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Lessons Learned – A cross-case analysis of four City Pilots implementing an interoperable Energy Management System

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Summary

The implementation of an interoperable Energy Management System, combined with installing new components in the energy system such as renewable energy generation or electric vehicle charging, comes with many challenges. Drivers within the level playing field help the implementation, and barriers cause delays or require workarounds. During the Interreg CleanMobilEnergy project, the drivers and barriers are recorded during the processes and by conducting interviews to deep dive into the details. This resulted in lessons learned, providing a valuable guide when replicating the implementation of the iEMS system.

Keywords: load management, smart grid, demonstration, renewable, charging.

1 Introduction

Efforts are made to fight climate change by integrating renewable energy sources (RES) into the local or regional energy grids. However, RES bring its own specific challenges as the generation of energy is intermitted and highly dependent on the seasonal weather conditions. Peak renewable energy (RE) production could result in net congestion and even curtailment of RE generation, which is undesirable. A solution could be to reinforce the grid, but this is generally an expensive undertaking. Another way is to implement an energy buffer to store the surplus of RE and use this stored energy when no or negligible RE is being generated. However, this requires the management of energy flows within a given system to optimise supply and demand based on a set of preferences and rules it is assigned to optimise against. In the Interreg CleanMobilEnergy (CME) project, an interoperable Energy Management System (iEMS) is being developed and implemented into four pilots within the Europe North-West Region. Different energy components are connected to the iEMS, which will control and optimise the energy system where possible, potentially increasing the self-consumption of RES or preventing the immediate need for grid reinforcement. The CME project consists of four City Pilots (CPs) in three different countries. The CME project started in 2017 and will end in 2022.

The four city pilots have different scales and configurations. In the Nottingham CP (UK), the Nottingham City Council (NCC) has implemented the iEMS in one of their depots. The depot has installed 138 kWp of solar panels and procured 40 Electric Vehicles (EVs) with vehicle-to-grid (V2G) capabilities. The council is in the process of procuring its EV chargers with V2G capabilities. In the Arnhem CP (NL), the iEMS is integrated on city-scale by connecting the complete EV charging system across the city, existing of 260 EV chargers (520 connectors), a solar park of 14 MWp, three wind turbines with a combined power of 7,5 MWp, a battery system of 500 kWh and a cold ironing system (a shore-based supply for auxiliary power at berth) which supplies up to 12 river cruise ships with electric energy. In the Schwäbisch Gmünd CP (DE), the iEMS is integrated into a building with a solar panel installation of 1.5 kWp, a battery of 4,5 kWh, and five Light Electric Vehicle (LEV) chargers which are powering three e-bikes and two kick scooters. Unfortunately, the London CP had to make a difficult decision to leave the project due to the implications of the covid-19 situation and was replaced by a City Pilot in Stuttgart. The Stuttgart CP (DE) deploys a total of nine LEV charging and parking modules for 30 LEVs. Five of these stations are connected to the grid, whereas four stations are fitted with a solar panel and a battery system. Some of the stations are mobile and will rotate within the city among the church organisation locations to trial LEVs as a potential substitute for their internal combustion engine (ICE) powered vehicles.

The development, as well as the implementation of the iEMS, took place during the installation of the different energy system components across the CPs. During this process, the four CPs (plus the London CP) and the iEMS developer came across different barriers and drivers to reach the point where the iEMS is able to successfully optimise the (local) energy system. This proved to be a valuable learning process from which the lessons learned have been captured. These lessons were documented by setting up a' capturing' process and supplemented by conducting interviews with the lead contacts of the CPs and the iEMS developer.

2 Methodology

This study aimed to collect both (positive) drivers and (negative) barriers experienced during the installation of energy system components and the implementation of the iEMS. There are three different approaches to capturing the lessons learned: (i) the integrated method, (ii) Post-facto, and (iii) the combined (integrated and post-facto) [1]. For this study, the combined approach is chosen.

2.1 The Integrated method

Over the course of the CME project, a monthly meeting is held to record the progress of each CP and document any identified driver or barrier in the 'status monitoring reports'. In addition, a drivers and barriers session was organised during one of the regular partner meetings.

2.2 The Post-Facto method

After the installation of energy system components and implementation of the iEMS, a series of interviews were organised with the CP leads and the iEMS software developer. The questions revolved around the general project and the pilots specifically, using the identified drivers and barriers from the status monitoring reports. These questions are categorised using the PESTEL (Political, Economic, Social, Technological, Environmental and

Legal) analysis method. The interviews were transcribed, coded, and analysed to identify a set of generalisable lessons.

3 Results

In this section, the results of the combined (integrated and post-facto) method in collecting the lessons learned by identifying drivers and barriers are discussed following the PESTEL analysis method. The PESTEL factors are defined as drivers and barriers that are related to:

- Political: governmental ambitions, (potential) policies that are formulated to help underpin these ambitions, but also ownership and the required commitment.
- Economical: commercial interest of partners in the project, different business case opportunities, and energy prices that influence the effectiveness of the project.
- Social: organisational knowledge, data privacy and human behaviour.
- Technological: technical expertise, specifications, the development and compatibility of components.
- Environmental: emission reduction, renewable energy, and circular economy.
- Legal: legislation, licenses and permits.

3.1 Political

National or local ambitions can act as a driver for the energy transition and, therefore in the adoption of the iEMS. The NCC has set an ambitious target of achieving carbon neutrality by 2028, which is more ambitious than the one set nationally. Also, church organisations such as the one in Stuttgart have their own sustainability ambitions. But for the iEMS implementation to succeed, multiple partners need to get involved. Many of these partners are often private organisations, such as in Arnhem. Private companies, such as the charge point operator, want to make a profit, and this does not always fit with the city's ambitions. There is a lack of incentive tools to help the public authority encourage the use of local and renewable energy; companies cannot be forced. Arnhem tried to involve the local distribution network operator (DNO), but their time (beyond attending normal operations) is occupied by reinforcing the grid to solve the more immediate network capacity issues, leaving them with little to no time for innovation projects. Ambitions and policies aimed at stimulating RES initiatives often come with a set of criteria and conditions that need to be met, which may have an impact on an energy system's design or possibly even any changes for optimisation being considered. For example, the Dutch subsidy policy SDE++ sets different conditions and annual subsidy rates based on whether the facility is set up individually, with a partner or if it is connected to a private grid (as well) **[2]**.

A major challenge identified in the implementation of the iEMS is the fragmentation of components ownership. Technically speaking, all components can be connected, but it is an organisational challenge to define the constraints of intervention on the system and to agree on setting the rules of production and consumption. It was easier for the city pilots of Nottingham, Schwäbisch Gmünd and Stuttgart as there is one organisation who has control over all of the connected components (although it can still be complex within an organisation where ownership is spread over multiple departments). In Arnhem, however, different actors such as the charge point operator (CPO) are involved and operate under the fundamental premise that they do not allow their assets to be controlled by a third party such as the iEMS.

Commitment is required for all participating organisations. The city council of Schwäbisch Gmünd had formulated high ambitions for themselves. This proved to be an important reason for their decision to allow the connection of the local solar park to the iEMS. Nevertheless, a change in management at the local DNO combined with other local policies formed a barrier to installing solar panels in the (historical) city centre, resulting in a lack of commitment. This caused a change of the initial plan for the Schwäbisch Gmünd CP to switch to a smaller setup. Change of staff also hindered the Nottingham pilot, primarily as it occurred at multiple departments involved in the pilot. The management of the operation was not easy for two other reasons in Nottingham: (i) the project was cross-functional, on both transport and energy, which is organizationally structured across multiple departments, and (ii) the NCC is primarily an administrative authority, which means that employees with technical skills and knowledge are less prolific and often not (consulted) at the decision-making level. This slows down the decision-making process itself. In the preparation of the London CP there was also an internal discussion between Transport for London (TfL) and the London underground engineers, as the decision for this pilot was not based on a conventional cost-benefit analysis but more to understand the technology and the potential benefits if the solar battery combination would be scaled up, it resulted in conflicts of interests and the decision to prioritise others.

3.2 Economical

When dealing with multiple actors who also have commercial interests, it is difficult to fully understand the potential economic implications of integrating the iEMS; for example, the costs difference between electricity from the grid and the electricity produced from the connected solar park in Arnhem is not known because the solar installation is owned by Sunvest who sells the energy to an intermediate party (Greenchoice) and not (directly) to the municipality; therefore this information is not shared. The battery, procured in the Arnhem CP, would best be utilised by connecting it to the solar park and using the stored energy for charging cars overnight. Whether it is feasible to realise this, such as from a legislative perspective or reconsidering ongoing contractual agreements, is currently still being explored and investigated with the different stakeholders.

The use of diesel generators in cruise ships during maintenance is a competitor to the cold ironing system in the harbour of Arnhem. Diesel has been a relatively cheap fuel and has a tax-free status compared to other fuels such as gasoline or electricity. Walvoorzieningen Nederland (WVNLD) explains that the covid situation had a big impact, and due to the energy price increase at the beginning of 2022, shipping companies are likely to use up their existing purchased stock of diesel, which was contractually purchased at a lower price, instead of using the cold ironing system.

The cost of the static batteries is not covered by the potential energy cost savings, especially since the city of Arnhem does not produce the renewable electricity itself but purchases it from Greenchoice, and the battery is not being used for FCR or energy tariff optimisation. Therefore, in the current state of the project, the deployment of the static battery does not lead to profitability. Open Remote states that in general, the installation of static batteries always makes the economic relevance of projects more fragile because they generate additional CapEx costs. As multiple actors are involved in the Arnhem CP, it is not possible for Arnhem to impose constraints of the energy management system on the components owned by other actors. Open Remote suggests that it might become possible by using economic incentives, redistributing the savings achieved by the iEMS among different actors. This would require a joint commitment or collaboration to develop a different business model and the ability to change existing (energy) contracts.

The London CP was not looking for profitability in the CME project, but rather for cost reduction. TfL is one of the biggest electricity users in the UK so it was worth investigating opportunities which can decrease electricity usage. Most of this electricity is used for the metro, any solar energy produced within this energy system would instantly be consumed by the metro. For the buildings that are not connected to the energy system of the metro, the iEMS could manage the expected surplus of energy generated by the solar panels to get the best out of the investment. Due to the covid situation, TfL experienced a drop in revenue and was not able to continue its activities on the CME project.

In Stuttgart, the LEVs have a relatively small consumption of energy for their small batteries. PV energy is the cheapest solution and the parking and charging stations can be moved without many costs. For now, the use of the LEV service in Stuttgart is offered for free within the CME project. Three different possible business cases were discussed for the future; (i) free usage, financed by the companies with a fixed monthly business contract with the operator, (ii) urban mobility service for professionals such as postal and delivery companies, and (iii) a mobility service for the people, financed by the city. The results of the CP, expected to run till the end of 2022, will be part of the considerations in making this decision.

A viable economic model is deemed possible for the Nottingham CP, given the size of the site. When activating V2G, attention must be paid to the potential impact on the life of the EV batteries in case it is determined that faster degradation seems to occur (for which evidence is not yet conclusive). As the pilot does not have a static battery yet, at least some vehicles should be connected to charge with energy generated by the solar installation during the day. With the high energy prices on the wholesale market, which could reach up to 50 pence/kWh, the production of renewable energy could be more financially interesting than purchasing it from the grid. The savings generated really depend on the variability of the energy prices and the availability of tariff flexibility. If in the UK the electricity network needs reinforcement, the costs of reinforcement are shared by the users who need it. If this is a single user, that user must pay for everything, but if another customer wants to use the reinforced network, the original user is reimbursed overtime for a portion of its investment.

Besides the funding of the CME project, the NCC only benefitted from the exemption of vehicle tax for electric vehicles. Arnhem received a one-time subsidy from the province and national government for the solar park (around 10% of the investment) and leased the site to Sunvest for 15 years. Sunvest receives a subsidy for generating sustainable energy (SDE+), however, if they would connect a battery storage system behind the meter to the solar park, they would impact the SDE+ feed-in subsidy status. In Germany, the Federal Ministry for Environment, Nature Conservation, Nuclear Safety and Consumer Protection (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz , or BMUV) grants €0.35/kWh for the CO_2 budget if it can be proven the vehicle is charged with locally produced renewable energy. This requires calibrated and certified sensors, which have not been purchased and therefore are not available in the Schwäbisch Gmünd CP at the moment. Especially with a larger fleet of (L)EVs such as in the Stuttgart pilot, it is interesting to make use of this subsidy. The Stuttgart CP expects they could generate €150 to €200 per station per year, depending on the traffic and weather. The benefits of off-grid stations mostly stem from their flexibility, especially on upfront costs in terms of permits and electric connections. It is estimated that, compared to mobile stations with a PV battery combination at current costs, the permanent station costs are 5 to 10 times higher. E-flow, the mobility provider in Stuttgart that develops and deploys these stations, is positive about the business model as the costs had gone down by a factor of 10 compared to 2007, when a similar type of station was deployed in a previous project.

Unicorn Engineering is a company in Schwäbisch Gmünd that has developed and assembled all the components in-house with the available technical expertise. The energy system is installed in their office building. Because they have assembled everything themselves, they estimate an energy cost price of about 10 cents per kWh over 10 years. A geopolitical barrier is the current supply chain disruption issue, with the implication of components being unavailable.

A non-disclosure agreement (NDA) was signed between Open Remote and partners when commercial data was involved.

3.3 Social

In Arnhem, the 'not in my backyard' effect (also known as the NIMBY effect) played a significant role. It delayed the construction of the solar and wind park due to a lengthy appeal process by concerned residents at the council of state, the highest administrative court in the Netherlands.

Technical solid (in-house) skills and understanding the market are deemed fundamental by the Nottingham CP to ensure maximum continuity in project management. When dealing with multiple departments within one organisation, it turned out that the legal team experienced difficulties with the terminology of the innovative technologies such as V2G, which caused delays in the procurement processes. Therefore, it is vital to engage with the departments that need to be involved at an early stage and educate the staff, including the decision-makers of the organisation, to have them understand what decisions are required to successfully enrol the desired technologies on site.

Data privacy has not been a big issue, according to the CPs. The vehicle data from the Nottingham and Schwäbisch Gmünd CPs are not linked to any of the end user's personal data. However, Open Remote notes that an issue of data privacy could arise should the iEMS be used in a broader context, for example, where private users would be incentivised to delay their charge for more flexibility (the longer the charging window, the cheaper the charge).

The Schwäbisch Gmünd CP noted that after replacing the traditional vehicle with the two LEV options, it seems that the kick-scooters were preferred by the employees of the company over the available e-bikes.

3.4 Technological

Implementing the iEMS system while integrating more components into the energy system, requires technical expertise, and having in-house expertise is a real driver. Both the London CP and the Schwäbisch Gmünd CP had in-house technical expertise at their disposal to develop, produce, assemble and program the components themselves to connect them to the iEMS. At the beginning of the Nottingham CP, the compatibility between the EVs and the charger units had not been anticipated properly for the 40 V2G enabled vehicles because there was limited in-house expertise available. Therefore, this city pilot was supported by Cenex, who provided the required technical expertise to write the procurement tenders, ensuring every detail is correct. V2G is a form of bi-directional charging, using the EV battery as an energy buffer to discharge the stored (renewable) energy when less or no RE is being generated. Depending on the configuration, the energy can be used behind the meter or through delivering grid services by feeding the energy back into the grid. To deploy V2G, the EVs and the chargers need to have the capabilities and be compatible with each other. Only a handful of EV models available on today's market are capable of performing V2G, mostly the Japanese brands, with the Nissan Leaf or the Nissan eNV-200 as the most popular models for DC-V2G using the ChaDeMo plug.

Open Remote highlighted the importance of a technically sound tendering process. To avoid or reduce any difficulties in the integration of, in this case, the static battery in the iEMS, the tender should describe precisely the data required, the data interface, responsibilities and ownership, and provide sufficient explicit technical details to the supplier (i.e., data frequency, OCPP standards, or equivalent).

Connecting the components within the energy systems to the iEMS was always possible. In some cases, the stability of the connection to the iEMS (or improving the control of the component) required more effort than anticipated. The Nottingham CP declared it may be ambitious to implement the iEMS with the size of the depot they are working with, but it can be done and thus it can also be replicated by other organisations, public or private, with similar characteristics. This is supported by the Schwäbisch Gmünd CP, which is a smaller pilot, and sees great value in using the iEMS. The interfaces between the components and the iEMS are more or less standardised and the iEMS is open source, using interfaces to the software that other companies can use.

As this project revolves around innovative technologies, the Stuttgart CP has been facing a number of challenges in developing the stations for charging and parking LEVs in terms of design and specifications. For example, the risk of the off-grid stations is a lack of solar energy in the winter. Stuttgart CP potentially sees a solution in the use of a larger battery (potentially of repurposed EV batteries) since the LEVs do not consume as much energy as passenger vehicles do. However, it would require the need to consider the additional (non-consumption) battery drain over time which occurs in batteries. The feasibility of this potential solution should still be investigated. Charging an e-bike in cold temperatures is another challenge and technical solutions are not on the market yet. Modified batteries will be used to become operational in the winter as well.

Technical constraints may cause delays as experienced in London and Arnhem CPs. In London, the initial prospected roof for the solar installation was considered too weak for the weight of the panels. In Arnhem, a larger capacity substation was required in order to install the shore power supply. This took a significant time of planning and implementation, as well as the cost of the new grid connection to WVNLD, who is operating the cold ironing system.

3.5 Environmental

The main objective for the CME project has been for the purpose of showcasing and learning from solutions that aim to reduce Greenhouse Gas emissions and therefore can be identified as one of the main drivers behind the individual CPs. Key aims for the project and each of the CPs is to evaluate the extent to which each of the implemented solutions, by means of steering by the iEMS, helps to contribute to this objective. For this purpose, a KPI methodology was developed and agreed upon to enable the analysis of the actual contributions as well as potential contributions (by means of simulations), for example to explore possible replication or scaling. However, at the time of this paper, the CPs are still operational and not all necessary (system related) data is available yet. It is therefore not yet clear what the results of these analyses are.

Though direct 'environmental' barriers had not been identified during the process, indirectly some barriers could be perceived as environmental barriers. As can be seen, influencing factors stemming from a political, economic, social and legal context can become inhibiting factors (barriers) to achieving the optimal situation to, for example, reduce emissions further or to increase (local) consumption of RE produced.

3.6 Legal

Legal barriers are mostly identified by CPs who deal with multiple actors within their pilot, such as at the Arnhem and Stuttgart CPs. In the Netherlands, and therefore the Arnhem CP, it is not possible to certify electricity discharged by the battery as renewable energy, even if the energy used to store in the battery was of renewable origin. Also, energy stored in a battery has been liable for being taxed twice, once being considered as consumption of energy and again when it was labelled as supply of energy. However, as of 1 January 2022, this Dutch legislation has changed to exempt the act of energy storage (store and release) from additional taxation [3]. Also, the battery owner would be considered as an electricity supplier, which requires a specific contract between the battery owner, its electricity supplier, and the DSO.

The possibility of developing a floating solar field was explored, but the Municipality of Arnhem finds it too early to provide a permit. Three wind turbines have been realised, but the fourth is delayed as there are discussions about the space it will take and the safety zone of the perceived location. A driver was identified in Arnhem by the fact that the municipality implemented an air quality-related legislation, forbidding river cruise ships in the maintenance harbour to use their onboard diesel power generators and obliging them to make use of the shore power supply.

Nottingham noted that in drafting a tender, the electrical regulations and compliance with the electrical network must be taken into account. An additional barrier proved to be the amount and type of data that potential V2G (service) providers requested and indicated they would need access to. Responsible personnel at NCC indicated these requests included sensitive data, which would make it difficult for NCC to provide due to data security policies and privacy legislation. More research is required to understand what the constraints are exactly.

Stuttgart is developing mobile units for parking and charging the LEVs as these are easy to move and connect. Placing permanent stations in Stuttgart would take years to get a public agreement. The building where the

Schwäbisch Gmünd CP takes place has monumental protection, and it was not allowed to place solar panels on the roof. Instead, solar panels were installed on the balcony.

Lastly, the London CP notes that the time relatively simple procurement takes is often underestimated, which is also seen in the procurement processes in the Nottingham CP in the procurement of the V2G units and the battery.

4 Discussion

A number of drivers and barriers have been identified in the uptake of new technologies in the energy system. The barriers often depend on the type of organisation it concerns. Public organisations often seem to have a shortage of technical expertise throughout the organisation and are bound to procurement rules that often take more time than anticipated. Details regarding the exact requirements could be further researched. Similar results in the procurement processes were seen in the Interreg SEEV4-City project [4], which involved the installation of similar technologies. Also, similarities are seen in the decision-making processes, underestimating tendering and staff change that hinders the continuation of the project. A few pilots are still in development, and the project continues to the end of the year 2022.

The integration of the iEMS shows the potential for controlling and optimising a large-scale energy system. Connecting the components of the energy system to the iEMS is technically possible, but the challenge lies in setting the intervention rules for each component. Further exploration of actors' willingness and potential models that would benefit all of the involved actors could potentially persuade commercial companies to get more involved. Such research would require interviewing organisations connected to the iEMS with their assets but who is not a partner of the consortia.

The insights and lessons learned from integrating the iEMS in different energy systems form a valuable guide when replicating the implementation of the iEMS into a new energy system of any organisation or scale.

5 Conclusion

Echoing the perception of the iEMS developer, it becomes apparent that the real challenges for the implementation of a smart grid are organisational in nature, concerning both internal and external stakeholders. A conscious and purposeful effort to engage with essential stakeholders from the early initiation stages (including residents to prevent the NIMBY effect) can pay dividends to the overall collaborative process and increase the chances of diminishing misconceptions or potential delays. Also, identifying potential bottlenecks in the enrolment of new technologies could prevent delays, and external expertise should be consulted to ensure sound compatibility of components and compliance with the electricity network, especially when tendering. These procurement processes should not be underestimated, as the pilots show these can be complicated and take longer than expected. It is a benefit that the iEMS is based on open-source software, which makes it more likely that an asset can be connected to the iEMS. Additionally, an inventory of potentially relevant legislation or policies, such as subsidies, helps to create the landscape in which the pilot is going to be designed. Subsidy schemes often have a set of strict criteria and conditions to determine if an initiative is eligible. The iEMS could be utilised as a tool in support of providing data when required.

Although, on the one hand, partners may be able to find common ground through the governmental or strategic ambitions and targets, commercial or responsibility-related interests can impact the effectiveness of the iEMS. For example, commercial partners may not be willing to put constraints on their assets controlled by the iEMS. A municipality does not have incentive tools to 'force' companies to put constraints on assets, so one may conclude that the more fragmented the ownership of the assets connected to the iEMS is, the more difficult it becomes to (agree on how to) manage the rules of the system. The redistribution of savings among the participating partners could be a way for partners to provide more control over their assets by the iEMS.

Responsibilities assigned to different authoritative bodies or internal departments can mean they feel the need to prioritise these interests or may not have the knowledge or information available to understand the scope of the decisions at hand fully. This could also be seen with DNOs being preoccupied with solving net congestion problems and concluding they did not have time and resources to participate in innovation projects while these initiatives are developed to help prevent net congestion simultaneously.

Bottlenecks in the process should always be expected. It can be beneficial to define a means or platform where such bottlenecks can be discussed to find a way forward or engage with cities (or other initiators) of similar projects to exchange information and experiences.

The steep energy prices increase in 2021, continuing in 2022, causes companies to rely on purchased stock at lower prices over cold ironing installations as it is a more economical choice. The municipality does have the power to ban the use of diesel generators in the harbour, but in the short term, the shipping companies might seek an alternative location.

Data privacy for users of vehicles turned out not to be an issue as the users could not be linked. However, if the iEMS is being used in an even more sophisticated way, with users being able to provide input for timed charging, data should be handled with care and comply with the applicable legislation and regulations.

Covid was an unforeseen event that caused the loss of a partner in the project due to significantly reduced revenues and various delays due to supply chain issues and lockdown measures.

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