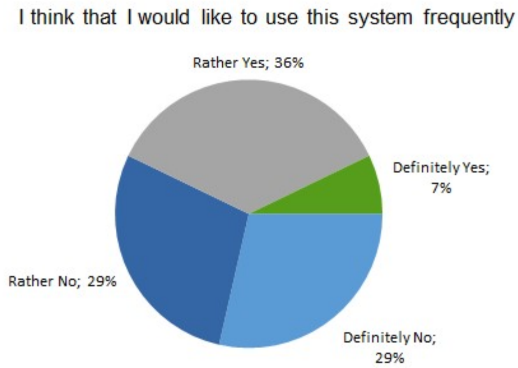


Figure 4: Willingness to use the system

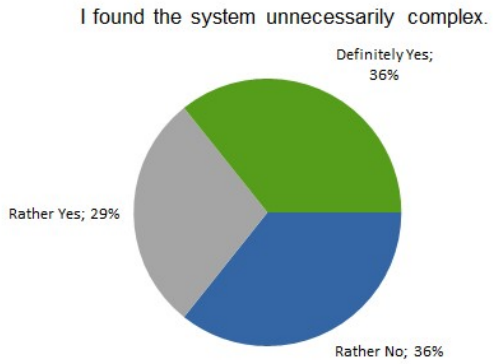


Figure 5: Complexity of the system

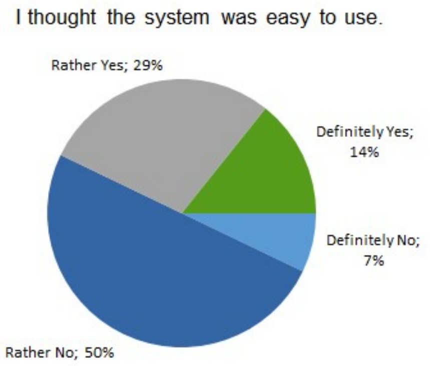


Figure 6: Easiness of the system

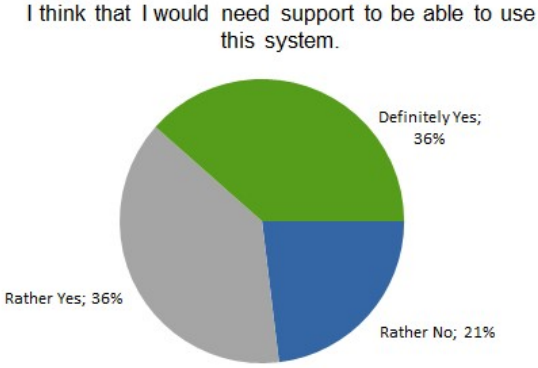


Figure 7: Need of support to use the system

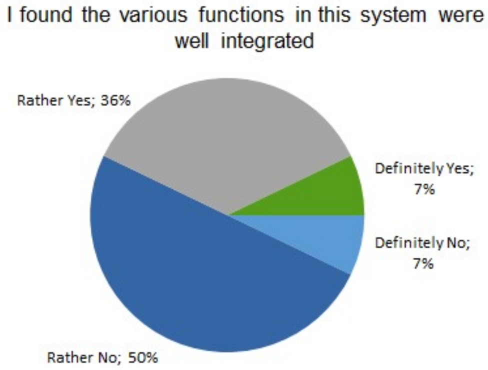


Figure 8: Functions' integration

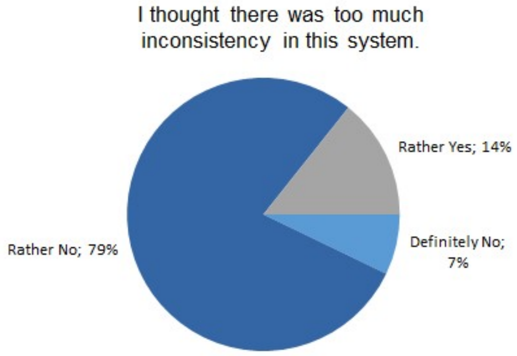


Figure 9: Inconsistencies of the system

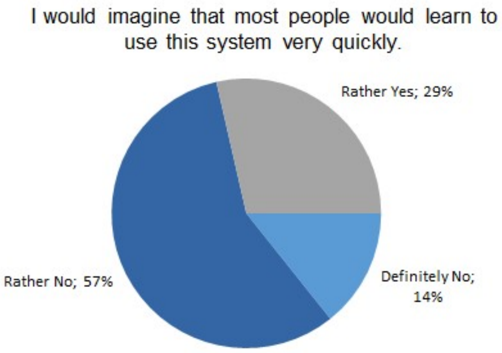


Figure 10: Speed of learning

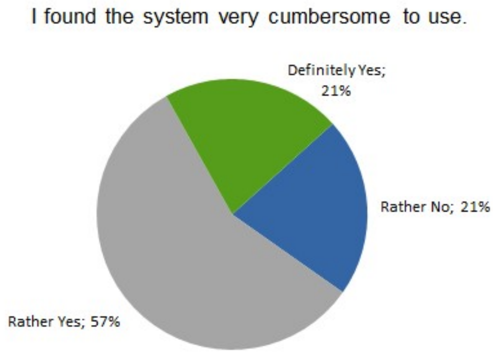


Figure 11: Difficulty of using the system

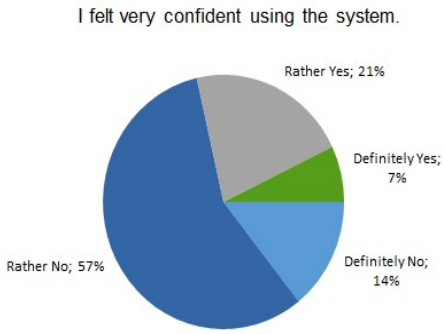


Figure 12: Feeling confident in using the system

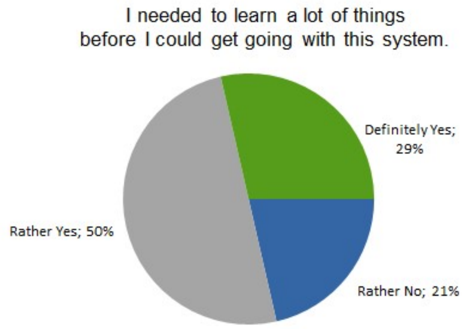


Figure 13: Skills needed

The suggestions on how to improve the NeMo Hyper-Network were mainly related to the need to provide a strong presentation (i.e. "dummies") of how to set up a node and to create services with guided tutorials and "hello world" examples. Overall, almost all respondents agreed on the need to integrate tools for creation, validation, testing, using services in a single framework. They should be really easy to use, well documented, with lot of examples and guides (at least) at two levels: for the quick starting and the more complex cases. The installation of a NeMo Node should be done by a single installation package: Download, open/install, configure and run, including guides at two levels (quick and detailed). Finally, the node should need much less computational requirements. Open/public NeMo Nodes should be accessible (and well documented in the guides) for people that want to start using/publishing services without creating any node (affiliated partners).

Technical information about the services published (input/output parameters and full query/response examples) is necessary. This information should be provided by the service owner, but NeMo should enable the way to do that. Swagger files could be a solution for this.

Based on the above, the following are possible actions for improvement:

1. Create a NeMo Developer Guide which, by examples, would give an end-to-end overview of the service creation and publishing.
2. Develop a new NeMo Node installation tool for an easier and guided installation as well for applying updates to an existing node.
3. Create a tool for writing and validating translation files. Currently, there is no way to validate a translation before reaching the stage of publishing the service. Also, the process of debugging a faulty translation is cumbersome, the developer needs access to the log files of the translation component.
4. Currently, for running the Service Creation Tool the developer needs to have Docker installed, as the tool runs inside a Docker Container. The tool should be installed locally without any third-party dependencies. Also, having an online web tool could also improve the user experience.
5. Establishing a web community where developers can share code and post issues.
6. Provide recipes/ code samples ranging from calling a service to building and publishing an atomic or a composite service.

3 Validation activities at the test sites

Apart from the validation of the core functionalities of the Hyper-Network presented in the previous chapter, each test site has validated the added-value of offering services via the Hyper-Network. Each site has selected services, as presented in Deliverable 6.2, and collected the perceptions, opinions and overall acceptance of electromobility actors in a structured way, using targeted questionnaires and forms that are included in the Annexes of Deliverable 6.2.

3.1 Validation activities in Italy

The Italian test site focused on the validation of a service providing secure access to dynamic vehicle data using the Extended Vehicle concept.

A demonstration took place on April 5th, 2019 at CRF premises in Orbassano (Italy), where NeMo presented its approach and outputs as regards the Extended Vehicle standard and its Neutral Server proposal, following the relevant ACEA and ISO work. The event was attended by members of the ACEA group 3 “ELECTRIC VEHICLE” and members of the EC. The specific architecture and service for the Extended Vehicle and Neutral Server (the Trustee services) as developed in NeMo and deployed by CRF and Renault, but also by HONDA, who has expressed great interest in this work and has officially joined NeMo as its first Associate Partner, were presented. Apart from the technical implementation, another very important aspect is the “double consent by the user” approach being followed.

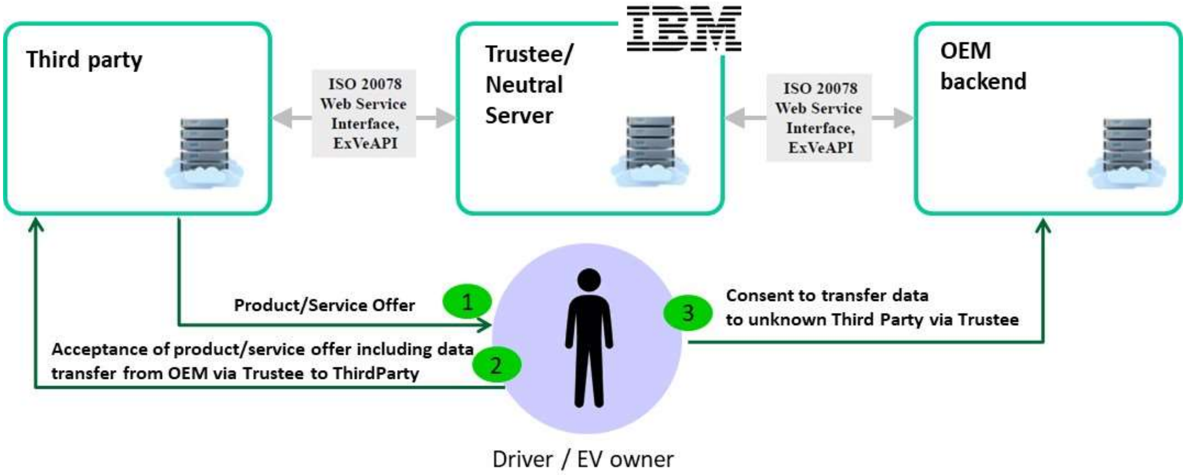


Figure 14: Double consent approach for secure dynamic access to vehicle data

The attendees had the opportunity to experience the demonstration of a real use case during short test drives in each of the three vehicles of the manufacturers, where the driver consents (twice) to sharing data from his/her EV with an external service provider (via the Neutral/Trustee Server and the Hyper-Network).

The representatives of ACEA and EC, as well as the FCA and CRF senior executives, were very interested and requested for all the possible documentation, especially because of the fact that NeMo is the first project, whose participants are also members in the ACEA working group, to show real implementation of their use cases. All the attendees agreed that in this way, the driver will experience improved services, as the service provider will have access to real vehicle data.

Apart from this demonstration to experts, a test with naïve users has been organised, focusing on the added value of an improved itinerary planning service, when having access to such information from the vehicle. This service is relevant to Business Scenario 2 of NeMo Deliverable 1.1, *"Consolidated Version of the Use Cases and Actors' Requirements"* that described the Itinerary Planning scenario, which aims to assist an EV driver in planning and driving an itinerary. The Itinerary Planning should take into consideration static restrictions and information (such as route, vehicle's charge capacity, etc.) as well as dynamic restrictions and information (such as remaining charge, weather, charge price, driving profile, etc.) and security sensitive situations (such as running out of charge in a highway with no emergency stopping lane).

Figure 15 below shows the overall architecture of the Italian test site. The data coming from the vehicle are exposed to the NeMo Hyper-Network by means of 2 services, TrusteeGetData() and the TrusteePutClearance().

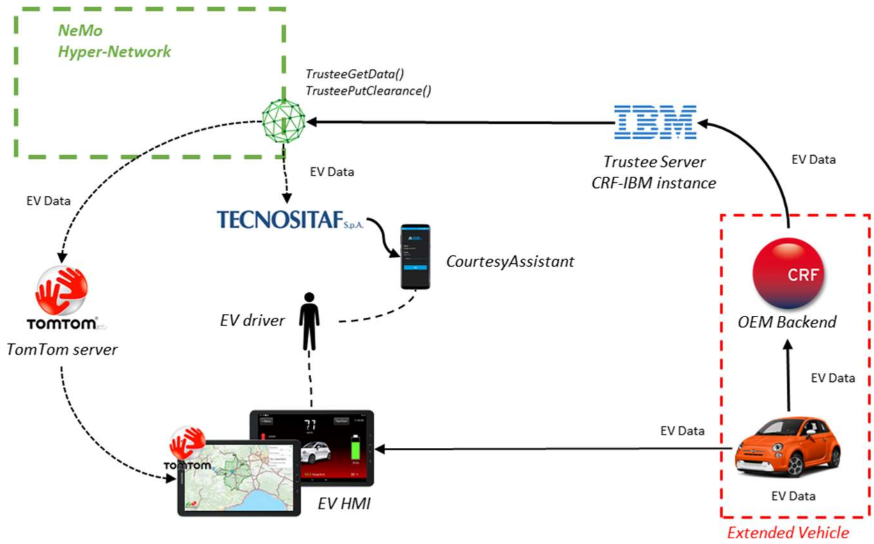


Figure 15: Overall architecture

The data provided by the TrusteeGetData() service are consumed by the TomTom server for building the additional features for the "Itinerary Planning" and also by TecnoSitaf, the motorway manager, for providing the CourtesyAssistant service to the motorway customers by means of an Android app.

The "Itinerary planning" involves an improved navigator able to provide to the driver a very rich driving experience by means of advanced features, such as: 1) a routing service taking into account the characteristics of the EV and the available charging points close to the probable route, 2) most probable route service that provides a set of probable trips that could be chosen by the driver, and 3) a continuous monitoring of dynamic EV battery data in order to be able to calculate and propose to the driver alternative routes and/or charging whenever an anomalous consumption or a traffic event happens.

The Italian tests took place on the A32 highway, starting near Km 0 and ending up in the test track managed by TecnoSitaf near Susa. It includes a highway tunnel of almost 1 km. The Italian test site includes also 2 charging points in the private areas of CRF and TecnoSitaf test track and 1 charging point in IRETI area (an IREN company) located in the west of Turin.

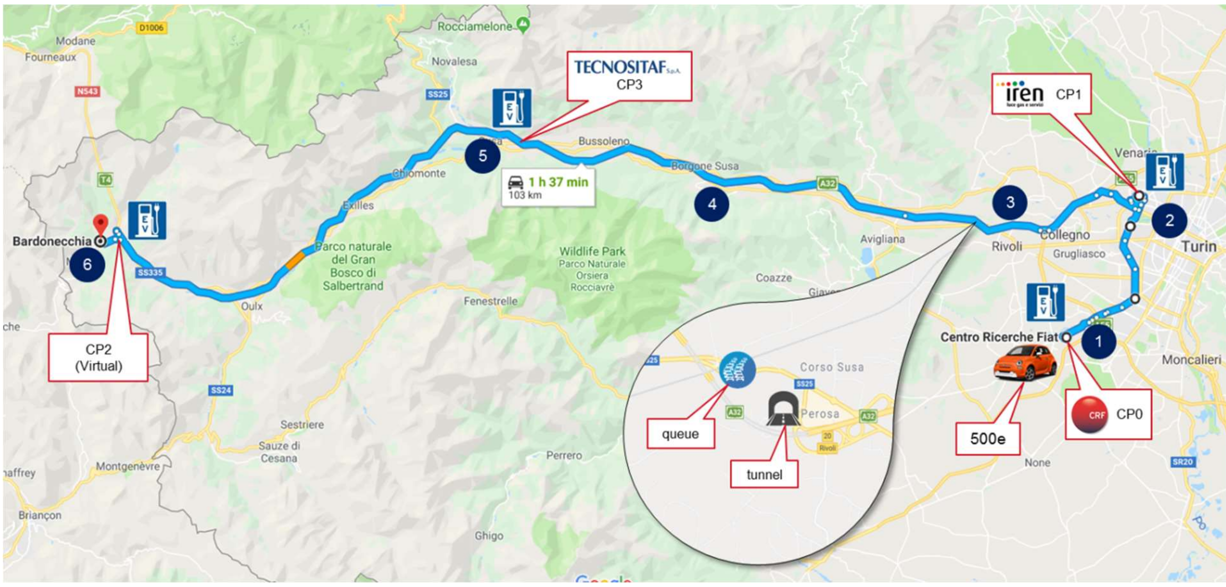


Figure 16: Journey of the Italian tests

The questionnaire in Annex 2 of Deliverable 6.2 was used to collect data from participants. Participants were given explanations of the general aim of the project and how to fill in the questionnaire. At the end of the testing they could take their time to complete the questionnaire.

Fourteen participants have been recruited internally. All of them had experience with traditional navigators.

A user testing calendar has been set. People were recruited in groups of 2/3 and a moderator was always on board. The moderator welcomed the participants and briefed them, using a written text, in order to communicate the very same information to all participants. In particular, they were briefed on:

- general introduction on NeMo project
- aim of the test
- what to observe
- how to complete the questionnaire (paper questionnaire was showed so that participants could focus their attention in order to properly answer the questions)

Figure 17: Itinerary Planning and Courtesy Assistant

After the briefing, the journey could begin. Users were asked not to comment aloud and not to share their considerations on the system in order to minimize mutual influence on final ratings. The navigator offered the following additional functionalities:

- suggestion of usual destination based on user habits (all users were people who do this trip on a daily basis)
- after confirming or inserting the final destination, the navigator proposed a stop at the nearest charging point and gave the possibility to book it
- as an unexpected queue caused an abnormal consumption, a new message of need for recharge appeared.

The moderator was always on board during the tests, highlighting the messages on the navigator as they appeared and explaining to participants the meaning of each message.

The average age of respondents was 42 years old. The youngest respondent was 24 years old; the oldest was 57. 38% of respondents were female; while the 62% were males. Their responses to the closed questions of the questionnaire are shown below.

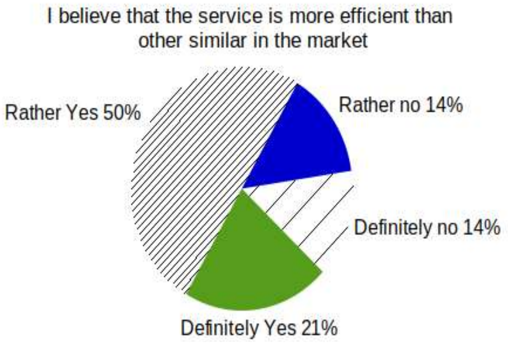


Figure 18: IT Itinerary Planning - efficiency of the service

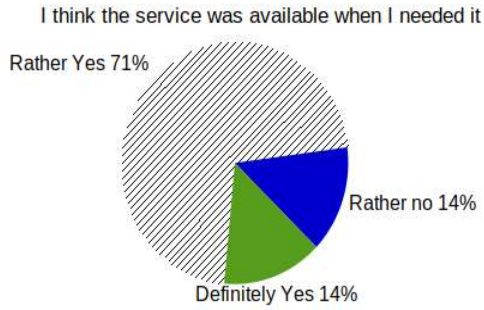


Figure 19: IT Itinerary Planning - service availability

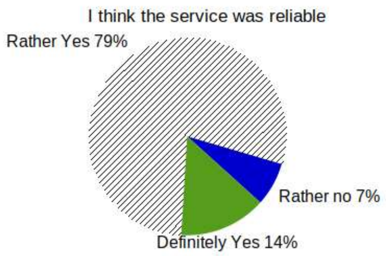


Figure 20: IT Itinerary Planning - service reliability

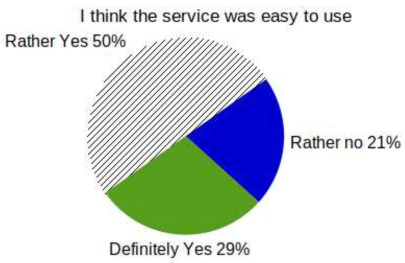


Figure 21: IT Itinerary Planning - easiness to use

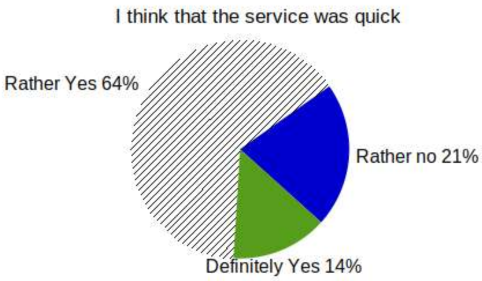


Figure 22: IT Itinerary Planning - quickness

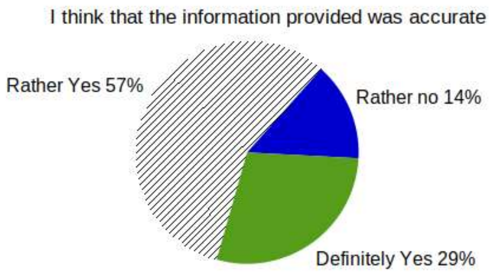


Figure 23: IT Itinerary Planning - information accurateness

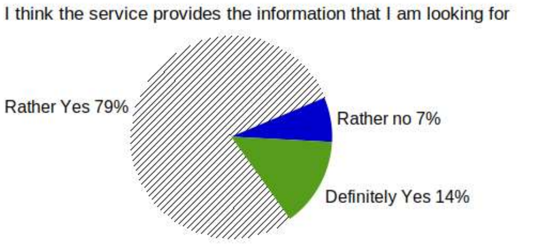


Figure 24: IT Itinerary Planning - information usefulness

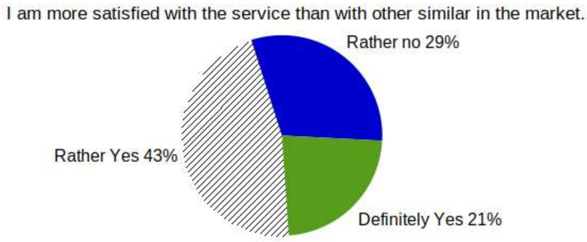


Figure 25: IT Itinerary Planning - satisfaction

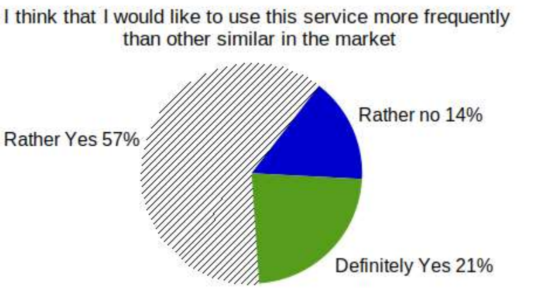


Figure 26: IT Itinerary Planning - willingness to use

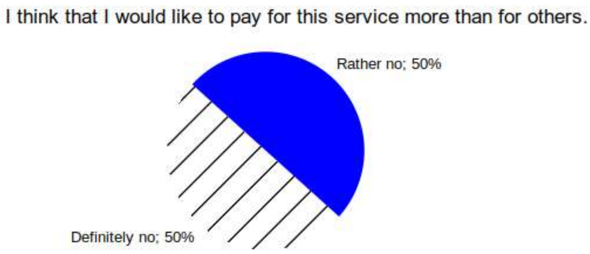


Figure 27: IT Itinerary Planning - willingness to pay

The Itinerary planning and courtesy assistant have been highly appreciated by the users. The possibility **to know in real time the distance** that the vehicle can travel, given a certain status of charge, has been considered very important for the users as it was able to reduce the range anxiety.

The possibility to **visualize** and **book** the **CPs along the route** was the other functionality of the service that was highly rated by the respondents. Although, one of them pointed out that the last generation of itinerary planning already provides these functionalities.

In terms of weakness and aspects of the service that should be improved, the respondents pointed out that, having **several screens** to present different types of information was not the best solution for the **driver,** who could be **distracted** while driving. Furthermore, the information was not always clear and this distracted even more the driver. It was, therefore, suggested to improve the service by integrating all the information into a single screen. Another weakness was related to the **speed of the service,** which depended on the network. When there was poor connectivity, the response of the service was also poor. With reference to the itinerary planning, one of the respondents pointed out that the closest CP suggested to the driver was located in the opposite direction of the final destination. The selection of the suggested CPs implied, therefore, to travel 15 additional km.

As a conclusion, the added-value of having access to real-time vehicle data via NeMo developments was appreciated by users. Their suggestions for improving the service are relevant and valuable, and should be considered by a service developer before market deployment.

3.2 Validation activities in Austria

The Austrian test site focused on validating scenarios relevant to "Smart charging" and "Cross-Provider/Border Booking, Authorization and Payment Management", both of which have been selected as priority areas (Business scenario 1 and 3 respectively) in NeMo Deliverable 1.1.

3.2.1 Validation of the "MicroGridInfo" service

The smart charging service ("MicroGridInfo") that is available in the NeMo Hyper-Network provides real-time information to a CPO in order to optimise technically and financially the offered charge plans and services.

The operation of (high-power) charge points incurs considerable power costs on the CPO side. This is in part due to the fact that grid costs have important components proportional to the peak power used within the invoicing period. Deploying a stationary battery to a charge point can lower these site costs in several ways, notably through peak-load shaving, i.e. provisioning of battery power during high-load times (thus reducing the peak load at the grid connection point and hence the grid costs), and through grid services provided to the Transmission System Operator (TSO), i.e. producing or consuming power at the request of the TSO (thus helping stabilize the grid and generating revenues on the reserve energy market).

This approach is pursued within the EU-funded project SYNERG-E (Action No: 2016-EU-SA-0013), whereby VERBUND and SMATRICS together with the German CPO Allego develop technical solutions including the hardware setup and the micro-grid management system operating at the site and interfacing with the reserve energy market, the real-time monitoring software, the components for simulating, evaluating, and optimizing the setup of such locations under given tariffs and contracts. The development of the business and in particular the definition of the role of the battery operator as a "Power Provider" and its contractual setup and tariff with the CPO are further important activities. Altogether, about 10 such high-power charge points will be commissioned within the project.

The CPO power costs at the site have multiple components including operational expenses (OPEX) costs (grid usage fees, electricity fees, taxes and levies) as well as capital expenditures (CAPEX) costs (grid connection fees). Using a battery, the "Power Provider" can reduce these site costs, but also has to consider additional CAPEX costs (battery purchase) and extra energy costs owing to battery cycle inefficiencies. The achievable CPO-side cost savings depend on the actual load profile, the energy and reserve energy prices, the regulated grid fees, the control algorithm of the battery (and its configuration) in the micro-grid, and the contractual setup between the Power Provider and the CPO as well as other actors. Figure 28 illustrates the actor contracts (cash flows) having an impact on the final CPO power costs at a site. Blue arrows indicate cash-flows. The dashed blue arrows indicate would-be cash-flows without a battery. The cash flow labelled CPO2PP is the final CPO power cost.

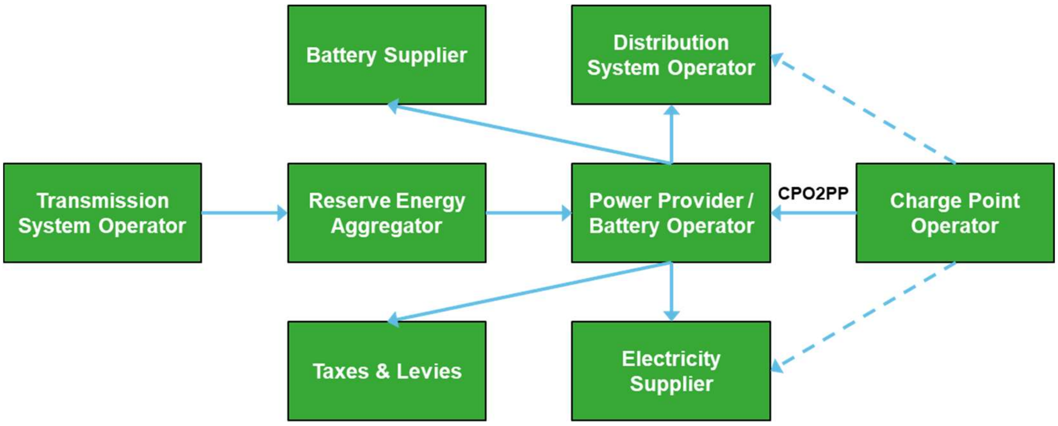


Figure 28: Contracts between actors at SYNERG-E high-power charge points.

The online monitoring of SYNERG-E charge points mostly covers electrical and operational data of the micro-grid. However, operational and financial performance metrics (including cost previews and cost saving metrics) will be generated offline and delivered to the CPO at regular intervals, e.g. monthly in the form of Excel sheets. The setup of SYNERG-E charge points does not include a software interface between the Power Provider's Micro-Grid Management System (MGMS) and the SMATRICS Charge Point Management System (CPMS).

Within NeMo a system and a RESTful web service were established for delivering operational and financial metrics about SYNERG-E charge points in real-time, enabling the CPO to tune its own business "online" (think of dynamic B2C pricing). This service is available as a NeMo service ("MicroGridInfo") via the NeMo Hyper-Network.

3.2.1.1 NeMo service implementation

A comprehensive software system for providing CPO power consumption and cost metrics in real-time has been implemented specifically for NeMo as a NeMo extension to the SYNERG-E reporting backend (synerge-reporting/nemoReport).

The service was developed in Python. The Flask library was used for providing RESTful API endpoints. The service uses disk-based caching, ensuring that requests of previously calculated data will hit the cache and thus return immediately.

Depending on the parameters of a request, the data retrieval and output calculation can be CPU and memory extensive. A solution for RAM-based caching of "expensive" intermediate results (and automatically clearing these caches if the server approaches its memory limit) has been put in place, enabling longer-running tasks and parallel execution of tasks on a single machine.

The service makes use of previously developed lower-level tools for analysing SYNERG-E micro-grids. During the implementation and testing phases, important issues in these low-level components were identified and fixed.

The system was deployed in the Microsoft Azure cloud (in the same resource space where the SYNERG-E cloud server VMs are running).

The service provides output in the following formats:

- JSON (via web API)
- JSON files (on disk)
- XLS files (on disk)
- PNG files (on disk)

The service user may request the following output data:

- The list of available SYNERG-E charge points enabled for the NeMo service
- Location meta-data
  … for a given SYNERG-E charge point:
  - name
  - geo-location
  - static setup data
- Operational and financial metrics as time-series…
  … for a given SYNERG-E charge point
  … for a given analysis time interval T (e.g. the last seven days)
  … for given granularities (hourly, daily, monthly)
  … both as "cumulative values" and "single values"[1]:
  - Energy Consumption (kWh)
  - CP Power Peak (kW)
  - Grid Power Peak (kW)
  - Power Peak Shaved (kW) = CP Power Peak - Grid Power Peak
  - Energy Cost (€)
  - Energy Cost w/o BESS (€)
  - Energy Cost Savings (€)
  - Energy Unit Cost (€/kWh) = Energy Cost / Energy Consumption
  - Energy Unit Cost w/o BESS (€/kWh)
  - Energy Unit Cost Savings (€/kWh)
  - Energy Cost Rate (€/h) = Energy Cost / T
  - Energy Cost Rate w/o BESS (€/h)
  - Energy Cost Rate Savings (€/h)
  - Power Peak Cost (€/kWp/h) = Energy Cost / CP Power Peak / T
  - Power Peak Cost w/o BESS (€/kWp/h)
  - Power Peak Cost Savings (€/kWp/h)

[1] For example, consider the "CP energy cost" metric in "daily" granularity for a time interval covering the "last 7 days". If we look at the 5th day in this sequence, the "cumulative value" corresponds to the cost sum over the first 5 days, while the "single value" corresponds to the added cost in the 5th day.

For service delivery in the NeMo Hyper-Network the service provider (in this case VERBUND) has set up and operates their own NeMo node, "created" the NeMo service (i.e. provide and install all necessary artefacts), and registered it in the NeMo marketplace; the service consumer (in this case SMATRICS) does not need to run a dedicated node but must be registered in the NeMo marketplace, in this case as an "affiliated partner" of VERBUND business partner via whose node SMATRICS can access NeMo environment and services.

The "NeMo node of the Austrian test site" has been provisioned as an Ubuntu Server 16.04. VM in the Microsoft Azure cloud (using the configuration "F4s_v2" with 4 VCPUs, 8 GB RAM, 8 disks, 8000 IOPs max, and 32 GB temp storage) and has been set up following the available documentation.

The MicroGridInfo API for SYNERG-E charge points was mapped to three different *NeMo Services*, namely the following RESTful GET endpoints:

- SynergeCP_GetLocationIdList_v0
- SynergeCP_GetLocationInfo_v0
- SynergeCP_GetLocationMetricHistory_v0

For each of these services, a semantic description (OWL-S file) as well as a PSM-to-CIM translation (Mapping XML file) was provided and stored in the project's central Code Repository (ICCS GitLab server), and a corresponding *Service* entry in the NeMo Marketplace was created. A dummy *Service Offering* comprising of all three services was created as well, and a NeMo Service Contract was set up that "buys" all three services for testing purposes. In order to test the execution of these NeMo services via the NeMo API, the Swagger UI running on the NeMo node was used as a front-end, for convenience.

The following figure shows the Austrian test site's IT architecture. NeMo and SYNERG-E software components interact in the VERBUND cloud to deliver the NeMo service via the Hyper-Network.

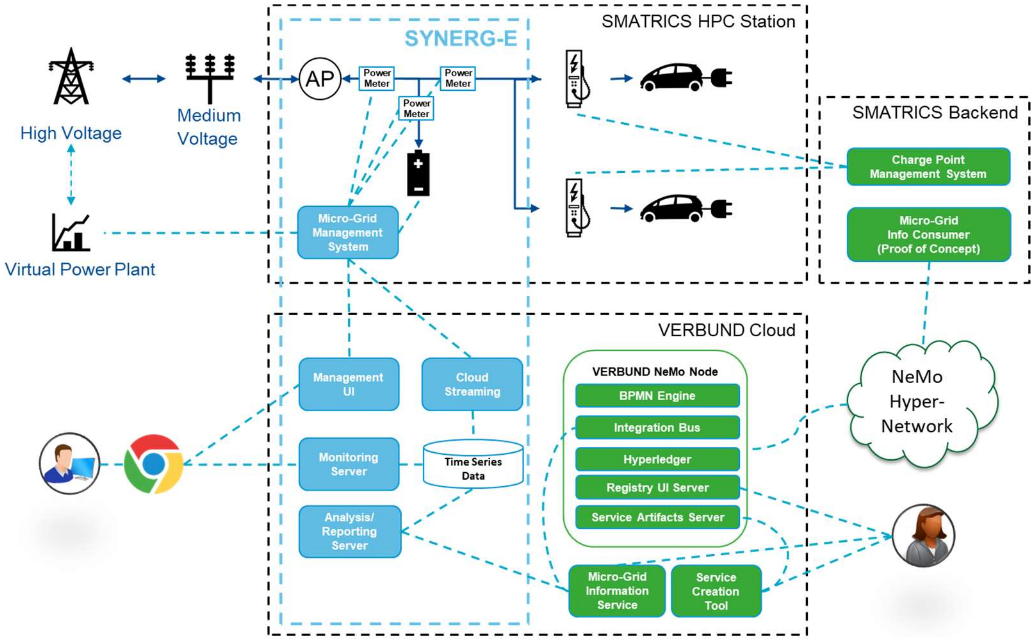


Figure 29: The architecture and environment of the Austrian NeMo test site

3.2.1.2 Mock data collection

As of July 2019, no SYNERG-E charge points were operational. The first three of these charge points were scheduled to start operation in September 2019, in the Austrian cities of Vienna, Innsbruck, and Feldkirchen/Graz. SMATRICS will operate these charge points and VERBUND will act as the battery operator and Power Provider.

For purposes of testing the MicroGridInfo NeMo service, location setups for these three sites were used that were rather close to the real setups but pointed to simulated data instead of real data for the operational metrics at the site (power consumed by the chargers, load on the grid, battery power, etc.). These simulated measurement data derived from two assumptions. Firstly, a load curve for the whole year of 2025 was used, as obtained for 450 kW charge points by SYNERG-E project partner Allego from e-mobility market simulations. Secondly, specific micro-grid management system settings (roughly optimized) were applied to control the simulated battery.

Tests have been performed with mock data from all three sites mentioned above. As an example, the mock configuration of a charge point is described in detail in Table 2. This configuration corresponds roughly to a “simulation twin” of the real charge point in Vienna, Ludwig-von-Höhnel-Gasse that will soon be operational.

Table 2: Configuration of mock charge point

Parameter	Value
Site:	
Name	sma1_wien_mock2025
Address	Ludwig-von-Höhnel-Gasse 4 1100 Wien, Austria

Geo-Position	48.15972347 °N 16.38483167 °E
CP load:	
Resolution	One data point per minute
Scenario	Scenario for a 450 kW charge point as projected for the year 2025 by Allego
Grid Connection:	
Country	Austria
Province	Wien
Grid level	6
Grid Connection Power	500 kW
Stationary Battery:	
Supplier	(real: ads-tec)
Power Capacity	300 kW (real: 280 kW)
Energy Capacity	300 kW (real: 240 kWh)
Charge or Discharge Energy Efficiency	95 %
Micro-Grid Management System (MGMS):	
Operation Mode	Peak-Load Shaving + Primary Reserve Grid Services to TSO (via Energy Aggregator)
Grid Power Limit for Peak-Load Shaving: Algorithm attempts to keep the grid load, averaged over 15-minute intervals, below this value.	200 kW
Target State of Charge of the Stationary Battery: Algorithm attempts to load/unload the battery to this level	70 %
Primary Reserve Recharge Strategy	Decide every 15 minutes whether to discharge or charge 5 kWh in the next 15 minutes (potentially shifting the operating point by +/- 20 kW)
Grid Services:	
Type	Primary Reserve calls only
Enabled	Full year 2025
Grid Frequency Data Source	Example data from the past
Maximum reserve power	300 kW
Tariffs/Prices/Taxes:	
Energy Aggregator Revenues from Primary Reserve services (paid by the TSO)	0.01 €/kW/hour @ 100 % reliability
Power Provider's Reserve revenue share	Unspecified
CPO's share of savings in kW-based grid fees	Unspecified
CPO's share of Power Provider's reserve revenues	Unspecified
Grid fees (regulated)	Various components. As valid in 2018, depending on the grid level and grid region (see above). The regulated CAPEX costs for grid access paid by the CPO are amortised over a period of 10 years, i.e. in our financial model, the CPO pays 10 % of

	these costs over the period of a year.
Energy Supplier tariff	0.04 €/kWh
Electricity levy	0,015 €/kWh
Grid Utilization tax rates	6.5 % of grid fees
Energy Utilization tax rate	6.5 % of grid fees
Value added tax rate	20 %

3.2.1.3 Validation activities

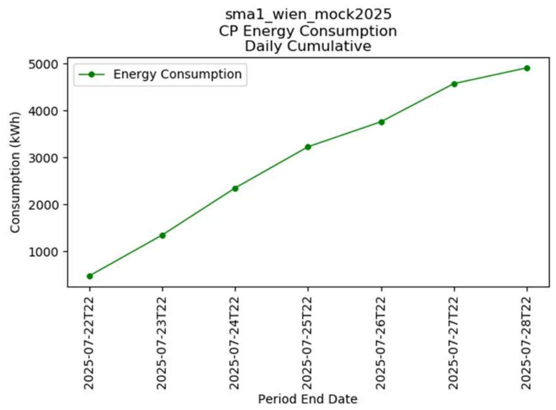
The developed service was tested extensively with three mock setups corresponding to future real charge points in Austria. For each test, hourly, daily, and/or monthly metrics were requested for multiple periods. The output of the service was repeatedly discussed with experts from VERBUND and stakeholders from SMATRICS.

The testing unveiled various issues that were fixed in an iterative manner and in due course:

- Output usability issues: Service output is now available also in tabular and graphical formats (besides the JSON format of the API response objects).
- Missing output: Specific metrics, such as the peak power and peak-power specific costs were added to enable better understanding of CP power cost time series.
- Performance issues: The response times (speed of calculations) were much improved by caching previous results on disk (and intermediate results in RAM).
- Memory issues: The evaluation of long and fine-grained time series in combination with multiple analysis periods and heavy caching caused out-of-memory events – these were addressed by clearing caches and resetting objects when the server approached zero memory.
- Wrong output: This was traced to subtle errors in caching, causing false cache hits, and it was fixed.

Table 3 following shows the complete data returned by one request for daily and hourly charge point metrics for the mocked charge-point “sma1_wien_mock2025” and a period of seven days (July 22-29, 2025) in graphical format.

Table 3: The daily and hourly charge point metrics as returned by the MicroGridInfo NeMo service for the mock charge point setup “sma1_wien_mock2025” for an example period covering seven days in July 2025.

<table>
<tr><th>Daily Charge Point Metrics</th><th>Hourly Charge Point Metrics</th></tr>
<tr><td>


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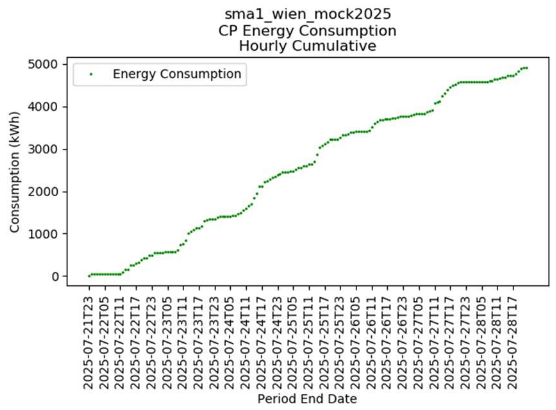

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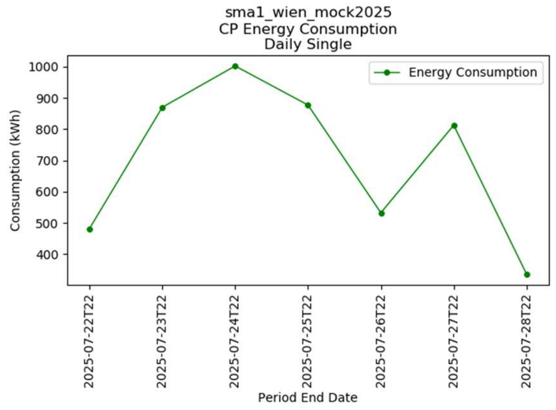

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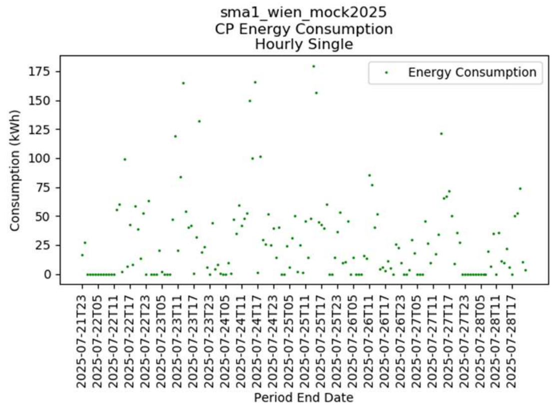

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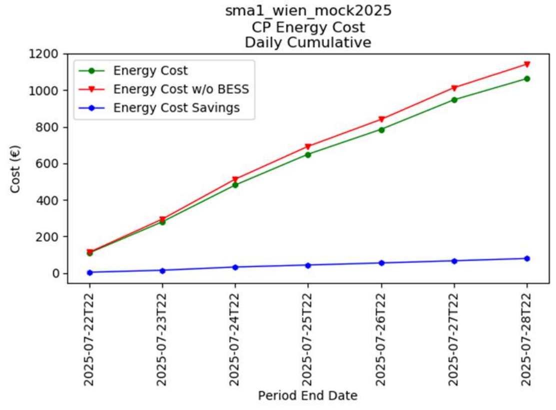

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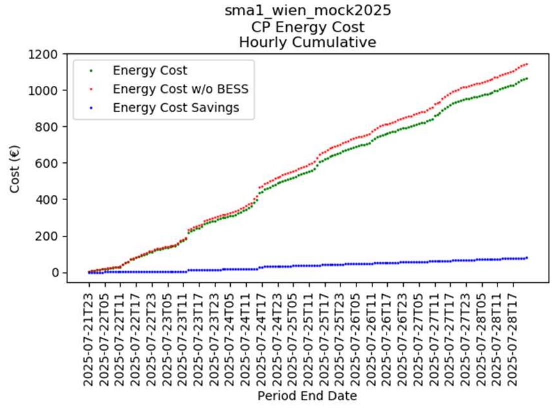

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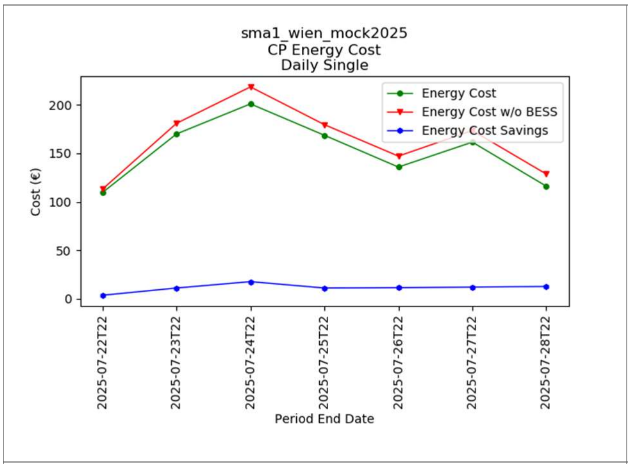
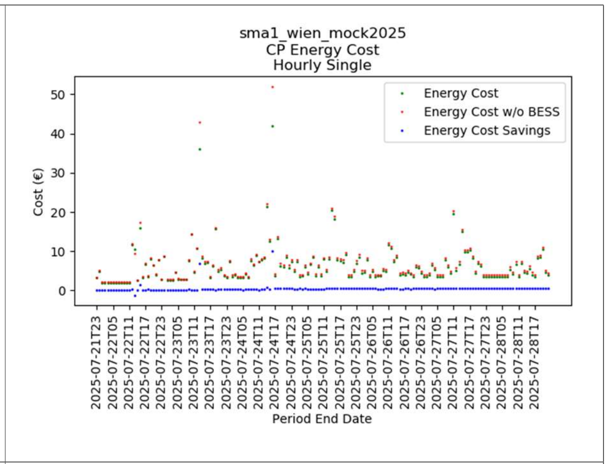
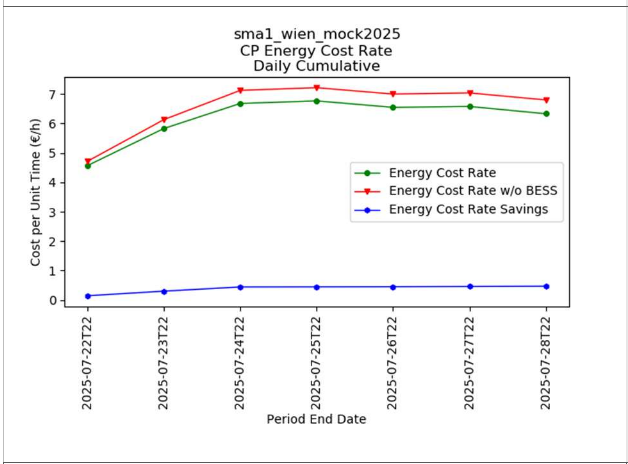
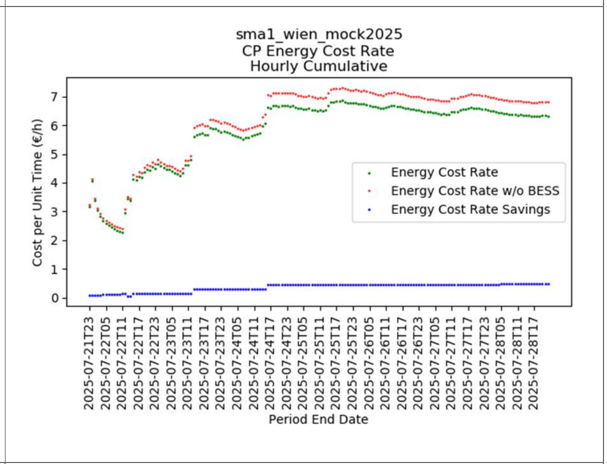
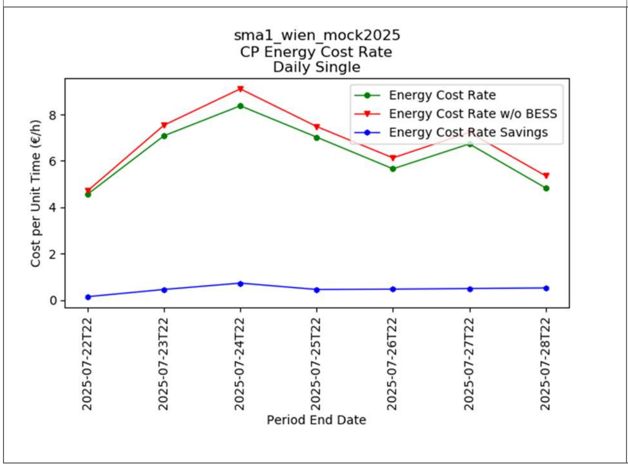
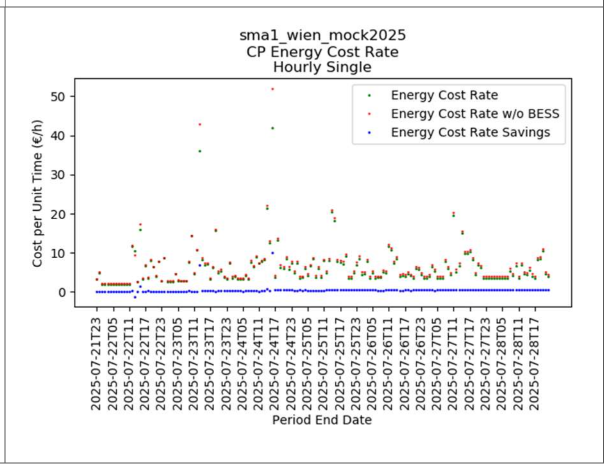

sma1_wien_mock2025
CP Energy Cost
Daily Single
Energy Cost
Energy Cost w/o BESS
Energy Cost Savings
Cost (€)
Period End Date

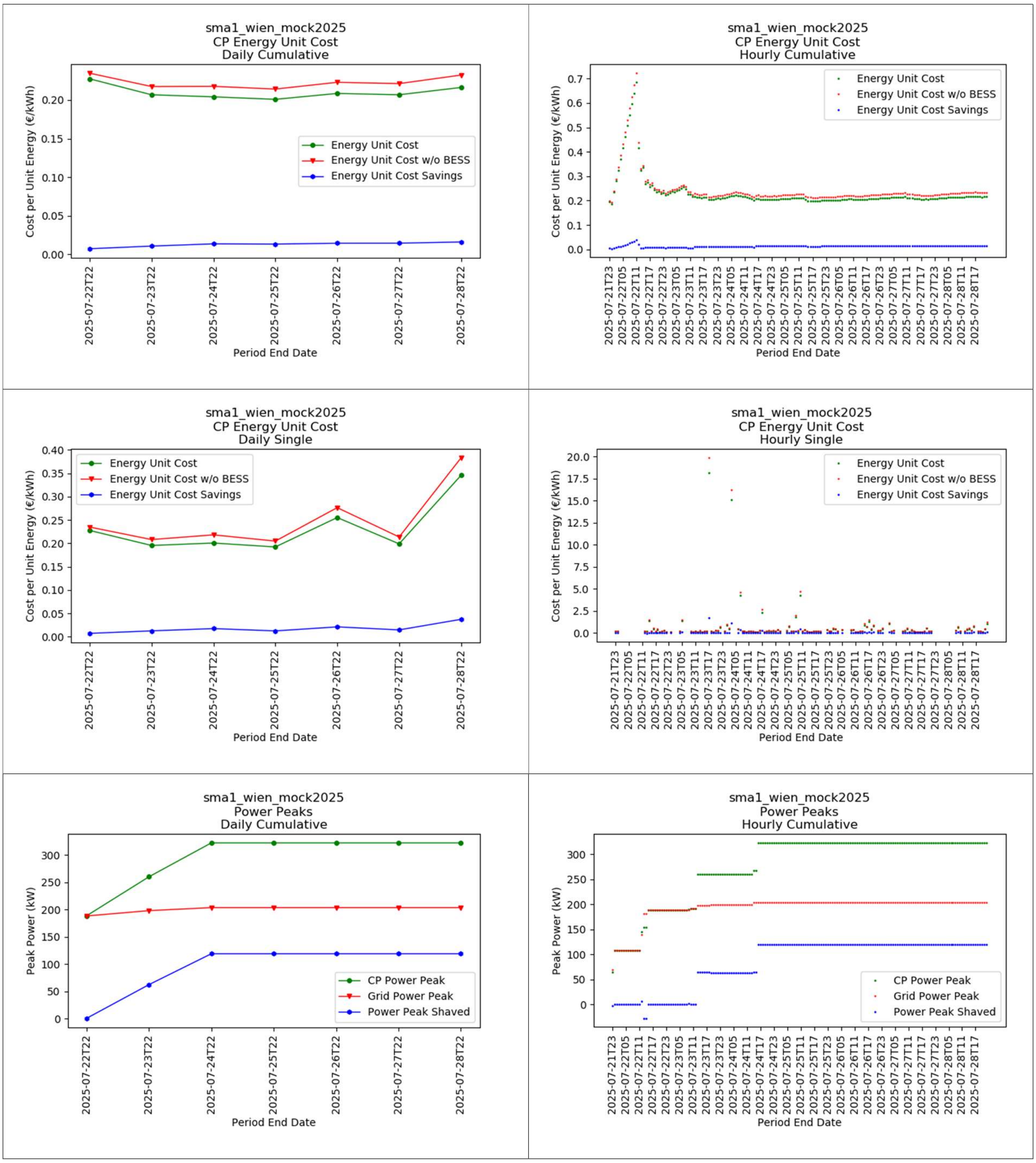

sma1_wien_mock2025
CP Energy Cost
Hourly Single
Energy Cost
Energy Cost w/o BESS
Energy Cost Savings
Cost (€)
Period End Date


sma1_wien_mock2025
CP Energy Cost Rate
Daily Cumulative
Energy Cost Rate
Energy Cost Rate w/o BESS
Energy Cost Rate Savings
Cost per Unit Time (€/h)
Period End Date


sma1_wien_mock2025
CP Energy Cost Rate
Hourly Cumulative
Energy Cost Rate
Energy Cost Rate w/o BESS
Energy Cost Rate Savings
Cost per Unit Time (€/h)
Period End Date


sma1_wien_mock2025
CP Energy Cost Rate
Daily Single
Energy Cost Rate
Energy Cost Rate w/o BESS
Energy Cost Rate Savings
Cost per Unit Time (€/h)
Period End Date


sma1_wien_mock2025
CP Energy Cost Rate
Hourly Single
Energy Cost Rate
Energy Cost Rate w/o BESS
Energy Cost Rate Savings
Cost per Unit Time (€/h)
Period End Date


sma1_wien_mock2025
CP Energy Unit Cost
Daily Cumulative
Cost per Unit Energy (€/kWh)
Period End Date
Energy Unit Cost
Energy Unit Cost w/o BESS
Energy Unit Cost Savings
sma1_wien_mock2025
CP Energy Unit Cost
Hourly Cumulative
Cost per Unit Energy (€/kWh)
Period End Date
Energy Unit Cost
Energy Unit Cost w/o BESS
Energy Unit Cost Savings
sma1_wien_mock2025
CP Energy Unit Cost
Daily Single
Cost per Unit Energy (€/kWh)
Period End Date
Energy Unit Cost
Energy Unit Cost w/o BESS
Energy Unit Cost Savings
sma1_wien_mock2025
CP Energy Unit Cost
Hourly Single
Cost per Unit Energy (€/kWh)
Period End Date
Energy Unit Cost
Energy Unit Cost w/o BESS
Energy Unit Cost Savings
sma1_wien_mock2025
Power Peaks
Daily Cumulative
Peak Power (kW)
Period End Date
CP Power Peak
Grid Power Peak
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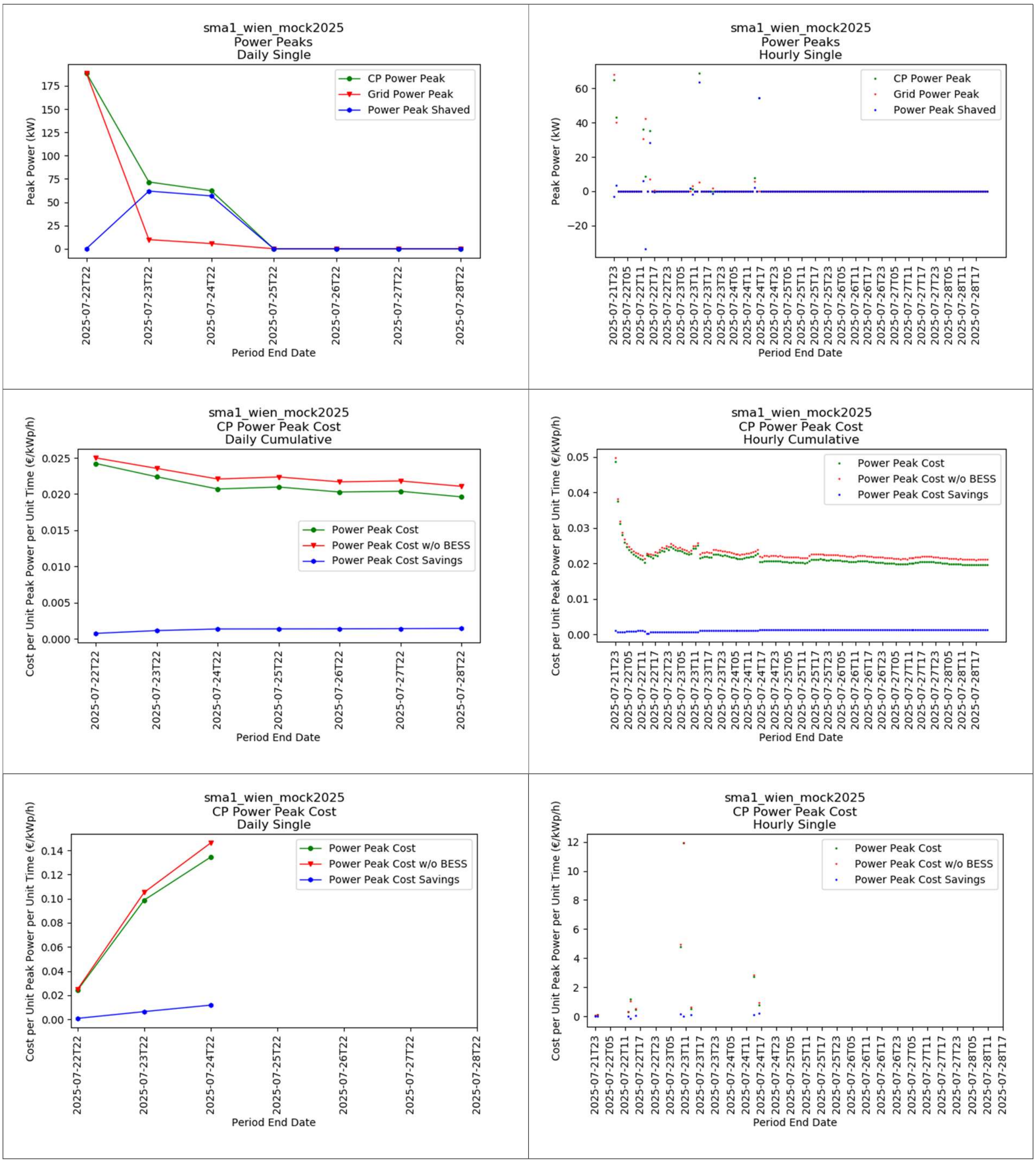
CP Power Peak
Grid Power Peak
Power Peak Shaved



The main indicator for evaluating the usefulness of the MicroGridInfo NeMo service for the business of a CPO operating SYNERG-E charge points is the "Economic optimisation of high-power charge sessions". The cost savings ("economic optimisation") that can be achieved with a managed stationary battery at the location depend on the actual location setup and the period of interest. Figure 30 illustrates the cumulative costs (with and without the stationary battery) and the cost savings achieved with the stationary battery for our example setup "sma1_wien_mock2025" for the whole year 2025 and in monthly resolution. In this dataset, the total CP Energy Cost without battery is 74,759 € whereas with battery it amounts to 68,544 €, corresponding to a total saving of 6,214 € or 8%.

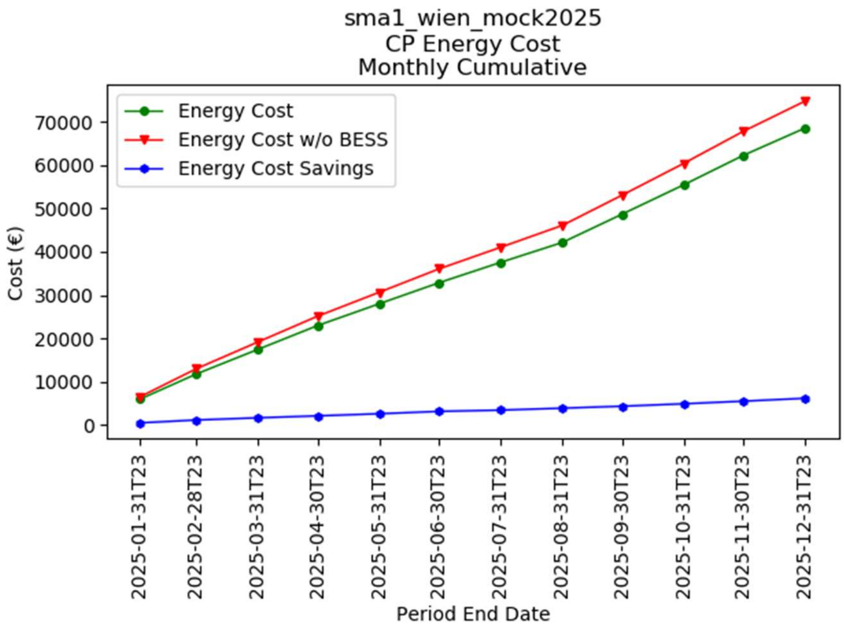


Figure 30: Monthly energy cost (and cost savings) ramp-up for the mock CP location “sma1_wien_mock2025” for the whole year 2025.

A limited number of experts and stakeholders were asked to provide their opinion on the added-value of offering the service via the Hyper-Network using the structured form of Deliverable 6.2. The fact that this was a B2B service with only two parties involved (VERBUND and SMATRICS) and the currently limited number of relevant locations (Vienna, Feldkirchen/Graz, Innsbruck) justifies the low number (6) of completed questionnaires.

According to the respondents, the service offers information relevant for the technical and economic optimization of charging services and it is the basis for enhanced offerings towards customers. They believe that a lot of detailed data can be provided for SYNERG-E high-power charge points through the NeMo MicroGridInfo service in real time.

The uniqueness of the service consists of the possibility of deriving **current** or historic cost of charging (€/kWh) based on the contractual setup of the site, the actors involved (CPO, Power Provider, Electricity Supplier, Distribution System Operator, Reserve Energy Aggregator, Transmission System Operator), the actual charge point load and the operation of the battery. Overall the API is simple and all things that an operator needs for location-based pricing are included. Furthermore, there are detailed insights into the power load and costs at the site, which can be very useful for the CPO operating the site, such as:

(1) Many different and detailed visualizations of the peak-shaving and of cost savings.

(2) Fast and efficient algorithm.

(3) Variety of output data.

The Power Provider does not only provide operational information of the storage battery system at the charging location (e.g. energy flows or peak powers before/after shaving) but also "translates" this service into estimated costs that build the basis for a CPO cost calculation for the upcoming charge session. A significant added-value is that the MicroGridInfo data will be available not only at local level, but also "online" via the Hyper-Network. Therefore, data can be made accessible for any other market participant (e.g. eMSPs).

The respondents' responses to the closed questions are given below.

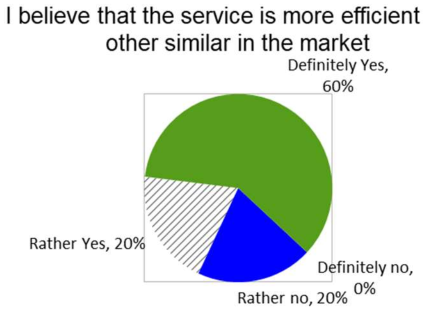


Figure 31: AT MicroGridInfo - efficiency

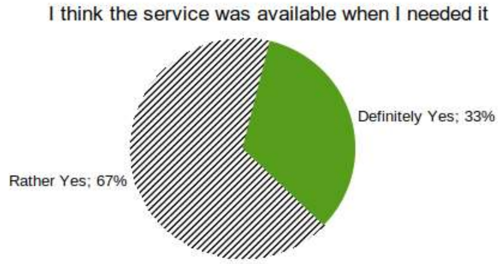


Figure 32: AT MicroGridInfo - availability

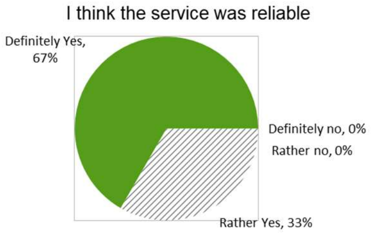


Figure 33: AT MicroGridInfo - reliability

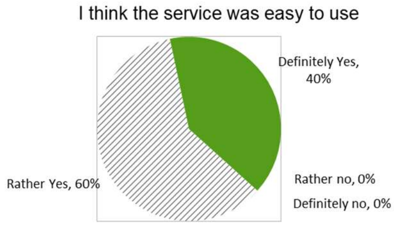


Figure 34: AT MicroGridInfo - easiness

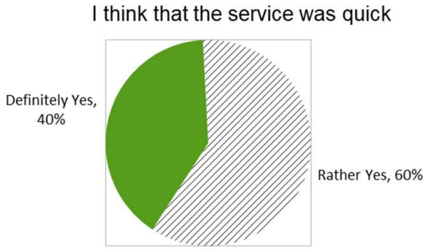


Figure 35: AT MicroGridInfo - quickness

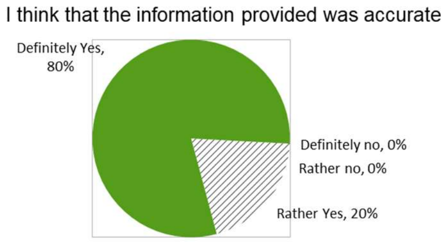


Figure 36: AT MicroGridInfo - information accurateness

The low level of satisfaction with the service is because the service was demonstrated with simulated data and the relation to real-life conditions is not established yet.

Furthermore, the respondents pointed out that the service has no direct customer relevance, but it is rather an API that will be in the future very useful. At this point, it has to be emphasized, that the MicroGridInfo service is not directed for end customers. The only potential users of the service are Power Providers (i.e. stationary battery system operators) on the one hand, and Charge Point Operators on the other hand, meaning MicroGridInfo is clearly defined as a B2B service. Price incentives towards end customers can only be granted by eMobility Service Providers (eMSPs) as the customer's contracting party. This will only be likely if a flexible B2B tariffing system is established between CPO and EMSP, meaning that the CPO forwards charge session cost savings to the EMSP in real-time.

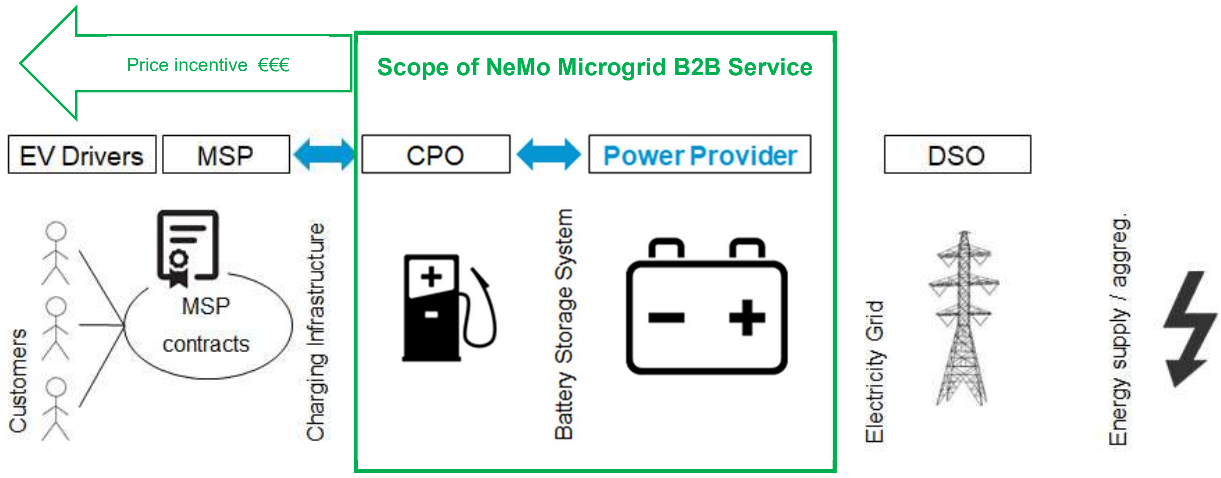


Figure 37: Parties involved in the MicroGridInfo Service

Furthermore, one weakness identified is that an efficient usage of information by the CPO requires adaptations of CPO side.

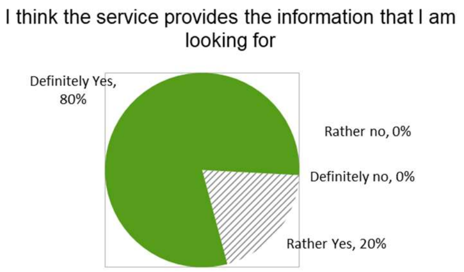


Figure 38: AT MicroGridInfo - information usefulness

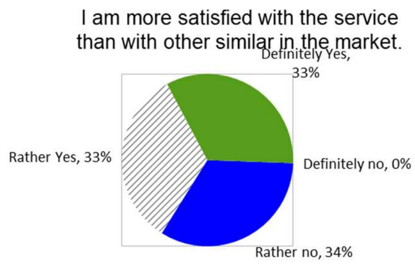


Figure 39: AT MicroGridInfo - satisfaction

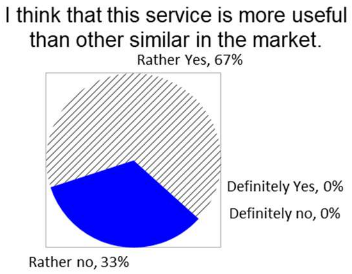


Figure 40: AT MicroGridInfo - service usefulness

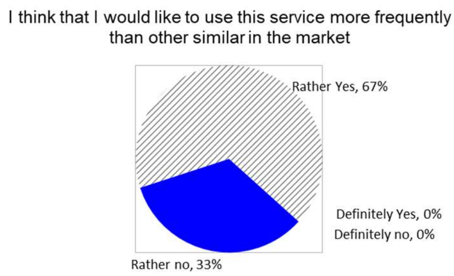


Figure 41: AT MicroGridInfo - willingness to use

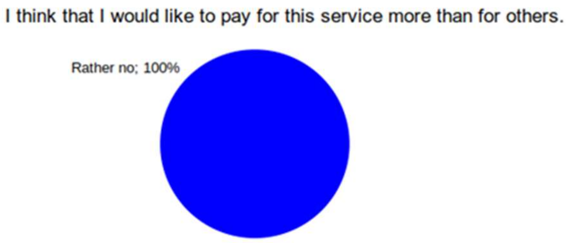


Figure 42: AT MicroGridInfo - willingness to pay

From technical point of view, respondents commented that the output graphics are rather abstract and maybe a visualization of the underlying calculations (e.g. for obtaining the costs) would help to understand them better. In general, the complexity of the underlying calculations and relations limit the understanding of the usual output without deep expert knowledge.

The respondents suggested to reduce the complexity of the underlying calculations and relations that limit the understanding of the usual output, as far as this can be possible.

3.2.2 Validation of the NeMo Inter-roaming possibility

For the validation in Austria, SMATRICS [CPO 1] has registered its charge points on the Hubject platform. Ze-Watt [eMSP 2] has registered the authentication tokens (unique IDs of its customers' RFID cards) on the GIREVE platform. SMATRICS is not registered on GIREVE, neither as eMSP nor as CPO. Vice versa, Ze-Watt is not registered on the Hubject platform. Also, there is no other bilateral agreement in any form between SMATRICS and ZeWatt. Based on this, the activities in Austria aimed to validate that Ze-Watt customers would be able to authorize and charge on a SMATRICS charging station by using an ordinary Ze-Watt RFID card.

As the complete SMATRICS network has been registered on the Hubject eRoaming platform, the usage and demonstration of the NeMo Inter-Roaming is possible on any of the approximately 450 charge points operative in Austria. The collection of data was processed in the SMATRICS IT environment.

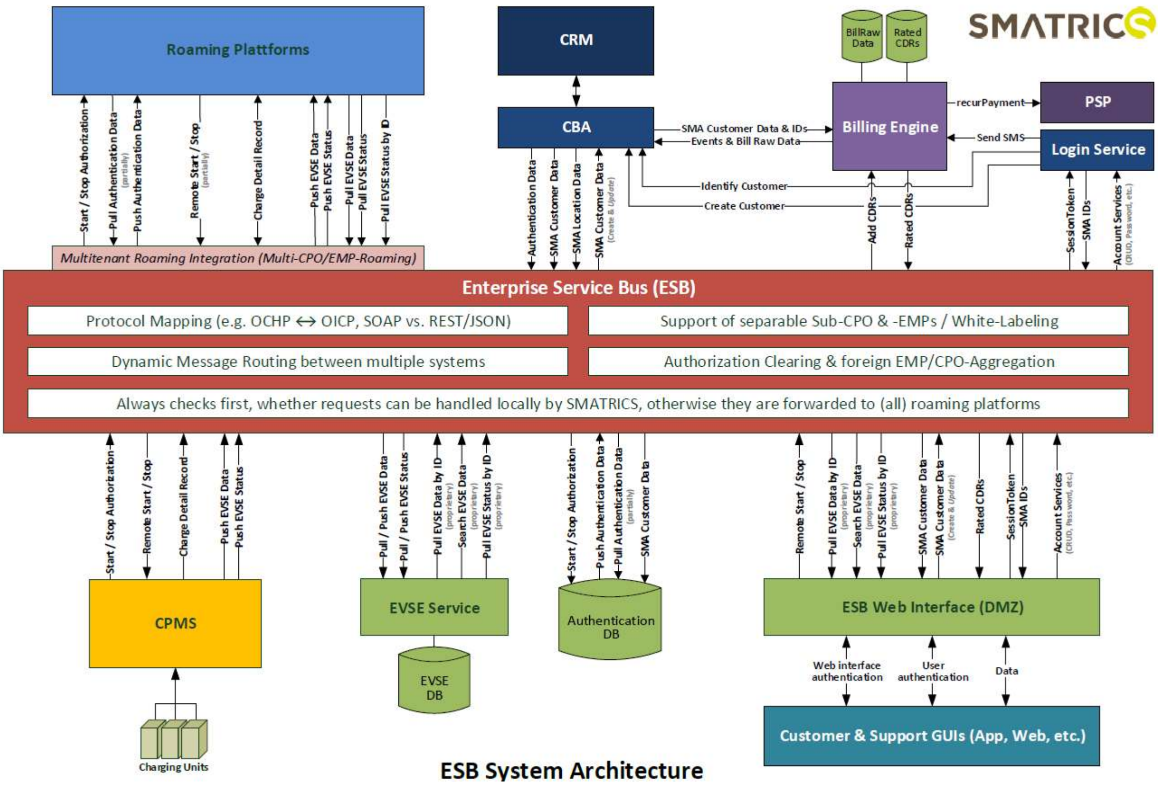


Figure 43: SMATRICS IT environment

When authenticating with the Ze-Watt RFID card, a live authorization request to the Hubject platform was triggered, as the Ze-Watt batch is not stored on the offline whitelist nor in SMATRICS internal IT systems.

The tests were done on a publicly accessible site in Vienna with the following location details.

Table 4: Austrian testing activities location details

Name	Location type	Address	Geo coordinates	Number of charge points	Available output power per point (kW)	Connector standard
Charger APCOA Mariahilf	Parking garage	Mariahilferstrasse 123, 1060 Wien VIENNA	48.1968664, 16.34069174	2	22	Type 2 plug

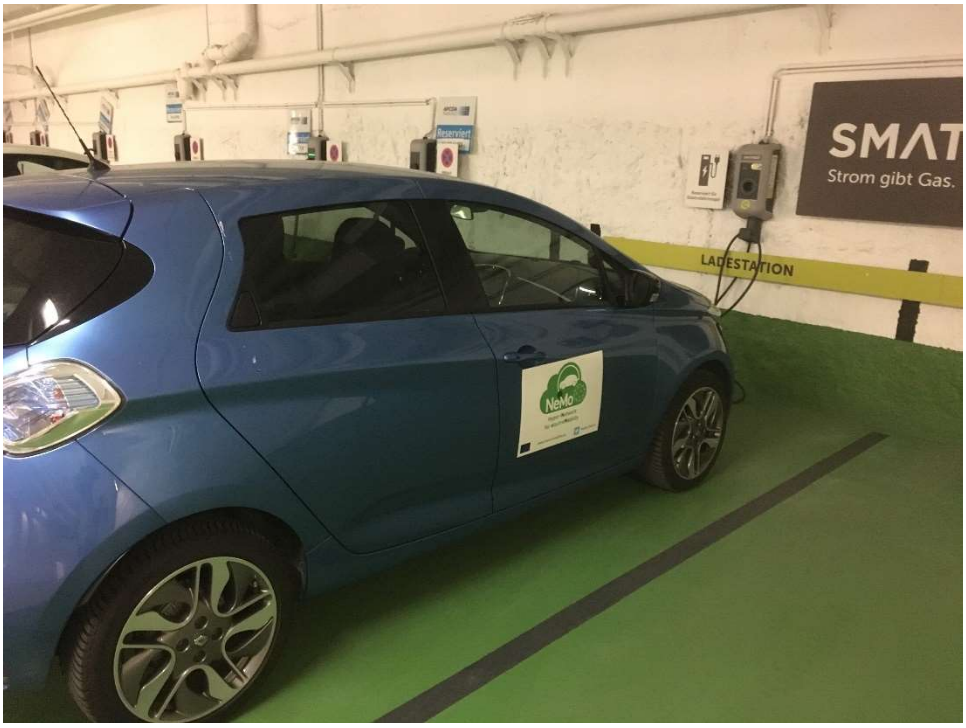


Figure 44: Vehicle charging in Austria

The activities involved the following steps with the respective results:

Table 5: Validation of the Austrian test site

	Result	Indication
Authorization attempt with a RFID card form an eMSP not permitted for Inter-Roaming	Authorization declined	Charging station LED indicators flashing in blue Charging session not started
Authorization attempt with a Ze-Watt RFID card	Authorization accepted	Charging station LED indicators flashing in green Charging session started Charge session uninterrupted

The details of the charge session are shown in the following figures.

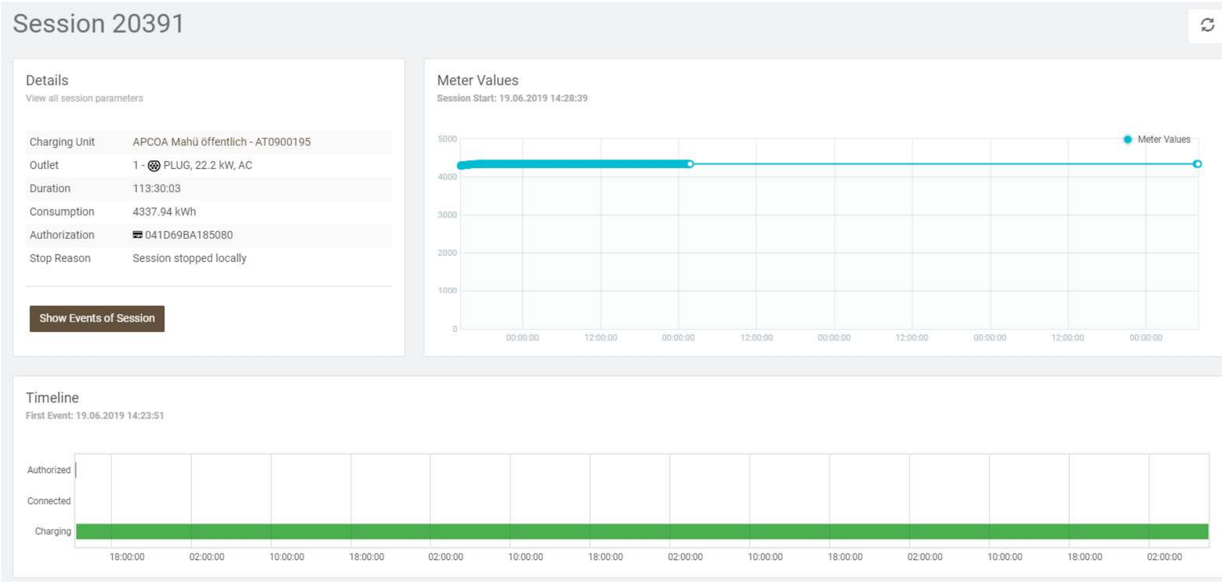


Figure 45: Austrian tests - details of charge session

Roaming Session

View all roaming session parameters

Id	16754
Create Date	19.06.2019 14:28
Hub Provider Id	FR*ZWM
Roamingsession Id	928a6642-2b83-4d83-bf1f-9e1b65e3966a
State	FINISHED
Transmission Date	24.06.2019 07:58
Uid	
Platform Id	1
Platform Name	Smatrics

Figure 46: Austrian tests – details of a roaming session

During the NeMo final cross-country drive 3 charge sessions were performed with the Ze-Watt card.

From the CPO point of view, the added-value of NeMo is that it offers the possibility to enable roaming with EMSPs even when not registered on the same eRoaming platform. This enlarges the potential customer base thus leading to a better usage rate of charging infrastructure. Furthermore, already registered charge points are automatically enabled for Inter-roaming after administration undertaken by the platforms. Overall, the CPOs mentioned that the Inter-Roaming protocol is a **good approach to push interoperability** and also to potentially strengthen the status of “smaller” eRoaming platforms. It minimizes the costs of operators and

EMSPs as it is only necessary to register to one platform. Furthermore, it is not necessary for the user to have multiple subscriptions at different platforms.

The possibility to charge using the Inter-Roaming protocol was appreciated by the final users who charged using it because it is easy to use. Their responses to the closed questions are shown below.

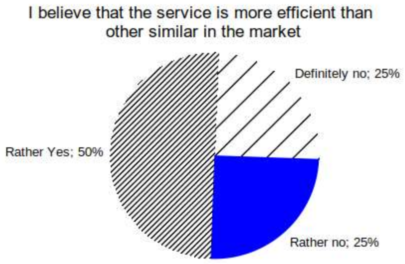


Figure 47: AT Inter-Roaming - efficiency

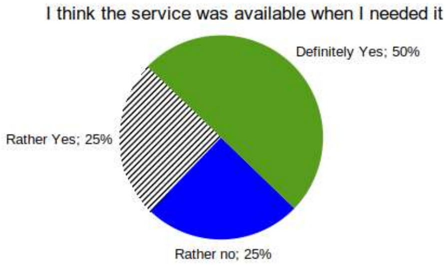


Figure 48: AT Inter-Roaming - availability

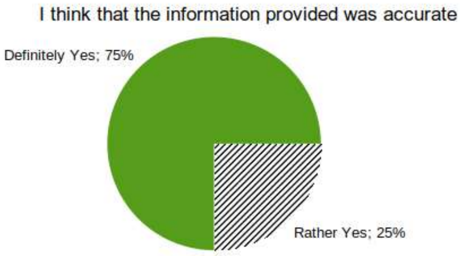


Figure 49: AT Inter-Roaming - accurateness

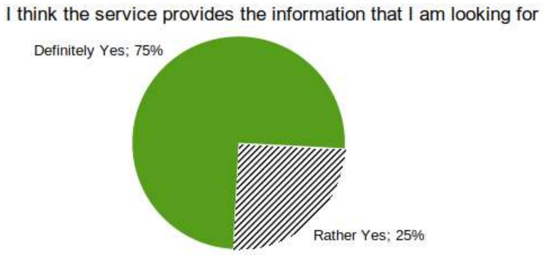


Figure 50: AT Inter-Roaming - information usefulness

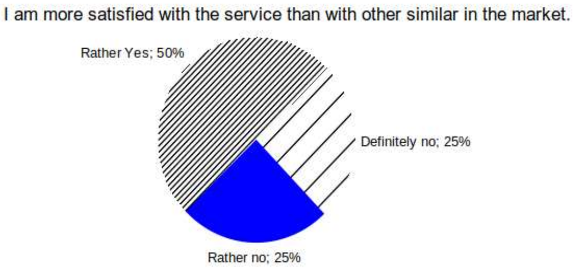


Figure 51: AT Inter-Roaming - satisfaction

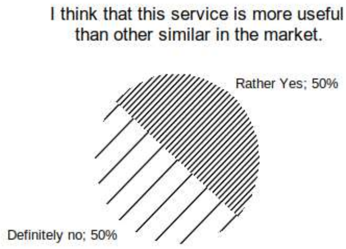


Figure 52: AT Inter-Roaming - usefulness

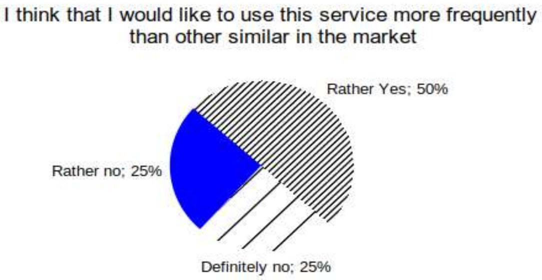


Figure 53: AT Inter-Roaming - willingness to use

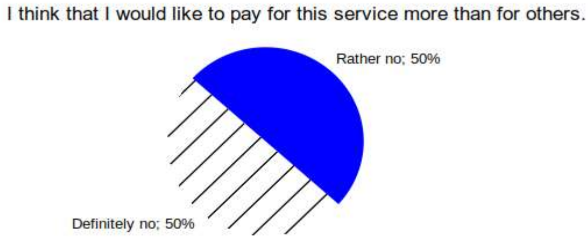


Figure 54: AT Inter-Roaming - willingness to pay

With reference to legal and operational aspects, still some challenges have to be overcome as among the eRoaming platforms there are different Service Level Agreements towards EMSPs and CPOs (e.g. regarding uptime) and also different standards regarding data privacy. For example: an EMSP is registered in Hubject that assures a Service Level which includes 98.5% uptime of the platform (assumption). With the Inter-Roaming possibility, also the guaranteed uptime of another platform is relevant.

Regarding data privacy, it must be noted that the unique IDs (RFID tokens) are regarded as customer related data, so this should be taken into account when preparing the contractual agreements and framework.

3.3 Validation activities in Germany

3.3.1 Validation of battery services

The German test site validated the battery services available in the NeMo Hyper-Network that can be used for scenarios relevant to “Smart charging”, “Itinerary Planning” and “Vehicle preparation for driver off”, (Business scenario 1, 2 and 7 respectively) in Deliverable 1.1 of NeMo.

The **AdaptiveSoC Estimation** intends to determine the optimum SoC for the battery for the next utilization cycle. An optimum of the SoC thereby can be described by the total SoC of the battery before drive-off, as well as the point in time at which the SoC will be required. The AdaptiveSoC service therefore requires external information (forecast) on the when and the how/what the next driving cycle after charging will be. Based on that information the AdaptiveSoC estimation service proposes a charging strategy with a charging profile (SoC change over time) and a final SoC value to be reached before drive-off.

The **Thermal Preconditioning** service intends to address two major goals. The first is the thermal preconditioning of the driver cabin (either cooling or heating) while still at the charging place. The required energy can thereby be utilized directly from the infrastructure and does need to be taken from the battery during the driving cycle. This extends the range of the vehicle or reduces the required SoC of the battery (in combination with the AdaptiveSoC Estimation service). The second is the enhancement of the overall vehicle efficiency, whereby waste energy during the charging process can be re-utilized for the cabin heating. This requires a well estimate (forecast) on when the next drive-off is most probable. The trade-off is between a too early (cabin conditioning energy demand increases) and a too late (preconditioning not complete or with impact to range on behaviour of SoC) drive-off estimate.

The **Battery Capacity Calculation** estimates the available charging capacity of the battery over time. It is rather a validation relevant indication for the battery, as the preceding two services shall have impact as well on the lifetime of the battery. The Battery Capacity Calculation service therefore observes the charge processes over a longer period and derives the capacity, by monitoring the charged energy and the SoC increase. The required input for the service thereby is the charging monitoring information.

The **Mobility Demand Prediction** is normally not battery service related, but mandatory in order to make the battery services testable. Different from a "normal" itinerary planning, the service aims for an itinerary forecast. The forecast has to be performed before the charging of the vehicle starts (very early stage). The generated forecast information, therefore, has to deal with uncertainties in scenarios of individual mobility. In order to predict the demand, the mobility history of natural persons is required. Further information would have been useful in order to enhance the prediction quality but were not applicable within the testing site.

As the services were not deployed to a real vehicle, no data was collected within real utilization scenarios. It is emphasised at this point, that especially the required integration into vehicle, component and infrastructure, including the required evaluation was not realizable due to the operational requirements of the services.

The testing activities and the testing approach have been selected to be identical as the overall testing scenario is a closed loop simulation, involving all described four services. In order to test the services, existing FOT data from an EV fleet was used in combination with a virtual testing environment. The general testing flow is depicted below. All simulation models have been realized in MatLab/Simulink. The interaction with the simulation environment included the interconnection with the NeMo services.

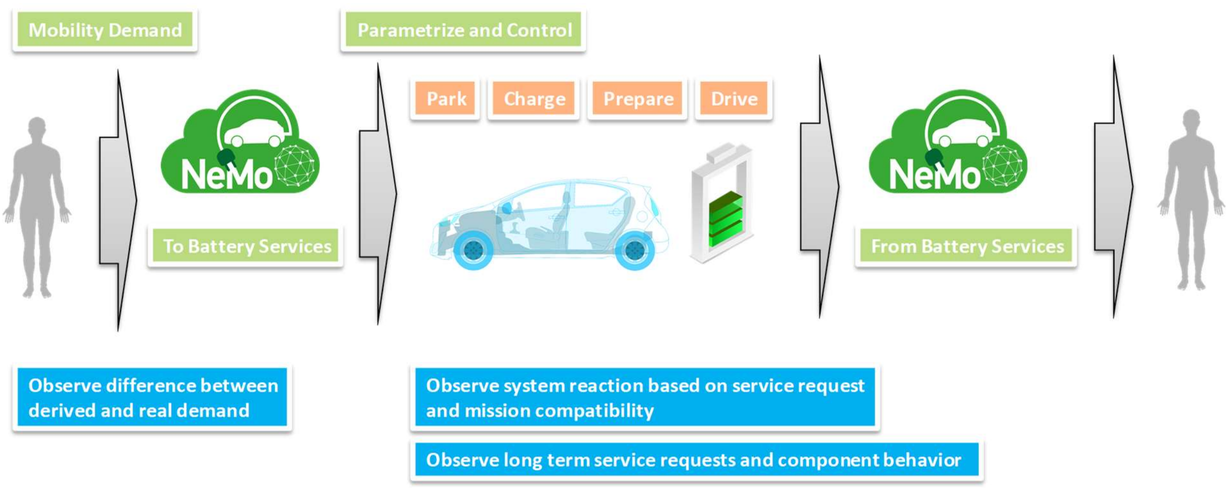


Figure 55: Test flow for the battery services

In closer detail, derived from the collected FOT data, virtual vehicle users have been modelled. This especially relates to the mobility profile of the users and the characteristics of the driving behaviour in a first step and are building the basis for the **Mobility Demand Prediction** service. Environmental data or social data that could lead to an improvement on the mobility demand prediction were not available. Evaluation on the service performance was then performed by a comparison on the predicted (forecast) and the real mobility data from the FOT dataset.

For the application scenario, the virtual users were then connected to a virtual Battery Management System (BMS) and a virtual battery in a second step. This BMS is the basis for the interaction of the **AdaptiveSoC Estimation** service and the **Thermal Preconditioning** service. The BMS thereby simulated the behaviour of a battery and a battery system. Simplified physical models for the cabin, the battery and the driving scenario had to be used. The simulation was used for the simulation of the charging cycle as well as for the vehicle drive cycle simulation. Validation of the services was only capable to verify the theoretical working principle of the services.

For triggering the simulation environment during demonstration, a web based and public accessible application, which can be seen as mock-up for a future customer application, has been realized. It was utilized as well during the demonstration purposes of the services.

Furthermore, a prototype implementation of the BMS interface required has been realized. It has been tested if the general approach of modifying BMS parameters could be implemented.

Figure 56: Prototype BMS interface

The later evaluation then was based upon a comparison on the difference of the predicted (a-priori prediction and definition of plan) and the estimated real system behaviour (a-posteriori alignment).

Table 6: Mobility prediction accuracy evaluation

a-priori estimate	Scenario A	Scenario B	Average
estimate higher than demand	2.77%	16.79%	6.28%
estimate correct	95.52%	74.59%	91.12%

estimate lower than demand	1.71%	8.62%	2.60%
missing distance	13,1km	62,4km	7,3km

In scenario A, the vehicle is used by one driver, in scenario B the vehicle is used by multiple drivers, while the average expresses the estimate based on FOT dataset utilized. The driving reserve is aligned to 10% of the ratio of battery capacity to the vehicle maximum range, with a minimum of 20km. The a-priori estimate higher than demand means the predicted mobility demand is more than driving reserve above the real demand; the estimate correct means the predicted mobility demand is at least the real demand but does not exceed the driving reserve; and the estimate lower than demand means that the predicted mobility demand is lower than the real demand. The full battery capacity is attributed at 30kWh (driving reserve 3kWh), with a range of 230km (driving reserve 23km) and at 130Wh/km energy per kilometre.

A demonstration event was held at FKA, where experts for component and EV development have been invited. The ideas and concepts of the following battery services have been presented to the audience in detail:

1. AdaptiveSoC Estimation
2. Mobility Demand Prediction
3. Thermal Preconditioning
4. Battery Capacity Calculation

Furthermore, the general practice on the creation of services and the utilization of services within the NeMo Hyper-Network have been exemplarily shown. Together with the presentations, a discussion between all participants has been arranged in order to clarify questions and to collect feedback and remarks on the specific service concepts as well as on the general approach. The auditorium was a selected group of well-known cooperation partners within the automotive industry, tier 1 suppliers and research facilities of the RWTH University of Aachen (or Rheinisch-Westfälische Technische Hochschule Aachen).

The questionnaires of Annex 2 of Deliverable 6.2 were handed out to all attendees after the presentation and discussion on the services and the utilization scenarios. The feedback was requested in order to identify the pros and cons of the presented services and their utilization. Overall, 11 questionnaires have been received. The responses to the closed questions are given below.

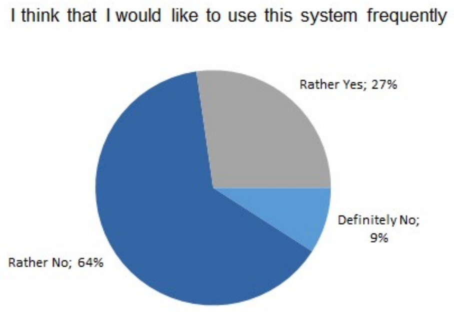


Figure 57: DE Battery - willingness to use

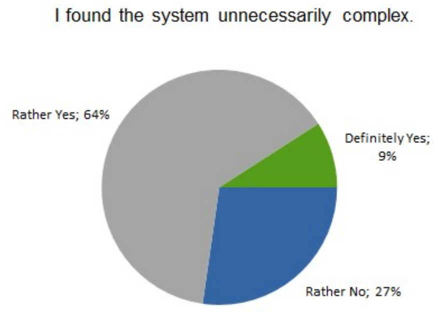


Figure 58: DE Battery - complexity

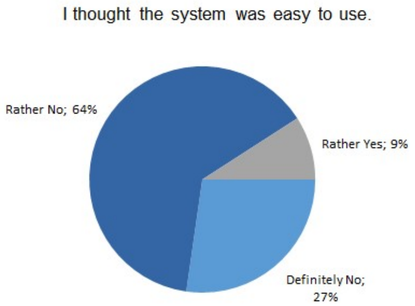


Figure 59: DE Battery - easiness

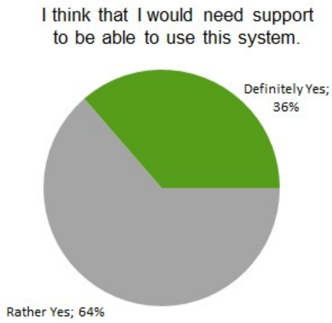


Figure 60: DE Battery - need of support

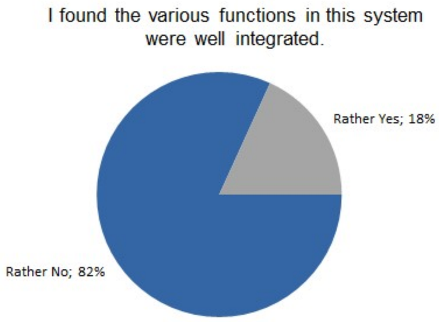


Figure 61: DE Battery - system integration

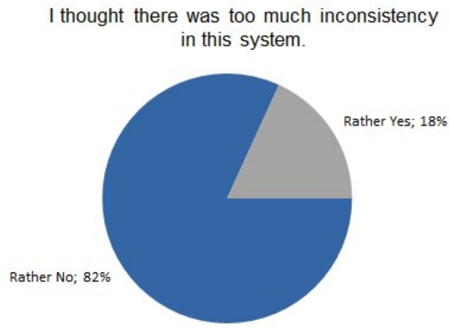


Figure 62: DE Battery - inconsistency

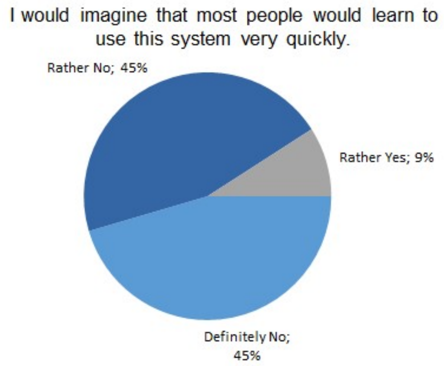


Figure 63: DE Battery - quick to learn

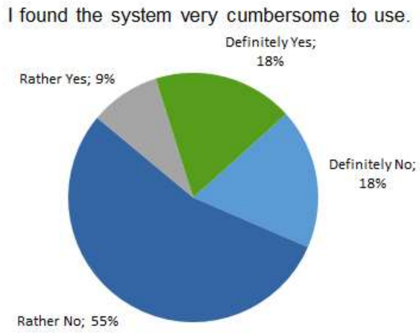


Figure 64: DE Battery - cumbersome to use

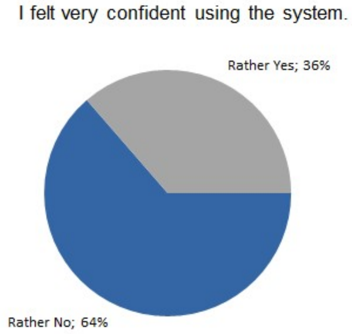


Figure 65: DE Battery - feeling confident

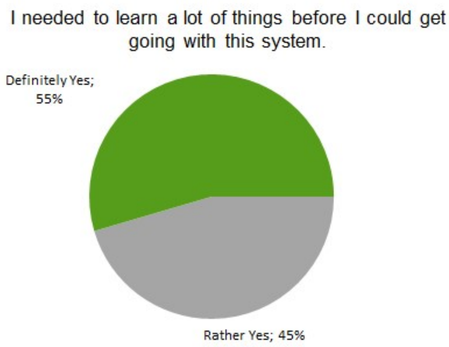


Figure 66: DE Battery - complexity

According to Figure 57, the 73% of the respondents are not willing to use the services. This can be explained by the complexity of the services which is shown in Figure 58, Figure 63 and confirmed in Figure 66. All these questions refer to the easiness/complexity of the services and are all coherent in terms of answers. More specifically, the users found the services too complex which is also confirmed in the open answers. It was pointed out that the data calculated, the data flow, ownership and transparency were not clear, thus creating less confidence in the results.

The respondents found the general idea of the simulated services as well as of their integration to NeMo very interesting and with great potential.

They suggested to reduce the complexity and improve the speed, because they found the services too slow, complex and difficult to use, although this was attributed to the prototype phase of the services.

3.3.2 Validation of Itinerary Planning

The German test site validated also the NeMo Itinerary Planning service, which corresponds to Business scenario 2 of Deliverable 1.1.

8 questionnaires were completed. 75% of respondents were female and the average age was 34.5 years old.

The added-value of the NeMo service that was highly appreciated by the users was the possibility to **get real time information** on the **near-by charge stations** as well as the possibility to have an overview of the distance that could be travelled, given the status of charge. The users also liked the possibility to have multiple infomobility services together. Their responses to the closed questions are shown below.

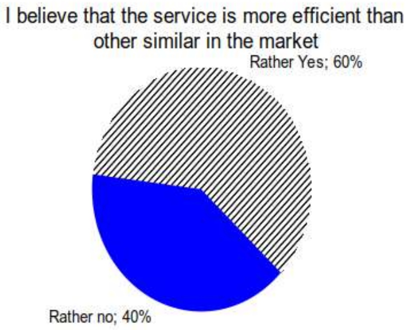


Figure 67: DE Itinerary Planning - efficiency

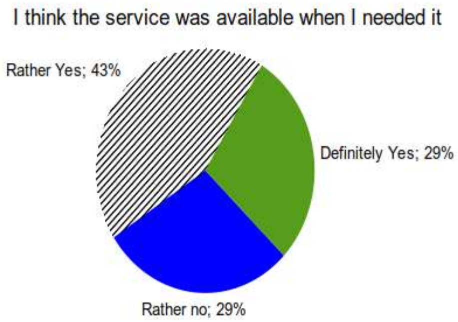


Figure 68: DE Itinerary Planning - availability

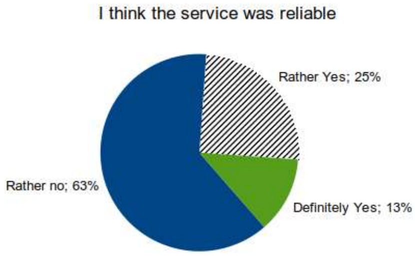


Figure 69: DE Itinerary Planning - reliability

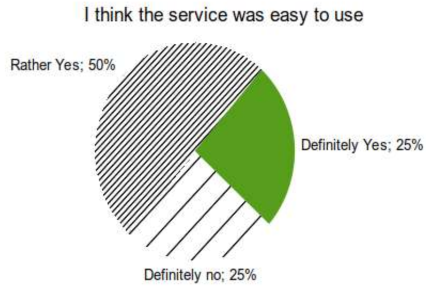
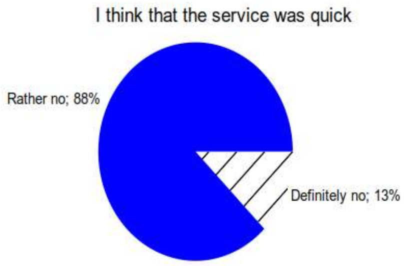


Figure 70: DE Itinerary Planning - easiness

The information provided was rather accurate as shown in Figure 72 although one of the respondents noticed that setting starting end point via drag and drop is not very exact, so it would be nicer to insert exact addresses.



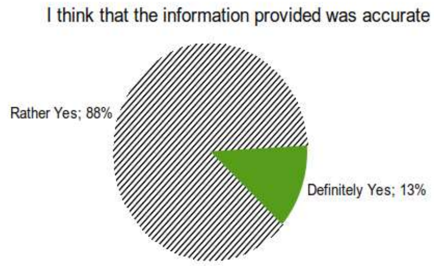
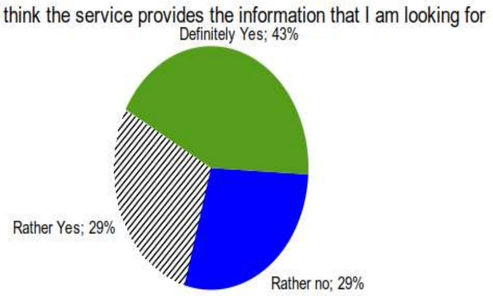


Figure 71: DE Itinerary Planning - quickness

Figure 72: DE Itinerary Planning - accurateness



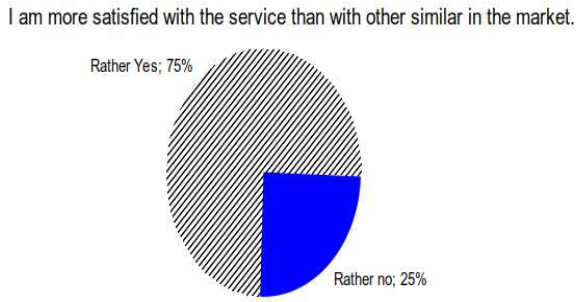
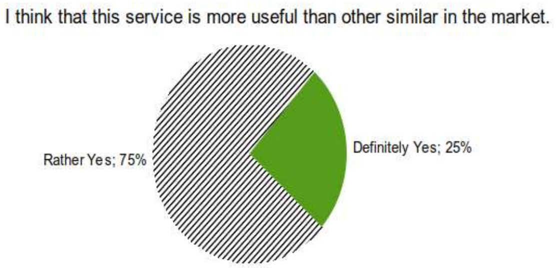


Figure 73: DE Itinerary Planning - usefulness of information

Figure 74: DE Itinerary Planning - satisfaction



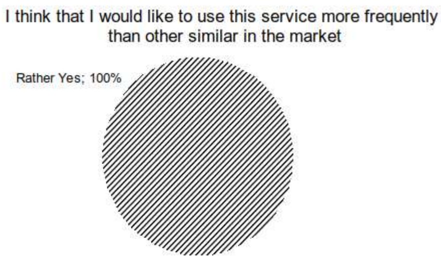


Figure 75: DE Itinerary Planning - service usefulness

Figure 76: DE Itinerary Planning - willingness to use

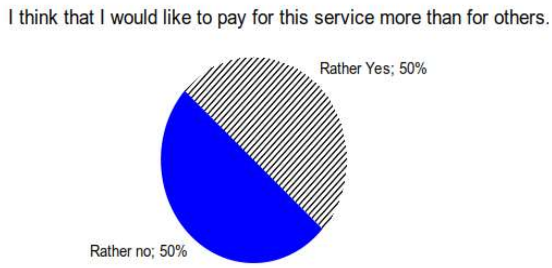


Figure 77: DE Itinerary Planning - willingness to pay

According to the respondents, the service was quite **slow** and this also reflects on the answers about the reliability. Figure 69 shows that the 63% of respondents answered that the Itinerary

Planning service was rather **not reliable**. Most importantly, Figure 71 shows that all users thought that the service was not quick enough.

With reference to the information provided, one of the respondents pointed out that it would be useful to **have more than one drive options** and that the information should be more accurate. This is in contrast with what is reported in Figure 72, in which all users answered that the information provided was accurate.

During the tests, there were some issues with the functioning of the device. More specifically, one of the respondents noted that, after setting the start, end point and pressing "plan", there was a long waiting time and the points randomly jumped to other positions. There was also a message saying that the vehicles seemed offline. Overall, the respondents suggested to have a full in-vehicle integration of the service and to include the possibility to show alternative routes.

75% of the respondents were rather satisfied with the Itinerary Planning (Figure 74) and most of them agreed that the service was more useful compared to other existing services (Figure 73). All of them express their willingness to use the service (Figure 76) but half of them (50%) were not willing to pay for it (see Figure 77).

The Itinerary Planning providing real-time information about nearby charge points and taking into account need for charge was considered very **useful to reduce range anxiety**. Users also liked that the service was free and that it provided several services into a single one.

3.3.3 Plug and charge demonstration

Plug and Charge was demonstrated in the facilities of "Hubject Innovation Lab" located in the EUREF Campus in Berlin. The demonstration involved a charging station and a vehicle both configured to support ISO 15118.

Plug and Charge was highly appreciated by the users because it allows for seamless charging the vehicle based on an existent contract, invoiced once per month, and without any other external devices. The Plug and Charge was considered **easy to use**, **secure** and **user friendly**.

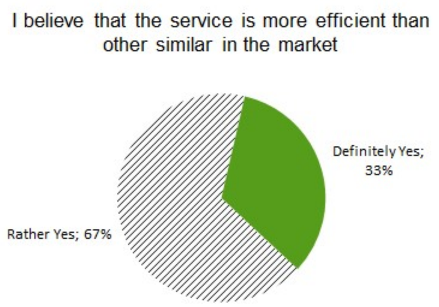


Figure 78: DE Plug and Charge - efficiency

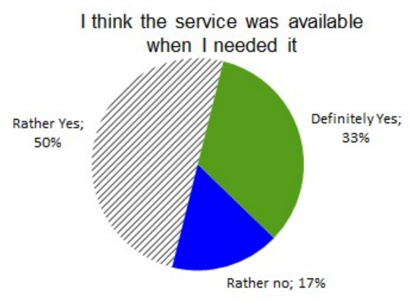


Figure 79: DE Plug and Charge - availability

Overall, all the questions received positive answers except for the limited availability of the service (Figure 79) that depends on the fact that there are a few charging stations and vehicles on the market enabling the Plug and Charge. Furthermore, one of the main weakness is the **lack of infrastructure** and the market players of the technology.

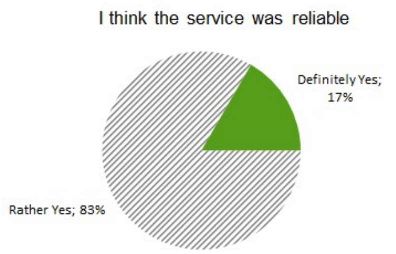


Figure 80: DE Plug and Charge - reliability

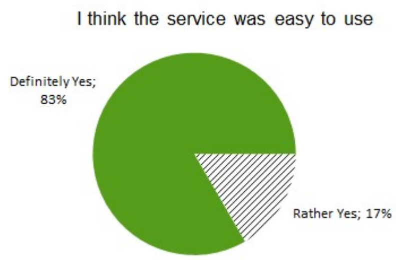


Figure 81: DE Plug and Charge - easiness

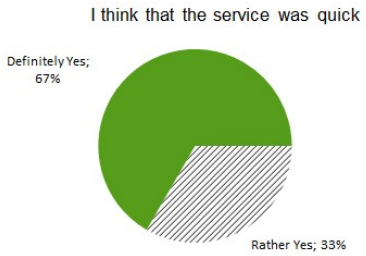


Figure 82: DE Plug and Charge - quickness

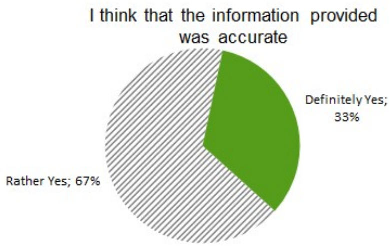


Figure 83: DE Plug and Charge - accurateness

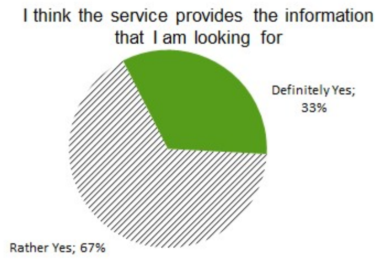


Figure 84: DE Plug and Charge - usefulness of the information

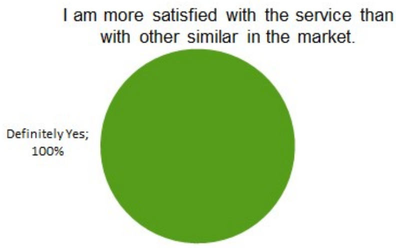


Figure 85: DE Plug and Charge - satisfaction

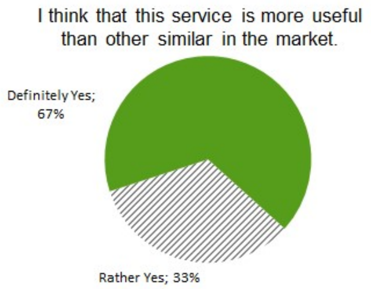


Figure 86: DE Plug and Charge - usefulness

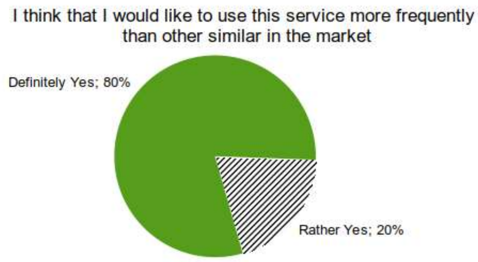


Figure 87: DE Plug and Charge - willingness to use

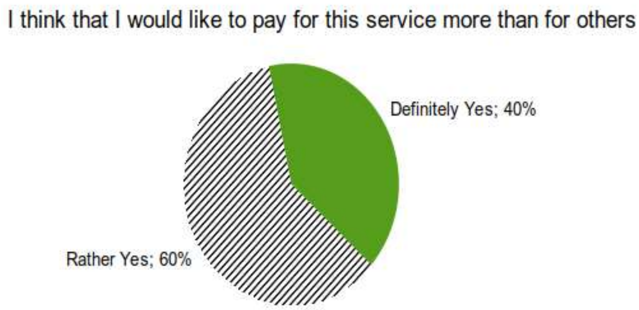


Figure 88: DE Plug and Charge - willingness to pay

Finally, it was suggested by the respondents to improve market knowledge about Plug and Charge with ISO 15118 and take into account this direction in the BAEM ecosystem.

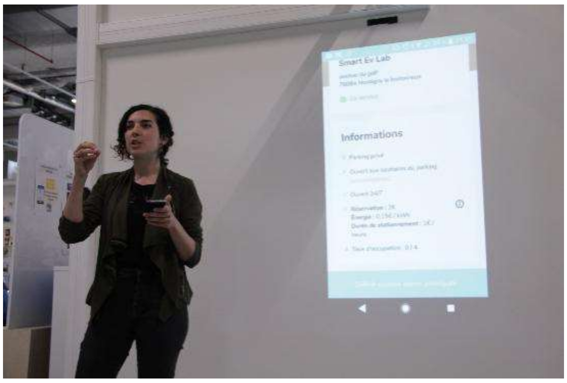
3.4 Validation activities in France

A demonstration event was held in the RENAULT Technocentre close to Paris on 23rd May 2019, at the "Smart EV lab" which is a homemade Renault laboratory, implemented for brainstorming, testing, validating, some technical bricks and services for the Electric Vehicle. Two services have been presented:

1. Charge point booking service (related to Itinerary Planning, Business Scenario 2 of D1.1)
2. E-mobility Report (Business Scenario 6 of D1.1)

It must be noted that the Itinerary Planning and the secure access to in-vehicle data were demonstrated in Turin on 5th April 2019.

After describing the project and the NeMo Hyper-Network, the Renault project leader of the *Charge Point Booking Service* presented the tool and the smartphone application developed by the web design company ADVENCY. A live demonstration has been done to show the functionalities of this service and the steps of the booking process.



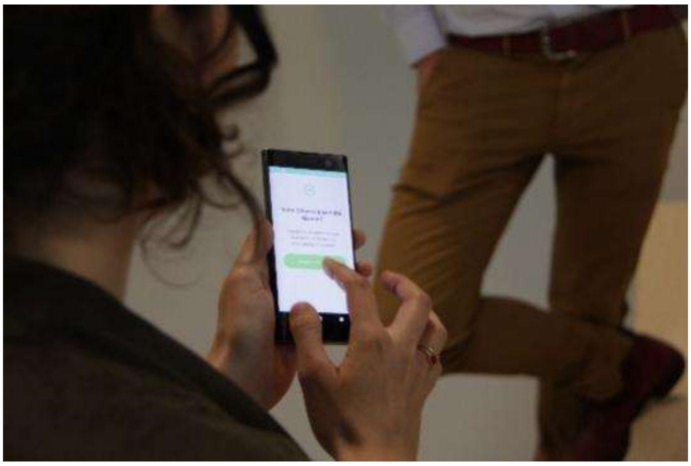



Figure 89: Demonstration of Charge Point Booking service

The service can be used by an eMSP to start a charge remotely on a charging point. The eMSP identifies itself (emspid), the charging point (eMI3 Id), the driver (eMAId) and its own charge session Id.

When the time slot is booked on the charge point, only the card of the person who booked it works during this time. For the demonstration two different cards were used to show that no one can charge when a time slot is already booked.

The E-mobility report and the different features of the tool were presented by GIREVE. This tool was presented live by using the dedicated website. The tool shows the number of status changes by charging point depending on the time slot, on the selected CPO and the area of interest. Different scenarios were demonstrated with success.

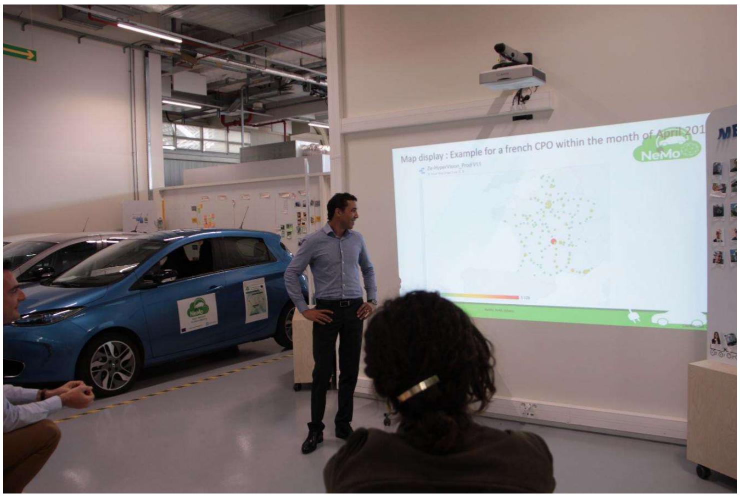


Figure 90: Demonstration of E-Mobility report service

The questionnaires have been sent to all the attendees to get their feedback on the added value of the services and to identify the strengths and weaknesses of the services and the possibility of improvement. 10 filled questionnaires were received for the Charge Point Booking and 3 for the E-mobility report, as the latter uses confidential and sensitive data so far.

3.4.1.1 Validation of Charge Point Booking

Regarding the Charge Point Booking, all the attendees were convinced about the added-value offered by the service but some of them have doubts regarding the will to pay for the service.

There is no identified competitor yet on the market, so this tool seems to meet the user's needs.

This tool is a real improvement for people who want to share a charging point within a small local community like a condominium, however, it will not prevent a car to stay in the parking place. The charging point is consequently not open for exceptional use by external users.

The people who tested the service were really satisfied with the user interface and they found it really easy to use even if some elements of the customer journey are still improvable.

A big advantage seen by the respondents is the complete integration within a standalone and independent application, not linked with any CPO or EMSP, that still has access to different types of data, and that manages the complete user experience from booking to payment.

Ideas of improvement have been identified:

- Include push notifications for alerting users about the charge point status like "charging point now available", "booked slot cancelled", "your charge is about to finish", "you have to move your car"
- Remove the RFID card and use other means of authentication
- Implement a chat among users of the application

The responses to the closed questions are shown below.

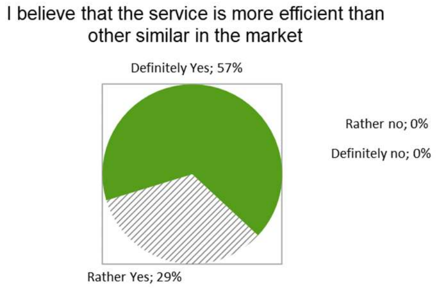


Figure 91: FR Charge point Booking - efficiency

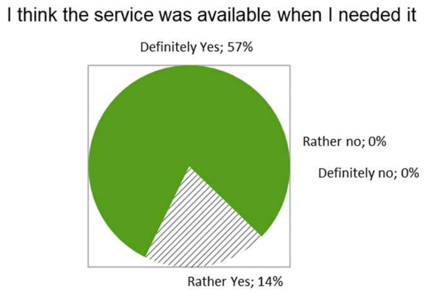


Figure 92: FR Charge point Booking - availability

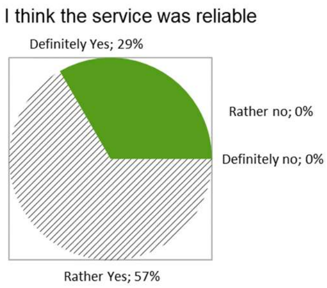


Figure 93: FR Charge point Booking - reliability

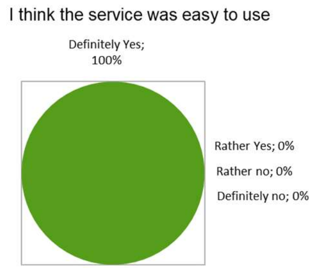


Figure 94: FR Charge point Booking -

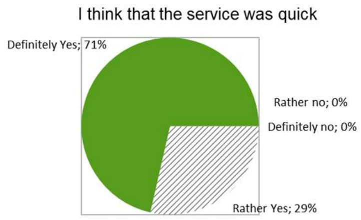


Figure 95: FR Charge point Booking - quickness

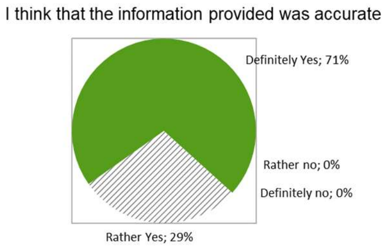


Figure 96: FR Charge point Booking - accurateness

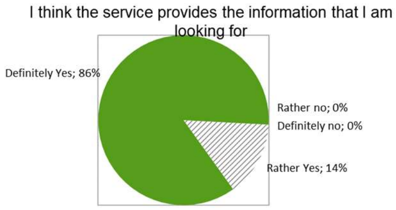


Figure 97: FR Charge point Booking – information usefulness

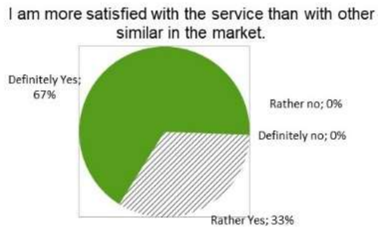


Figure 98: FR Charge point Booking - Satisfaction

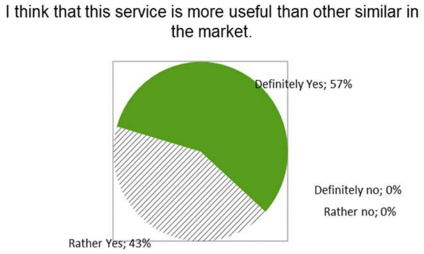


Figure 100: FR Charge point booking - Service usefulness

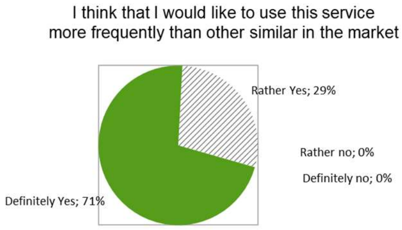


Figure 99: FR Charge Point Booking - willingness to use

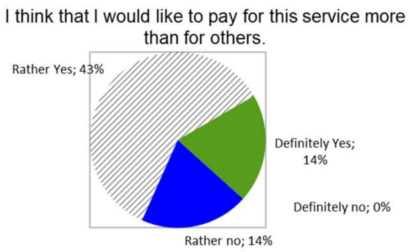


Figure 101: FR Charge Point Booking - willingness to pay

3.4.1.2 Validation of E-mobility Report

Regarding the E-mobility report, all the respondents were satisfied about the added-value of this service and the majority would even be ready to pay for it. But the need for providers is mandatory for progressing further with this service, and sharing the data contained in this tool. As possible improvement it was suggested to improve the graphics and the UX/UI. For avoiding confidentiality issues, a version with anonymized data would be good to get an overview of the network without getting the name of the concerned CPO.

The main added value of the service was that data come from all actors connected to the NeMo Hyper-Network. Furthermore, the possibility to request updates on the service to the provider regarding the specific needs was pointed out as one of the main strengths of the service. Furthermore, the users appreciated the diversity of filters to get the needed information and the adaptability, consistency and volume of data.

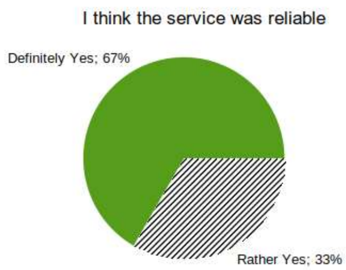


Figure 103: FR eMobility Report - reliability

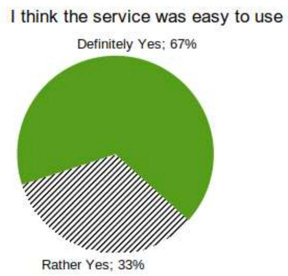


Figure 102: FR eMobility Report - easiness

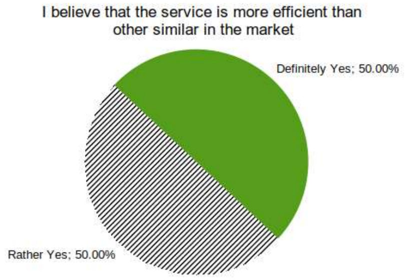


Figure 104: FR eMobility Report - efficiency

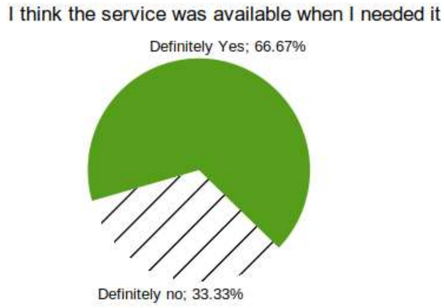


Figure 105: FR eMobility Report - availability

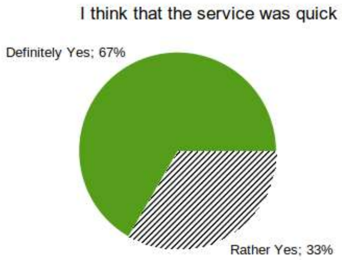


Figure 106: FR eMobility Report - quickness

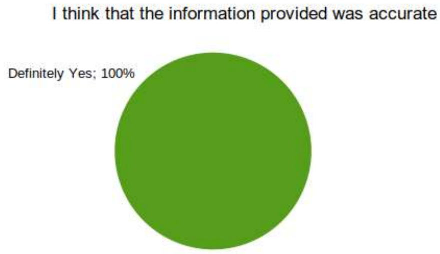


Figure 107: FR eMobility Report - accurateness

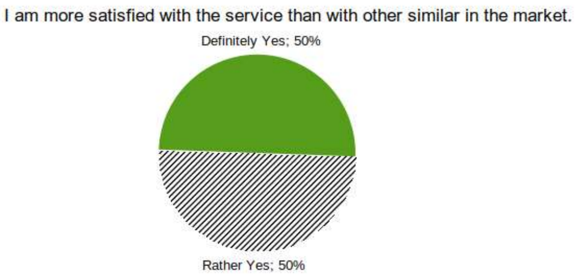


Figure 108: FR eMobility Report - satisfaction

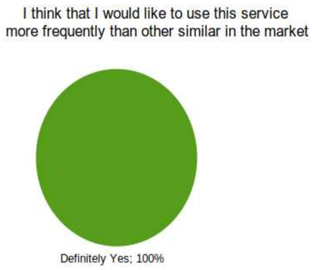


Figure 109: FR eMobility Report - willingness to use

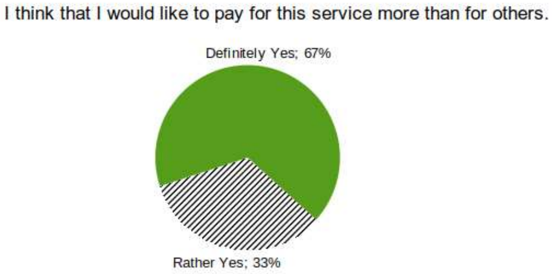


Figure 110: FR eMobility Report - willingness to pay

Concluding, the respondents pointed out that the support of the providers is needed, or actions towards supporting the framework for having more reports. Finally, a better UX/UI should be provided.

3.5 Validation activities in Spain

The Spanish test site evaluated the CP prediction and the Service Brokerage services, both related to the Business Scenario 5 (Horizontal/Actor profiling services) of Deliverable 1.1.

The Service Brokerage service aims to assist end users choosing the right charging station in terms of availability and price, while avoiding system congestion due to high demand of specific resources. This service is fed with the data generated from the EV driver monitoring & profiling and the CP monitoring & profiling. While the CP availability prediction service forecasts the charge point availability upon the CP monitor and profiler.

Apart from the experts' perceptions and opinions via the questionnaire survey planned in Deliverable 6.2, an analytical evaluation of the performance of the services was also conducted.

3.5.1 Experts' opinions

A group of key electromobility actors and big data professionals have been selected to give their vision and feedback of the CP prediction and the Service Brokerage services.

Given the fact that the services are B2B ones and their output is an API for use by experts, the respondents were selected to have technical profiles and expertise in electromobility services. Their profiles were:

- Data scientists
- Data Analysts
- Charging Point Operators
- Public Authorities
- Electromobility Service Providers

In total 7 participants have been recruited and the completion of questionnaires has been done in the form of one by one interviews, to minimize the influence of other users on the answers.

The average age of the participants was 37 years old. The youngest respondent was 25 years old and the oldest was 55, while 57% of respondents were female and 43% were male.

The participants were explained the main objectives of NeMo and the aim of the tests, and were presented with a general overview of the Spanish test site and of the services developed. Each participant completed two questionnaires, one for the CP prediction service and the second one for the Service Brokerage service.

3.5.1.1 CP Prediction

The participants had no experience with similar services, as there are no similar services in the market. The results of the validation questionnaires for the CP Prediction service are shown below.

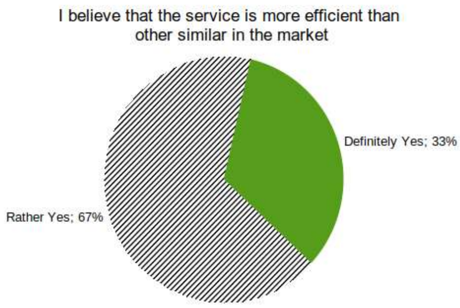


Figure 111: ES pilot - CP Prediction - service efficiency

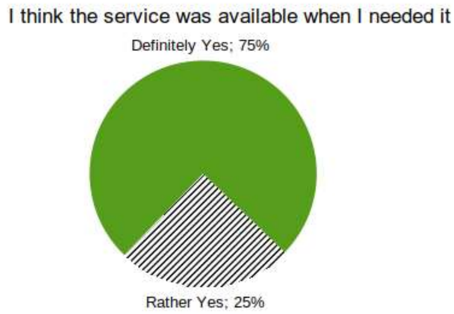


Figure 112: ES pilot - CP Prediction – service availability

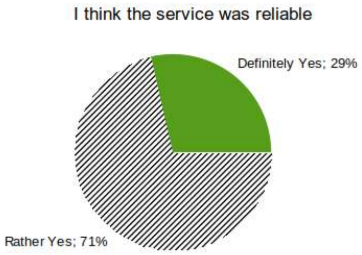


Figure 113: ES pilot - CP Prediction - service reliability

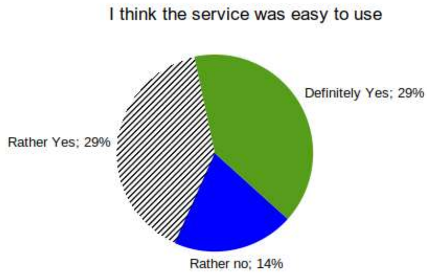


Figure 114: ES pilot - CP Prediction - easiness to use

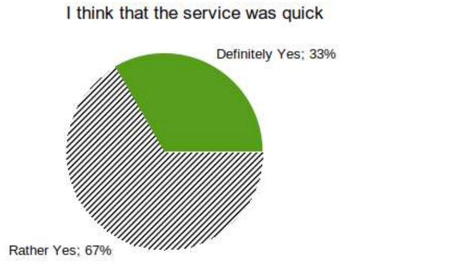


Figure 115: ES pilot - CP Prediction – service quickness

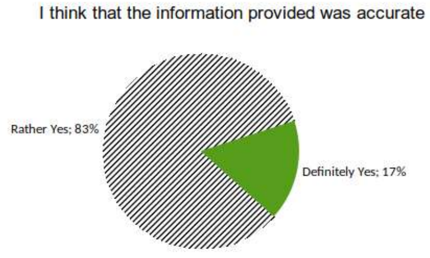


Figure 116: ES pilot - CP Prediction - information accurateness

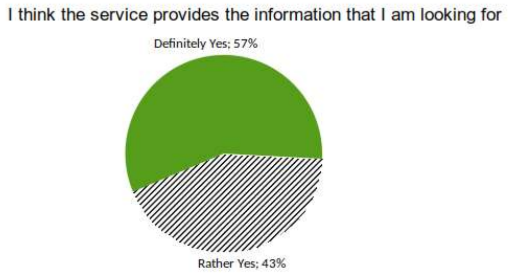


Figure 117: ES pilot - CP Prediction – information usefulness

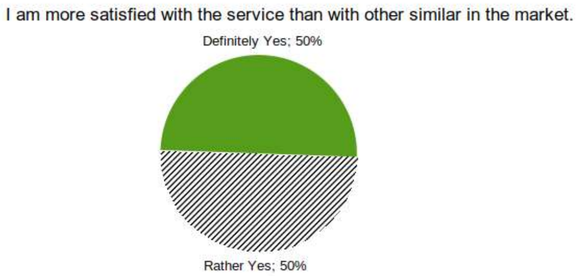


Figure 118: ES pilot - CP Prediction - satisfaction

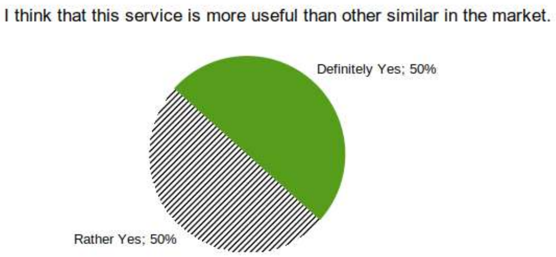


Figure 119: ES pilot - CP Prediction - service usefulness

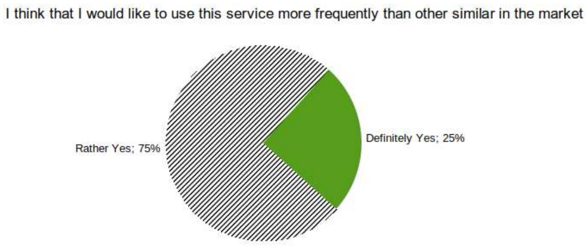


Figure 120: ES pilot - CP Prediction – intention to use

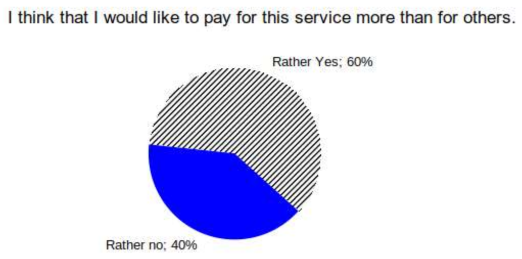


Figure 121: ES pilot - CP Prediction - willingness to pay

In general, the respondents agreed that the CP Prediction service gives really valuable information that can add intelligence to other services, and it can be very useful for users in cities like Barcelona to know in advance which CPs will most probably be occupied. Using this service, the EV drivers are offered better services to plan their routes and helps them reduce range anxiety.

On the other hand, the weaknesses of the service were the uncertainty of not knowing whether the CP will be occupied when the user arrives, also one respondent was not sure about the added value that such prediction gives to the user, the users already have the occupancy information in real time.

The respondents said that this service is adding value and should be included in existing electromobility apps, and could be also linked to other electromobility services, for example in booking a CP.

3.5.1.2 Service Brokerage

The brokerage service aims to assist end users choose the right charging station in terms of availability and price, while avoiding system congestions due to high demand of specific resources. This service is fed with the data generated from the EV driver and the CP monitoring & profiling services. The experts' responses for the Service Brokerage are the following.

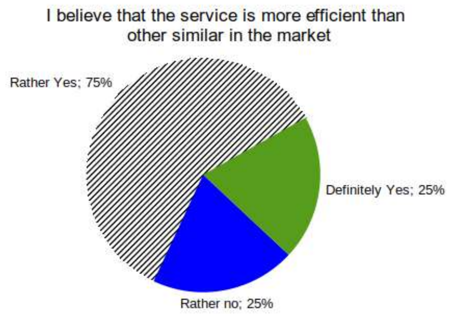


Figure 122: ES pilot - Brokerage - efficiency of the service

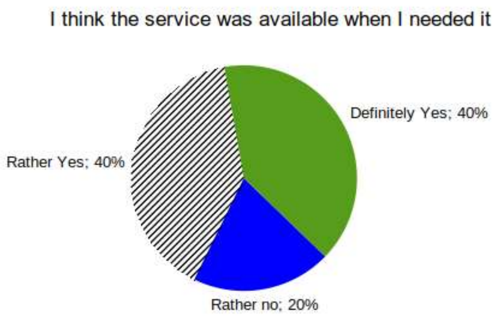


Figure 123: ES pilot - Brokerage - service availability

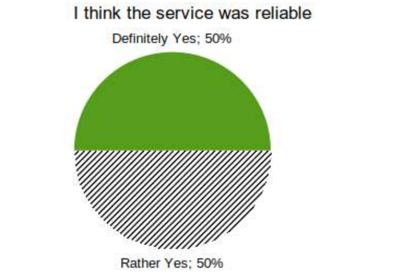


Figure 124: ES pilot - Brokerage - service reliability.

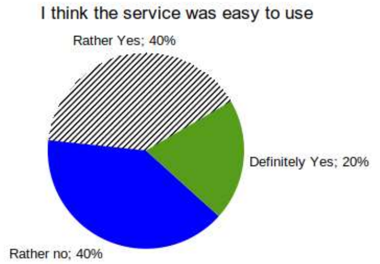


Figure 125: ES pilot - Brokerage - easiness to use

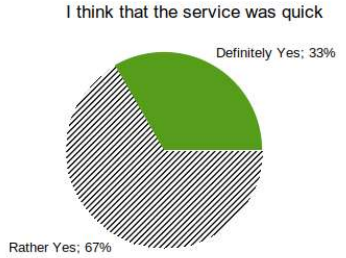


Figure 126: ES pilot - Brokerage - quickness

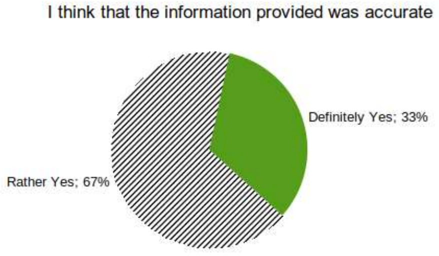


Figure 127: ES pilot - Brokerage - information accurateness

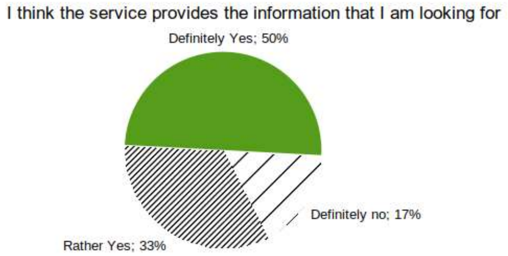


Figure 128: ES pilot - Brokerage - information usefulness

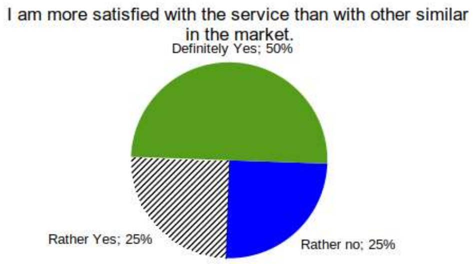


Figure 129: ES pilot - Brokerage - satisfaction

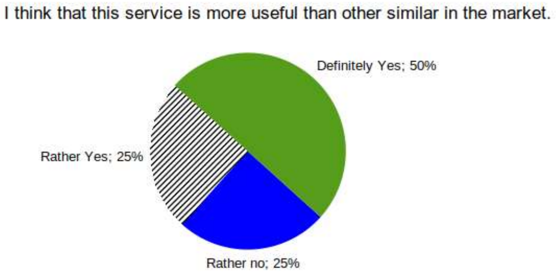


Figure 130: ES pilot - Brokerage - usefulness

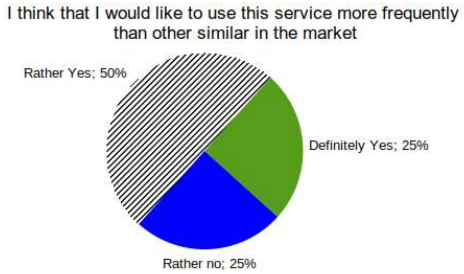


Figure 131: ES pilot - Brokerage - willingness to use

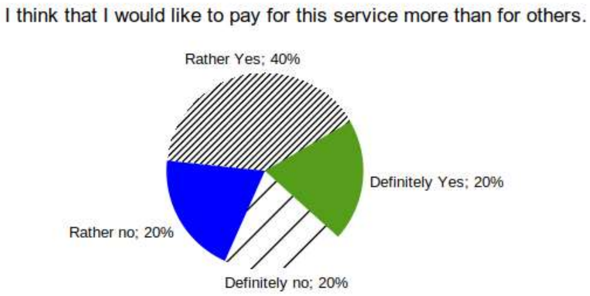


Figure 132: ES pilot - Brokerage - willingness to pay

Likewise, in the case of the Service Brokerage service, those surveyed thought that the service can be really useful for electromobility service providers (and ultimately for EV drivers), as it allows a better understanding of the electromobility paradigm and is ideal for the system as it may decrease the charging peaks.

In terms of weaknesses of the service, the respondents pointed out that every EV driver has its own routine which is hard to change, so the proposals that are near, in distance and time, to the CP that the user usually charges, should be the ones prioritised. Another interesting point raised by a respondent was that a service using this Brokerage must be developed thinking from the side of the user and without adding economic interests, as the private companies could pay so that their CPs are those most frequently suggested.

3.5.2 Evaluation of the Service Brokerage performance

A set of KPIs from Deliverable 6.2 were calculated to evaluate the performance of the Service Brokerage service.

The Service Brokerage service uses data generated from the EV driver monitor & profiling and the CP monitoring & profiling. The CP monitoring and profiling model contains short and long-range predictions which work in conjunction, therefore different timeframes have been evaluated, the next 20 minutes, the next 60 minutes and the next 48 hours. The period chosen for evaluation is the Monday 19th August 2019. Real data from all the public charging points of

Barcelona at three different moments of the day have been used, the first one in the morning, the second one at noon and the third one in the afternoon.

Table 7: Summary of the analysed timestamps

Prediction at	Timestamp	
19/08/2019 07:40	Next 20 minutes	19/08/2019 08:00
	Next 60 minutes	19/08/2019 08:40
	Next 48 hours	21/08/2019 07:40
19/08/2019 12:10	Next 20 minutes	19/08/2019 12:30
	Next 60 minutes	19/08/2019 13:10
	Next 48 hours	21/08/2019 12:10
19/08/2019 15:00	Next 20 minutes	19/08/2019 15:20
	Next 60 minutes	19/08/2019 16:00
	Next 48 hours	21/08/2019 15:00

One of the issues of the service brokerage is that it needs a high volume of users to give intelligent suggestions; thereby, a simulation of electromobility drivers has been executed, as defined in D6.2. Thus, the users of the service were simulated but the calls to the services developed in WP5 are real queries, so user profiles were created containing their visited places.

The testing process included the following steps:

1. A percentage of the users from the mobility life simulator were assigned as EV owners
2. The recurrent places and schedules from every EV driver were inferred using the EV driver monitoring & profiling:

The activities performed by the users from the mobility life simulator have been classified in six different groups.

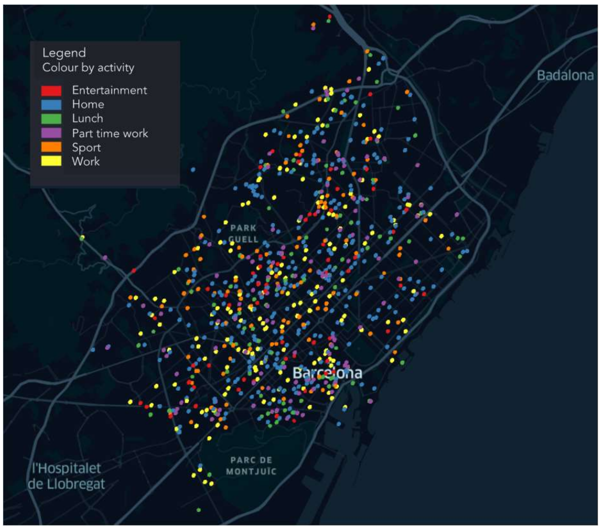


Figure 133: Recurrent activities from the simulated users

The classification of the groups was made according to the type of place and schedule of the activity to better understand the places the simulated users were visiting during the simulated period.

Figure 134: Recurrent Places for a specific user for one week

For example, the previous figure shows the recurrent places visited during a week for a specific user. This means that that there are five places that the model detected that the user attends with frequency and a similar schedule.

3. The simulated EV drivers made charging requests
4. The CP availability forecast was extracted from the CP monitoring & profiling
5. The system provided suggestions to the simulated EV drivers about the best charging spot and schedule

Figure 135: CP Suggestions for the 26/07/2019 for the previous user

A comparison between a scenario of the users charging without the Broker suggestions and with the Broker suggestions has been performed.

First, a comparison of the main metrics of occupancy has been performed. The standard deviation is lower in the scenario with the Broker, meaning that this scenario lowers the peaks and distributes the charging requests in means of moment of the day and location of the CPs.

Looking at the average occupancy of every CP, the maximum value in the scenario with Broker is found 1.53 and in the scenario without Broker the maximum value is 1.59.

In terms of the average occupancy per hour, the scenario without the Broker has a higher occupancy.

Table 8: Metrics of occupancy of the scenarios with and without broker

Scenario	Standard Deviation Occupancy	Max Occupancy per CP	Max Occupancy per hour
With broker	0.483	1.533	0.631
Without broker	0.654	1.587	1.125

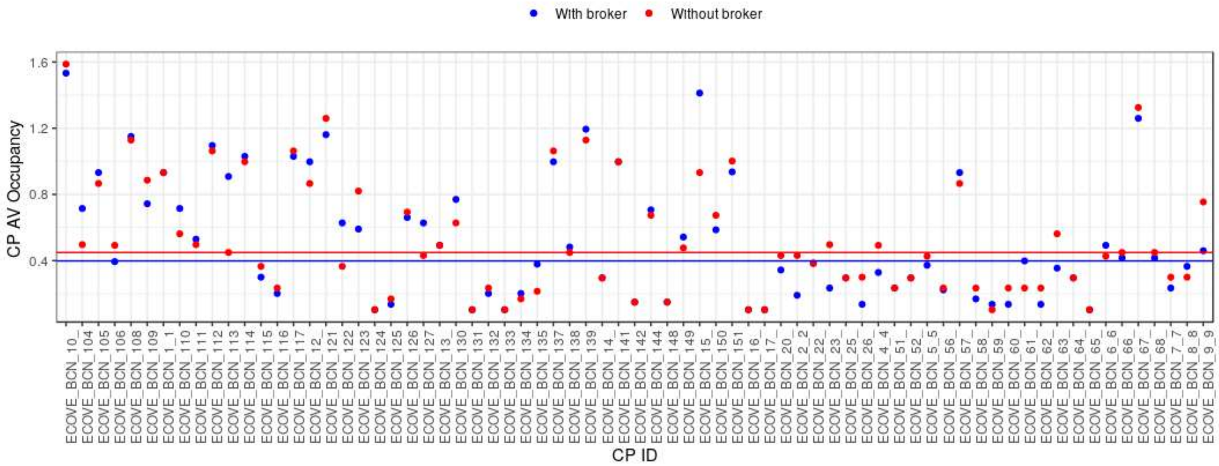


Figure 136: Scatterplot displaying the daily average occupancy for every CP and the median of the system

Continuing with the comparison analysis of the scenarios, the following picture shows the CPs with low occupancy (in yellow), the CPs with a medium occupancy (in green) and the CPs with a high occupancy (in red). It clearly shows that the scenario with the Broker has a higher number of CPs in green, meaning that the average occupancy is medium.

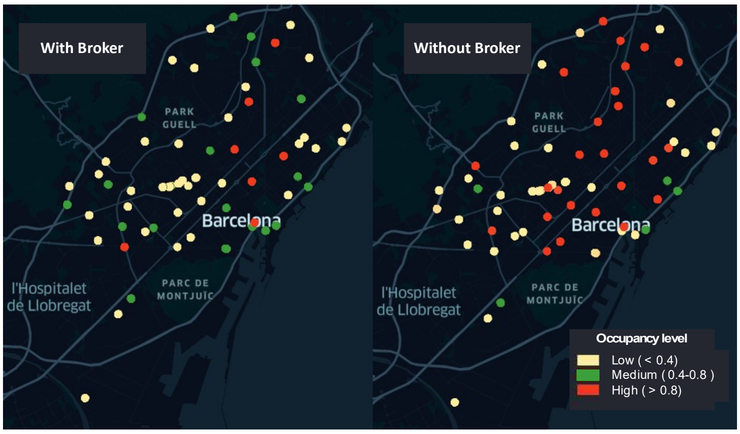


Figure 137: Occupancy level in both scenarios

Table 9: Occupancy level in the scenarios with Broker and without Broker

Scenario	Very Low (0 - 0.2)	Low (0.2 - 0.4)	Mid (0.4 - 0.6)	High (0.6 - 0.8)	Very High (0.8 - 1.0)	Over Occupancy	Peak (>2)
With broker	34.63%	18.17%	12.49%	8.29%	11.89%	14.25%	0.28%
Without broker	47.54%	16.32%	4.16%	3.35%	13.92%	10.97%	3.74%

Finally, the collisions among the users in the CPs have been analysed, meaning the number of users that can't charge their vehicles because the CP is occupied by another user.

This graph shows the average collisions for every CP, it can be noticed that in most of the charging points the collisions are higher in the scenario without Broker.

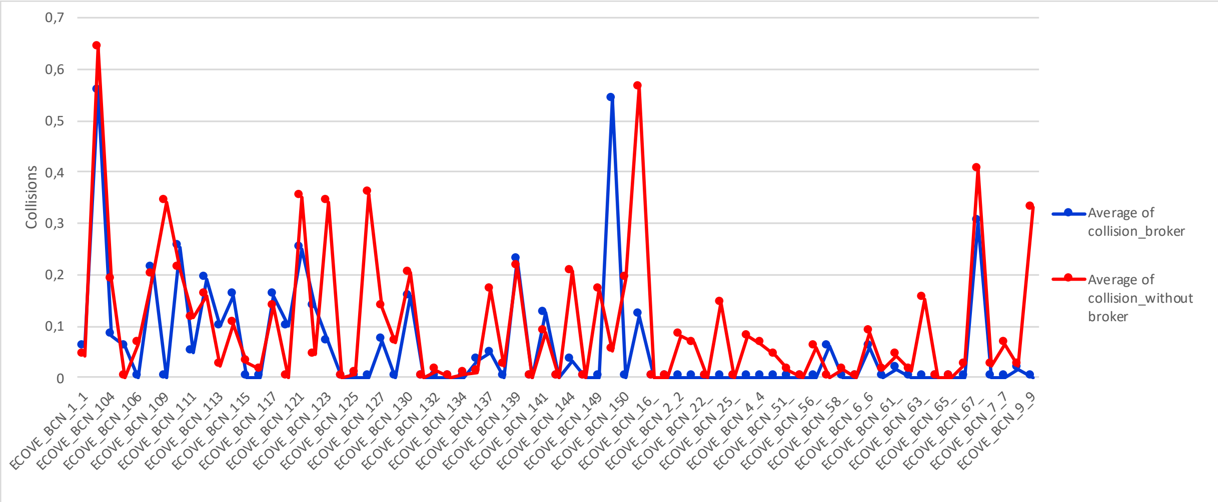


Figure 138: Comparison of average of collisions in the scenarios with and without Broker

In the following graph the maximum number of collisions that occurred in the simulated day is plotted. It can be observed that the scenario without Broker exceeds in multiple charging points a queue higher than three people, whereas in the scenario with Broker the maximum number of collisions is below three.

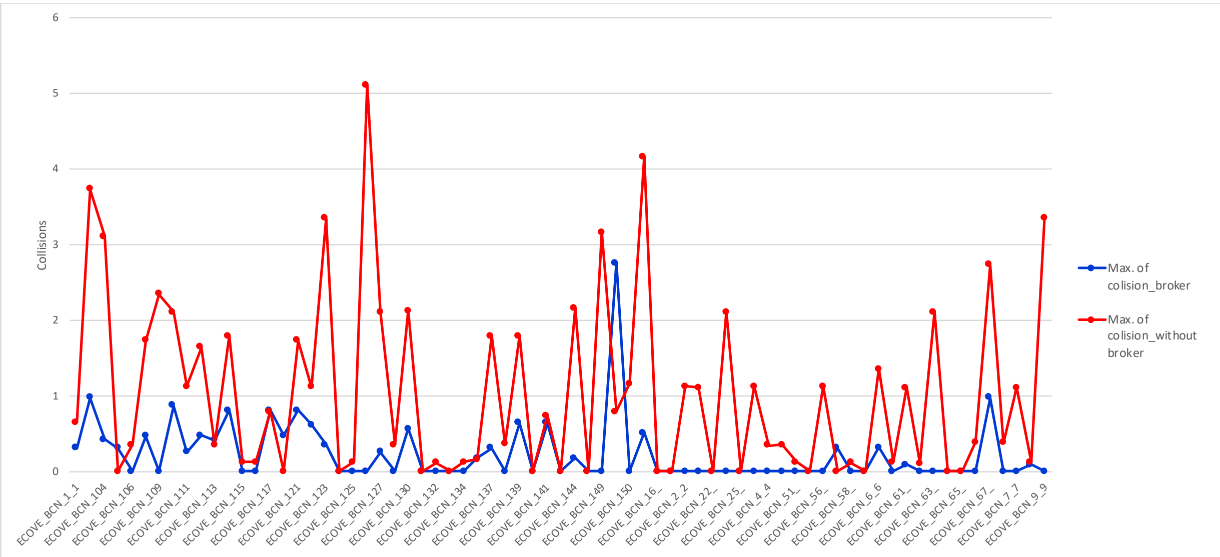


Figure 139: Comparison of maximum of collisions in the scenarios with and without Broker

Specific indicators described in D6.2 were used to further evaluate the technical performance of the CP prediction and the Service Brokerage services.

These indicators show that the difference between the real occupancy and the predicted occupancy is between 10% and 20%. On the other side, the indicators related to the Service Brokerage show that this service increases the number of users being able to charge, and it minimises the number of CPs over occupied and under occupied.

Table 10: CP prediction and Service Brokerage services specific measurements

Indicator	Calculation method	Result
CP prediction		
Previous 10 min prediction	$\lvert Realavailability - Predictedavailability \rvert$	0.15
Previous 60 min prediction	$\lvert Realavailability - Predictedavailability \rvert$	0.22
Previous 2 days prediction	$\lvert Realavailability - Predictedavailability \rvert$	0.11
Service brokerage		
CP usage rate	$\left(\frac{CPusage - CPusagewithbroker}{CPusage}\right) \cdot 100$	The Broker increased by **9.1%** the number of users being able to charge
Over-occupancy	$\left(\frac{occup. - occup.withbroker}{occup.}\right) \cdot 100$	Without Broker the number of CPs with high occupancy increases by **7.74%**
Under-occupancy	$\left(\frac{Underoccup. - Underoccup.withbroker}{Underoccup.}\right) \cdot 100$	Without Broker the number of CPs with low occupancy increases by **27.15%**

3.5.3 Study about booking service functionalities

In parallel, a study about the needed functionalities of a booking service was organised, to provide guidelines to make a booking service user-friendly and reliable. To achieve this, an analysis of the perceptions of electromobility stakeholders regarding a booking service has been performed.

A process of co-creation has been followed to match the operational perspective of service providers, charging point operators, parking operators and authorities with user preferences, needs and expectations.

First of all, the operational perspective of the services was analysed by organising a total of 15 one-to-one interviews. The profiles of the interviewees were:

- Charging Point Operators
- Electromobility service providers
- Governments
- Parking Operators
- EV drivers

For the analysis and interpretation of the qualitative data, the following topics were discussed with the interviewees:

- General opinion of the booking
- User experience
- Type of parking spot

- Type of charging point
- Type of reservation
- Operation time
- Payment
- Sanctions

Afterwards, to gather a wider opinion of users and catch their preferences, needs and expectations, a questionnaire was created for EV drivers. To present and understand the results from the interviews, the different categories and subcategories were analysed depending on the type of user.

The main barriers about a booking service were:

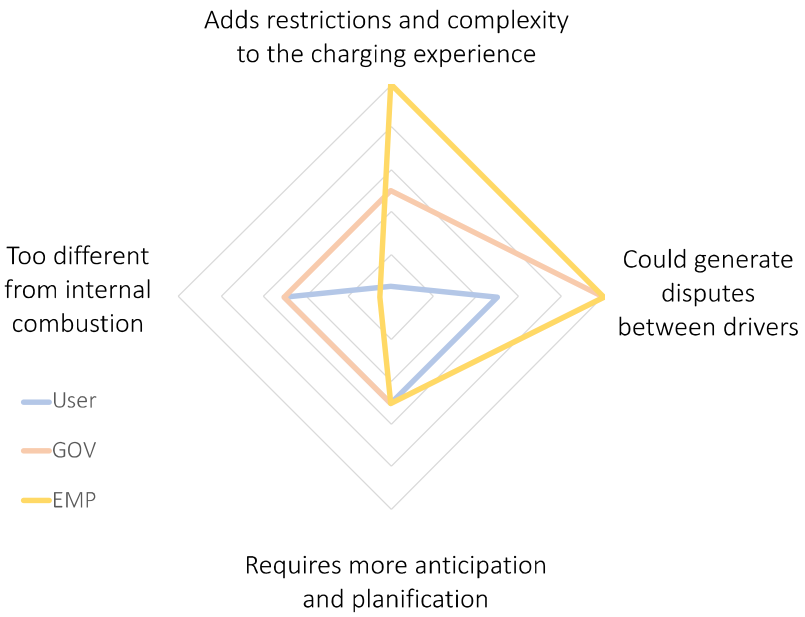


Figure 140: Main barriers for the booking service

Other comments from the interviewees regarding the general booking or the user experience were:

- The booking benefits the driver, knowing in advance that he/she will be able to charge the EV is really useful and minimises the waiting time.
- The booking works as a warranty that the driver will be able to charge, but in the interviewed person's opinion, it is always better to have more CPs than implementing the booking service.

The majority of the respondents agreed that fast charging points are suitable for short-term bookings and long travels planning. Slow charging points are suitable for long-term bookings.

The types of booking analysed were the following:

- *Short-term booking*: the user visualizes the free CPs and can book one to guarantee that it is still free at time of arrival
- *Long-term booking:* the user can book the CP for a time slot with more than 24h advance
- *Periodic booking:* the user can book a specific time slot with a certain periodicity

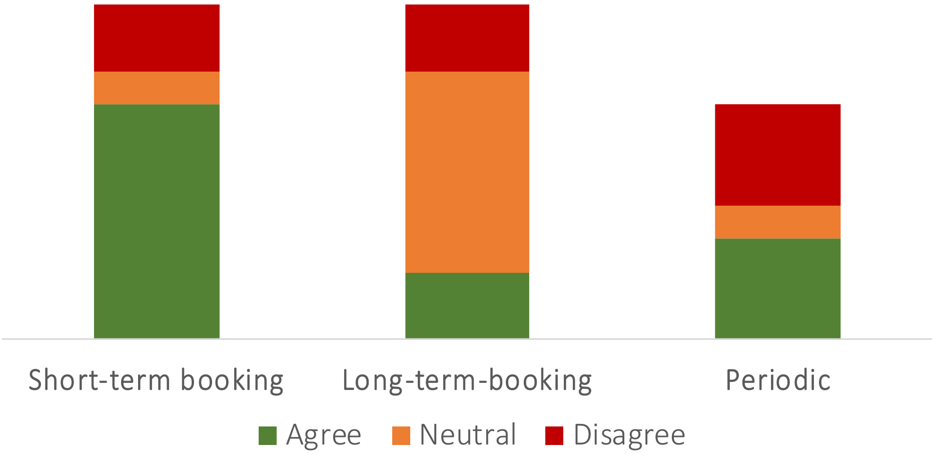


Figure 141: Preferences from the interviewees regarding the type of booking

65% of the mobility stakeholders interviewed agreed that the user should pay to reserve a CP. Two EV drivers pointed out that if a user books a CP, the charging tariff could be cheaper, to incentivise the service.

To the topic whether the user should pay a cancellation fee, the answers according to the interviewee's profiles were:

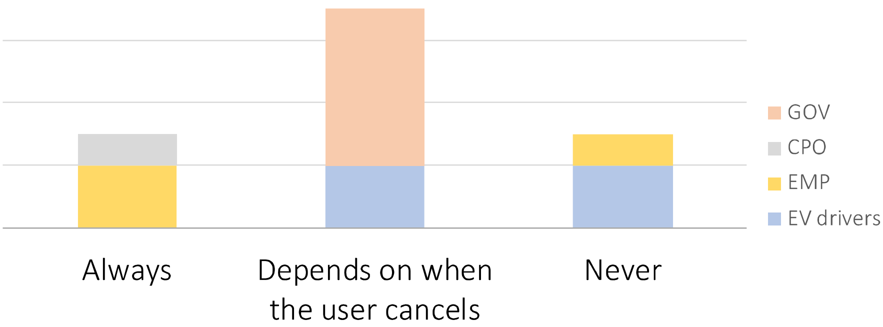
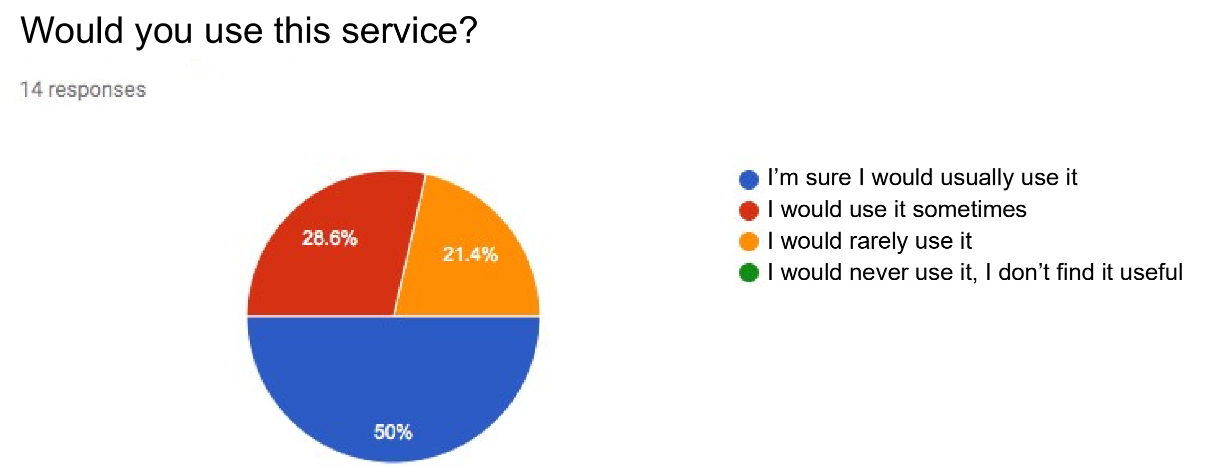


Figure 142: Answers to the cancellation fee topic according to the interviewees' profiles

Most of them agreed that if the cancellation is done with enough time in advance, the user should not be charged with a cancellation fee.

The following graphics show the results of the questionnaires answered by the 15 EV drivers:



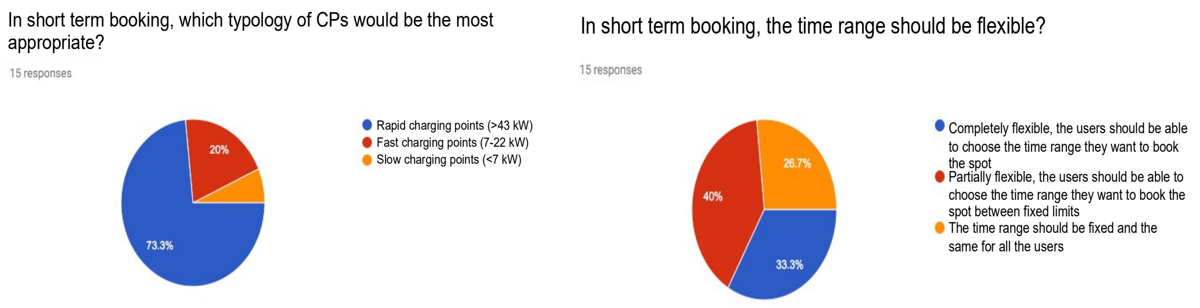
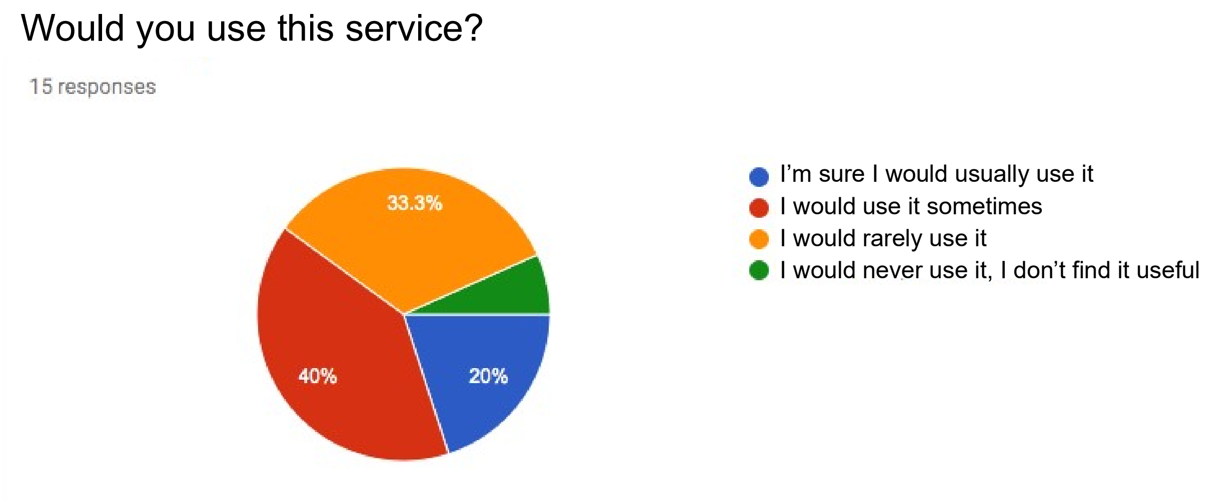


Figure 143: EV drivers' responses about short-term booking



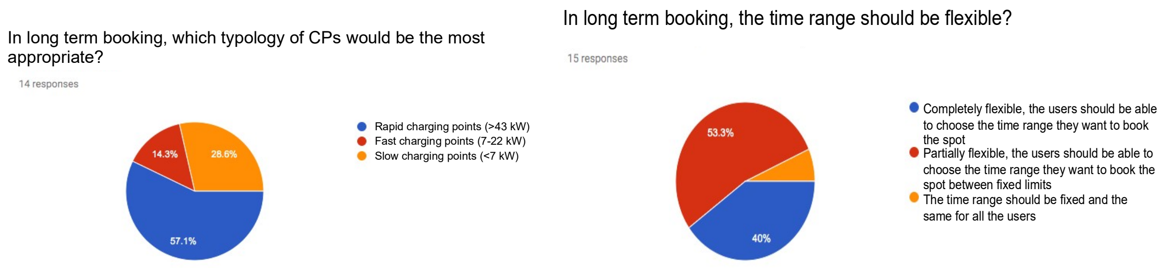
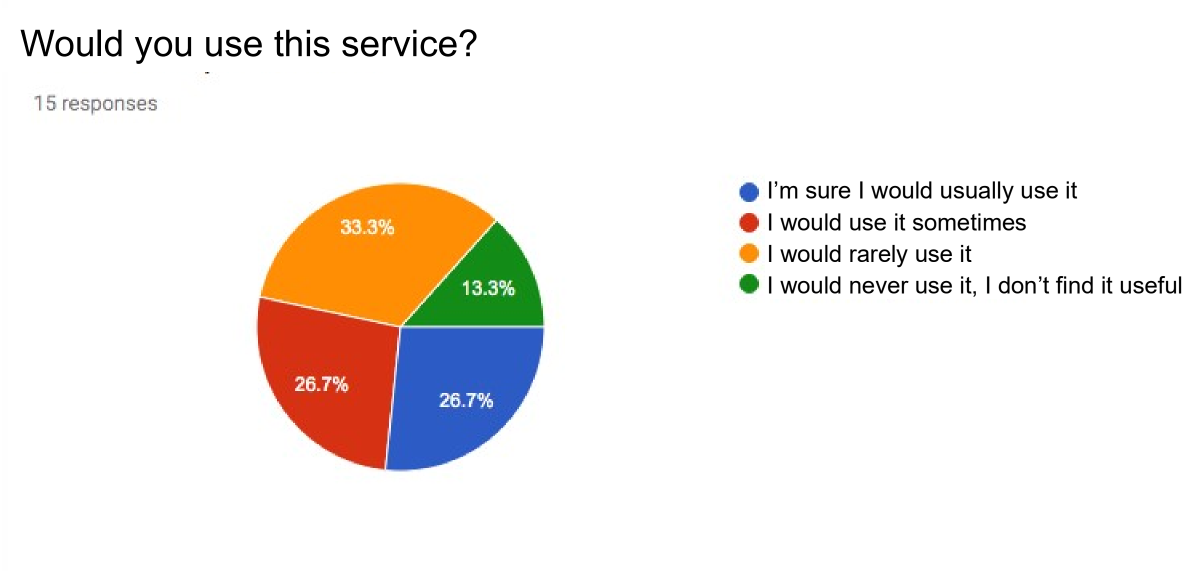


Figure 144: EV drivers' responses about long-term booking



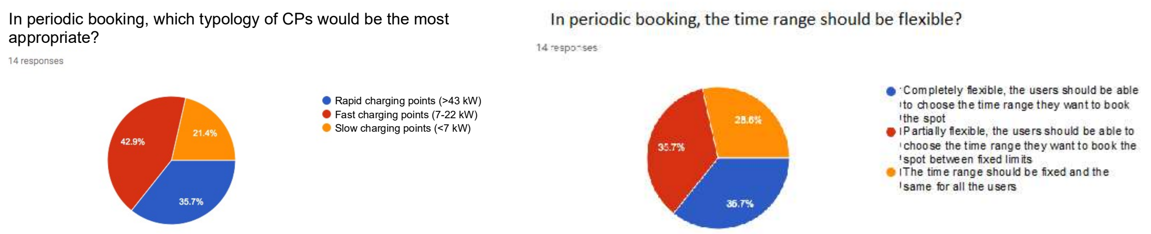


Figure 145: EV drivers' responses about periodic booking

4 Validation during cross-country driving

4.1 First NeMo cross-country drive

The first NeMo cross-country test drive was held from 2nd to 4th October 2017, with the objective of having a baseline of the EV driver's experience when trying to charge at charging stations in different countries. During this test drive two Renault ZOE electric cars were used, with two drivers each. The drivers were from NeMo partner organisations and three out of the four did not have prior experience in the use of EVs.

The two NeMo vehicles took different routes from Turin to Barcelona, covering a distance of over 950km. This was done because at higher speeds the car battery becomes depleted at a faster rate, so each car followed a different itinerary, swapping each day between an "eco-route" using national and regional roads and a "fast route" using motorways.

Each car needed to charge between 3 and 5 times per day on the route from Turin to Grenoble (Day 1), to Narbonne (on Day 2) and to Barcelona (on Day 3). Vehicles were only charged at public charging stations and not during overnight stops.

The four NeMo drivers were provided with a route plan and roaming charging cards, such as the Renault ZE Pass and ChargeMap applications. Some of the charging stations were linked to these networks, while others were not. In addition, different smartphone applications sometimes needed to be downloaded for authentication and payment for charging the vehicle.

After the end of their trip, the four NeMo drivers have highlighted the following key issues:

- Long distance trips with EVs need to be carefully planned to ensure the locations of charging stations are known, including availability of charging at overnight stops;
- Several charging stations that are not connected to a roaming network required an application to be downloaded for charging the vehicle. In these cases, drivers needed a smartphone with data or Wi-Fi and access to their online banking in order to be able to download the required application and charge the vehicle;
- Plenty of time is needed for a long-distance journey, with more planning needed compared to a petrol or diesel car, as regular stops of up to an hour were needed to charge, depending on the type of charging station and the driving speed;
- Booking of a charging station was impossible: in general, the NeMo drivers decided to stop at locations where there was a charging station available, even if charging was not necessary, as a precaution in case the next charging station was unavailable or impossible to use;
- Significant differences were noticed in authentication: apps, card, ID, etc., as well as the Human Machine Interface (HMI), design of charging stations and choice of plug types.
- Variation in pricing was identified: some charging sessions were free, some stations indicated the price immediately and, in some others, where a roaming card was used, the price was only communicated afterwards.

In most cases access was not a problem due to low usage level of the charging stations. But with increased use of electric vehicles, this is likely to change. To this end, long waits or diversions to alternative stations will be increasingly necessary, unless infrastructure keeps up with demand.

4.2 Final NeMo cross-country drive

From May 20th to June 29th 2019, a 5,000 km drive across nine European countries, going through the five project test sites in Barcelona, Paris, Berlin, Vienna and Turin, was organised, to demonstrate the possibility to "charge anywhere with only one contract" using the NeMo Hyper-Network and its developments. The objective was to simulate a real-life road trip by electric car and assess the impact of NeMo work towards achieving electromobility charging services interoperability.

The test drive was articulated into five segments, with a detailed itinerary crossing 9 countries and 5.000 km, as follows:

1. Barcelona to Paris
    a) Barcelona to Lyon
    b) Lyon to Paris
2. Paris to Eindhoven
3. Eindhoven to Berlin
4. Berlin to Vienna
5. Vienna to Barcelona

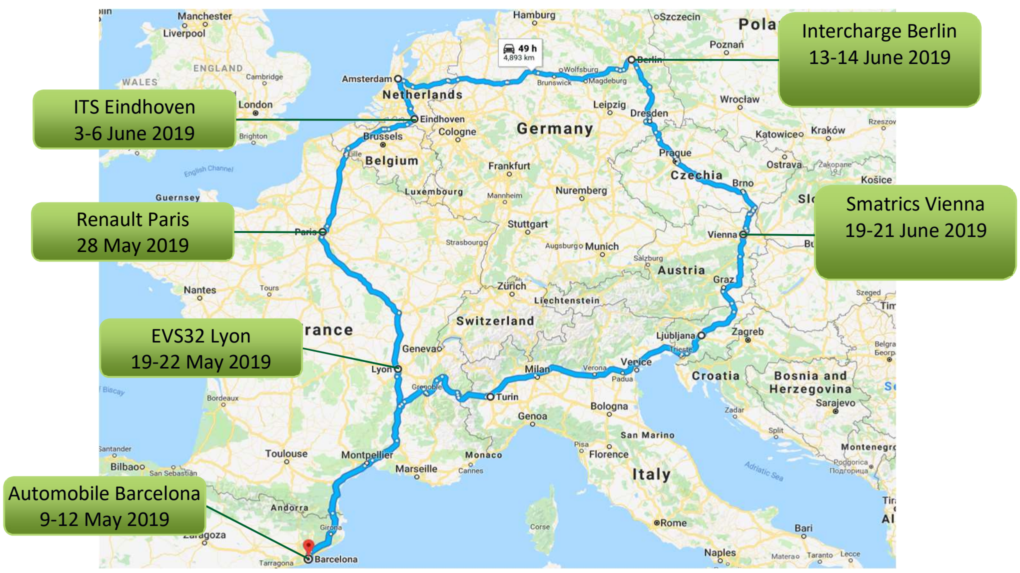


Figure 146: Final cross-country drive

The purpose was to interoperably use electromobility services while travelling through 9 different countries, in order to demonstrate the NeMo pan-European eRoaming capabilities and the interoperable use of services for accessing and charging at charging stations. The NeMo Hyper-Network offers a seamless charging experience for the EV Driver, as independently of the EMP contract the driver can charge at charging stations belonging to all connected CPOs and via the NeMo Inter-roaming protocol to all CPO partners of all connected eRoaming Platforms. The following services were used during the cross-country drive:

- Exchange of POI data
- Authorization
- Exchange of Charge Detail Records

The two eRoaming Platforms (Hubject and GIREVE) were inter-connected and connected to NeMo via the Inter-Roaming protocol. Seven Pan European Roaming Agreements were signed in order for the commercial EMSPs and CPOs participating under the platforms in the cross-country drive to enable roaming with providers of the other platform. These were:

1. EnBW (EMP/H) with SMEG (CPO/G)
2. EnBW (EMP/H) with SDE34 (CPO/G)
3. EnBW (EMP/H) with FR*CPO (CPO/G)
4. ZE-Watt (EMP/G) with Innogy (CPO/H)
5. ZE-Watt (EMP/G) with Allego (CPO/H)
6. Alizé (EMP/G) with Innogy (CPO/H)
7. Alizé (EMP/G) with Allego (CPO/H)

The 14 drivers that participated were equipped with 3 RFID cards, including a card from EnBW (an EMSP connected only with Hubject), a card from Ze-Watt (an EMSP connected only with Gireve) and a card from Alizé (an EMSP connected only with GIREVE) as agreed upon the 7 Pan European Agreements. The drivers were able to charge via the NeMo capabilities along the route in CPOs that were chosen to be only connected to different eRoaming platform than the one of the EMSP to whom the card belonged, for example enabling charging with a ZE-Watt card (GIREVE EMSP) in an Innogy CP (Hubject CPO), and therefore demonstrating the inter-connectivity offered via NeMo,.

Compared to the first drive, the difference was that some of the drivers were already familiar with the vehicle and with the type of CPs expected.

Overall, the general impressions of the drivers after the long-distance trip was that they were satisfied and less anxious when planning to charge at a CP that was possible thanks to the Hyper-Network, and the CPOs and eMSPs interconnection using the NeMo Inter-Roaming protocol.

The drivers' satisfaction was relevant with the provision of information about interconnected (via the NeMo Inter-Roaming protocol and agreements between service providers) charging stations (see Figure 147). 65% of responses show that drivers were satisfied with this possibility. The rest responses were related to charging stations that are not interconnected.

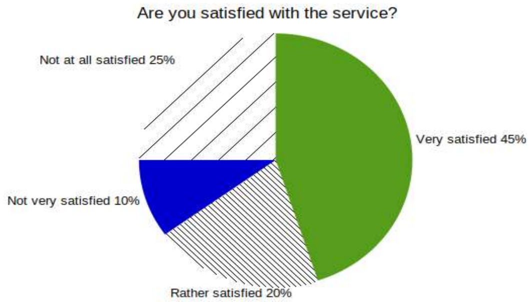


Figure 147: Final drive - Satisfaction with the information about interconnected charging stations

Drivers were much less anxious when planning to charge at a charging station that was interconnected via NeMo than when planning to charge at a charging station that was not interconnected, as shown below. It must be noted that drivers had information about charge points and whether they were interconnected or not.

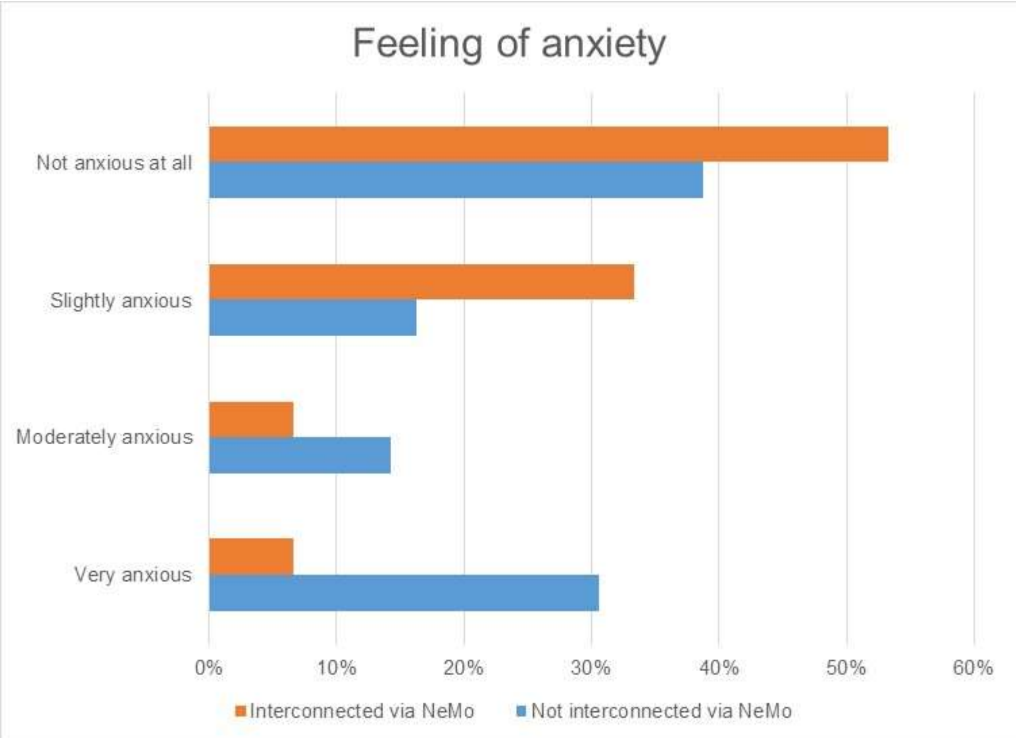


Figure 148: Range anxiety per CP interconnected to NeMo or not

Still, for the total drive, the feeling of anxiety pertains. The drivers' feeling of anxiety during the first and final drives are shown below. In the first test drive, 50% of answers were "Not anxious at all", while this is less in the final drive at 42%, the final test drive included a greater number of CPs in more regions. It must be therefore highlighted that not all the CPs used in the final drive were interconnected via NeMo and their number was much higher than in the first drive.

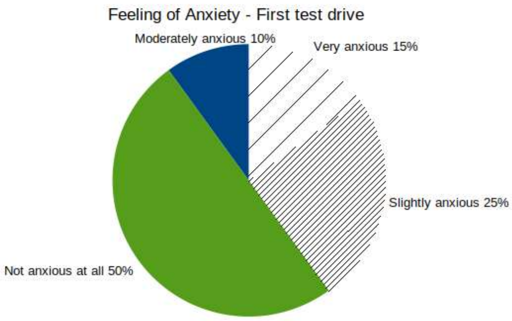


Figure 149: First drive – range anxiety

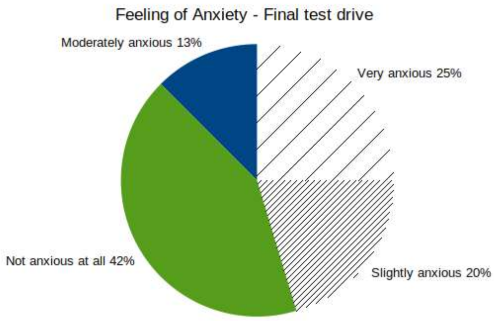


Figure 150: Final drive – range anxiety

Similarly, drivers found it more difficult to charge in the final drive (see Figure 152) compared to the first one (see Figure 151). This is again due to the higher number and diversity of charge points used in the final drive (65 CPs) compared to the first drive (22 CPs).

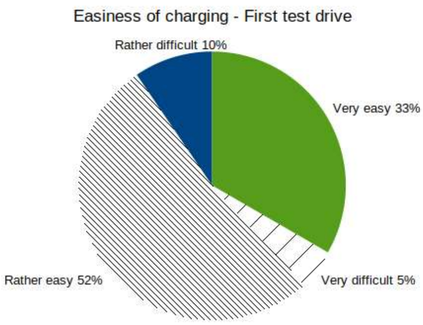


Figure 151: First test drive - Easiness of charging

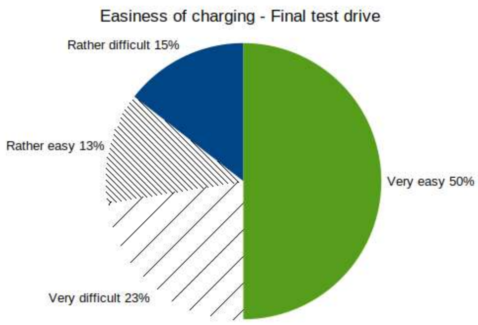


Figure 152: Final test drive - Easiness of charging

Finally, apart from authentication and payment services interoperability, other problems still existed, as described below:

- A lot of time is still needed for a long-distance trip with an electric vehicle. During the drive, the drivers always arrived one hour later than expected. Furthermore, the stop duration depended essentially on the possibility to find a working charging point on the road. In some cases, the stop had to last two hours.
- There is always a risk the charging station is not available. Therefore, it is prudent to avoid postponing charging until the last possible charging station.
- It is never possible to book a charging point. Time is easily lost because CP is not available or impossible to use. Essentially, it is necessary to get out of the highway to find a charge point. In some stations, there were also problems with language.
- Long distance trip still needs to be carefully planned to ensure that the location of CPs is known, especially at overnight stops. But it is also possible to plan the next charging

stop by driving and by using applications like the NeMo Itinerary Planner or others. Still, the availability or operational status of the charge point remains unknown.

- The use of many charging stations is not always intuitive, so for novices it can present difficulties. The location of charging stations is always different (i.e. one of them was located on a payment parking station, and another one was in the middle of nowhere so difficult to find). The charging process was also different for each charging point and this could be confusing and frustrating.
- Most stations had a combined or type 2 plug. For the Zoe all plugs were compatible. For a vehicle using ChaDeMo, there are some stations that cannot be used (mostly the ones located in towns); the ones on motorways tended to have multiple plug types. Same for the HMI, the CPs on highways or operated by big companies tended to have a good on-screen HMI available in different languages. Some of the small local stations in some towns had no HMI and only a rudimentary sticker with pictograms or instructions in the national language only. How to pay (what EMSP cards are accepted, if credit/debit cards are accepted) was not always obvious, especially on the small charging stations.
- Sometimes a price was given on a sticker (connection fee, then fee per minute or per kWh), but the final payment was not communicated unless the user would go online (card issuer website or app).
- Finally, for charging stations that are not interconnected, the number of payment methodologies are limited. Overall, a good quality smartphone was needed to charge the vehicle at those, while as a form of payment, PayPal was the most efficient.

The participants in the drive had to fill in a questionnaire to evaluate the charge point itself. One of the questions dealt with the easiness to find the charge point. The drivers knew the address of the CP, so the question was related to the easiness of finding the CP once the driver arrived at the indicated address. Figure 153 shows that the majority of the CPs were easy to find during the test drive, still some of them were not easy to find even though the drivers had reached the address.

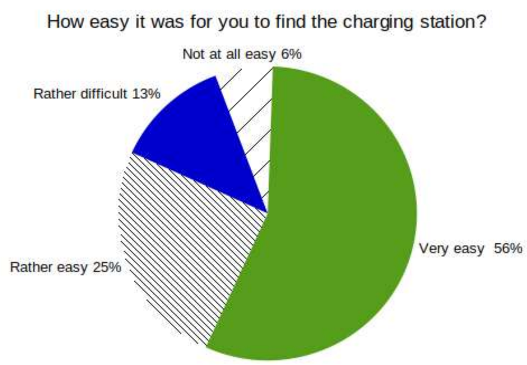


Figure 153: Final drive – easiness to find the CP after arriving at its location

5 NeMo impact assessment

This section presents an assessment of the expected NeMo impact using a set of measurable indicators that have been formed by the consortium per expected impact from the call text.

Impact 1: Improved attractiveness of EVs

The NeMo Hyper-Network will enable service providers to offer improved, added-value services to their customers, thus making driving and charging an EV an attractive experience. Since the Hyper-Network functionalities are addressing electromobility stakeholders and not EV drivers directly, this impact could be indirectly estimated during the project course, by collecting information on the **satisfaction** level of stakeholders about the different NeMo functionalities that have been validated in the test sites. Some direct measurements of drivers' **satisfaction** out of the charging experience were collected during the cross-country pilots.

The measure that can be considered as a proxy of the increased satisfaction thanks to NeMo is the answers to the following question: "I am more satisfied with the service than with other similar in the market". The responses "Definitely Yes" and "Rather yes" summed up to 64% of responses as regards the Itinerary Planning with dynamic access to vehicle data in Italy, 50% for the MicroGridInfo in Austria, 50% for the Inter-Roaming possibility in Austria and 75% in Germany, 67% for the Charge point booking in France, 50% for the E-mobility report in France, 50% for the CP prediction in Spain and 75% for the Service Brokerage in Spain. As regards the direct measure of EV drivers' satisfaction due to the information about interconnected charging stations, this was 65% during the final test drive of NeMo. Although the sample was limited due to the needed expertise of stakeholders and due to confidentiality issues, it seems that in most cases NeMo has managed to achieve an improved satisfaction compared to existing services.

Impact 2: Progress on ICT-based technologies for coordinated EV recharging

NeMo has created an ICT backbone for interoperable electromobility services creation and provision, data availability in common formats and secured data exchange when needed among the correct actors. Indeed, the Hyper-Network is operational and currently comprises of 8 Nodes and 4 Affiliated Partners, and 32 active registered services. Its functionalities can be effectively used to coordinate a balanced EV charging, considering the users' needs and the infrastructure requirements and availability. Services aiming to shape and balance demand have been demonstrated and show promising results towards achieving this impact. For example, the interviewees in the Italian test site appreciated the functionalities offered and showed that they found of added value the possibility to be redirected to the most suitable CP upon consideration of the vehicle and the conditions statuses. Charging using the NeMo Inter-roaming protocol, as tested in the cross-country drive, led to a 65% of driver satisfaction over the possibility to charge under a common ICT umbrella without sacrificing drivers' comfort thanks to the increase of interconnected charging stations (charges made upon the CPOs and EMSPs per roaming agreements). Furthermore, the "MicroGridInfo" service of NeMo provides real-time information to a CPO in order to optimise technically and financially the offered charge plans and services and it was demonstrated that it can result in **savings around 8% as regards the total CP energy costs**. The use of the NeMo Service Brokerage service can increase the **number of users being able to charge for a given set of CPs** while at the same time **minimising the number of CPs over occupied and under occupied**.

Impact 3: Contributions to standardisation strengthening the competitiveness of the European industry and Impact 6: Standardised BMS components and interfaces

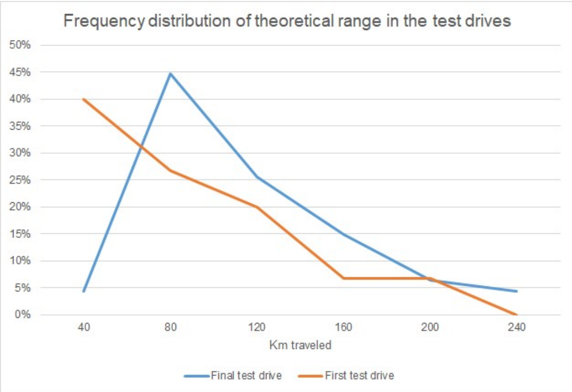
The **NeMo Common Information Models** (CIM), one of NeMo's main work towards harmonization of data and interfaces for the whole electromobility ecosystem, have been submitted for consideration to the eMobility ICT Interoperability Innovation association, eMI³, which is an open group of significant actors from the global EV market who joined forces to harmonize the ICT data definitions, formats, interfaces, and exchange mechanisms in order to enable a common language among all ICT platforms for EVs. The CIM remains an open and living protocol that is continuously extended and updated according to the electromobility actors' needs. The CIM specifically models the vehicle battery. Within the course of the project several models have been updated on occasion incorporating feedback once the actual services developed, or from external sources, like at the integration of Honda. This resulted in the publishing of the second version of CIM, which is already available on the NeMo website and openly accessible.

Also, the **interest of electromobility actors** to join the Hyper-Network work and discussions is an indicator of its contribution to standardisation. Apart from the two OEMs within the consortium (CRF and Renault), Honda has also expressed its great interest for NeMo's achievements by becoming a NeMo Associate Partner and having participated in NeMo's demonstrations on the sharing of EV data via the NeMo Trustee service. Two energy actors (Iren and Verbund), three EMSPs and five CPOs have participated in the project tests and discussions. Two eRoaming Platforms (Hubject and GIREVE) are connected to NeMo while the connection of a 3rd eRoaming Platform is in process and will be completed by the end of 2019. Also, there are currently 7 Pan European Roaming Agreements as follows:

8. EnBW (EMP/H) with SMEG (CPO/G)
9. EnBW (EMP/H) with SDE34 (CPO/G)
10. EnBW (EMP/H) with FR*CPO (CPO/G)
11. ZE-Watt (EMP/G) with Innogy (CPO/H)
12. ZE-Watt (EMP/G) with Allego (CPO/H)
13. Alizé (EMP/G) with Innogy (CPO/H)
14. Alizé (EMP/G) with Allego (CPO/H)

Impact 4: Improvements in the cost-performance ratio of EV contributing to quicker market take-up and Impact 5: Enhancements to vehicle range

This was indirectly estimated via the increase of the EV theoretical range due to the NeMo Hyper-Network services. This was indirectly estimated when comparing the **distance travelled between charging stations** in the first and final NeMo drives, as shown below.



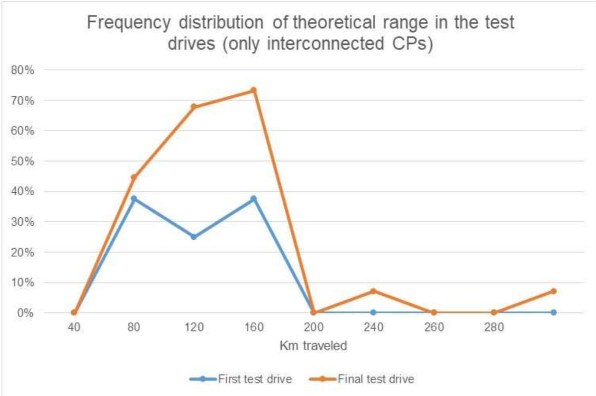


Figure 154: Frequency distribution of the distance travelled between CPs in the test drives (left: all CPs, right: only interconnected CPs)

Figure 154 shows the theoretical range in the First and Final drives. The left figure shows that the theoretical range has increased in the Final test drive compared to the First one. When considering only the interconnected CPs, the curve of the theoretical range calculated for the Final test drive is larger, especially after the 80 Km travelled. Although the number of observations available for the two test drives is different, it is observed that the Final test drive has demonstrated an increased theoretical range with a peak of Km travelled which is a proxy of the theoretical range, of about 160 Km for interconnected CPs instead of 80 Km when all CPs are considered.

6 Conclusions

This deliverable presented the results of the NeMo Hyper-Network validation activities in the test sites and during the cross-country test drives, as well as through a Hackathon.

The NeMo Hyper-Network was perceived by service developers as very useful to create added-value electromobility services and to collect existing services and data in a single environment, interoperable and accessible by all connected actors. In the future, the operators of the Hyper-Network should create instructions and guidelines to facilitate its learning and use.

Overall, the NeMo services validated in the test sites were positively evaluated by electromobility actors and several comments have been provided to further improve them.

The cross-country drive, on the other hand, has demonstrated that range anxiety is still an issue today for EV drivers and there is a clear need for provision of electromobility services targeting long distance travels. Indeed, drivers were much less anxious when planning to charge at a charging station that was interconnected via NeMo than a charging station that was not interconnected, and this is an indicator about NeMo's impact on drivers' experience as well as EVs market acceptance.

In conclusion, the results of the testing activities in NeMo are encouraging about its future. Electromobility actors and EV drivers were satisfied with the Hyper-Network functionalities and there is an interest by stakeholders to continue the work in this direction and establish an association that will manage and operate the Hyper-Network after the project end.

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