CLEANMOBILENERGY

A Smart Energy Management System Integrating Renewable Energy and Electric Vehicles

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Abstract— The project CleanMobilEnergy integrates various renewable energy sources, storage devices, electric vehicles and optimisation of energy consumption through one unique smart energy management system. The development of this intelligent Energy Management System (iEMS) will increase the economic value of renewable energy and significantly reduce CO2 emissions. The iEMS will assure the smart integration through interoperability based on open standards for data flows and analysis tools.

CleanMobilEnergy makes it possible for renewable energy sources to be used locally, so electric vehicles can be charged with 100 % renewable energy offered at an optimum price. Electrical energy from the grid will only be required when prices are low or renewable energy sources are not available, the iEMS monitors and optimises the system 24hours a day, 7 days a week.

One generic transnational iEMS will be adapted to the 4 specific city pilots in Arnhem, London, Schwäbisch Gmünd and Nottingham. These pilots range from small towns to large cities. The 4 city pilots cover different types of renewable energy, storage and electric vehicles as well as different contexts and diverse city environments.

Keywords-component; energy storage, energy management system, charging, renewable energy

I. INTRODUCTION

The EU‘s 2030 Framework for climate and energy sets targets for cutting 40% of CO2 emissions, increasing the share of renewable energy to > 27% and > 27% energy savings. With an integrated approach CleanMobilEnergy contributes to reaching the target for CO2-reduction as well as the share of renewables. Currently, cities are increasingly investing in a CO2-neutral urban future by developing new renewable energy resources (RES). However, these RES are not being used efficiently. RES production peaks during daytime while cities' energy consumption peaks in the evening and nights (charging of EV's). Due to this mismatch RES-installations are disconnected from grid or renewable energy is sold under cost price (undermining RES-business cases). This results in unprofitable or suboptimal RES-businesscases, continued use of carbon intensive energy and unnecessary high CO2 emissions.At the same time, cities are investing in charging infrastructure for EV's. This boosts market uptake of electrical vehicles (EV's) which is now accelerating, strongly increasing the demand for electricity: Charging an EV doubles the average energy consumption of a household! Since charging mainly takes place in the evening (when RES supply is low and electricity is carbon intensive) this strongly increase CO2-emissions.The goal of CleanMobilEnergy is to design an integrated solution that resolves the mismatch between consumption and renewable energy-production in such a way that GHG-emissions are minimised, businesscases for RES are more profitable (and attractive for roll-out to other cities), and the expanding EV-fleet charged with 100% renewable energy. Partners are installing a wide range of storage means and are jointly developing an integrated energy management system to controll energy streams between RES, storage and charging.

II *USE OF RENEWABLES AND CHARGING INFRASTRCUTURE*

At this moment renewable energy sources (RES) such as solar plants and wind farms are usually connected to the grid and operate autonomously. Only on a smaller scale (households, parking area's) charging cars (EV's) and RES is combined.

Both solar energy and wind energy have a time dependent production curve, which does not usually overlap with the needed energy. At some moments solar fields are disconnected from the grid because of a low demand. The same goes for wind farms. When at a later time energy consumption peaks, energy from fossil fuel sources is used (local energy mix, which in the Netherlands consists of 39 % Natural Gas, 15 % Coal, 38 % Oil, and 6 % others, renewable energy is only 6 % in 2015).

One category of consumers is our EV fleet. In the Netherlands this is a rapidly growing market (128.000 cars in july 2018). The charging infrastructure needed is also growing and is usually connected to the grid as well (35000 charging points in 2018 and 1000 fast charging points).

III *MISALIGNMENT OF DEMAND AND PRODUCTION*

Electric vehicles and solar technologies are reaching market matureness. However we see cities (amongst others local governments, grid and charging point operators) struggling with the development of charging infrastructure, its organisation and financing. The largest challenge encountered is how to arrange integration at a larger scale in and around the city. Growth in solar renewable energy in the city creates an energy production peak between 10 and 16 hours, the overall energy demand peaks of a city are between 7-9 in the morning and 17-20 in the afternoon/evening.

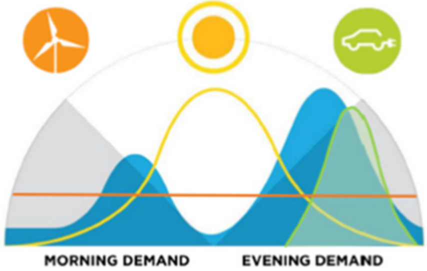

Figure 2: 'Peak shaving' of morning- and evening energy demand.

The CleanMobilEnergy project addresses the need for combined electric mobility and renewables, facilitated by ICT at different city scales and city environments. The four participating city pilots are all executing various initiatives, demonstrating how the two sectors, energy and mobility can enforce instead of blocking each other. Another important element introduced to realise the CleanMobilEnergy goals is energy storage.

We already observe the impact of these mismatches in different cities, not being able to electrify their bus fleet or limiting the EV charging area or intensity. Also, the electricity grid faces problems in not-so-well connected areas. On top of this, we observe a rapid growth in electricity substituting gas or other fossil fuel in (North West) Europe.

These problems will aggravate rapidly if we do not act now and invest in our future, especially zero-emission mobility, clean energy, smart storage (in EVs and 2nd life batteries) flexible energy usage. Europe cannot afford to extend the electricity grids (expensive infrastructure) to satisfy the energy demand at peak moments. These peaks require extra energy for a few hours a day during a couple of months a year. When cities cannot adapt to the flexibility of clean energy sources their capability to become CO2 neutral is impossible, maintaining a huge fossil fuel dependence.

In order to face these challenges a series of technologies are available, but only implemented limited and fragmented. Smart electric vehicle charging is emerging, as well as bi-directional usage of batteries in EVs (V2G) the storage market (both electricity and heat) is in fast development and flexible demand initiatives are more and more present in daily life. However technology integrating multiple services (mobility, electricity and heat) devices (EVs, solar panels, e-boilers) working beyond building and organisations borders at neighbourhood level or beyond is absent.

VI *SOLUTION PROPOSED BY CME*

As said much of the technology for this new approach of 'smart balancing' exists, but is fragmented: there are different types of storage solutions (2nd life car batteries, modular power cells, EV's and neighbourhood batteries). There are Energy Management Systems in use with which optimise energy flows for their specific devices. But systems covering the overall energy analysis at neighbourhood scale are necessary. For a residential neighbourhood the energy flow through the day is completely different from an industrial, university or centre neighbourhood. Smart charging intervention pilots showed the need to know all electricity demands real-time before sensible interventions are possible. However, a comprehensive technical approach that integrates an (open architecture) EMS, EVs and local storage solutions does not yet exist. Within CME, these different components are integrated into one intelligent system, the so-called interoperable Energy Management System (iEMS). The iEMS of CME introduces a system that integrates existing but fragmented solutions for this, based on (predictions of) energy & mobility flows. The City Pilots in CleanMobilEnergy go beyond the existing situation. The iEMS will be developed, piloted, combining RES, mobility and storage functions in real-life conditions to explore different combinations of usage, on-site RES production, storage & distribution technology and energy use.

CME will learn from and improve this integrated system in situations with different user groups, supply and demand patterns, regulatory systems and energy markets.

V *FOUR CITY PILOTS*

The cities in CME are ranging from small size towns to large cities, installing different components for renewable energy production, storage and charging of EV's and connecting these components through the iEMS. These pilots are chosen to represent a wide range of city sizes and environments (such as residential, industrial areas and controlled environments such as city depots). They utilise different storage media (modular battery system, new batteries, second life batteries and car batteries). These environments and storage media are representative for NWE and are easily replicated to other cities across NWE. The 4 pilots:

1. Schwäbisch Gmünd: small city, small RE production and storage facilities in residential area;

2. Arnhem: medium size city, large RE production, large storage in industrial area;

3. Nottingham: medium size city, large RE production, medium size storage (EV's) in controlled area (depot);

4. London: large city, large RE production at multiple locations and large storage in controlled areas with separate grid (depot).

The 4 pilots will be implemented in parallel, coordinated through the activities by the London partner TFL. In the 1st phase implementation plans have been made. In the 2nd phase, components will be installed and operated on standard practice for ~1 year to provide validated detailed baseline energy & environmental data. In the second phase also the iEMS developed is integrated into operational city pilots. The 3rd phase consists of operating and monitoring performance (including CO2 reductions) of the combined system. This will be done by TfL, Arnhem, EIFI and Nottingham. IAU Ile de France will develop business cases and work to monitor and influence end user behaviour. Evaluating the rules to decide where power is directed (iEMS rules) is crucial in this project.

Schwäbisch Gmünd (D)

The increasing discrepancy between the feed-in tariff and the PV electricity production costs will lead to a further reduction in the cost-effective PV system size with higher self-consumption shares. On the basis of these cost estimates, the lowest average electricity costs with a PV output of 0.6 kWp / MWh are obtained in the medium term. This could lead to a self-consumption ratio of 40% and an autonomous gain of 25%. The pilot will offer the possibility of a holistic application. The generated in-house energy is transportable, i. e. the consumer is not tied to the pure use in a battery store, but can use it individually, for example in his household applications such as an e-bike to drive to work or a cargo pedelecs for commercial deliveries. The pilot will install a total of 42 kWh battery storage. Combined with 20kWp installed PV in total. To do so, there will be LEV infrastructure at the Pilots as well as identified charging points across the city these will allow charging for the cities LEVs (concentrating on the “last mile”). The identified charging points are linked to the existing national project EMiS - Electric mobility in Stauferland - Integrated in urban development and climate protection. The results of this Pilot will be transferred into the EMiS project.

The aim of the Pilot in Schwäbisch_Gmünd is to link the CME project with the district of Hardt to a sustainable mobile district. The project is thus an ideal complement to the development plans within the framework of the EUROPAN competition. In the project on the Hardt, first in close proximity to the location iLive – Young living on the “Sonnenhügel” - Sharing offers in the form of (E-) Carsharing and PedelecSharing. This will further expand the city's car-sharing offer and more over the last mile solution. In doing so it will be more feasible to attract and use more e-vehicles. At the same time, one of the two existing pedelec stations is to be retrofitted for a fully automatic rental system at the station in order to function as a counterpart to the rental station on the Sonnenhügel (climate protection concept V1 and V2). Further, one additional station will be build. The rental system will dock at the existing and future bicycle and pedelec rental stations in the city and region of Stuttgart and will thus be fully compatible. This also provides the basis for a pedelec-based mobility solution during the Remstal Garden Show 2019.

The City Pilot consists of:

• PV installation and battery storage. These are linked to the iEMS. Each unit will include 8,4 kWh, connected to the installed PV, focused on charging LEVs

• Charging and exchange stations for batteries serve as a temporary storage and are integrated in the electricity grid

• Analysis of data usage and electricity flows, etc.to support balancing;

• Establishment of a lease and rent LEV infrastructure with integrated LEV and battery exchange stations, parking management, etc.;

• Use of smart battery storage system for grid regulation

The integration of light-electric vehicles in an autarchic energy management of a city:

• The use of an interoperable, smart and scaleable battery system as a stationary and mobile storage

• Installation of battery exchange stations which also serve as a temporary storage and integrated into the electricity grid

• Focusing on light-electric vehicles for short distances of 10-25km.

The iEMS implementation in Schwäbisch Gmünd will focus at high level of energy autonomy at small city scale, distributed devices over the municipality, various solar installations, LEV-charginginfrastructure & buildings where energy is consumed & stored.

Arnhem (NL)

The project location for the Arnhem investment is located in an industrial area, where a solar field will be realized (10 MWp) , and in the near future 4 wind turbines.

The solar field is not part of the investements, but will be the only provider of renewable energy to this pilot. Connected to the solar field, partners will jointly develop:

- A innovative storage facility of 500 kWh, including all hardware (cables, small buildings etc.)

- A cold ironing (shore to ship power supply) installation for 18 river barges in the Nieuwe Haven;

- A charging plazas with for 40 passenger cars and taxis;

- A CME-system location (computer plus software) to govern energy flows.

The CME energy management system for implementation in Arnhem is developed jointly within the CME consortium. In parallel the Arnhem the City Pilot is designed and a functional and a technical specifications document are made. This is all done in close cooperation with all regional stakeholders and the WPT1 (iEMS) and WP Implemetation city pilots leaders. This process is executed within the city, building on the transnational CME system and providing feedback at both local and transnational level.

Based upon the specification documents the system is installed, including a settings and dashboard for individual and overall decision making and setting of rules, a forecasting module on expected generation and the connections with the Arnhem connected devices.

Stationary storage will be connected to the EV charging station, solar field and dock the incorporation of the energy management system. The use of renewable energy for mobility and ships will be optimized. This represents an important saving in CO2 emissions, in comparison with the default electricity consumption by EVs and diesel generators in the boats.

Arnhem has a target to realize 5 solar fields by 2020. CME results will be used to implement storage, EV charging and the iEMS in combination with these fields in the next 5 years.

Nottingham (UK)

The City Pilot will take place at Nottingham City Council's Eastcroft Depot. This is the largest of NCC's operational sites and is located to the South East of the City. The site briefly comprises of: a number of office buildings, waste transfer station, materials storage, salt dome, vehicle wash and refuelling, vehicle test centre, and fleet parking including refuse lorries, vans, minibuses and pool cars, as well as some employee parking.

The project is planning to reserve an area of the site to house a number of pieces of equipment to be tested through the pilot. The equipment to be installed is as follows:

- 40 battery electric V2G compatible vans and cars. These vehicles will be managed by NCC Parking, Fleet and Transport teams and operated by various departments within the Council. The vehicles will be based overnight at Eastcroft Depot

- Up to 40 V2G bi-directional charging units to enable the vehicles to be used for energy storage and grid balancing services

- Installation of a minimum of 88kW of solar PV on the Tamar Building at Eastcroft Depot, an office building used by NCC's Parking and Fleet teams

- Procurement and installation of a 378kW/676kWh lithium Ion battery, to store and distribute excess renewable energy generated by the PV system

- Flow of energy between the components above will be controlled by a purpose built 'Interoperable Energy Management System' (iEMS). This element of the project will be led by a European project partner (LIST) with NCC shaping the output and making a financial contribution through the wider

CleanMobilEnergy project

Figure 5: Indicative location of project equipment at NCC's Eastcroft Depot, including Electric Vehicles, V2G charging units, Solar PV and large scale stationary battery.

The aim of the project is to develop and test the iEMS, with the following objectives:

- Maximise use of locally generated renewable energy in office buildings and when charging ULEVs in order to reduce running costs and carbon emissions

- Reduce grid peak demand by using vehicles for short-term storage, feeding residual charge back into the grid as required

- Explore other financial benefits associated with large scale and aggregated battery storage, including maximising time of use rates, sale of electricity back to the grid, avoiding demand charges, participating in demand response programmes. The project will also help to reduce air pollution in the city, by moving away from fossil fuel use and support the Council's ambition to become a self-sufficient energy city.

London (UK)

The London pilot will build on TfL's own programme of PV installation at its buildings, large and small, around the city, ReFit. This will be linked with use of TfL's own private city wide AC electricity grid. This grid provides the power for the London Underground rail system and is built and maintained to far higher standard of reliability than the national grid.

The pilot will be delivered at one of its very large railways engineering workshops at Acton in west London Acton REW). The site will be equipped with:

- Up to 1.5MW peak generating capacity of PV.
- Battery storage (optimum size to be determined).
- Up to 20 V2G bi-directional charging units installed though the Innovate UK funded EFlex project.
- V2G capable vehicles from the TfL support fleet.
- A comprehensive Building Management System.
- Connection to the national electricity grid.
- Connection to the TfL private AC grid.

Connections, which will ultimately be managed by the iEMS, will be made between the all of the systems listed above. Once operational the iEMS will be required to balance the supply and demand of all these systems to maximise use of the renewable energy while ensuring all users have a reliable and consistent energy supply. In particular there will be a focus on delivery of cost effective energy supplies with a strong consideration of how future large scale renewable energy sources can effectively be used in managing TfL's energy demands. Initial considerations indicate there may be a role for such systems in managing the peaks and troughs in TfL's daily electricity demands.

Economic decision making will also be a key requirement of the London implementation of the iEMS. Although it is expected the most beneficial use of any surplus electricity will be to feed it into TfL grid to offset electricity purchase there will be a requirement for active decision making of the relative merits of this use against resale of electricity and participation in demand response markets.

The project ultimately contributes to TfLs strategic objectives to decarbonise London's transport networks and the Mayor's goals

of a zero carbon city by 2050.

Acton Railway Engineering Workshop London: one of the pilot sites

__VI DEVELOPMENT OF INTEGRATED ENERGY MANAGEMENT SYSTEM__

CleanMobilEnergy will develop a transnational interoperable integrated Energy Management System (iEMS) that predicts, measures and allocates energy and resources intelligently in cities to decrease CO2 emissions, maximize renewables uptake and allow cost efficiency. Together with partner cities and local stakeholders the iEMS will be designed and developed through

transnational workshops on requirements and specifications for the city pilots to make optimal use of renewables energy, eMobility and storage in cities and reduce carbon emissions by replacing fossil fuels effectively and intelligently. During workshops and development phases cities and stakeholders will shape the iEMS to better integrate economic, social and environmental benefits and looks at the trade-off.

The main objective is to equip cities with the iEMS connecting to all local Energy Management Systems, enhancing them with functionalities for intelligent renewable usage and emission reduction.

Development of this iEMS will have 4 main phases:

Phase 1: Functionalities for the iEMs are determined according to the cities' and stakeholders' requirements and the need for replication and up-scaling to other European cities. This phase is lead by the cities. Knowledge institutes will provide inputs to assure technical feasibility and innovation.

Phase 2: The architecture and functionalities for the iEMS will be designed, based on existing systems and knowledge to avoid replication and ensure the applicability of the iEMS to all city pilots. The designing phase will be concluded by a transnational procurement for the development of the iEMS.

Phase 3: During the development and implementation phase LIST and the City Partners will work with the core system provider on the iEMS to ensure interoperability and transnationality.

Phase 4: During a testing, improvement and monitoring phase where the city pilots in WPT2 will provide the operational test beds and monitoring case studies: therefor 42 months are needed

__VII MONITORING AND RESULTS__

At the start of CME a baseline for all pilots will be established by IAU Ile de France, so that the project results can be referenced. CleanMobilEnergy will result in a reduction of CO_2 emissions which are quantified below for each location:

-Arnhem provides 100% RES to EVs (220 ton/yr)+ docked ships optimizing solar energy yield (740 ton/yr).

-Nottingham leverages solar energy + V2G in a grid-constrained area (330 ton/yr)+ 2 depots using 100% RES (175 ton/yr).

-Schwäbisch Gmünd houses use innovative batteries (105ton/yr), fuelling 50 electric bikes (100ton/yr).

-London:100% RES for 50 EVs (530 ton/yr)+ 2 depots (200 ton/yr): 730 ton/yr.

Total CO2-reduction in 2021 will be 2400 ton/yr. Additionally the project will yield extra renewable energy production of 12,4 MW.

Project Partner IAU Ile de France will also monitor the four pilots and calculate the CO_2 reduction achieved.

More information on
http://www.nweurope.eu/cleanmobilenergy