KPI results - baselines and final results

capturing the baselines and final measurements to report the KPI results on OPs and project lev

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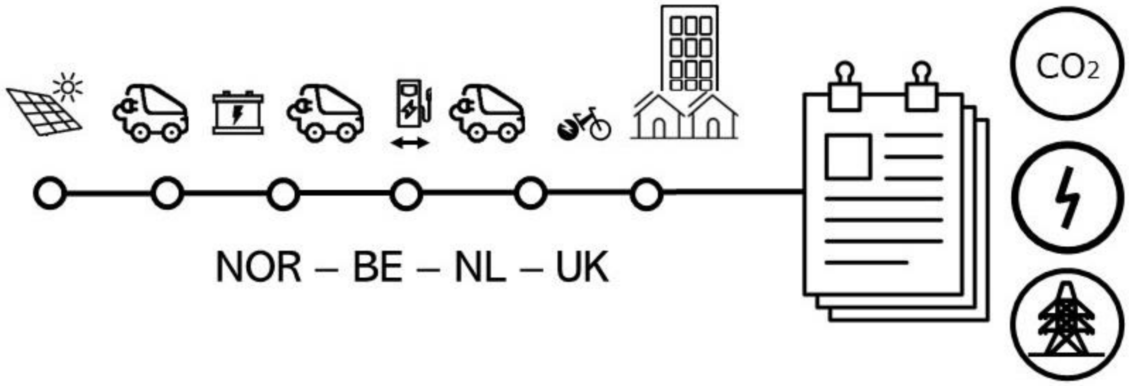
KPI Results - Baselines and Final Results



Capturing the baselines and final measurements to report the KPI results on OPs and project level

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With additional contributions from all SEEV4-City pilot partners.

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Executive Summary

SEEV4-City is an innovation project funded by the European Union Interreg North Sea Region Programme. Its main objective is to demonstrate smart electric mobility and integration of renewable energy solutions and share the learnings gained. The project reports on the results of six Operational Pilots (OPs) which have different scales and are located in five different cities in four different countries in the North Sea Region.

Loughborough OP (United Kingdom) is the smallest pilot, being a household with a bi-directional EV charging unit for the Nissan Leaf, a stationary battery, and a PV system. In the Kortrijk OP (Belgium), a battery system and a bi-directional charging unit for the delivery van (as well as a smart charging station for ebikes) were added to the energy system. In Leicester (United Kingdom), five unidirectional charging units were to be accompanied by four bi-directional charging units. The Johan Cruyff Arena OP is a larger pilot in Amsterdam, with a 2.8 MWh (partly) second life stationary battery storage for Frequency Control Regulation services and back-up power, 14 fast chargers and one bi-directional charger. Integrated into the existing energy system is a 1 MW PV system that is already installed on the roof. In the Oslo OP, 102 chargers were installed, of which two are fast chargers. A stationary battery energy storage system (BESS) supports the charging infrastructure and is used for peak shaving. The FlexPower OP in Amsterdam is the largest OP with over 900 EV charging outlets across the city, providing smart charging capable of reducing the energy peak demand in the evening.

Before the start of the project, three Key Performance Indicators (KPIs) were determined:

A. Estimated CO_2 reduction
B. Estimated increase in energy autonomy
C. Estimated Savings from Grid Investment Deferral

For each of these KPIs, a target and a baseline were set for each OP as well as the project overall. The end measurements are compared to the baseline and the results are shown in the table below.

Key Performance Indicator	Target	Results
Estimated CO_2 reduction	150 tonnes CO_2 annually	2786 tonnes CO_2 annually*
Estimated increase in energy autonomy	25% increase	2% increase*
Estimated Saving from Grid Investment Deferral	More than €100 million	Replaced by peak demand reduction

*Note: includes pilot results from partial simulation

The project exceeded its CO_2 reduction target, mainly thanks to the Frequency Control Regulation (FCR) services by of the Johan Cruyff Arena stationary battery storage (BESS) and the replacement of internal combustion engine vehicles by electric vehicles (all OPs) using the implemented solutions.

The combined Energy autonomy across the project increased slightly, although not as much as targeted. With 2%, the increase in energy autonomy was less than anticipated, largely because initial plans changed, and some OPs did not install (additional) new renewable energy sources. Another reason is that the V2X technology is not mature and still (too) expensive, so it was not possible to utilise the technology to its full potential. At the moment, there are little to no financial incentives to increase energy autonomy for the smaller pilots; additionally, other services such as FCR generate more revenue.

To calculate the potential deferred in grid investment, the project group needed to have access to the actual costs made by DNOs, but this proved to be too difficult, as it relates to sensitive commercial/financial data. Therefore, the project team decided to use the pilot's peak demand reduction instead, which gives a good representation of grid investment deferral. Ballpark calculations for the Netherlands suggest that upscaling these technologies over the next 10 years could defer €172 million in grid investments.

Delays in procurements due to Covid-19 and (internal) organisational processes, meant that some results do include simulated results using the available data.

Table of Contents

EXECUTIVE SUMMARY 2

GLOSSARY 5

1. INTRODUCTION 6

2. OPERATIONAL PILOT RESULTS 9

2.1. Loughborough OP: Single household 9
2.1.1. Baseline and Final Measurements values 11
2.1.2. Operational Pilot – Key Performance Indicator results 12

2.2. Kortrijk OP: City Depot and Sport Centre 13
2.2.1. Baseline and Final Measurement Values 15
2.2.2. Operational Pilot – Key Performance Indicator results 16

2.3. Leicester OP: City Hall 17
2.3.1. Baseline and Final Measurement Values 19
2.3.1. Operational Pilot – Key Performance Indicator results 20

2.4. Amsterdam Stadium OP: Johan Cruyff ArenA 21
2.4.1. Baseline and Final Measurement Values 23
2.4.2. Operational Pilot – Key Performance Indicator results 24

2.5. Oslo OP: Vulkan parking garage 25
2.5.1. Baseline and Final Measurement Values 27
2.5.2. Operational Pilot – Key Performance Indicator results 28

2.6. Amsterdam City OP: FlexPower 29
2.6.1. Baseline and Final Measurement Values 31
2.6.2. Operational Pilot – Key Performance Indicator results 32

3. SEEV4-CITY PROJECT RESULTS 33

3.1. KPI A: CO_2 reduction 34

3.2. KPI B: Energy Autonomy increase 35

3.3. KPI C: Grid investment deferral 36

4. CONCLUSIONS RELATED TO THE KPIS 38

REFERENCES 40

Glossary

Term	Definition
BSS	Battery storage system
CO_2	Carbon di-oxide. When using the CO_2 reference in this report it refers to all Greenhouse Gases (GHG). It is common practice to express the extent of any GHG in its CO_2 equivalent (CO_2eq).
DNO	Distribution network operators (a term traditionally used in UK) are the operating managers (and sometimes owners) of energy distribution networks.
DSO	Distribution system operators (a term used across Europe) are the operating managers (and sometimes owners) of energy distribution networks. More capable of managing the increasingly complex interrelationships on the network than DNOs.
EV	Electric Vehicle – Plug-in Hybrid or Battery Electric Vehicle.
FCR	Frequency containment reserve – The aim of FCR is to stabilise frequency disturbances in the grid, regardless of the cause and location of disruptions.
ICE	Internal Combustion Engines (using fossil fuel)
KPI	Key Performance Indicator – a means to measure and quantify the achievement of key desired results.
NSR	North Sea Region of Europe
OP	Operational Pilot
PV	Photovoltaic energy generation with solar panels. For the purpose of SEEV4-City, where we use the term PV, in fact all forms of RE sources can be used in its place.
RE	Renewable Energy, sustainable and clean energy such as solar, wind, hydro.
SEEV4-City	Project abbreviation: Smart, clean Energy and Electric Vehicles for the City.
SC	Smart Charging - The application of smart technology solutions that enable flexible approaches to EV charging for the purpose of achieving desired objectives for key stakeholders.
V2B	Vehicle-to-Building, bi-directional charging technology where energy can flow in both directions between vehicle and buildings such as offices, sports facilities, factory etc.
V2G	Vehicle-to-Grid, bi-directional charging technology where energy can flow in both directions between vehicle and the energy grid.
V2H	Vehicle-to-Home, bi-directional charging technology where energy can flow in both directions between vehicle and a home.
V2X	Vehicle-to-X, a collective term for all variations of bi-directional charging technology such as V2H, V2B and V2G.
V4ES	(electric) Vehicle for Energy Services (eV4ES)- Collective or umbrella name for different kinds of (ancillary) Smart Energy Management services that involve EVs such as Smart Charging, V2G and the other services.
ZE km	Zero Emissions or 'green kilometres' for the operational use phase of a vehicle. The ZE km does not take into account emissions from the entire life cycle assessment (LCA) of energy source or vehicle, and is intended as the EV equivalent of 'tailpipe' emissions for ICEs to indicate the number of km that are driven on renewable energy.

1. Introduction

The EU Interreg North Sea Region (NSR) funded project SEEV4-City has as its main objective to demonstrate smart electric mobility solutions, integrating renewable energy sources and encouraging their take-up in cities. The project has six Operational Pilots (OPs) in four different NSR countries. This report is part of a collection of reports published by the project covering a variation of specific and cross-cutting analysis and evaluation perspectives. It documents the comparison between the starting situation (baseline) and the final measurements, to outline the end-results all six OPs. Below an indication of the set of repots is provided, including an indication where this report fits in.

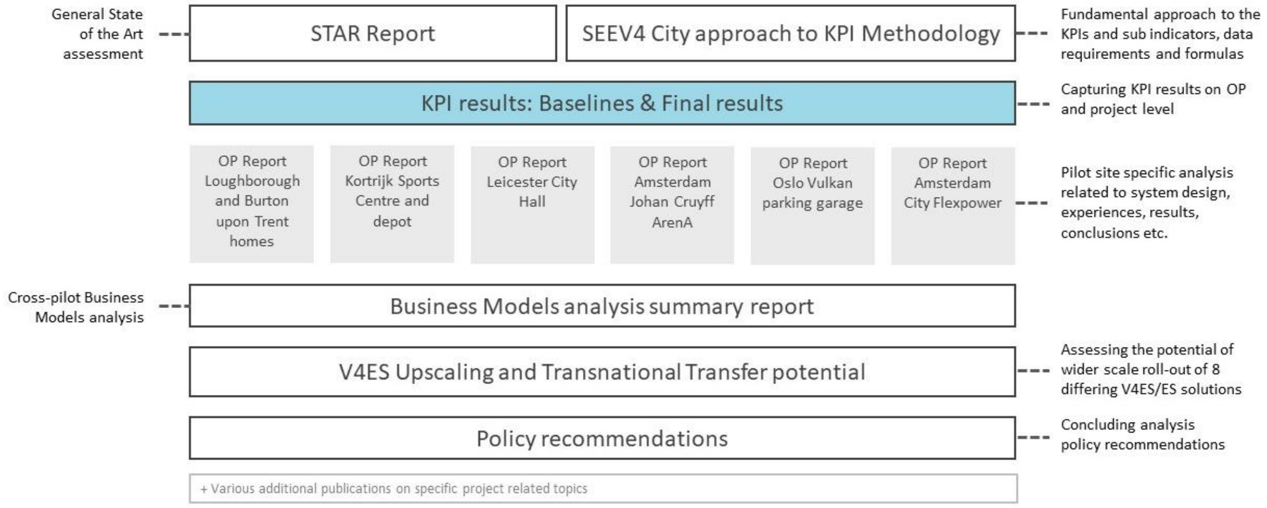

Figure 1 - Deliverable report structure for the SEEV4-city project

The project deliverables include reporting on the results from six OPs regarding contribution to the following three Key Performance Indicators (KPIs):

A. Estimated CO_2 Reduction

This estimated CO_2 Reduction KPI is divided into three different ways of achieving CO_2 reduction: (i) emission savings related to a solution, (ii) internal combustion engine (ICE) vehicle replacement and, (iii) zero-emission kilometres increase.

(i) Emission savings related to a solution are calculated compared to the electricity demand otherwise entirely taken from the grid energy mix. By integrating smart charging solutions and vehicle-for-energy-services (V4ES), the EV charging speed can be reduced or shifted to hours where the energy mix of the grid has a lower CO_2 footprint.

(ii) Existing ICE vehicles can be replaced by their electric equivalent or an electric bike, which have lower CO_2 emissions.

(iii) Lastly, one could increase zero-emission kilometres by increasing EV charging from renewable energy as much as possible.

B. Estimated Increase in Energy Autonomy

For Energy Autonomy, the energy independence of the grid is expressed as a percentage and is approached as follows: Self-sufficiency is the rate of how much of the self-generated renewable energy (RE) is self-consumed compared to the total amount of energy consumed. Self-consumption, however, refers to the rate of how much of the self-generated renewable energy is self-consumed. The percentage of grid independence can be increased by installing renewable energy generation and using stationary battery storage systems to store energy for later use, instead of feeding it back into the grid.

C. Estimated Savings from Grid Investment Deferral

Charging electric vehicles is very demanding for the energy systems and requires sufficient local and central capacity to facilitate this. When the capacity becomes limited due to the increasing number of EVs needing to be charged, the grid capacity may need to be reinforced. However, grid reinforcement is costly. Therefore, using V4ES (including smart charging and V2G) is a better way to reduce the peak demand of the local network, which consequently leads to avoiding expensive grid investments.

Each of the SEEV4-City pilots adopts different system components and has their unique approach within its system boundaries. The six OPs do not use the same combination of features, a selection of an overall set of design components (as visualised in Figure 2) are applied across the OPs albeit in different combinations.

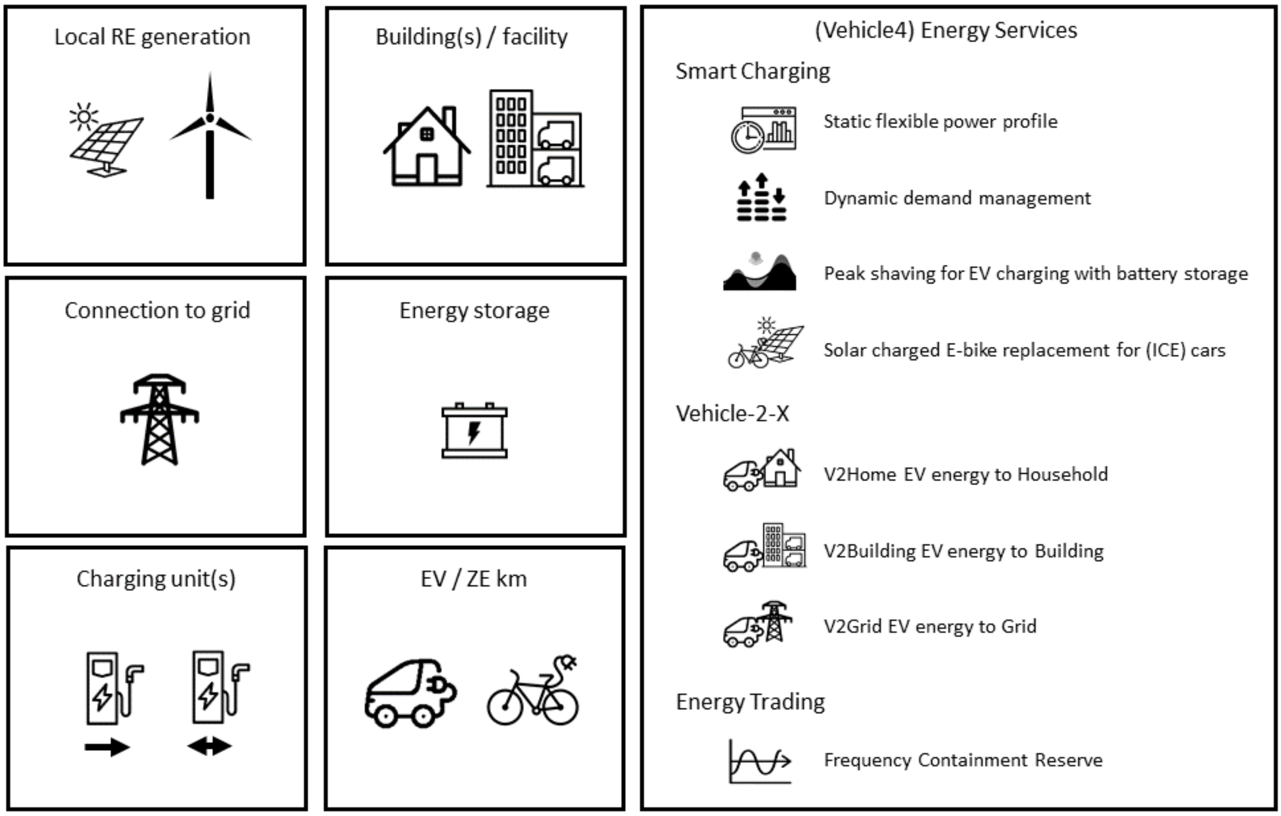

Figure 2 SEEV4-City – Technology Overview – system design components of various managed features used within Operational Pilots boundaries

To create consistency in calculating individual results a KPI Methodology was established through a collaborative exercise between partners of different work packages within the project. See report: 'SEEV4-City's approach for KPI Methodology' for more details regarding the sub-KPIs and corresponding calculation methods.

The KPIs include targets for the individual the individual OPs as well as the project as a whole (Table 1). All targets were set at the start of the project. The KPI targets mentioned in this report are adapted from the Project Management Plan.

Table 1 Key Performance Indicator Project Targets

Key Performance Indicator	Target
Estimated CO_2 reduction	150 tonnes CO_2 annually
Estimated increase in energy autonomy	25% increase
Estimated Saving from Grid Investment Deferral	More than €100 million

Using the agreed KPI methodology, a baseline is captured for each OP. By applying that same KPI methodology, the results (final measurements) are determined at the end of the project. These results allow for a comparison of the baseline and the end-results. After that, the implications of selected technologies and V4ES strategies could be assessed.

This report describes the site-specific context of all OPs in section 2, in terms of what technologies it adopts reflected in a Technology Overview – system design components, followed by a schematic overview of how these technologies interact with each other and ending with a measurements table which includes the baseline, and the end measurement results. In this document, the OP results data obtained from the six pilot reports are harmonised according to the SEEV4-city KPI Methodology approach and may therefore have minor differences.

Note that, when discussing the CO_2 saving results, negative numbers in the measurement tables indicate a reduction in CO_2 emissions, and vice versa. The cumulative effects of all projects together are discussed in section 3, and the conclusions and recommendations follow in section 4.

2. Operational Pilot Results

This chapter outlines a summary description of each of the OPs within the SEEV4-City project, providing a general indication of each OP's local context as background information to the KPI methodology and baseline measurements in this report. More detailed information for each OP is provided and elaborated on in the individual Operational Pilot reports, see https://www.seev4-city.eu/publications/.

2.1. Loughborough OP: Single household

Phase 1: Loughborough

In Loughborough (United Kingdom), a domestic OP was implemented to identify the (possible) added value of smart charging (SC) and vehicle-to-home (V2H), using local PV generation and battery storage for optimised energy management in the household (Figure 3). The energy system consisted of a 4 kilowatt-peak (kWp) photovoltaic (PV) system, a 2 kilowatt-hour (kWh) battery energy storage system (BESS) with a fixed 400 W charge/discharge converter and a 24 kWh Nissan Leaf. The Nissan Leaf has bi-directional charging capabilities and is connected to the mains supply via a bi-directional charger. Cenex UK managed this household-scale pilot. Other stakeholders were Moixa who operates the PV – BESS combination, Viricity working on the EV usage data and Potenza providing the bi-directional charger.

Overview Loughborough	
Number of EVs	1
EV battery size	24 kWh
Est. Average Annual Mileage (per EV)	13,000 km
Total EV Charging units	1
V2X	1
Size of PV/ PV generation	4 kWp (3691 kWh/annum)
Size of static Battery Storage	2 kWh/400 W
Total Annual Energy Consumption	4142 kWh/annum

Phase 2: Burton-upon-Trent

After running for almost a year, several issues arose at the OP location in Loughborough (offline due to construction work, data issues of customised system and the homeowner moving to a new house). Therefore, a new but comparable location was sought and found. In the fall of 2019, this OP continued in Burton-upon-Trent with a similar arrangement as the Loughborough pilot and was considered as a second phase of the Loughborough OP. Moixa installed A PV system of 3.864 kWp with a 3 kWh BSS, which has improved efficiency and is capable of 760 W charge/discharge on a variable power rate. A 2018 Nissan Leaf (40 kWh) was used, which is a newer type compared to the initial OP in Loughborough. The vehicle connects to the grid for Vehicle-2-Grid operations instead of a fully integrated V2H arrangement. Cenex UK managed the OP and Moixa operated the PV – Battery system. OVO Energy provided the Bi-directional charger and the aggregated V2G service.

Overview Burton-upon-Trent	
Number of EVs	1
EV battery size	40 kWh
Est. Average Annual Mileage (per EV)	13,000 km
Total EV Charging units	1
V2X	1
Size of PV/ PV generation	3.860 kWp
Size of Battery Storage	3 kWh/760 W
Total Annual Energy Consumption	4142 kWh/annum

A technology overview (Figure 3) illustrates what technologies and services take place at both Loughborough and Burton-upon-Trent.

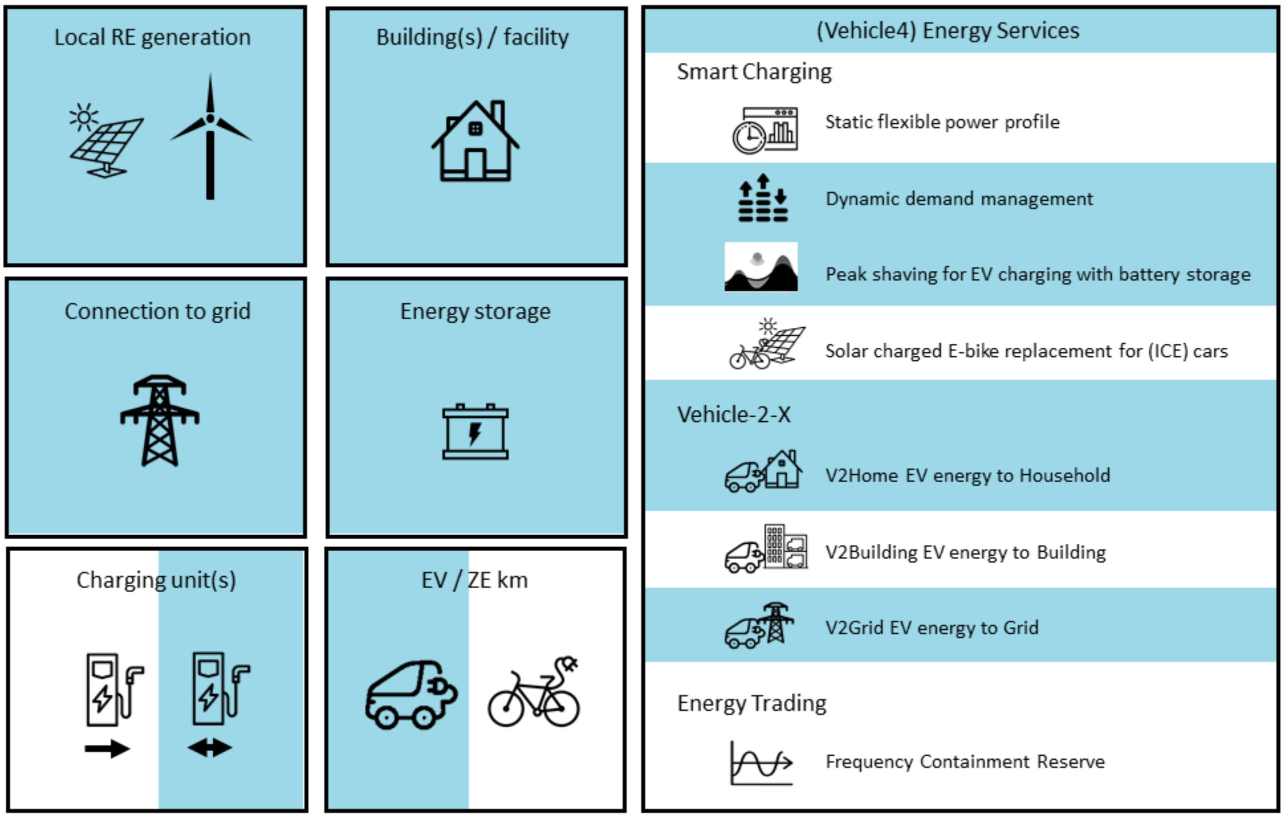

Figure 3 Technology Overview – system design components Loughborough OP/Burton-upon-Trent

A simplified schematic overview of the Loughborough/Burton-upon-Trent pilot is provided in Figure 4 Schematic overview of the Loughborough OP, which illustrated the relations between each component of the pilot.

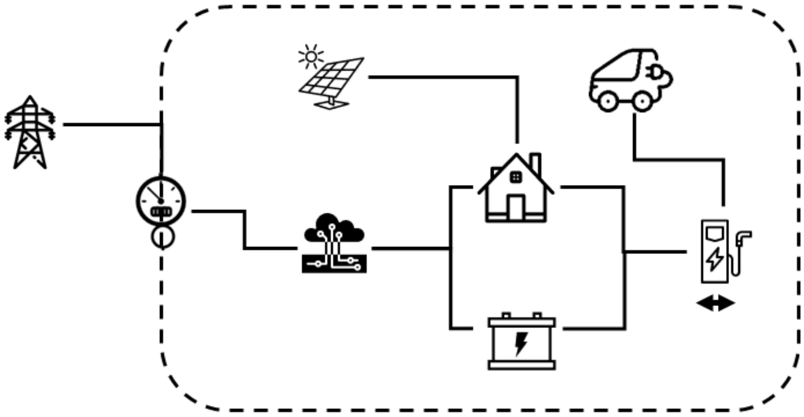

Figure 4 Schematic overview of the Loughborough OP

The targets for the Loughborough OP were determined before the project start and are indicated in Table 2.

Table 2 Targets for the Loughborough OP

KPI		*Targets for the OP*
A	CO_2 Reduction	2 – 5 tonnes yearly
		(sub-KPI) ZE km Increase factor: 2.4
B	Energy Autonomy Increase	From 37 to 72% → Δ +35

2.1.1. Baseline and Final Measurements values

Table 3 Baseline and Final Measurements for the Loughborough OP [1]

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
A. CO_2 Reduction				
A.1	Pilot CO_2 footprint	2.04 tonnes	1.00 tonnes	-1.04 tonnes
A.1.1	CO_2 related to baseline demand	1.63 tonnes	1.51 tonnes	-0.12 tonnes
A.1.2	CO_2 related to use of battery: EV	0	0.22	0.22
A.1.2.1	CO_2 related to use of battery: Ebikes	N/A	N/A	N/A
A.1.3	CO_2 related to use of battery: BSS	0	0	0
A.1.4	CO_2 savings by PV production	-0.85	-0.85	0
A.1.5	ICE replacement CO_2 savings (EV)	1.26	0.12 tonnes	-1.14 tonnes
A.1.5.1	ICE replacement CO2 savings (Ebike)	N/A	N/A	N/A
A.1.6	Zero Emission kilometres increase (EV)	0	3,478	3,478
A.1.6.1	Zero Emission kilometres increase (Ebike)	N/A	N/A	N/A
A.2	Grid Services	N/A	N/A	N/A
A.2.1	FCR – Frequency Containment Reserve	N/A	N/A	N/A
A.2.2	Battery as back-up services (replacement of diesel generators)	N/A	N/A	N/A

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
B. Energy Autonomy Increase				
B.1	Self Sufficiency	25.0%	30.1%	5.1% point increase
B.2	Self Consumption	48%	65%	17%
B.3	PV to Baseline Demand	1.6	1.5	-0.1
B.4	PV to EV	0.0	0.4	0.4
B.4.1	PV to Ebike	N/A	N/A	N/A
B.5	PV to BSS	0.0	0.2	0.2
B.6	PV to Grid	1.8	1.1	-0.6

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
C. Grid Investment Deferral				
C.1	Peak Demand Value			-12,3%*

* Simulated results

2.1.2. Operational Pilot – Key Performance Indicator results

In the initial stage, the baseline was logged to enable a comparison with the situation where new components are integrated within the pilot's energy system. By using this comparison, the impact of the new configuration was assessed. The results (Table 4) of this pilot shows 1.04 tonnes of CO_2 reduction on an annual basis. Energy autonomy increased by 5,1% and the operational costs were reduced by £188. The Loughborough OP did not fully reach the initial targets; however, the new energy system improved the situation on all levels.

Table 4 Targets and Results for the Loughborough OP [1]

KPI		***Target for the OP***	***Results for the OP***
A	CO_2 Reduction	2 – 5 tonnes yearly	1.04 tonnes
		(sub-KPI) ZE km Increase factor: 2.4	
B	Energy Autonomy Increase	From 37 to 72% → Δ +35%	5.1% increase

2.2. Kortrijk OP: City Depot and Sport Centre

Overview Kortrijk OP	
Number of EVs	1
Number of E-bikes	3 (0.5 kWh each)
Total EV Charging units	1
V2X	1
Size of PV/ PV generation	78.75 kWp
Battery storage	6 kWh
EMS	Self-developed, python-based

In Kortrijk (Flanders, Belgium), an OP ran at the city's technical services depot, adjacent to a sports centre also operated by the city. This commercial-scale OP has a PV system that currently covers about 30% of the total energy consumption of the site with a power of 78.75 kWp and was installed before the SEEV4-City pilot's starting point. One uni-directional EV charging point is operational for a full electric postal delivery van (Nissan e-NV200).

Katholieke Universiteit Leuven (KUL) developed the smart energy system for the city depot of Kortrijk for a temporary implementation at the city depot of Kortrijk (Figure 5). A self-developed Python-based EMS system with algorithms for optimisation purposes monitors and controls a BSS of 6 kWh. The Nissan e-NV200 was used for bi-directional charging in the form of vehicle-to-building (V2B). The bi-directional charger was supplied by eNovates and programmed by the KUL. Three E-bikes complement the energy system with a smart charging station, each having a capacity of 0.5 kWh.

A technology overview (Figure 5) illustrates what technologies and services took place at the city depot and sports centre of Kortrijk.

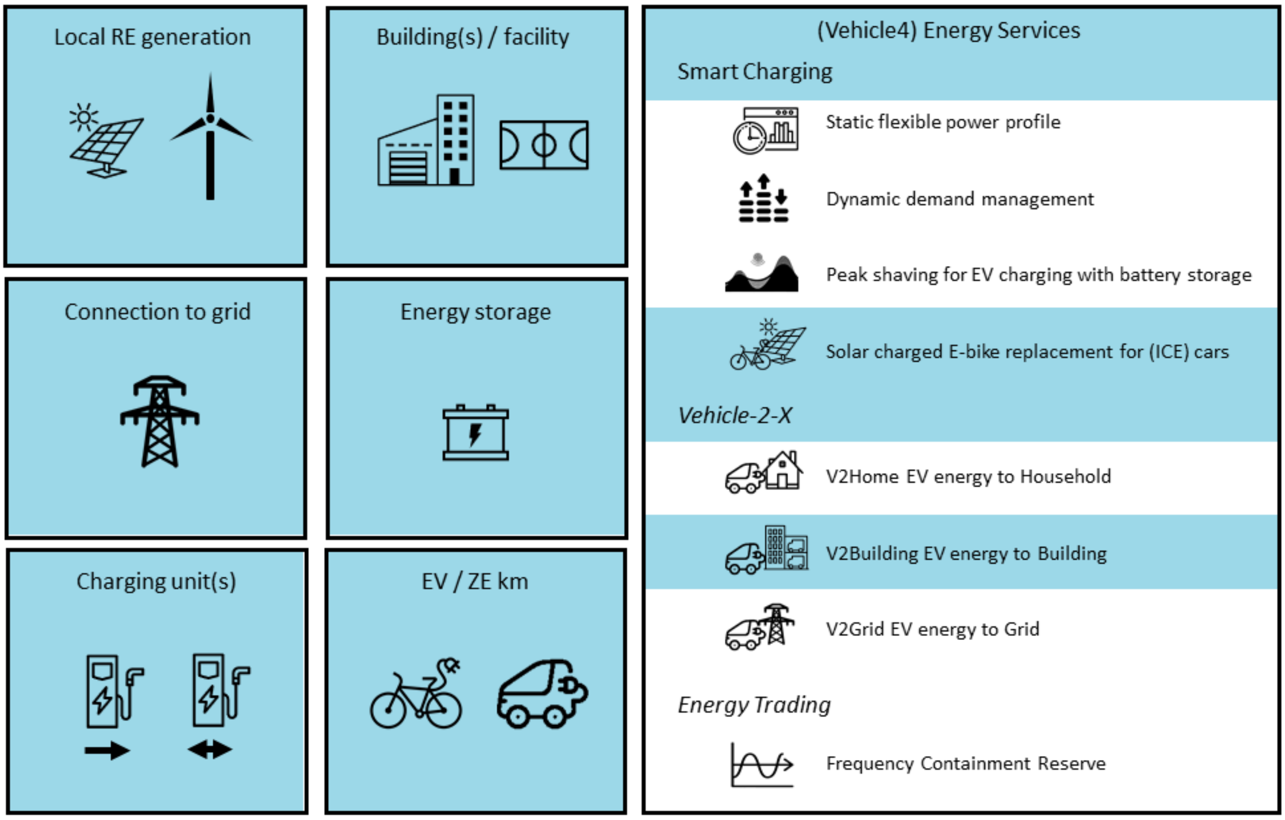

Figure 5 Technology Overview – system designcomponents Kortrijk OP

A simplified schematic overview of the Kortrijk OP is provided in Figure 6, which illustrates the relations between the different components of the pilot's energy system.

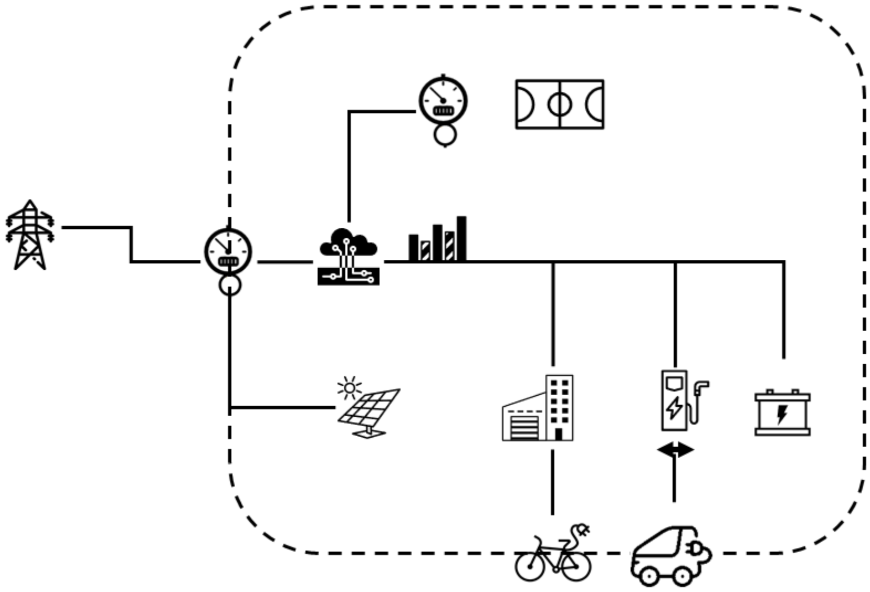

Figure 6 Schematic overview of the Kortrijk OP: City depot and sport fields

The targets for the Kortrijk OP were determined before starting the project. Table 5 provides these targets.

Table 5 Targets for the Kortrijk OP

KPI		*Targets for the OP*
A	CO_2 Reduction	5 – 15 tonnes yearly
		(sub-KPI) ZE km increase factor: 2
B	Energy Autonomy Increase	From 29 to 39% → Increase 10%

2.2.1. Baseline and Final Measurement Values

Table 6 Baseline and Final Measurements for the Kortrijk OP [2]

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
A. CO_2 Reduction				
A.1	Pilot CO_2 footprint	42.19 tonnes	34.01 tonnes	-8.18 tonnes
A.1.1	CO_2 related to baseline demand	45.73 tonnes	45.73 tonnes	+0.00 tonnes
A.1.2	CO_2 related to use of battery: EV	0.00 tonnes	0.42 tonnes	+0.42 tonnes
A.1.2.1	CO_2 related to use of battery: Ebikes	0.00 tonnes	0.06 tonnes	+0.06 tonnes
A.1.3	CO_2 related to use of battery: BSS	0.00 tonnes	0.05 tonnes	+0.05 tonnes
A.1.4	CO_2 savings by PV production	-12.71 tonnes	-12.71 tonnes	+0.00 tonnes
A.1.5	ICE replacement CO_2 savings (EV)	2.44 tonnes	0.24 tonnes	-2.20 tonnes
A.1.5.1	ICE replacement CO2 savings (Ebike)	6.73 tonnes	0.22 tonnes	-6.51 tonnes
A.1.6	Zero Emission kilometres increase (EV)	0 km	7,220 km	+7,220 km
A.1.6.1	Zero Emission kilometres increase (Ebike)	0 km	11,000 km	+11,000 km
A.2	Grid Services	N/A	N/A	N/A
A.2.1	FCR – Frequency Containment Reserve	N/A	N/A	N/A
A.2.2	Battery as back-up services (replacement of diesel generators)	N/A	N/A	N/A

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
B. Energy Autonomy Increase				
B.1	Self Sufficiency	23.9%	25.2%	+1.3%
B.2	Self Consumption	78.1%	82.4%	+4.3%
B.3	PV to Baseline Demand	61.65 MWh	60.78 MWh	-0.87 MWh
B.4	PV to EV	0.00 MWh	2.70 MWh	+2.70 MWh
B.4.1	PV to Ebike	0.00 MWh	0.20 MWh	+0.20 MWh
B.5	PV to BSS	0.00 MWh	1.38 MWh	+1.38 MWh
B.6	PV to Grid	17.33 MWh	13.93 MWh	-3.40 MWh

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
C. Grid Investment Deferral				
C.1	Peak Demand Value	146.0 kW	138.6 kW	-7.4 kW (-5%)

2.2.2. Operational Pilot – Key Performance Indicator results

In the initial stage, the baseline was logged to enable a comparison with the situation where new components are integrated within the pilot's energy system. By using this comparison, the impact of the new configuration was assessed. The results (Table 7) of this pilot were simulated due to the Covid-19 outbreak. Compared to the baseline, this pilot would achieve 8.2 tonnes of CO_2 reduction yearly, which would surpass the minimal range or the target. Energy autonomy would increase from 23.9% to 25.2%, an increase of 1.3% points. Peak demand would be reduced by -7.5 kW, which would be -5%.

Table 7 Targets and Results for the Kortrijk OP [2]

KPI		*Target for the OP*	*Results for the OP* *(simulated due to COVID-19 outbreak)*
A	CO_2 Reduction	5 – 15 tonnes yearly	8.2 tonnes
		(sub-KPI) ZE km increase factor: 2x	From 0 km to 7,220 km (EV) From 0 km to 11,000 km (ebikes) Total: +18,220 km per year
B	Energy Autonomy Increase	From 29 to 39% → Increase 10%	Increase by 1.3% points, from 23.9% to 25.2%
C	Grid Investment deferral (by peak reduction)	Target is at national scope	Target is at national scope For the Kortrijk OP: Peak demand -7.4 kW (-5%), Peak injection -4.1 kW (-7%)

2.3. Leicester OP: City Hall

Overview Leicester OP	***Final System Design Data***
Numer of EVs	4
Total EV Charging units	9
Uncontrolled	5 (7 kW)
V2X	4
Size of PV/ PV generation	23.5 kWp / 16,622 kWh
Total Annual Energy Consumption*	773,396 kWh/annum

In Leicester (United Kingdom), the OP is based at the City Hall headquarters of Leicester City Council. The City Hall has a 23.5 kWp PV system, consisting of 90 solar panels, which were already in place before participating in the SEEV4-City project. The PV system provides 2.5% of the office building's energy consumption. The fleet consists of four Nissan Leaf's, which are charged by the charging infrastructure that consists of five uni-directional chargers. The Council has plans to install four additional bi-directional chargers. Initially, the uni-directional charge units were to be replaced by the four bi-directional charge units; however, due to the growth of EVs within the municipality's fleet, they have decided to add the bi-directional charge units rather than replacing the older units.

A technology overview (Figure 7) illustrates what technologies and services take place at the Leicester City Hall.

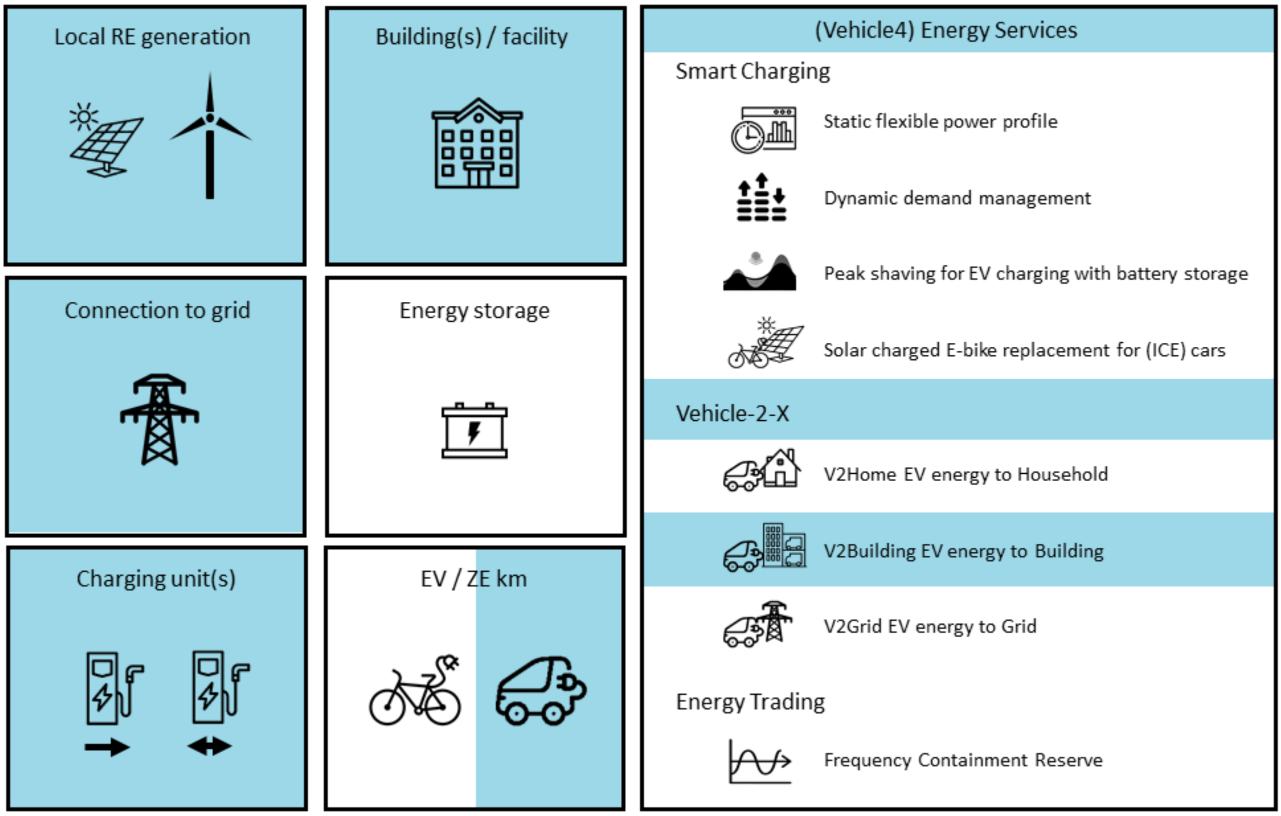

Figure 7 Technology Overview – system design components of the Leicester City Hall OP

A simplified schematic overview of the Leicester City Hall OP is provided in Figure 8, which illustrates the relations between the different components of the pilot's energy system.

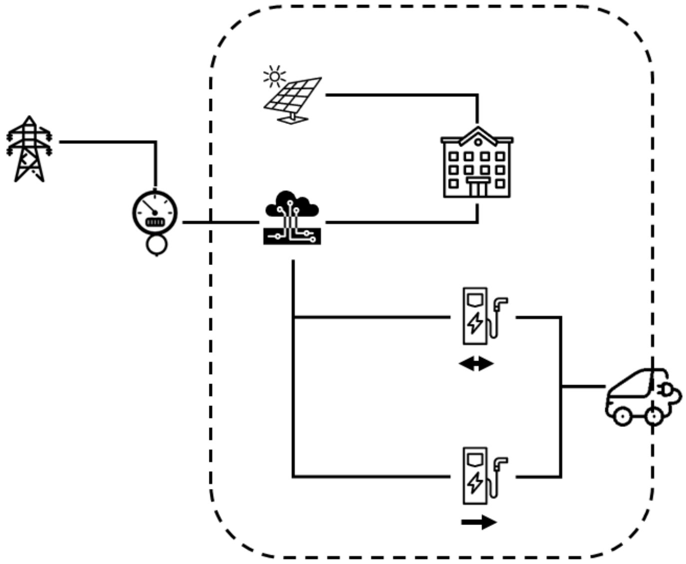

Figure 8 Schematic overview of the Leicester OP: City Hall

The targets for the Leicester City Hall OP were determined before starting the project. Table 8 provides these targets.

Table 8 Targets for the Leicester City Hall OP

KPI		*Targets for OP*
A	CO_2 Reduction	2 – 5 tonnes yearly
		(sub-KPI) ZE km increase factor: 1.3
B	Energy Autonomy Increase	From 36 to 37% → Δ +1%

2.3.1. Baseline and Final Measurement Values

Table 9 Baseline and Final measurements for the Leicester OP [3]

		(i) Initial stage	**(ii) End of Project**	
		Value	**Value**	**Compared to (i)**
A. CO_2 Reduction				
A.1	Pilot CO_2 footprint	258.6 tonnes	248 tonnes	-5.0 tonnes
A.1.1	CO_2 related to baseline demand	257 tonnes	257 tonnes	0 tonnes
A.1.2	CO_2 related to use of battery: EV	0	0.9 tonnes	0.9 tonnes
A.1.2.1	CO_2 related to use of battery: Ebikes	N/A	N/A	N/A
A.1.3	CO_2 related to use of battery: BSS	N/A	N/A	N/A
A.1.4	CO_2 savings by PV production	-4.9 tonnes	-4.9 tonnes	0 tonnes
A.1.5	ICE replacement CO_2 savings (EV)	6.5 tonnes	0.6 tonnes	-5.9 tonnes
A.1.5.1	ICE replacement CO2 savings (Ebike)	N/A	N/A	N/A
A.1.6	Zero Emission kilometres increase (EV)	0 km	26,793 km	26,793 km
A.1.6.1	Zero Emission kilometres increase (Ebike)	N/A	N/A	N/A
A.2	Grid Services	N/A	N/A	N/A
A.2.1	FCR – Frequency Containment Reserve	N/A	N/A	N/A
A.2.2	Battery as back-up services (replacement of diesel generators)	N/A	N/A	N/A

		(i) Initial stage	**(ii) End of Project**	
		Value	**Value**	**Compared to (i)**
B. Energy Autonomy Increase				
B.1	Self Sufficiency	2%	2%	0%
B.2	Self Consumption	100%	100%	0%
B.3	PV to Baseline Demand	16,622 kWh	15,312 kWh	-1,310 kWh
B.4	PV to EV	0	1,310 kWh	1,310 kWh
B.4.1	PV to Ebike	N/A	N/A	N/A
B.5	PV to BSS	N/A	N/A	N/A
B.6	PV to Grid (virtual carport)	0	*41% EA**	*41% EA**

* Simulated results

		(i) Initial stage	**(ii) End of Project**	
		Value	**Value**	**Compared to (i)**
C. Grid Investment Deferral				
C.1	Peak Demand Value	250 kW	254 kW	4 kW

2.3.1. Operational Pilot – Key Performance Indicator results

In the initial stage, the baseline was logged to enable a comparison with the situation where new components are integrated within the pilot's energy system. By using this comparison, the impact of the new configuration was assessed. The results (Table 10) of this pilot are simulated due to delays in procurement during the project lifetime. Compared to the baseline, this pilot would achieve a CO_2 reduction of 5.0 tonnes per year. By the installation of planned components, the Leicester OP would exceed the initial set target for CO_2 reduction.

Table 10 Targets and Results for the Leicester OP [3]

KPI		*Target for OP*	*Results for the OP*
A	CO_2 Reduction	2 – 5 tonnes yearly	5.0 tonnes/year
		(sub-KPI) ZE km increase factor: 1.3	26,793 km/year (1.07 x increase)
B	Energy Autonomy Increase	From 36 to 37% → Δ +1%	0%
C	Gris Investment Deferral (by peak demand reduction)	N/A	N/A

2.4. Amsterdam Stadium OP: Johan Cruyff ArenA

Overview JC ArenA OP	
Total EV Charging units	15
Uncontrolled	0
Smart Charging	14
V2X	1
Size of PV/ PV generation	1 MWp / 857 MWh
Battery Storage System	2.8 MWh / 3 MW

In Amsterdam (the Netherlands) one OP is based at the Johan Cruyff Arena, a sports and events stadium with a capacity of 55,000 seats and up to 68.000 visitors during concerts. Before joining the SEEV4-City project, a PV system of 1 MWp was installed on the roof of the venue. The PV system produces around 8% of the total energy consumption of the stadium. A BSS of 2.8 MWh is installed and has an output of 3 MW. The BSS consists of 148 Nissan Leaf battery packs of which about 40% are second-life batteries and is used to support the energy system during event days and Frequency Containment Reserve (FCR) grid services outside event days (Figure 9). The solar panels on the roof of the Arena are all around. Since autumn 2019, 14 fast chargers and one V2X charger were installed within the energy system. More V2X units were planned for installation; however, the prices of the V2X unit did not go down as fast as anticipated. The Mobility House manages the smart energy system. Stakeholders in this OP are the Amsterdam Johan Cruyff ArenA, Eaton, Nissan, The Mobility House, Bam and Liander as the network operator.

A technology overview (Figure 9) illustrates what technologies and services take place at the JC ArenA Amsterdam.

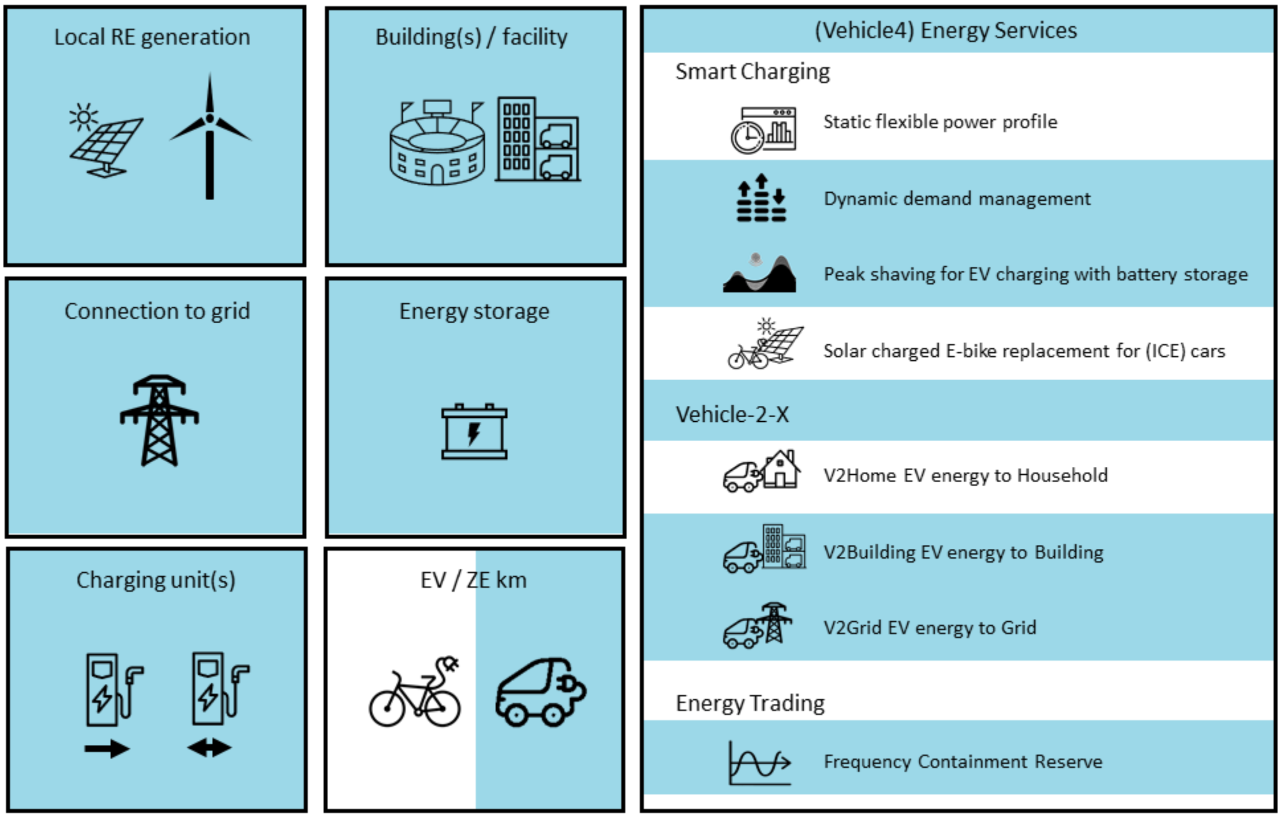

Figure 9 Technology Overview – system design components of the JC ArenA OP

A simplified schematic overview of the JC ArenA OP is provided in Figure 10, which illustrates the relations between the different components of the pilot's energy system.

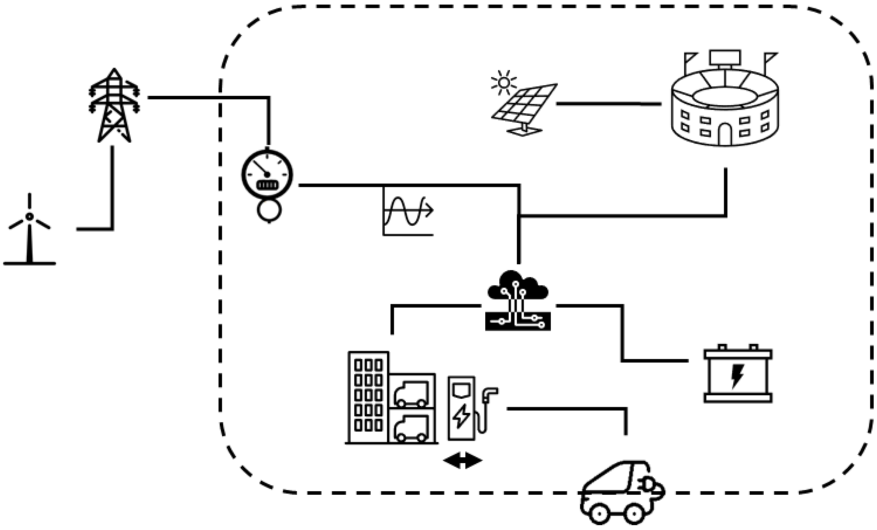

Figure 10 Schematic overview of the Amsterdam Stadium OP: Johan Cruyff ArenA

The targets for the JC Arena OP were determined before starting the project. Table 11 provides these targets.

Table 11 Targets for the JC ArenA OP

KPI	*Targets for OP*
CO_2 Reduction	15 – 40 tonnes yearly
	(sub-KPI) ZE km increase factor: 3
Energy Autonomy Increase	Remains constant 8%

2.4.1. Baseline and Final Measurement Values

Table 12 Baseline and Final measurements for the JC ArenA OP [4]

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
A. CO_2 Reduction		**3,789**	**1,776**	**-2,012**
A.1	Pilot CO_2 footprint	3,789 tonnes	3,669 tonnes	-120 tonnes
A.1.1	CO_2 related to baseline demand	3,987 tonnes	3,987 tonnes	0
A.1.2	CO_2 related to use of battery: EV	0	62 tonnes	62 tonnes
A.1.2.1	CO_2 related to use of battery: Ebikes	N/A	N/A	N/A
A.1.3	CO_2 related to use of battery: BSS	0	0	0
A.1.4	CO_2 savings by PV production	-399 tonnes	-399 tonnes	0
A.1.5	ICE replacement CO_2 savings (EV)	201 tonnes	20 tonnes	-182 tonnes
A.1.5.1	ICE replacement CO2 savings (Ebike)	N/A	N/A	N/A
A.1.6	Zero Emission kilometres increase (EV)	0	178,204 km	178,204 km
A.1.6.1	Zero Emission kilometres increase (Ebike)	N/A	N/A	N/A
A.2	Grid Services	0	-1,893 tonnes	-1,893 tonnes
A.2.1	FCR – Frequency Containment Reserve	0	-1,890 tonnes	-1,890 tonnes
A.2.2	Battery as back-up services (replacement of diesel generators)	0	-3 tonnes	-3 tonnes

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
B. Energy Autonomy Increase				
B.1	Self Sufficiency	7.6%	8.8%	+1.2%
B.2	Self Consumption	76%	88%	+12%
B.3	PV to Baseline Demand	654 MWh	744 MWh	90 MWh
B.4	PV to EV	0	12 MWh*	12 MWh*
B.4.1	PV to Ebike	N/A	N/A	N/A
B.5	PV to BSS	0	0	0
B.6	PV to Grid	203 MWh	101 MWh	-102 MWh

*Simulated results

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
C. Grid Investment Deferral				
C.1	Peak Demand Value - BSS Peak Demand Value – 14 EV charging stations	3.0 MW 308 kW	2.7 MW 145 kW	-0.3 MW (-10%)* -163 kW (-53%)

*Simulated results

2.4.2. Operational Pilot – Key Performance Indicator results

In the initial stage, the baseline was logged to enable a comparison with the situation where new components are integrated within the pilot's energy system. By using this comparison, the impact of the new configuration was assessed. The results (Table 13) are calculated with the energy use and PV production data of 2017 as a reference, as for this year the best energy data was available. Altogether, the Johan Cruyff ArenA OP saves 2,012 tonnes of CO_2 annually, exceeding the target over 50 times. The battery contributed significantly by operating FCR services to the electricity grid using the 3 MW stationary battery storage. The energy autonomy was to remain constant, as there was no additional renewable energy source installed but raised slightly by 1.2% by reconnecting the PV to more transformers. With the BSS a 10% peak demand reduction is possible. The 14 EV chargers are demand controlled to keep the total charging demand below 145 kW, giving a peak reduction of 53% and savings on cabling of 15 k€ (so saving 92 €/kW).

Table 13 Targets and Results for the JC ArenA OP [4]

KPI		***Target for OP***	***Results of the OP***
A	CO_2 Reduction	15 – 40 tonnes yearly	2,012 tonnes yearly
		(sub-KPI) ZE km increase factor: 3	From 0 to 178,204 km
B	Energy Autonomy Increase	Remains constant	+1.2 %
C	Grid Investment Deferral:	N/A	
	• by peak demand reduction with BSS		10% peak reduction (0.3 MW) *
	• By demand management		163 kW peak reduction (53%)

*Simulated results

2.5. Oslo OP: Vulkan parking garage

Overview Oslo OP	
Total EV Charging units	102
Uncontrolled	100
Uncontrolled DC fast charging	2
Battery storage system	50 kWh

In Oslo (Norway), the OP takes place in the Vulkan parking garage, which is owned by Aspelin Ramm (AS). The garage is fitted with 100 AC charge units with single outlets. Also, two DC fast charging units are installed with an output of 50 kW, having both ChaDeMo and CCS outlets. A BESS is installed with a capacity of 50 kWh and 50 kW inverter. The BESS is used to phase-balance the charging system and for peak shaving. The complete energy system was installed (custom-built) and is managed and monitored by Fortum (Charge & Drive), who is the innovation partner of both Aspelin Ramm and Oslo City Council. Parking is currently still free at night-time for residential parking (since Oslo City Council pays Aspelin Ramm for this, to relieve the pressure on on-street public EV charging stations). Four car-sharing companies are making use of the parking garage, alongside users across the city paying for the parking and EV charging separately. In Norway, the energy generated is mostly renewable, thanks to its hydropower facilities.

A technology overview (Figure 11) illustrates what technologies and services taking place at the Oslo Vulkan Garage OP.

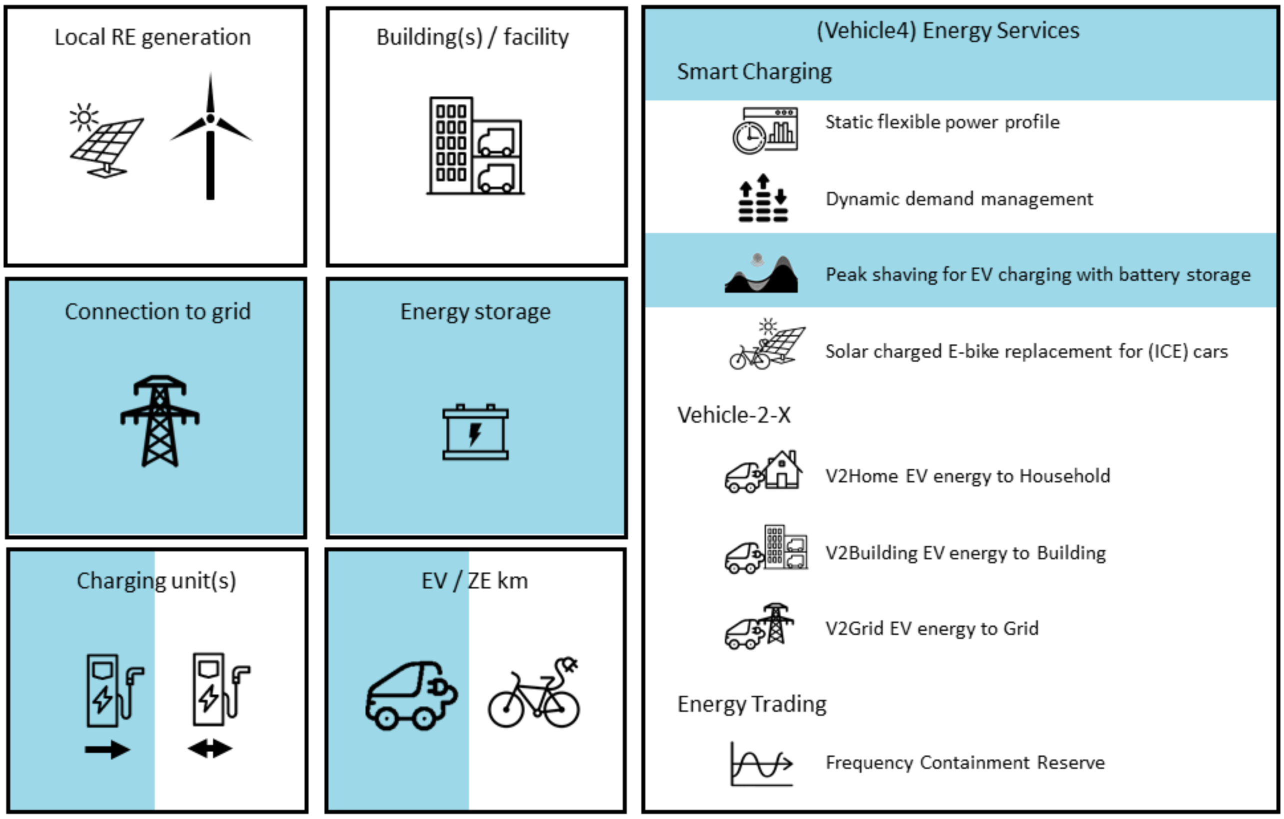

Figure 11 Technology Overview – system design components Oslo Vulkan OP

A simplified schematic diagram of the Oslo OP is shown in Figure 12, which illustrates the relations between the different components of the pilot's energy system components.

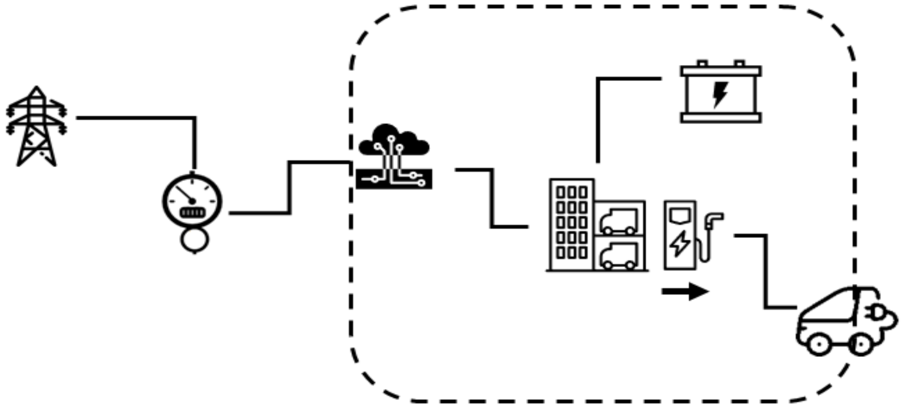

Figure 12 Schematic overview of the Oslo OP: Vulkan parking garage

The targets for the Oslo OP were determined before starting the project. Table 14 provides these targets.

Table 14 KPI targets for the Oslo Vulkan OP

KPI		*Targets for OP*
A	CO_2 Reduction	90 – 120 tonnes yearly
		(sub-KPI) ZE km increase factor: 1.5
B	Energy Autonomy Increase	From 8 to 10% → Δ +2%
C	Grid Investment deferral (by peak demand reduction)	20% Peak Reduction

2.5.1. Baseline and Final Measurement Values

Table 15 Baseline and Final measurements for the Oslo Vulkan OP [5]

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
A. CO_2 Reduction				
A.1	Pilot CO_2 footprint	-153	- 912 tonnes/year	-759 tonnes
A.1.1	CO_2 related to baseline demand	N/A	N/A	N/A
A.1.2	CO_2 related to use of battery: EV	+2.4	+14.3 tonnes	+11.9 tonnes
A.1.2.1	CO_2 related to use of battery: Ebikes	N/A	N/A	N/A
A.1.3	CO_2 related to use of battery: BSS	N/A	N/A	N/A
A.1.4	CO_2 savings by PV production	N/A	N/A	N/A
A.1.5	ICE replacement CO_2 savings (EV)	-156	-926 tonnes/year	-771 tonnes
A.1.5.1	ICE replacement CO2 savings (Ebike)	N/A	N/A	N/A
A.1.6	Zero Emission kilometres increase (EV)	708,000	4,210,405 km	3,502,405 km
A.1.6.1	Zero Emission kilometres increase (Ebike)	N/A	N/A	N/A
A.2	Grid Services	N/A	N/A	N/A
A.2.1	FCR – Frequency Containment Reserve	N/A	N/A	N/A
A.2.2	Battery as back-up services (replacement of diesel generators)	N/A	N/A	N/A

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
B. Energy Autonomy Increase				
B.1	Self Sufficiency	0	0	0
B.2	Self Consumption	0	0	0
B.3	PV to Baseline Demand	N/A	N/A	N/A
B.4	PV to EV	N/A	N/A	N/A
B.4.1	PV to Ebike	N/A	N/A	N/A
B.5	PV to BSS	N/A	N/A	N/A
B.6	PV to Grid	N/A	N/A	N/A

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
C. Grid Investment Deferral				
C.1	Peak Demand Value	378 kW	328 kW	-50 kW (13%)

2.5.2. Operational Pilot – Key Performance Indicator results

In the initial stage, the baseline was logged to enable a comparison with the situation where new components are integrated within the pilot's energy system. By using this comparison, the impact of the new configuration was assessed. The results (Table 16) show a reduction of 759 tonnes CO_2 per year, which exceeds the earlier set targets. The zero-emission kilometres increased by a factor of 5.95, with over 4 million km/year. It turned out that no renewable energy sources were installed, based on the building owner's local decision, which means there is no energy autonomy increase. Peak demand reduction is 13% by utilising the BESS.

Table 16 Targets and Results for the Oslo OP [5]

KPI		***Target for OP***	***Results for OP***
A	CO_2 Reduction	90 – 120 tonnes yearly	759 Tonnes/year
		(sub-KPI) ZE km increase factor: 1.5	5.95 (i.e. 4,210,405 km/year
B	Energy Autonomy Increase	From 8 to 10% → Δ +2%	N/A
C	Grid Investment deferral (by peak demand reduction)	20% Peak reduction	13%

2.6. Amsterdam City OP: FlexPower

Overview FlexPower	
Total EV Charging units (sockets)	912
Smart Charging (sockets)	912

Another OP in Amsterdam is called FlexPower which consists of multiple EV charging units across the city and has smart charging capabilities using profiles (Figure 13). FlexPower was developed to reduce the peak power demand and is to be implemented in the following phases (albeit not all within the lifetime of the SEEV4-City project): (i.) controlled smart charging with static profiles during the week, (ii.) including PV generation prediction for profile development, (iii.) real-time monitoring and switching of smart charging intensity depending on RES generation and EV demand and probably (iv.) V2G implementation. In phase one, FlexPower consisted of 52 smart charging poles (104 sockets) installed across the city), charging rates during non-peak hours were capped at a maximum of 24.2 kW, while the rates of charging during peak hours were capped at 5.5 kW. Most charging stations have a standard 3 x 25A connection to the electricity grid, with a 16A fuse on each connector. A 3 x 35 A connection was needed to enable charging at higher power (22 kW). These were equipped with a 1.6 OCPP protocol, making it possible to apply a predetermined capacity profile. There were six different Static Smart Charging (SSC) profiles for morning, evening, and weekend. At the end of 2018, 456 charging stations were upgraded to 3 x 35 A and made ready for the second phase of the FlexPower project. In May 2019, smart charging profiles were activated on 456 charging poles (912 sockets). The municipality of Amsterdam is trying to balance the supply-demand dynamics with the use of locally generated renewable energy. The network operator is Liander and the smart charging points are installed and managed by Elaad, Vattenfall and Heijmans.

A technology overview (Figure 13) illustrates what technologies and services take place at the Amsterdam Flexpower OP.

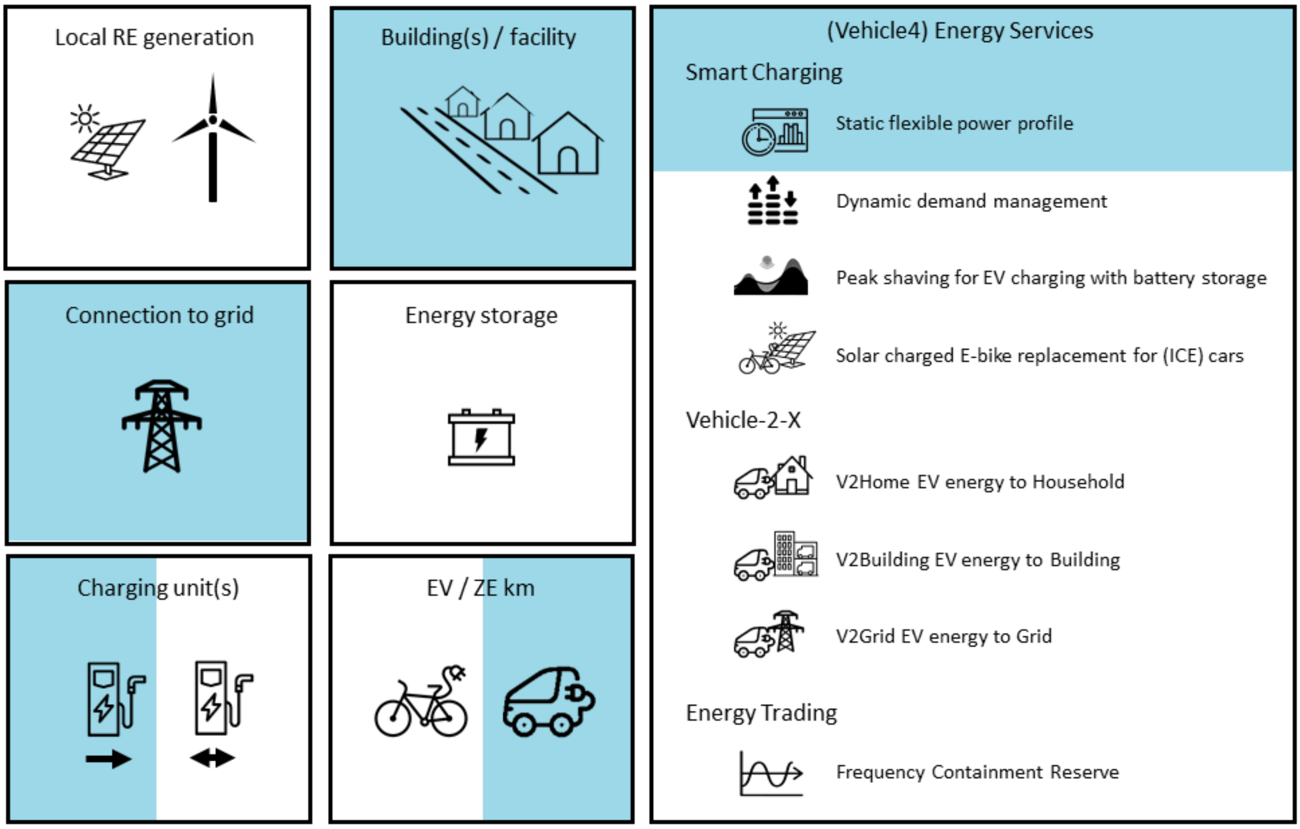

Figure 13 Technology Overview – system design components Amsterdam FlexPower OP

A simplified schematic overview of the Oslo OP is provided in Figure 14, which illustrates the relations between the different components of the pilot's energy system.

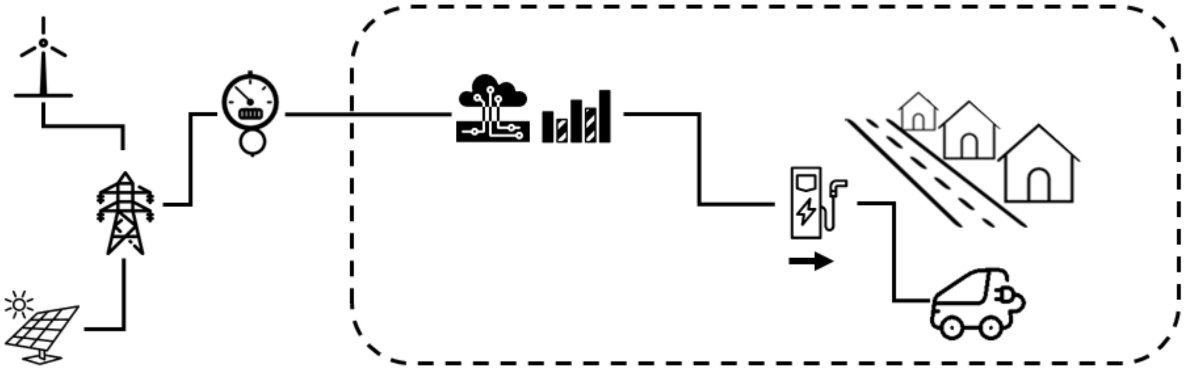

Figure 14 - Schematic overview of the Amsterdam City OP: FlexPower

The targets for the FlexPower Amsterdam City OP were determined before starting the project. Table 17 provides these targets.

Table 17 KPI targets for the FlexPower OP

KPI		*Targets for OP*
A	CO_2 Reduction	10 – 20 tonnes yearly
		(sub-KPI) ZE km increase factor: 2.9
B	Energy Autonomy Increase	From 10 to 25% → Δ +15%

2.6.1. Baseline and Final Measurement Values

Table 18 Baseline and Final measurements for the Flexpower OP [6]

		(i) Initial stage	**(ii) End of Project**	
		Value	**Value**	**Compared to (i)**
A. CO_2 Reduction				
A.1[1]	Pilot CO_2 footprint FlexPower 2	2,002.3	2,000.9	-1.4 tonnes
A.1.1	CO_2 related to baseline demand	N/A	N/A	N/A
A.1.2	CO_2 related to use of battery: EV	2,002.3	2,000.9	-1.4 tonnes
A.1.2.1	CO_2 related to use of battery: Ebikes	N/A	N/A	N/A
A.1.3	CO_2 related to use of battery: BSS	N/A	N/A	N/A
A.1.4	CO_2 savings by PV production	N/A	N/A	N/A
A.1.5	ICE replacement CO_2 savings (EV)	N/A	N/A	N/A
A.1.5.1	ICE replacement CO2 savings (Ebike)	N/A	N/A	N/A
A.1.6	Zero Emission kilometres increase (EV)	0	18,026 km	18,026 km
A.1.6.1	Zero Emission kilometres increase (Ebike)	N/A	N/A	N/A
A.2	Grid Services	N/A	N/A	N/A
A.2.1	FCR – Frequency Containment Reserve	N/A	N/A	N/A
A.2.2	Battery as back-up services (replacement of diesel generators)	N/A	N/A	N/A

		(i) Initial stage	**(ii) End of Project**	
		Value	**Value**	**Compared to (i)**
B. Energy Autonomy Increase				
B.1	Self Sufficiency	N/A	N/A	N/A
B.2	Self Consumption	N/A	N/A	N/A
B.3	PV to Baseline Demand	N/A	N/A	N/A
B.4	PV to EV	N/A	N/A	N/A
B.4.1	PV to Ebike	N/A	N/A	N/A
B.5	PV to BSS	N/A	N/A	N/A
B.6	PV to Grid	N/A	N/A	N/A

		(i) Initial stage	**(ii) End of Project**	
		Value	**Value**	**Compared to (i)**
C. Grid Investment Deferral				
C.1	Peak Demand Value	994 kW	524 kW	Average peak reduction of 470 kW per evening (53%)

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[1] As reported in the Flexpower OP report, the CO_2 reduction of Flexpower 2 was -0.33 kg CO_2/MWh. The total demand was 4196.3 MWh in the period May 2019 /May 2020, so CO_2 savings are 1.4 ton CO_2/year.

2.6.2. Operational Pilot – Key Performance Indicator results

In the initial stage, the baseline was logged to enable a comparison with the situation where new components are integrated within the pilot's energy system. By using this comparison, the impact of the new configuration was assessed. The results (Table 19) show a CO_2 reduction of 0.33 kg per MWh by integrating the smart charging technology of FlexPower. The average peak reduction achieved is 470 kW.

Table 19 Targets and results for the Flexpower OP [6]

KPI		*Target for OP*	*Results for OP*
A	CO_2 Reduction	10 – 20 tonnes yearly	1.4 tonnes
		(sub-KPI) ZE km increase factor: 2.9	N/A
B	Energy Autonomy Increase	From 10 to 25% → Δ +15%	N/A
C	Grid Investment deferral (by peak demand reduction)	The maximum peak power should be reduced.	Average peak reduction of 470 kW per evening (53%)

3. SEEV4-City Project results

This section summarises the overall results of the SEEV4-City project. The initial targets and overall results are shown in Table 20. The CO_2 emissions reduction result transcended the target achieving 2786 tonnes CO_2 annually. The largest contributor to this CO_2 reduction value is the JC ArenA stationary battery system deployed to provide FCR services. Energy Autonomy increased from 15% in the initial stage to 17% in the final stage, resulting in a 2% increase. Some initial pilot plans changed to less or no additional RES installation or relocated to buildings with pre-existing RES available. Calculating the estimated savings from grid investment deferral was replaced with a peak demand reduction value, as the information required for calculating the estimated savings from grid deferral is a complex task that requires inaccessible commercial/financial data from the DNO/DSOs.

Table 20 SEEV4-City OP targets and results

Key Performance Indicator	Target	Results
Estimated CO_2 reduction	150 tonnes CO_2 annually	2786 tonnes CO_2 annually*
Estimated increase in energy autonomy	25% increase	2% increase*
Estimated Saving from Grid Investment Deferral	More than €100 million	Replaced by peak demand reduction

*Note: includes simulated pilot data

3.1. KPI A: CO_2 reduction

In Table 21, the CO_2 reduction project results are shown for KPI A.1 and A.2, including the sub-KPI values. Within the sub-KPI's of A.1 – Pilot CO_2 footprint, the replacement of ICE cars or vans achieved the most considerable reduction of about 900 tonnes. The zero-emission kilometres increased by almost 3.7 million km a year.

Within the sub-KPIs of A.2 – Grid services, the FCR services of the Johan Cruyff ArenA battery energy storage system achieved a significant CO_2 emissions reduction of nearly 1,900 tonnes, as mentioned earlier.

Table 21 SEEV4-City total CO_2 reduction results

		(i) Initial stage	**(ii) End of Project**	
		Value	**Value**	**Compared to (i)**
A. CO_2 Reduction				
A1+A2	**Total CO2 reduction**	**5,940 tonnes**	**3154 tonnes**	**-2,786 tonnes**
A.1	Pilot CO_2 footprint	5,940 tonnes	5047 tonnes	-894 tonnes
A.1.1	CO_2 related to baseline demand	4,291 tonnes	4,291 tonnes	0
A.1.2	CO_2 related to use of battery: EV	2,005 tonnes	2,079 tonnes	+74 tonnes
A.1.2.1	CO_2 related to use of battery: Ebikes	0	0.06	0.06
A.1.3	CO_2 related to use of battery: BSS	0	0.05	0.05
A.1.4	CO_2 savings by PV production	-418 tonnes	-418 tonnes	0
A.1.5	ICE replacement CO_2 savings (EV)	56	-905 tonnes	-961 tonnes
A.1.5.1	ICE replacement CO2 savings (Ebike)	7	0 tonnes	-7 tonnes
A.1.6	Zero Emission kilometres increase (EV)	708,000	4,444,125 km	3,736,125 km
A.1.6.1	Zero Emission kilometres increase (Ebike)	0	11,000 km	11,000 km
A.2	Grid Services	0	-1,893 tonnes	-1,893 tonnes
A.2.1	FCR – Frequency Containment Reserve	0	-1,890 tonnes	-1,890 tonnes
A.2.2	Battery as back-up services (replacement of diesel generators)	0	-3 tonnes	-3 tonnes

3.2. *KPI B: Energy Autonomy increase*

Table 22 provides an overview of the KPIs within the Energy Autonomy increase domain. As mentioned earlier, the self-sufficiency increased by 2%. The self-consumption, which represents the percentage of the local generation that supplies the demand to the total energy locally generated [7], rose from 42% to 45%; an increase of 3%.

With 2%, the increase in energy autonomy was less than planned. An important reason is that the V2X technology is still (too) expensive and in the early stages of technical development, so it was not possible to utilise the technology to its full potential. Another reason is that at the moment there is no financial incentive to increase energy autonomy for the smaller pilots, whilst other services, such as FCR, generate more revenue.

EVs, E-bikes and stationary batteries were introduced in the OPs. We can see that, in the new energy system configurations, a significant amount of PV generated energy was used to charge the EVs and less PV energy was exported back to the grid. With the deployment of the technologies used in SEEV4-City, the project managed to reduce the renewable energy generation export the grid by 48%, which is a positive result, indicating an increase in self consumption and energy autonomy.

Table 22 SEEV4-City total Energy Autonomy Increase results

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
B. Energy Autonomy Increase				
B.1	Self Sufficiency	15%	17%	2%
B.2	Self Consumption	50%	56%	6%
B.3	PV to Baseline Demand	17,339 MWh	16,118 MWh	-1,221 MWh
B.4	PV to EV	0	1,325 MWh	1,325 MWh
B.4.1	PV to Ebike	0	0.2 MWh	0.20 MWh
B.5	PV to BSS	0	1.6 MWh	1.6 MWh
B.6	PV to Grid	222 MWh	116 MWh	-106 MWh

3.3. *KPI C: Grid investment deferral*

The reduction of peak demand value can be an indicator of the grid investment deferral. The actual grid investment deferral is a complex task and requires access to commercially sensitive data from DNOs, which the project group did not have access to. We received a ballpark figure from a DNO of €100/kW for the Netherlands, which enables a ballpark calculation for FlexPower. For the Johan Cruyff ArenA OP, the calculated savings are €92/kW. For other countries, such values were not available; therefore, an indication of peak demand value reduction is provided for most of the individual pilots (Table 23).

SEEV4-City demonstrates avoided grid investments that can be obtained by introducing smart charging and storage services as used in the FlexPower and the Arena OP at large implementation (in 10 years). For the Netherlands, we used the EVEC (electric vehicle expansion calculator) model to calculate the potential savings by implementing smart charging at a large scale. In the model, we use the energy numbers and profiles as stated in the SEEV4-City KPI approach to Methodology report [7]. The base demand and EV demand are merged whilst the PV production is deducted, showing the largest power demand of 8.97 GW on December 16, 18:00 (Figure 15).

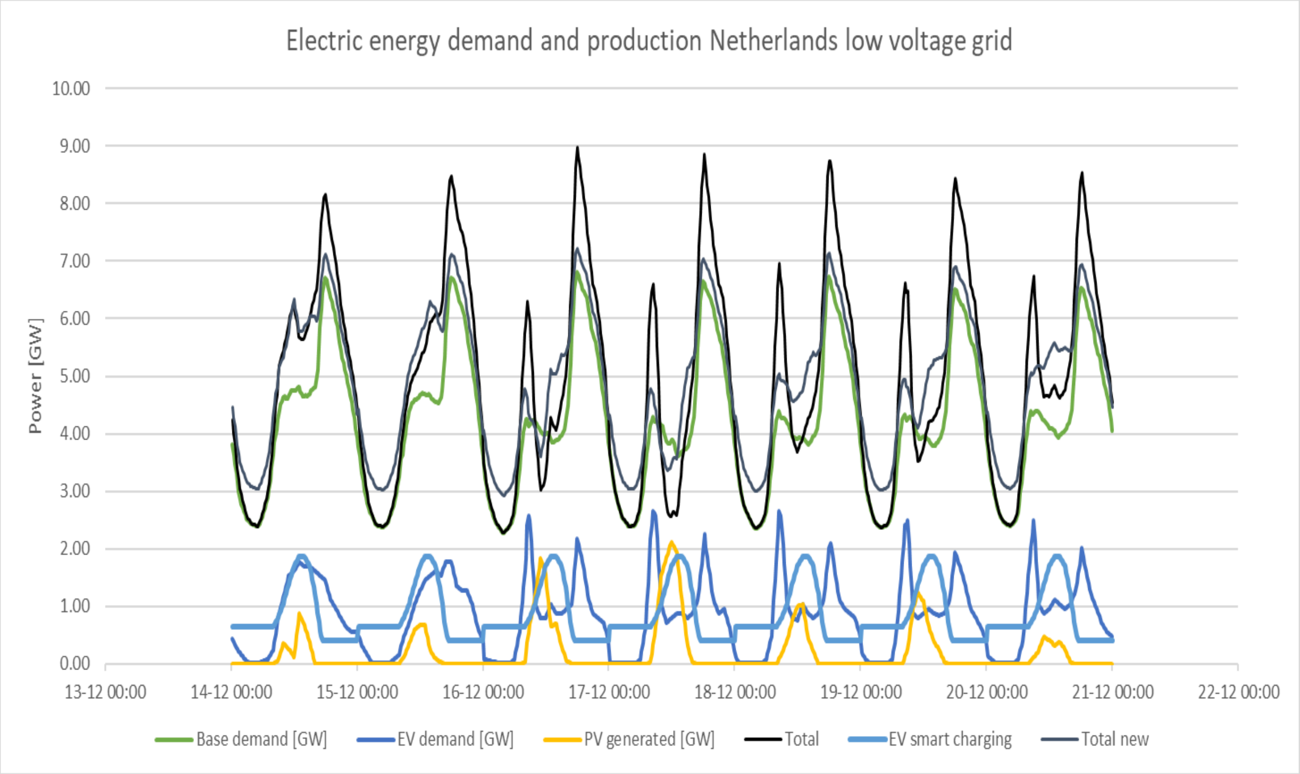

Figure 15 Electric energy demand and production Netherlands low voltage grid

By applying a smart charging strategy with the EV morning peak shifted to around midday, and by shifting the EV evening peak to late in the evening and early morning, the new maximum power demand becomes 7.25 GW, which is 1.72 GW less (19%). Multiplied by 100 €/kW, this 1.72 GW reduction results in €172 million grid investment deferral. The FlexPower and ArenA OPs demonstrate that with the current state of the art technology, a 53% peak reduction is possible. Although we did not have enough data to make the right calculations of the grid investment deferral, the EVEC simulation indicates that savings in the order of 100 million within 10 years are possible if we extend this from the Netherlands to the other SEEV4-City countries.

Integrating systems such as FlexPower and the demand management in the Johan Cruyff Arena requires digital infrastructure investments which must be deducted from the savings figure; however, these can be minimised by adopting the SEEV4-City FlexPower technology, leapfrogging the development phase.

During the project, a noticeable increase of services emerged on the market that provides aggregated grid services via either smart charging solutions or V2G.

Table 23 Grid Investment Deferral

		(i) Initial stage	(ii) End of Project	
		Value	**Value**	**Compared to (i)**
C. Grid Investment Deferral				
C.1	Peak Demand Value	See individual pilots		

4. Conclusions related to the KPIs

The Smart, Clean Energy and Electric Vehicle for the City (SEEV4-City) project integrated several innovative technologies to optimise supply from renewable energy sources and demand, including charging of electric vehicles in six pilots of different scales in different North Sea regions and cities of Europe. The project partners set three Key Performance Indicator targets for: A. CO_2 reduction, B. Energy Autonomy and C. Grid investment deferral. Based on the end-results we can conclude the following:

CO_2 reduction

Through six operational pilots of different scales in different cities and countries, the project exceeded the initial target for CO_2 reduction. This is mainly thanks to the Frequency Control Services of the stationary battery storage at the Johan Cruyff ArenA OP, as the 3 MW BESS allows the gas- and coal-fired electricity generation facilities to produce at higher efficiencies. Electrifying the vehicle fleets, or replacing ICE vehicles with ebikes, using the different pilot-solutions is also saving CO_2-emissions and improves the number of clean kilometres (ZE-kms), especially when charged from renewable energy.

Calculating CO_2 reduction improvements of a solution by comparing the footprint of the local energy system with the footprint of the grids energy mix at moment of consumption, is an often used and accepted approach in both literature and other projects. Although the footprints of individual pilots do show CO_2 reductions for the site outside ICE to EV replacement, the question remains whether this results in actual CO_2 reduction across the board or whether it shifts the emissions savings from one location to another. This question has been a lively subject of discussion amongst the partners of the SEEV4-City project and warrants further research.

Energy Autonomy

In terms of Energy Autonomy, the project gained on average 2% from 15% to 17%, which is lower as targeted. Main reason for this was that as the pilots progressed the operational pilot plans changed during the design decision stages, such as relocating to facilities that already had a PV system (Kortrijk) and thus were not considered a solution addition; or it could not implement a PV system after all, as in the case of Oslo OP where it was preferred to use the roof for other purposes and its electricity could already be fed by the hydropower electricity grid.

Analysing the data of the pilots that are generating electricity from onsite RE (in this case, PV), proved that less energy was being exported to the grid than in the baseline situation. While available consumption data across the rest of the site did not explain the decrease in export, pre-COVID-19, the number of EVs using the site had often been increased. From this, it can be concluded that a larger proportion of the PV generated electricity was used for EV charging. The self-consumption increased, while the self-sufficiency percentage (SEEV4-City's primary indicator for EA) is not impacted that much.

The project's objective to analyse the effect of Vehicle-to-Grid (V2G) on a larger scale through these pilots turned out to be a bigger challenge in practice than anticipated for several reasons. It had been the project's assumption the market for bidirectional charging equipment and availability of commercial products would have matured more since the initial project proposal. Consequently, determining the site and hardware requirements for some pilots, involving numerous stakeholders, as well as the ensuing procurement process turned out to be much more complex and time consuming. This resulted in the fact that (parts of) the envisioned solution could not be implemented within the project's timeframe, thus making it more difficult to meet the initial objective.

Although the analysis that were performed (in part simulation effects using actual site data) do indicate that Vehicle-to-Grid still holds potential as the automotive and energy markets continue to mature. But from the experiences during the lifetime of this project it has to be concluded that currently smart charging installations seemed more practical, easier to implement and scalable.

Grid Investment Deferral

Proving the grid investment deferral target over a time period of 10 years turned out to be ambitious with current scales of the pilots and limited available information of the costs-structures of grid(components). However, with the indication provided by a Dutch DNO for costs/kW investment, it could be determined that upscaling a pilot such as FlexPower over the country of the Netherlands could potentially exceed the project's target on grid investment deferral. DNOs should be able to provide more detailed estimations of grid deferral per kW or provide more insights into the cost related to grid reinforcements. More intricate figures from the DNOs (in both the Netherlands as well as in other pilot countries) could help to assess the impact of future projects more accurately when it comes to grid investment deferral.

As a supplement for this target, project partners explored the investment deferrals on a local level by measuring peak reduction versus the onsite capacity. For JC ArenA for example, a peak reduction of max 53% can be achieved, which can be translated into a savings of 15K€ mainly on local cabling (since the grid connection capacity is more than sufficient).

To summarize, the experiences of the project demonstrate the importance of identifying and having access to relevant data from start to finish, including those from external sources and stakeholders. It is a key element for those considering smart charging solutions, to make design decisions that will match the objectives a solution should (help) achieve and to learn from the implementation of innovative technologies.

The SEEV4-City project demonstrated that optimising supply from renewable energy and demand (including EV charging) can make a positive impact on CO_2 reduction and costs. Capital investment costs were relatively high, but due to expected technology and regulatory developments, upscaling, replicating and mass adoption, costs will come down. Following the market trends, it is noticed that the emerging services on the market are focussing more on stabilizing the grid using electric Vehicle-for-Energy-Services (such as FCR/FFR), rather than increasing a site's energy autonomy. Such services can impact the grid investment deferral; therefore, it is important to take such services in consideration at critical locations that experience grid stress.

For more detailed conclusions and recommendations from individual pilots and the solutions they implemented as well as topic specific reports, we recommend reading the pilot-dedicated Final Reports and the reports on Business Model analysis, Policy recommendations and Upscaling and Transnational transfer potential.

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