D9.7: REPLICATION POTENTIAL OF TECHNOLOGIES IN THE EU

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D9.7: Replication potential of technologies in the EU. Actions plans for the INCIT-EV cities & TEN-T corridors

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Technical References

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[1] PU = Public

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0 EXECUTIVE SUMMARY

This document is the deliverable "D9.7 – Replication potential of technologies in the EU. Actions plans for the INCIT-EV cities & TEN-T corridors" of the H2020 project INCIT-EV (project reference: 875683).

The main objective of this deliverable is to use feedback from the different use cases done during the INCIT-EV project, in order to assess the potential for replicating these experiments in other territories, or in real condition for the experiments conducted in laboratories. The result of this analysis will feed directly the DSS for further market replication.

The delivery of this deliverable is done in accordance to the description in the Grant Agreement Annex 1 Part A with no time deviation and no content deviation from the original planning.

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ACRONYM LIST

Table 1 Acronym List

Acronym	Definition
AC	Alternative Current
BM	Business Model
DC	Direct Current
DSO	Distribution System Operator
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
TSO	Transmission System Operator
WPT	Wireless Power Transfer

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1 INTRODUCTION

The rapid transition towards electric mobility is a critical component in the global strategy to mitigate climate change and reduce dependence on fossil fuels. Within this context, the development and deployment of efficient and scalable electric vehicle charging solutions have become crucial. INCIT-EV has pioneered several innovative charging solutions aimed at addressing key challenges in EV infrastructure, such as integration with renewable energy sources, grid stability, and user convenience. This study focuses on evaluating the replication potential of these experimental charging solutions across different urban and rural settings.

During INCIT-EV, various charging technologies has been tested, including static and dynamic wireless charging, Vehicle-to-Grid (V2G) chargers, and ultra-fast DC charging stations. Some of these experiments were conducted in real-world environments, such as the urban landscape of Paris or the public transport infrastructure of Torino, to gather comprehensive data on performance, user acceptance, and technical feasibility, and other in more controlled environments. The project's multidisciplinary approach, involving collaboration between research centers, local governments, and industry stakeholders, ensures that the findings are robust and widely applicable.

This study aims to assess the scalability and adaptability of these charging solutions in diverse geographical and socio-economic contexts. By analyzing the technical specifications, installation challenges, regulatory hurdles, and user behaviour observed during the project, we seek to identify best practices and potential barriers to widespread adoption. Those analyses may be key inputs for cities or regions looking to implement advanced EV charging infrastructure, contributing to a more sustainable and resilient transportation ecosystem.

1.1 Contribution from partner table

Table 1 - Contribution table

Partner	Task	Contribution
VEDECOM	9.5	Task leader, interviews and analyses, writing deliverable
CIRCE	9.5	Contribution to interviews
POLITO	9.5	Contribution to interviews
Eesti Energia	9.5	Contribution to interviews
TotalEnergies	9.5	Contribution to interviews
WeDriveSolar	9.5	Contribution to interviews

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1.2 Relation to other project activities table

Table 2 - Relation to other project activities table

Partner	Task	Relation to other project activities
All	2.5	Key points for charging infrastructure deployments
VEDECOM	7.3, 8.3	Feedback from use case development and deployment
CIRCE	7.4	Feedback from use case development and deployment
POLITO	8.2	Feedback from use case development and deployment
Eesti Energia	8.4	Feedback from use case development and deployment
TotalEnergies	7.2	Feedback from use case development and deployment
WeDriveSolar	7.2	Feedback from use case development and deployment

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2 CHARGING INFRASTRUCTURE DEPLOYMENT AND REPLICATION

2.1 Replicability of innovation

In the realm of project management, the term 'replicability' often conjures thoughts of Six Sigma methodologies or lean management techniques aimed at process optimization. However, in the case of transitioning from a prototype to a fully operational product—a process akin to industrialization—the scenario diverges significantly. This distinction is particularly pronounced in the development of charging infrastructure, a sector that intersects consumer products, urban planning, and civil engineering, presenting a unique and broad field of application.

The development of such infrastructure spans several phases:

1. **Planning**: This initial phase is where the foundational strategies and objectives are established.
2. **Design**: This phase can be further subdivided into:
   a. *Concept Design*: Early sketches and formulations of the project are developed.
   b. *Preliminary Design*: Initial design iterations are created, detailing more specific project features.
   c. *Detailed Design*: Final design specifications are produced, ready for implementation.
3. **Tender**: This stage involves the solicitation and selection of contractors to carry out the construction work.
4. **Construction**: The physical building of the infrastructure.
5. **Maintenance**: Ensuring the facility remains functional and safe post-construction.
6. **Operation**: The day-to-day management and utilization of the completed facility.

Moreover, the complexity of some charging infrastructure installations brings their implementation closer to that of a factory, which has to adapt to the environment in which it is built. Planning for constructed facilities bears several unique characteristics that must be considered from the outset:

- Each facility is custom-designed and constructed, typically requiring a significant time to complete.
- Both design and construction must adhere to site-specific conditions.
- Projects are influenced by various locational conditions such as weather, labor availability, and local building codes.
- Anticipating future requirements is challenging due to the long service life of facilities.
- Technological complexities and market demands may necessitate design changes during construction.

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A pivotal aspect of infrastructure development is also design innovation, necessitating robust communication between design and construction teams. New facilities may require advanced technology for operation in challenging environments, such as severe climates or areas with restricted accessibility. Large-scale projects with unprecedented demands also require comprehensive technological feasibility studies that should cover:

- Project Type: Defined by the technology it requires.
- Project Size: Measured in financial expenditure, design engineer's hours, and construction labor hours.
- Design Considerations: Including sourcing of any specialized technology that may require licensing agreements.
- Project Location: Challenges may include environmental protection, labor productivity, and specific risks.

Innovative design is not solely about balancing operating and capital costs; superior designs can enhance both simultaneously. Unfortunately, potential opportunities to reduce schedule times and costs are often overlooked because construction is treated as a process isolated from financial planning and design. A closer integration of these disciplines could lead to more efficient construction practices and better-designed facilities.

So the journey from an experimental prototype to a fully operational charging facility is intricate and demands meticulous planning and innovative thinking at every stage. By understanding the unique challenges of constructed facility planning and emphasizing the synergy between design, technology, and construction, stakeholders can significantly improve the efficacy and sustainability of infrastructure projects.

2.2 Charging infrastructure deployment: highlight from D2.5

In addition to those general method for replicability, D2.5, some key points have been identified for charging infrastructure deployment. Here is a reminder of those key points, that will be used as an input to conduct our analysis:

A. **Logistics for the distribution of electric chargers within cities and in the periphery. What type of charger** to install, where to install them, and how many to install? Some recurring questions are:
   1. Overnight charging infrastructure. Nighttime public charger availability and usage conflicts
   2. Fast charging for daily operation
   3. Opportunity charging within cities. Insufficient interurban public charging infrastructure
   4. Increase accessibility and availability in the number of charging stations.
   5. Street Parking Solutions for EV Users without garages
   6. Insufficient private and /or public infrastructure. Charger Proximity
   7. Lack of Pre-Installation in Flat Building Garages
   8. Complexity of domestic charger infrastructure

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B. Technical constraints of the e-chargers. Some recurring questions are:

9. Compatibility and interoperability of charging stations specially AC
10. Accelerated charging stations commissioning (provisioning the appropriate power supply)
11. Vehicles with limited charging capacity (less than 50 kW)
12. Limited battery lifespan and interoperability
13. Obsolete Chargers Unfit for Reuse
14. Development of Payment Systems Integration
15. Raw materials for electromobility scarcity

C. What is the best way to incentivize the installation of electric chargers? Some recurrent problems are:

16. Volatility in subsidy programs
17. Need to incentive grid infrastructure update.
18. Insufficient Public Support for Charging Infrastructure Development

D. How can we reinforce the electrical grid to undertake the transition to electric vehicles? Some recurring aspects to address are:

19. Disparity on authorization bureaucracy according to voltage level.
20. Charging Speed Challenges
21. Uncertainty in Optimal Mix of Charging Technologies
22. Medium-Voltage Line Availability and Profitability
23. Smart and bidirectional charging (V2G)

E. **The business models are another very important aspect. Electric chargers are often public-private** partnership models where the investor is awarded the service for a number of years and, in return, pays for the investment, the consumed grid energy, and compensates the contractor per kWh. In exchange, they receive the benefit of the charging process. Whether the service is public, private, or mixed, a minimum number of charging events per year must occur, otherwise the investment will not be recouped. There is a significant number of opportunity chargers in public areas that operate at a deficit. Some common problems associated with this subsection are**:**

24. Preference of investors for low power charging by costs
25. Atomization and dependency on Asian producers
26. Dynamic charging costly and inefficient
27. Guarantee technical feasibility and economic viability with a robust demand forecasting and strategic planning.
28. Population density affect profitability of charging stations.
29. Municipal Resistance to Electric Vehicles and Street Parking
30. Inadequate Offerings and Standards for Inductive Static Charging
31. Range Considerations for long Travel Charging
32. Pre trip recharge planning due to infrastructure scarcity.

F. Some citizens and public administrations are not in favor of the electric transition, they are not aware, or they are not trained in new technologies. Specific concerns are:

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33. Misinformation on the available charging infrastructure
34. Change combustion-centric mentality (not need to full charge)
35. Bureaucratic Hurdles in Charging Infrastructure Deployment

G. Finally, there is a problem of standardization and interoperability of different developed systems and their use in different geographies, especially on roaming.

36. Standardizing European Interoperability for Charging Infrastructure
37. Resolve connectivity problems in underground charging stations. Regulatory Gaps
38. Roaming charging solutions minimizing downtime

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3 REPLICATION POTENTIAL OF USE CASES: PROPOSED METHODOLOGICAL PROTOCOL

3.1 Goal

This method will be carried out in two phases.

The aim of the first phase is to gather as much information as possible through interviews with the people who carried out the various use cases. The data gathered will then enable us to develop an analytical framework for replicating these use cases in other situations, based on the characteristics identified.

Then, in a second phase, another wave of interviews will be carried out with candidate sites, to project the different UCs and gather the opinions of the sites' experts.

3.2 Method choice

To obtain as much information as possible about the experiments carried out and to analyse their potential for replication, we will conduct individual semi-directive interviews with the experts involved in the various case studies.

This will make it possible to list everything that has worked, as well as any blocking points encountered, and in that case any solutions to be planned, to identify the replication potential on other territories. The advantage of this method is that it allows to follow the experts' logical path, differentiating the points that come spontaneously to their mind and which are therefore of particular importance, while maintaining a structured framework that ensure to not stray from the initial topic.

3.3 Method's description

3.3.1 First round of interviews: Feedback interviews

3.3.1.1 Participants

The participants in this first round of interviews are all the people in charge of the various use cases, as experts on the subject. A second round of interviews was considered with other people who had worked on these use cases in case of missing information, but it was not necessary. This analysis does not include the feedback of the UC 1.c, as the person in charge did not answer to the interview demands.

3.3.1.2 General methodology for feedback interviews

Feedback is the enrichment of knowledge for an individual or a learning organization. It aims to capitalize on the lessons to be learned from past or current successes or failures, so as to reduce the vulnerability and/or increase the resilience capacities of a human entity, organization, ecosystem or natural habitats. Feedback

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mainly concerns incidents, near misses, accidents, major accidents and crises, or, where applicable, crisis simulations, crisis exercises, etc. It is based on a formal analysis of experiences that have been undergone or voluntarily organized. It puts in place "an organized and systematic approach to gathering and exploiting the signals given by a system", so that the entity practicing it can benefit from present or past errors, innovations or progress (technical, methodological, organizational...), "to better control the future", risks and crises. Experiences can be positive, neutral or negative. Depending on the case, "feedback" may be provided by the entity itself (company staff, for example), or by external customers or service users.

Semi-directive interview is a widely-used type of interview, as it represents an intermediary between directive interviewing (defined structure and strict order and wording of questions) and non-directive or free interviewing (absence of structure or pre-defined questions). Semi-directive interviews have a structure and questions which, unlike directive interviews, can be adapted according to the responses obtained. This method will thus enable us to meet the objectives of this first phase by giving respondents sufficient freedom, while maintaining a framework so as not to run the risk of deviating into irrelevant questions, and to cover all the points to be raised. The adaptability offered by semi-structured interviews makes it easier to understand the respondents' ideas, and individualized follow-up allows us to explore each logic in the most appropriate way.

Individual interview is the most adapted type for this kind of feedback. Firstly, the various use cases have little or no relationship with each other. Even if this could be interesting in other contexts, notably to assess synergies in case of cohabitation between different use cases on a territory, it is therefore not necessary to cross the views of different stakeholders on these subjects to evaluate the replicability potential. Second, involving only one expert at a time allows for more spontaneity, and to gather the thought processes specific to each experiment, with key points emerging naturally. It allows to gather this information and understand the perceptions and thought processes specific to each experiment without being influenced or disturbed in the discourse by other people. Those kinds of interviews allow us to delve more deeply into certain critical points more spontaneously than a written report, although they can also be more subject to time bias: the most recent elements are the easiest to trace, but it may be done with less retrospect.

3.3.1.3 Interview procedure.

Each interview is scheduled to last 1h30. In practice, most interviews lasted 1h.

The interview structure is as follows:

- Introduction
- Presentation of the expert (free speech)
- Presentation of the use case (free speech, followed by questions to obtain details on the experiment and technical, environmental, economic points, etc.).
- Feedback (free speech, followed by questions on critical points of the project, test procedures, user feedback, project expectations vs. results obtained...)
- Replicability (possibility and easiness of replicability, conditions for replicability, possible operating models, points to be checked, points to be resolved or blocking points without a solution for replicability...)
- Conclusion and possible additional points added by the expert.

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The expert was left to speak as freely as possible, with only stimulus and requests for clarification when certain points were missing.

3.3.1.4 Analysis & replication potential

We will provide a comprehensive evaluation and formulate recommendations regarding the replication potential of various charging technologies based on a detailed analysis of the interviews with key stakeholders and a review of relevant literature. By synthesizing insights from these interviews and contextualizing them within the broader body of academic and industry research, we aim to identify best practices, potential challenges, and strategic opportunities for scaling up these innovative solutions in diverse settings. This approach ensures that our recommendations are both grounded in practical experience and informed in a wider approach by academic works in the field.

3.3.2 Second round of interviews: Replication interviews

Then a second round of interviews was initially planned with the two replication sites of Bursa and Nordeney, in order to project the different use cases on those sites. Feedback from experts of these replication sites would have helped to consolidate the replication potential analysis based on the points raised by the ones of the experimentation sites. For reasons of timing, this second round of interviews could not be held.

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4 REPLICATION ANALYSIS AND RESULTED ACTION PLANS

4.1.1 UC1a

Demo site: Utrecht, Netherlands.

This experiment focuses on smart charging in the Netherlands, specifically in the city of Utrecht. In this area, there are few private parking spaces, and electric vehicle owners must rely on public charging infrastructure. Additionally, the country's electrical grid is highly congested. The aim of this use case is to leverage the natural flexibility of on-street residential charging to relieve the grid when necessary.

To sell this service, the service provider must enter the congestion market, which requires a minimum system size: between 100 and 200 chargers are needed. It is noted, however, that the algorithm optimizing the flexibility of the chargers becomes less efficient when the number of stations becomes too large.

This market is relatively less profitable compared to other flexibility services, yet it remains essential. A reform of this market might be necessary if the service is to develop. It could also rely on other flexibility services to complement them.

There are no specific data requirements. Coordination on multiple levels is necessary, involving charging station operators, their owners, grid managers, and sometimes public authorities. In cases involving multiple grid managers, a coordination platform may be needed.

Users were generally receptive to this experiment, with very few issues reported. However, users do not want it to impact their vehicle usage. The system is acceptable to them as long as it does not change their experience. There is no financial compensation for users for this flexibility, but the benefits are global (e.g., reduced grid congestion, allowing for more charging opportunities).

There is no impact on transport networks. This technology is ready for commercialization, with no significant technical or regulatory barriers. The main obstacle to its large-scale development is the lack of a strong business case, as other markets are more attractive, but the interviewees expressed optimism about the broader application and replication of these projects across Europe, predicting that grid congestion and the need for sustainable energy solutions would become more prevalent, creating more opportunities for similar projects.

Main action plan:

- Develop a more scalable smart charging algorithm to maintain high efficiency and effectiveness, even as the number of chargers increases. Consider using machine learning to continuously improve system performance based on real-time data.
- Develop and testing other business models within field operational tests, through European projects, and applied in a competitive context where other solutions are available.

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4.1.2 UC1c

4.1.2.1 Feedback interviews highlights

Demo site: Utrecht & suburban area, Netherlands.

This experiment focuses on bi-directional charging and takes place in the Netherlands, in Utrecht and its suburbs. Using a fleet of approximately 100 shared bi-directional cars and 700 AC bi-directional chargers, the experiment aims to leverage the significant capacity of car batteries to provide grid services.

The Netherlands, particularly Utrecht, faces a highly congested electrical grid due to strong incentives for heat pumps, solar panels, and electric vehicles. Although there is a platform available for offering services to support the grid, it is not yet ready for Vehicle-to-Grid (V2G) applications. The platform is designed more for large grid connections like factories, whereas V2G requires managing several hundred small grid connections.

While AC bi-directional chargers are relatively common, a significant issue for the large spread of this use case is the compatibility of the cars. V2G-compatible cars are a recent development. Originally, Renault had plans to release such vehicles earlier but changed their strategy. Hyundai developed V2G vehicles but encountered problems with the communication protocol. Technically, there are no significant issues with deploying the solution. The primary challenge lies in the slow market introduction of AC V2G-compatible cars, but the infrastructure is prepared, and there are no additional costs for charging stations or grid connections. As soon as the cars become available, the system can scale up rapidly. Replicating this project today would be easier due to better timing and the availability of V2G-compatible vehicles.

Initially, an experiment in a village near Utrecht used two vehicles and two chargers with plans to expand to five; however, there was insufficient demand for car sharing. However, the experiment in Utrecht proved successful.

Supportive public policies in Utrecht have played a crucial role. The law only requires one parking space for every three new homes, and parking in the city is not free, thereby encouraging car sharing. Moreover, the chargers used in the experiment were not public but were reserved for shared cars through an arrangement with the town council. The solution tested in Utrecht is currently being rapidly deployed in other cities, such as Amsterdam and Rotterdam.

Utrecht is at the forefront of V2G technology, with prerequisites for V2G incorporated into the installation of chargers and excellent cooperation from the city. However, the legal and regulatory environment is more challenging. For example, there is double taxation on energy (both when it is received and when it is reinjected), which hampers market development by reducing profitability.

The business model for this experiment is multifaceted, as it is difficult to make a profit solely from car sharing. Therefore, several services are provided simultaneously: car sharing, charging, consumption optimization, energy trading (e.g., charging cars when prices are very low and reinjecting electricity when they are high), and electric grid services. While there may be a long-term concern about the profitability of this model with an abundance of V2G vehicles consuming renewable electricity, this is not seen as a risk within the next decade. Therefore, the scaling of this experiment could help to develop car sharing solutions.

Volume is critical for the system's success, requiring sufficient demand and a large enough fleet of cars. Without adequate scale, the system cannot operate efficiently.

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Data collection and management is also quite easy, as the cars are shared, meaning the companies already possess the necessary data, and vehicle behaviour is largely predictable due to the reservation schedule. This may be more challenging with private cars, but it is not yet a concern.

On the financial part, funding from European projects were very useful to develop the system, but the system is now self-sustaining and does not require subsidies.

To finish, a good user interface is crucial for the system's success.

4.1.2.2 Main actions plan

- Integrate V2G compatible cars into a carsharing fleet, and work with automotive manufacturers to ensure a supply of V2G-compatible cars.
- Optimize the user interface, by conducting surveys and focus groups with current and potential users to gather feedback on the existing interface and identify areas for improvement.
- Run large field operational tests, with more vehicles and larger area, to gather more comprehensive data on performance, usage patterns, and grid impact.
- Engage proactively with local and national regulators to help shape policies and regulations that support V2G technology, including advantageous tariffs, subsidies, and maybe either legal recognition of V2G services.

4.1.3 UC2 & UC3

4.1.3.1 Feedback interviews highlights

Demo site: Paris (UC2) & Versailles (UC3), France.

Those two use cases are very similar and focuses on dynamic wireless charging, commonly known as the "electric road." This technology aims to charge electric vehicles (EVs) while they are in motion, thereby reducing the need for large batteries and static charging infrastructure.

UC3 targets high-speed environments, with charging speeds between 90-120 km/h and a power output of 30kW. The primary goal is to use energy directly from the road to reduce the battery size required, with an evident application for trucks. By creating electric corridors along highways, trucks can continuously charge while driving, thereby minimizing downtime and enhancing the efficiency of logistics operations. The experimentation took place in Versailles, in France.

UC2 focuses on low-speed or stopped wireless charging in urban areas, with an experimentation in Paris, in France. This solution first targets a professional audience, including taxis, VTC (private hire vehicles), and logistics/transport actors. One of the main challenges in a city like Paris is determining the optimal locations for these charging zones. Properly implemented, 100 km of electric road in Paris could allow vehicles to operate with batteries designed for only 50-60 km, reducing the need for static charging. This system is particularly advantageous for professional uses or car sharing and can help city planners manage urban logistics more efficiently.

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The installation of such systems, while requiring meticulous planning, is not exceedingly challenging. Roads in Paris are typically refurbished every 10-20 years, providing a window for integrating this technology into existing infrastructure projects. However, certain areas with large metal conduits might be unsuitable for installation. The electric road solution requires less public space compared to traditional chargers, as the technology is embedded in the road itself, eliminating the need for additional parking spaces and sidewalk charging stations.

This technology also contributes to better equilibrium in the electric grid. Implementing this solution involves coordinating multiple stakeholders, including Distribution System Operators (DSOs), building contractors, coil installers, and town councils. Despite the complexity, it is comparable to traditional road construction projects.

Cost-wise, the electric road may be more expensive than static chargers, but it offers global and long-term savings, particularly by reducing the size of EV batteries. User acceptance remains a critical challenge, as the technology can be perceived as intrusive due to concerns about electromagnetic waves. The connection to the system is automatic, requiring no user confirmation, which enhances convenience but may also raise privacy concerns.

Effective coordination between different operators of the wireless road is essential to ensure universal accessibility and prevent monopolistic scenarios. Interoperability between systems and standardization are crucial for widespread adoption. This solution also aligns with broader urban planning goals, prompting a re-evaluation of the role of cars in city environments.

For dynamic wireless charging to be viable in an urban setting, it requires deployment in very large cities with several million inhabitants, particularly if reserved for professional use. The initial deployment faces a "chicken and egg" problem: infrastructure providers need a sufficient number of compatible cars to justify the investment, while users require adequate infrastructure to adopt compatible vehicles. Development of static wireless charging can help bridge this gap.

There are no significant technological barriers to deploying this solution. The main issues revolve around market readiness and user acceptance. Once these are addressed, dynamic wireless charging has the potential to revolutionize urban and long-haul transportation.

4.1.3.2 Main actions plan

- Raising public awareness about the risks of this technology, for example by designing and implement comprehensive educational campaigns to inform the public in social media and collaboration with classic media
- Develop and deploy also static charging solutions in order to assure synergia between technologies
- Collaborate with standards organizations and industry leaders to develop universal standards for both static and dynamic wireless charging.
- Work with automotive manufacturers to ensure that new vehicles are equipped with built-in capabilities for static wireless charging, to solve the chicken and egg problem of vehicles and infrastructure. This might involve retrofitting existing vehicles or incorporating charging capabilities in new designs.
- Implement large scale pilot sites across varied urban settings to test the technology under different urban layouts and traffic conditions.

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- Gather data on usage patterns, charging efficiency, maintenance needs, and user satisfaction from these pilot sites to inform further development and refinement of the technology.
- Develop a strategic plan for the deployment of charging stations in locations that maximize usage and convenience for drivers, in collaboration with city planners to integrate wireless charging infrastructure in the future road works.

4.1.4 UC4

4.1.4.1 Feedback interview highlight

Demo site: Torino, Italy.

This experiment focuses on utilizing a high voltage DC grid, specifically a tramway system, to charge electric vehicles. Taking place in Torino, in Italy, the project is located in a public parking lot managed by the local public transport company. The demo site features ten low-powered DC chargers and one ultra-fast DC charger (150 kW), all connected directly to the tramway grid. This grid's overcapacity is used to charge vehicles directly with DC power, while smart charging stabilize voltage spikes and improve tramway grid performance.

The parking lot is designed for commuters, allowing them to park their vehicles and take the tramway for the last mile into the city center, having positive effects in city center's traffic.

The implementation of such infrastructure faces bureaucratic and regulatory hurdles, particularly regarding complex energy metering, certification processes, and commercialization challenges. For example, billing issues arise between public transport operators, who do not pay taxes on energy, and private companies selling charging power, highlighting the need for clear financial frameworks.

With over 400 cities worldwide operating tramways, the replication potential of this technology is significant. High population density is not a major barrier, as electric transport systems in dense cities are often over-dimensioned, while the distribution grid tends to be congested. This solution can also be adapted to other DC power sources, such as photovoltaic parks or high-speed train lines.

The business case for fast charging appears stronger than for slow charging. While slow charging is common and offers minimal component savings compared to slow AC charging, fast charging benefits significantly by avoiding the costs of dedicated substations and converters, reducing expenses by almost fourfold. Electric grids for tramways are highly standardized, with the primary challenge being to persuade operators to deviate slightly from their standards.

The cost-effectiveness of the installation increases with the power extracted, suggesting an interest in grouping charging stations. However, no critical market mass is necessary for profitability; a single installation can be self-sufficient. Potential business models include the tramway grid operator managing the system entirely or partnering with a company to handle the municipality's needs.

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4.1.4.2 Main actions plan

- Organize consultation sessions with key stakeholders including transportation company, industry experts from tramway grid development and local government groups to gather diverse insights and concerns regarding the current regulatory framework, and write new regulations or amendments to existing ones, in order to create a supportive legal environment that facilitates innovation while protecting public interests.
- Analyze the data collected in the project to validate a business model. This analysis should cover financial viability, actors acceptability, scalability potential, and alignment with regulatory requirements.

4.1.5 UC5

4.1.5.1 Feedback interview highlights

Demo site: Tallin, Estonia.

This experiment takes place in Tallinn, Estonia, with the goal of utilizing superfast chargers (200kW) to charge EVs in less than 15mn, and to compensate reactive energy in the grid when not in use for charging, and to sell this service in flexibility markets.

For entry into these markets, at least 1MW of capacity is required. The primary targets are peri-urban areas, such as nearby factories that need to compensate for their reactive energy, and highways. Locations are chosen based on criteria like proximity to highways and factories for effective reactive energy compensation.

Although no real implementation is currently planned due to market evolution, there is a growing need for more flexibility from public chargers. The main challenge lies in ensuring the integration and functionality of all components, managing the project, and writing comprehensive reports. Past issues included charging specific EV models like Tesla cars due to protocol mismatches.

The market strategy involves integrating EV charging services with flexibility markets to balance the grid and reduce fees. There are no specific installation requirements apart from having a strong grid connection and adhering to safety standards. Regulatory constraints for installing fast chargers are minimal, but the business model for reactive power compensation remains underdeveloped. Currently, reactive power compensation relies primarily on capacity payments, which are quite ineffective. Designing a reactive power market could be beneficial and help this technology to emerge.

4.1.5.2 Main actions plan

- Identify industrial sites where the technology could be useful and engage discussions with them to scale the experiment and easily reach the capacity needed to enter into flexibility markets
- Formalize the business model for selling reactive power in flexibility markets. This involves defining how to monetize the compensation of reactive energy effectively and aligning with market needs.

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4.1.6 UC6

4.1.6.1 Feedback interview highlights

Demo site: Zaragoza, Spain.

The use case focuses on high-power bi-directional charging and took place in Zaragoza, Spain. The experimentation aimed to develop technology that enables electric vehicles (EVs) to both charge and discharge in the electric grid, creating synergies with renewable energies. This technology allows EVs to store surplus energy from sources like photovoltaic panels or wind and support the grid with distributed battery storage, thus enhancing grid stability and renewable energy integration.

A key aspect of the use case is the potential of using EV batteries, which are often idle, to provide services to the grid, including active and reactive power. To do so, there is a strong need for communication protocol standardization, with car manufacturers needing to implement Vehicle-to-Grid (V2G) capabilities in vehicles. Currently, only a few commercial vehicles are V2G ready. Once the cars will exist, there is no real technical barrier to spread this technology.

User acceptance and comprehension are also crucial, with a strong need to explain the benefits of V2G and its minimal negative impact on users.

The technology is not significantly more expensive than conventional chargers and faces no technical or regulatory constraints for installation. Although this specific case study is not intended for home charging due to its three-phase technology, it can be easily adapted for such use. This use case is particularly interesting for countries with congested electric grids or isolated electric systems, where the combination of EV batteries and other batteries can be beneficial.

No specific data requirements exist beyond usage patterns, which are easy to collect. However, a critical mass of users is needed for the technology to be profitable.

Currently, the high cost of batteries makes V2G less profitable due to the aging of the battery caused by V2G. However, with cheaper batteries in the future, V2G is expected to become more viable. There is optimism about the role of EVs in supporting renewable energy and grid stability in the future.

4.1.6.2 Main actions plan

- Collaborate with automotive manufacturers and international standards organizations to develop and standardize V2G communication protocols, ensuring broad compatibility and ease of integration.
- Continue the development and optimization of bi-directional charger technology to improve efficiency, reduce costs, and minimize the impact on EV battery life.
- Implement larger-scale pilot tests in multiple locations to evaluate the technology under different grid conditions and with diverse user bases, such as urban areas with grid congestion and remote areas with isolated grids.
- Launch educational campaigns to raise awareness about the benefits of V2G technology, focusing on its environmental impact, potential cost savings, and grid stability enhancements.

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4.1.7 UC7

4.1.7.1 Feedback interview highlights

Demo site: Zaragoza, Spain.

The use case focuses on high-power (50kW) static wireless charging and is being tested in Zaragoza, Spain. Originally designed for public transport and taxis, such as buses at bus stops or red lights and taxis waiting for customers, this technology can also be used for private vehicles. Currently, no commercially available vehicles support this technology, only prototypes. However, vehicles compatible with dynamic charging can also utilize static charging.

The need for strong standards in future compatible vehicles is crucial, as interoperability is important. One of the main advantages of static wireless charging is that it requires no interaction between the driver and the infrastructure, making it almost as efficient as conductive charging with minimal power losses. While the technology is currently unidirectional, it could evolve to support bi-directional charging and provide grid services.

A challenge in implementing this technology is ensuring the vehicle is properly aligned with the coils for efficient charging, and different car heights may also pose an issue. The cost of installing static wireless charging is comparable to that of a classic charging station, and it can be installed anywhere, though it is particularly useful in cities for short opportunity charging. There are no specific regulatory problems, but the coils require a cooling fluid, adding to maintenance needs.

The technology does not significantly impact traffic, city organization, or the electric grid. Scaling up involves replicating the system as needed, requiring only compatible cars. Some companies are interested in developing compatible cars if the technology proves ready, although the chicken-and-egg problem persists: infrastructure needs compatible cars to develop, and compatible cars need infrastructure to be mass-produced. Today's vehicles can be adapted relatively easily, adding only a few dozen kilograms.

Concerns about public safety and awareness, particularly regarding electromagnetic fields, are addressed through secured testing areas, and other experiments indicate the risk is extremely low. Wireless charging reduces the need for user interaction, enhancing convenience and safety. Efficiency improvements and better user interfaces are expected to make wireless charging more feasible and attractive.

Continued testing and development will address current technical issues, paving the way for broader application and standardization. This technology has the potential to transform urban charging infrastructure by providing a seamless, efficient charging solution for various vehicle types.

4.1.7.2 Main actions plan

The action plan would be more or less the same than the one of UC2 and UC3 :

- Collaborate with standards organizations and industry leaders to develop universal standards for both static and dynamic wireless charging.
- Work with automotive manufacturers to ensure that new vehicles are equipped with built-in capabilities for static wireless charging, to solve the chicken and egg problem of vehicles and

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infrastructure. This might involve retrofitting existing vehicles or incorporating charging capabilities in new designs.

- Implement large scale pilot sites across varied urban settings to test the technology under different urban layouts and traffic conditions.
- Gather data on usage patterns, charging efficiency, maintenance needs, and user satisfaction from these pilot sites to inform further development and refinement of the technology.
- Develop a strategic plan for the deployment of charging stations in locations that maximize usage and convenience for drivers, in collaboration with city planners to integrate wireless charging infrastructure in the future road works.

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5 ACTION PLANS – BURSA AND NORDENEY CASES

5.1 Bursa

Bursa, a large city located in northwestern Turkey, is known for its historical significance and economic strength. As an industrial hub, Bursa is a significant player in the Turkish automotive industry.

Bursa's robust automotive industry, which includes several major car manufacturing plants (Renault, Fiat, Karsan, Bosch, Valeo…), provides a strong foundation for experiments related to electric vehicle (EV) charging technology. The presence of these industries not only facilitates technological adoption but also ensures a supportive ecosystem for automotive innovations. This could be particularly beneficial for bi-directional charging and high-power charging systems that require close collaboration with automobile manufacturers.

As a rapidly growing city, Bursa is continuously expanding its urban infrastructure. The city's efforts in modernizing public transportation and road networks can be aligned with the implementation of advanced charging infrastructures, such as dynamic wireless charging systems embedded in roads or utilizing existing tramway grids for EV charging as seen in the use cases.

The success of these initiatives in Bursa would also depend on the local and national regulatory frameworks. Supportive policies, such as incentives for renewable energy usage, EV adoption, and smart city initiatives, would be critical. The Turkish government's recent focus on increasing the production and use of electric vehicles aligns well with this, potentially smoothing the path for regulatory approvals and public-private partnerships.

The willingness of the local population and businesses to adopt new technologies plays a crucial role. The population of Bursa is quite young (average age 35 years old in 2020) and the city's industrial presence makes the population in constant contact with innovation, so should be quite open to embracing innovative solutions like wireless charging infrastructures.

Given the characteristics and capabilities of Bursa, let's assess the feasibility of each discussed use case and suggest potential action plans for their implementation:

5.1.1 UC1a & UC1c: Smart Charging and Bi-directional Charging

Feasibility in Bursa:

- **Highly feasible**. Bursa's robust automotive industry and a growing number of electric vehicles make it a prime candidate for smart and bi-directional charging technologies. The city's existing electrical infrastructure and the presence of leading automotive companies offer a solid foundation. This could also help to integrate renewable energies more widely, while about 2/3 of the electricity in Turkey is generated from gas and coal.

Action Plan:

1. **Partnerships with Local Automakers**: Collaborate with automotive manufacturers to integrate bi-directional charging capabilities in vehicles produced locally.

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2. **Pilot Programs**: Launch pilot programs in areas with significant EV usage to test system efficiency and user acceptance.
3. **Infrastructure Upgrade**: Invest in upgrading electrical grid capabilities to handle smart charging demands and bi-directional energy flows.
4. **Public Awareness Campaigns**: Educate the public on the benefits of smart and bi-directional charging to boost adoption.

5.1.2 UC2 & UC3: Dynamic Wireless Charging

Feasibility in Bursa:

- **Feasible**. Implementing dynamic wireless charging requires significant changes to existing infrastructure, which might be challenging but possible given Bursa's ongoing urban development projects.

Action Plan:

1. **Feasibility Studies**: Conduct detailed studies to assess the technical and economic viability of embedding charging technology in city roads.
2. **Stakeholder Engagement**: Engage with city planners, transport authorities, and potential technology providers to align efforts and resources.
3. **Integration into Roadworks**: Plan to incorporate wireless charging strips during scheduled road refurbishments or new construction projects.
4. **Public Awareness Campaigns**: Inform local residents of the benefits of the technology and the absence of any particular risks associated with it.
5. **Pilot Zones**: Establish specific zones for initial deployment, focusing on areas with high traffic of commercial vehicles or public transportation.

5.1.3 UC4: Utilizing Tramway Grids for EV Charging

Feasibility in Bursa:

- **Highly feasible**. Bursa's existing tramway system provides a good opportunity to leverage overcapacity for EV charging, similar to the use case discussed.

Action Plan:

1. **Technical Assessment**: Evaluate the current capacity and compatibility of the tramway's electrical infrastructure for EV charging.

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2. **Collaboration with Transport Authorities**: Work closely with local transport authorities to coordinate the dual use of tramway grids. As stated during the interview, the most difficult part to achieve may be to convince the tramway operator deviate from its strict rules of use
3. **Demonstration Project**: Implement a small-scale demonstration project at tram stations or nearby parking areas to test system performance and user engagement.
4. **Regulatory Framework Development**: Develop and adjust local regulations to facilitate the commercialization of this dual-use technology.

5.1.4 UC5 & UC6: High-Power Charging and Bi-directional Grid Services

Feasibility in Bursa:

- **Feasible**. These technologies require high initial investments and a clear regulatory environment for grid services, which could be developed with strong government backing. The presence of so many industries make the reactive energy compensation options proposed in use case 5 particularly interesting.

Action Plan:

1. **Market Analysis and Regulatory Support**: Analyze the market for high-power charging and grid services and work with regulators to create supportive policies.
2. **Collaboration with Energy Providers**: Partner with local energy providers and manufacturers to ensure the integration of EV charging with grid management.
3. **Infrastructure Development**: Focus on areas with high EV traffic potential, such as commercial hubs, and high interest zones, such as factory neighbourhoods, for infrastructure development.
4. **Incentive Programs**: Introduce incentives for businesses and consumers to participate in these new charging models.

5.1.5 UC7: Static wireless charging

Feasibility in Bursa:

- **Highly feasible**: Bursa's larger scale and extensive urban transport system provide again a suitable testing ground for high-power static wireless charging. The city's focus on technological advancement and industrial growth, particularly in the automotive sector, supports the integration of advanced technologies.

Action Plan:

1. **Integration into Public Transport Networks**: Install static wireless charging systems at major bus terminals, taxi stands, and tram stops across the city, where buses and taxis frequently idle, waiting for passengers.

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2. **Collaboration with Automotive Manufacturers**: Work with local automotive manufacturers to explore the development of vehicles that are compatible with static wireless charging, potentially setting a trend for future vehicle production.
3. **Urban Planning Inclusion**: Include provisions for static wireless charging in the city's urban development plans, particularly in new developments or when refurbishing existing areas.
4. **Public Awareness and Incentives**: Launch a public awareness campaign to educate the population on the benefits of wireless charging technology. Consider incentives for taxi and bus companies to upgrade their fleets to compatible models.
5. **Evaluation and Expansion**: After initial implementation, evaluate the system's impact on traffic flow, pollution levels, and urban aesthetics, with plans for further expansion based on successful outcomes.

5.2 Nordeney

Norderney, which is one of the 7 East Frisian Islands in Germany, presents a different context compared to a large city like Bursa. Mainly known as a touristic destination, with a quite small area (26 square kilometres, 14km by 2.5km), a relatively small population and an economy focused on tourism, Norderney's approach to infrastructure and technology need to be adapted to its characteristics, with strong environmental focus and a limited infrastructure. Let's evaluate the feasibility of each use case on Norderney and suggest potential action plans:

5.2.1 UC1a & UC1c: Smart Charging and Bi-directional Charging

Feasibility in Norderney:

- **Highly feasible**. The increasing number of tourists using electric vehicles and a small, manageable infrastructure make smart and bi-directional charging a practical option, especially for balancing seasonal energy demands. It can also be of a great help to support renewable energy integration. The solution based on car sharing could also be extremely interesting for local population, due to the low necessity to own a car for everyday life in such a small island.

Action Plan:

1. **Pilot Smart Charging Programs**: Target areas with high tourist influx for pilot programs to optimize local grid usage and introduce bi-directional charging facilities.
2. **Partnerships with EV Rental Services**: Collaborate with local vehicle rental services to ensure that rental fleets include bi-directional capable EVs.

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3. **Infrastructure Assessment**: Assess the existing electrical infrastructure's capability to handle new charging technologies and plan upgrades if necessary, and seek for synergies with solar panel or wind turbines.
4. **Community Engagement and Incentives**: Engage with residents and businesses to promote the adoption of these technologies through incentives like reduced charging rates during off-peak hours.

5.2.2 UC2 & UC3: Dynamic Wireless Charging

Feasibility in Norderney:

- **Low to moderately feasible**. The concept of embedding charging systems in roads might be more challenging on a small island due to the cost and logistical constraints but could be justified in high-traffic tourist areas or main routes.

Action Plan:

1. **Feasibility Study for Tourist Areas**: Conduct studies to explore the practicality of installing dynamic charging systems along routes frequently used by tourist buses or rental cars.
2. **Integration into Existing Traffic Flows**: Consider integrating this technology during routine road maintenance or upgrades to minimize disruption.
3. **Demo Installation at Key Points**: Install demo units at key points like major parking lots or near popular attractions to gauge effectiveness and gather public opinion.
4. **Stakeholder Collaboration**: Work closely with local tourism boards and environmental groups to align the project with environmental and economic goals.

5.2.3 UC4: Utilizing Tramway Grids for EV Charging

Feasibility in Norderney:

- **Not feasible**. Given Norderney's lack of a tramway system, this use case isn't applicable. However, similar concepts could be adapted for other types of local public or tourist transport systems if available. If there is any project of solar or wind farm on the island, the potential for using its infrastructure to support EV charging stations at transport hubs or terminals can be explored.

5.2.4 UC5 & UC6: High-Power Charging and Bi-directional Grid Services

Feasibility in Norderney:

- **Low feasible**. The integration of high-power charging can support the rapid turnover of tourist vehicles, especially during peak seasons, but the grid may not be strong enough to support fast charging solutions. The interest of reactive power compensation is also quite low.

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Action Plan:

1. **Target Key Locations**: Install high-power chargers at strategic locations like ferry terminals and large hotels.
2. **Renewable Energy Integration**: Leverage Norderney's renewable energy projects to provide clean power for high-power charging stations and explore bi-directional capabilities to store excess energy.
3. **Subsidies and Incentives**: Seek subsidies for renewable energy integration and provide incentives for businesses to install and maintain high-power charging infrastructure.

5.2.5 UC7: Static wireless charging

Feasibility in Norderney:

- **Highly feasible**: Given Norderney's size and focus on sustainable tourism, static wireless charging could be particularly beneficial for maintaining the aesthetic of the landscape while providing necessary services. This technology, especially if used in buses and taxis, can reduce the visual impact of charging stations and maintain the natural beauty of the island.

Action Plan:

1. **Pilot with Public and Tourist Transport**: Integrate static wireless charging pads at bus stops or taxi stands where vehicles spend time idling. This would be ideal for vehicles that shuttle tourists between major attractions and accommodations.
2. **Engagement and Partnerships**: Collaborate with vehicle manufacturers and local transport companies to ensure that new or existing vehicles are compatible with static wireless charging technology.
3. **Infrastructure Investment**: Invest in the necessary infrastructure at key points around the island, considering the high traffic areas during tourist season.
4. **Monitor and Evaluate**: Implement a monitoring system to evaluate the efficiency and effectiveness of the charging technology in reducing wait times for charging and its acceptance by the public and tourists.
5. **Sustainability Messaging**: Promote this initiative as part of Norderney's commitment to environmental sustainability, enhancing its appeal as an eco-friendly destination.

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6 CONCLUSIONS

Those analysis highlight significant insights and strategies for the replicability of the developed charging solutions. Across these use cases, the recurring themes include the importance of regulatory support, market readiness, technological compatibility, stakeholder collaboration, and user acceptance. Each of these factors plays a crucial role in determining the success and scalability of innovative EV charging solutions.

Market Challenges

Despite technological readiness, market limitations such as profitability issues and the need for market reform can hinder large-scale deployment. Market structures for these services need to be developed to make them financially viable. Market viability is also often dependent on sufficient demand and vehicle compatibility.
The ability to leverage EVs for grid services (e.g., relieving grid congestion) is valuable but requires substantial numbers of connected chargers or vehicles to be effective. It can also help some new markets to emerge, such as car sharing.

User Acceptance

Ensuring that technology implementations do not disrupt user experience is critical for adoption. Incentives might not always be financial but can appeal to broader benefits such as environmental impacts. Addressing user concerns about new technologies (e.g., electromagnetic waves from dynamic charging) is crucial for acceptance.

Regulatory, and Technical Readiness

All the use cases suggest that the technology is available and feasible, but regulatory environments and market readiness can be significant barriers. Regulatory and billing complexities need clear frameworks to facilitate integration between public and private sectors.
The development of vehicle standards is essential for the scalability of all those technologies, and especially static wireless charging where standards still barely exists. Interoperability across different vehicle models and manufacturers will be a cornerstone of widespread adoption. For example, V2G is not available due to a lack of interoperable by OEMs use of existing ISO 15118-20 communication protocols.
This standardization is even more essential as it enhance the potential for integrating charging technology with existing infrastructure projects (like road refurbishments for wireless charging) that would be more cost-efficient and optimize the deployment process.

Stakeholder collaboration

The success of such technologies relies on the availability of compatible vehicles and the readiness of the market to adopt new standards. This implies a strong involvement of all stakeholders in the chain to disseminate these technologies, since the lack of cooperation of a single player, even if seemingly peripheral, can hinder the development of these technologies. Public authorities also have key roles in order to facilitate the installation of those technologies, ensuring responsiveness as well as an adapted regulation

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