smart en. city

TOWARDS SMART ZERO CO_2 CITIES ACROSS EUROPE

VITORIA-GASTEIZ + TARTU + SØNDERBORG

Deliverable 7.7: Mobility action monitoring program

WP7, Task 7.2

Date of document

29/11/2018 (M34)

Deliverable Version:	D7.7, V.1.0
Dissemination Level:	PU
Author(s):	M. Ángeles Gallego (CAR), Julia Vicente (CAR), David Grisaleña (VIS), Aitor Albaina (CEA), Jaanus Tamm (TAR), Iben Nielsen (SON), Patxi Saez de Viteri (MON)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691883

Document History

Project Acronym	SmartEnCity
Project Title	Towards Smart Zero CO_2 Cities across Europe
Project Coordinator	Francisco Rodriguez Tecnalia francisco.rodriguez@tecnalia.com
Project Duration	1st February 2016 - 31st July 2021 (66 months)

<table>
<tr><td>Deliverable No.</td><td colspan="3">D7.7 Mobility action monitoring program</td></tr>
<tr><td>Diss. Level</td><td colspan="3">Public</td></tr>
<tr><td>Deliverable Lead</td><td colspan="3">CAR</td></tr>
<tr><td rowspan="3">Status</td><td></td><td colspan="2">Working</td></tr>
<tr><td></td><td colspan="2">Verified by other WPs</td></tr>
<tr><td>X</td><td colspan="2">Final version</td></tr>
<tr><td>Due date of deliverable</td><td colspan="3">30/11/2018</td></tr>
<tr><td>Actual submission date</td><td colspan="3">30/11/2018</td></tr>
<tr><td>Work Package</td><td colspan="3">WP 7 – Monitoring and evaluation / T7.2 – Monitoring program</td></tr>
<tr><td>WP Lead</td><td colspan="3">CAR</td></tr>
<tr><td>Contributing beneficiary(ies)</td><td colspan="3">CAR, SON, TAR VIS, CEA, MON</td></tr>
</table>

Date	Version	Person/Partner	Comments
04/04/2017	V.01	Mª Ángeles Gallego (CAR), Julia Vicente (CAR)	Preliminary structure of the document
30/10/2018	V.02	Mª Ángeles Gallego (CAR), Julia Vicente (CAR)	Updated version of mobility protocol. Chapters on mobility actions monitoring for the three cities to be checked and completed
07/11/2018	V.03	Jaanus Tamm (TAR)	Review and addition of contents from Tartu
13/11/2018	V.04	Iben Nielsen (SON)	Review and addition of contents from Sonderborg

15/11/2018	V.05	Mª Ángeles Gallego (CAR), Julia Vicente (CAR)	Consolidation of contributions from Tartu, Sonderborg.
16/11/2018	V.06	David Grisaleña (VIS)	First inputs for Vitoria's sections 4.1 and 4.2
20/11/2018	V.07	Mª Ángeles Gallego (CAR), Julia Vicente (CAR)	Consolidation of contributions from Vitoria
22/11/2018	V.08	Mª Ángeles Gallego (CAR), Julia Vicente (CAR)	First consolidated version for revision.
26/11/2018	V.09	Patxi Saez de Viteri (MON)	Revised version
27/11/2018	V.010	David Grisaleña (VIS), Aitor Albaina (CEA)	Further inputs for Vitoria's section 4.3
29/11/2018	V.011	Mª Ángeles Gallego (CAR), Julia Vicente (CAR)	Final consolidation of inputs and comments from revision. Fine tuning.
29/11/2018	V.1.0	Mª Ángeles Gallego (CAR), Julia Vicente (CAR)	Final version for submission

Copyright notice

Table of content:

0 Publishable Summary 8
1 Introduction 9
1.1 Purpose and target group 9
1.2 Contributions of partners 9
1.3 Relation to other activities in the project 9
2 Overall Approach 11
3 Revision of the Mobility evaluation Protocol 12
3.1 Scope of the protocol 12
3.2 Assessment methods 14
3.3 SmartEnCity evaluation approach 16
3.3.1 Baseline design 17
3.3.2 Post-intervention design 19
4 Vitoria-Gasteiz mobility action monitoring 21
4.1 Collection of KPIs & city indicators applicable for the mobility action evaluation 22
4.2 Non-KPI related monitoring requirements 26
4.3 Monitoring equipment and other sources of information 27
5 Tartu mobility action monitoring 29
5.1 Collection of KPIs & city indicators applicable for the mobility action evaluation 31
5.2 Non-KPI related monitoring requirements 34
5.3 Monitoring equipment and other sources of information 34
6 Sonderborg mobility action monitoring 37
6.1 Collection of KPIs & city indicators applicable for the mobility action evaluation 37
6.2 Non-KPI related monitoring requirements 40
6.3 Monitoring equipment and other sources of information 40
7 Commissioning plan guidelines 41
8 Deviations to the plan 42
9 Outputs for other WPs 43

List of Tables:

Table 1: Abbreviations and Acronyms 7
Table 2: Contribution of partners 9
Table 3: Relation to other activities in the project 10
Table 4: Objectives to be achieved through the interventions 12
Table 5: KPIs agreed for evaluating sustainable mobility actions (from D7.2, D7.3).....15
Table 6: Baseline scope 17
Table 7: Deployment of mobility actions in Vitoria-Gasteiz city 21
Table 8: KPIs for the evaluation of EVs performance in Vitoria-Gasteiz city 23
Table 9: KPIs for the evaluation of e-buses performance in Vitoria-Gasteiz city...........24
Table 10: KPIs for the evaluation of charging points' performance in Vitoria-Gasteiz city...25
Table 11: Indicators applicable to the mobility actions evaluation for Vitoria-Gasteiz .26
Table 12: Monitoring equipment for Vitoria-Gasteiz 27
Table 13: Other sources of information for Vitoria-Gasteiz.......................................28
Table 14: Deployment of mobility actions in Tartu city 29
Table 15: KPIs for the evaluation of charging points' performance in Tartu city 31
Table 16: KPIs for the evaluation of the e-bike rental system in Tartu city....................31
Table 17: KPIs for the evaluation of the bikeshare system in Tartu city 32
Table 18: KPIs for the evaluation of the biogas buses in Tartu city 32
Table 19: KPIs for the evaluation of reused batteries in Tartu city................................33
Table 20: Indicators applicable to the mobility actions evaluation................................34
Table 21: Monitoring equipment for Tartu 35
Table 22: Other sources of information for Tartu 36
Table 23: Deployment of mobility actions in Sonderborg city 37
Table 24: KPIs for the evaluation of the biogas buses in Sonderborg city 38
Table 25: KPIs for the evaluation of charging points' performance in Sonderborg city 39
Table 26: Indicators applicable to the mobility actions evaluation for Sonderborg 39

List of Figures:

Figure 1: Deliverable D7.7 in the framework of the evaluation scheme 43

Abbreviations and Acronyms

Abbreviation/Acronym	Description
AEMET	Agencia Estatal de Meteorología (Spanish' State Meteorological Agency)
API	Application Programming Interface
BB	Biogas Busses
CAN	Controller Area Network
CIOP	City Information Open Platform
CP	Charging Point
EV	Electric Vehicle
FEV	Fully Electric Vehicles
GPS	Global Positioning System
ICE	Internal Combustion Engine
ICT	Information and Communication Technologies
IPMVP	International Performance Measurement and Verification Protocol
IT	Information Technology
LH	Light House
KPI	Key Performance Indicators
M&V	Measurement and Verification
MW	Mega Watt
PO	Project Officer
PV	Photo Voltaic
RoI	Return of Investment
SCADA	Supervisory Control And Data Acquisition
SmartEnCity	Towards Smart Zero CO_2 Cities across Europe

Table 1: Abbreviations and Acronyms

0 Publishable Summary

The objective of the monitoring program task under WP7 (monitoring and evaluation) is the definition of monitoring programs for the LH cities. Three parallel documents are being generated covering the monitoring and metering aspects for three main pillars of the project: the district intervention actions, the vehicles and urban mobility actions and the actions related to the integrated infrastructure pillar. In the case of the present deliverable, related to vehicles and urban mobility, the three lighthouse cities have implemented a set of changes via amendment and this has caused a modification in the initial delivery date of D7.7, which is no longer July 2017 (M18), but November 2018 (M34) to represent the real actions to be implemented on the lighthouse cities.

This specific report compiles the monitoring program for the actions related to the vehicles and urban mobility actions for the three LH cities participating in SmartEnCity project, following the evaluation strategy drawn through the different documents delivered previously on WP7 and applying the evaluation protocols of each city. This document jointly with the other two monitoring deliverables and the data collection approach deliverable show how the data gathering and collection from the different sources (dwellings, buildings, district, vehicles, etc.) will be done to allow the proper evaluation of the final performance.

All the necessary requirements defined up to now for the interventions have been taken into account to define systems for monitoring, metering and data acquisition. These must be chosen according to the set of KPIs selected to quantify the result reached after the execution of the interventions and actions in each LH city as it was established in the evaluation protocols defined in D7.3 and D7.4. Those documents include a preliminary version of the mobility protocol for evaluation. To reflect the final mobility actions to be undertaken on the cities a new version of the mobility protocol for evaluation is included in this deliverable as well.

It was intended to include on this document more specific details of devices and monitoring equipment to be installed, but in some cases there are still some measures to be defined via amendment and the final monitoring equipment is still subject to changes. Therefore, all the available and secured information at this stage has been included. More specific information will be added in subsequent related deliverables.

In the meantime, a follow-up process will be done to check periodically the advances of the interventions, and the implementation of the different measures, as well as the data collection process. This will be contemplated on internal periodic reports and also on the supervision of the interventions deliverables (D7.10 and D7.11) while a final revision of the monitoring equipment will be done within D7.12 deliverable by the end on the project.

1 Introduction

1.1 Purpose and target group

This deliverable aims to provide a specific description of the monitoring equipment to be installed relative to the mobility actions. The initial KPIs included in D7.3 "Evaluation Protocols", the revised version of the mobility protocol included in section 3 of this same document and, in some cases, indicators coming from the D7.4 "City impact evaluation procedure", are further deployed to match the monitoring equipment that will provide the information for the project interventions at evaluation stage.

The direct target group are the three LH cities.

1.2 Contributions of partners

The following Table 2 depicts the main contributions from participant partners in the development of this deliverable.

Participant short name	Contributions
CAR	Responsible partner for the whole document. Contribution of introductory sections and mobility protocol. Compilation of contributions from the rest of partners.
FED, CEA	Specific contribution from Vitoria-Gasteiz: consolidation of KPIs, monitoring requirements and monitoring equipment.
TAR	Specific contribution from Tartu: consolidation of KPIs, monitoring requirements and monitoring equipment.
ZERO, SONF	Specific contribution from Sonderborg: consolidation of KPIs, monitoring requirements and monitoring equipment.
MON	Deliverable review

Table 2: Contribution of partners

1.3 Relation to other activities in the project

The following Table 3 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the SmartEnCity project and that should be considered along with this document for further understanding of its contents.

Deliverable Number	Contributions
D7.3 & D7.4	Reference for the evaluation protocols and project impacts measurement.
D7.6 & D7.8	Other two twin monitoring documents, referred to the district retrofitting and the integrated infrastructures actions respectively.

D7.5, D7.10, D7.11	Supervision of interventions in LH projects (Versions 1, 2 and 3). The monitoring and commissioning aspects treated here are reflected on those 3 documents.
D7.9	Data collection approach. This document includes a detailed description of connections between KPIs and data sources with high interconnection to the monitoring process.
D3.2, D4.2, D5.2	Integrated planning reports for the three LH cities. Each of these documents gather information applied to all project domains including building retrofitting, integrated infrastructures, ICT deployment (SmartEnCity platform) and sustainable mobility that have been valuable to report the monitoring basis.
D7.12	Monitoring summary. This document foreseen for the end of the project will contain specific information gathered from the project actuations based on the monitoring documents.

Table 3: Relation to other activities in the project

2 Overall Approach

The current deliverable belongs to *Task 7.2 Monitoring Program and subtask 7.2.2 Vehicle and urban mobility actions monitoring program*, which aim at the definition of a comprehensive and complete monitoring program. All the necessary requirements to ensure the adequate fulfilment of monitoring, metering and data acquisition have been specified here.

The content of this deliverable is structured as follows:

- Introduction, objectives and expected impacts. This section introduces the purpose of the document, the relations with other project tasks and contributions from different partners.
- Section 3 provides the revision of the mobility evaluation protocol, which was last described in D7.3. Latest changes on mobility measures have been taken into account.
- Sections 4, 5 and 6: KPIs are reviewed in the light of the latest changes after the amendment and the redefinition of the mobility measures. Non-KPI related monitoring requirements are included to complement the information provided only by the KPIs. Finally, the monitoring equipment and other sources of information are described to the best of our knowledge, taking into account that there are still some mobility measures subject to changes in the lighthouse cities
- Section 7 contains the guidelines for the commissioning plan including the main steps that have to be followed for a complete procedure.
- Final general sections 8 and 9 include the potential deviations to the plan (none mayor in this case) as well as the relation of this document with the previous and future reports to come in further stages of the project that will be fed with the information contained in this deliverable.

3 Revision of the Mobility evaluation Protocol

D7.3 SmartEnCity Evaluation Protocols included a preliminary version of the mobility protocol and a list of potential KPIs in section 9. Both are intended to evaluate the effects of the mobility interventions.

The current deliverable contains an updated version of the mobility evaluation protocol, based on updates from the mobility actions to be implemented in the three LH cities. These updates have been officially approved in the amendment signed on June 2018. Related KPIs have also been reviewed accordingly.

3.1 Scope of the protocol

The new set of actions from each city is presented within chapters 4, 5 and 6 of the current document, together with the specific list of KPIs and monitoring equipment to be put in place in order to register the required data that will be used to calculate such KPIs.

Mobility interventions in SmartEnCity project have been defined to achieve a set of impacts which are directly connected with technical, environmental, social and economic objectives. Next table is an update from Table 47 (Deliverable 7.3) and shows the different types of interventions, together with the expected technical, environmental, social and economic objectives. This table is now updated taking into account the latest changes from last amendment (June 2018).

Type of intervention	Technical objectives	Environmental objectives	Social objectives	Economic objectives
Electric buses line EVs (logistics) Public charging E-bike rental system (e-bikes and charging stations) Biogas buses Reuse of EV batteries EVs (passengers) EVs Intelligent recharging points Public transport planning tool	Reduce the traffic congestion Improve the efficiency of urban transport systems Decrease energy consumption in urban transport	Reduce the CO_2 emissions associated to urban transport	Improve the quality of life and the acceptance of the project by vehicles drivers	Reduction of the energy costs of drivers Decrease the payback of investment intervention

Table 4: Objectives to be achieved through the interventions

Technical and environmental objectives

Decrease of energy consumption in urban transport

Through the deployment of a fleet of electric vehicles, the SmartEnCity project aims to reduce the energy expenditure in urban transport. Since electric vehicles are more efficient than equivalent performance ICE (Internal Combustion Engine) vehicles when compared on a tank-to-wheel basis, a global energy saving can be expected from their introduction in the urban vehicle fleet. Unfortunately, ICEs still perform better in terms of range.

An extended use of bikes, together with an efficient public transport service (buses) should lead to a decrease of private vehicles use, and therefore is expected to have an effect on **traffic congestion reduction and thus reduction of CO_2 as well.**

The introduction of new EVs and the replacement of traditional buses with biogas ones will help to improve air quality through a **reduction of emissions** in general and CO_2 in particular, but won't have any effect on traffic flow.

The replacement of old vehicles with more efficient ones (EVs) will contribute to **decrease energy consumption**. Additionally, a potential increase of public transport use (as an alternative to private one) should have an influence on the energy consumed.

The introduction of efficient last mile delivery services will lead to a better quality of service that comes in consequence of the **reduction of delivery times**.

Reduction of the CO2 emissions associated to urban transport: EVs have zero emissions and that's already an advantage when compared to ICEs. However, the electricity generated during the charging process comes from a mix of energy, which is clean as long as it is generated by renewable energy sources. In most cases, there will be a balance between fossil and renewable energy sources (this will differ depending on the country). Regarding biogas buses, combustion of biogas, like natural gas, produces carbon dioxide (CO_2), a greenhouse gas. However, the carbon in biogas comes from organic matter that fixed this carbon from atmospheric CO_2. Thus, biogas production is carbon-neutral and does not add to greenhouse gas emissions. Further, any consumption of fossil fuels replaced by biogas will lower CO_2 emissions.

Increase the efficiency of public transport: An efficient public transport in terms of timely arrivals and departures and enough coverage with as many stops and vehicles as required to cover citizens' needs will lead to a natural preference for public transport instead of private one. In the end, traffic congestion will be reduced and air quality will be improved.

Increase the efficiency of freight delivery: An efficient freight delivery service leads to a reduction in delivery time delays. Shorter delivery times mean less traffic flow and in the end less traffic congestion.

Social and economic objectives

The introduction of EVs and biogas buses can increase the **social acceptance** of drivers towards this type of vehicles due to the environmental related advantages, as well as the reduction in the operation cost.

Finally, as a consequence of the access to a better price (for EVs) or a cheaper fuel (in the case of biogas buses), the return of investment (RoI) for this type of vehicles might decrease.

As cascade funding is not an option anymore, **alternative financial means** will have to be considered in order to make EV prices more appealing (e.g. national grants).

Bike parking stations offer a safe and convenient parking that will probably favour the use of bikes (either conventional or electric).

3.2 Assessment methods

The assessment of the effects of these interventions will be performed by means of the mobility protocol, through the calculation of a set of KPIs (updated from the tentative list provided in D7.2). Part of them will be commonly adopted by the three cities, but others will be specific for each city. The calculation method will be also specific as it will entirely depend on the available monitoring devices and infrastructure.

This protocol will detail the way in which the final performance of the mobility interventions will be evaluated, by comparing with the period immediately previous to the interventions, which is called "baseline".

Data collected to calculate the KPIs and feed the evaluation protocol will come mainly from two sources:

- Data registered by sensors & monitoring equipment installed in the vehicles or available at traffic platforms. These will be used mainly to calculate technical and environmental KPIs.
- Information coming from data bases, historical records, statistics, surveys. Surveys will be useful to evaluate the social and economic KPIs, which will be addressed by other protocols (Social Acceptance and Economic Performance protocols).

The list of KPIs already agreed by the three LH cities is presented in the table below:

Type	Action	General objective	Category	List of indicators
Technical indicators	**Implementation of mobility actions** *(Last mile vehicles, bikes)*	Reduce the traffic congestion	Logistic indicators	Traffic flow by vehicle type - peak
				Traffic flow by vehicle type - off peak
				Flow (at a specific reference point)
				Average vehicle speed (peak / off-peak)
				Average time for a reference distance
				Average occupancy
	Implementation of mobility actions in freight *(Last mile vehicles)*	Increase the efficiency of freight deliveries	Logistic indicators	Accuracy of timekeeping for freight

	Implementation of mobility actions in public transport *(electric and biogas buses)*	Increase the efficiency of public transport		Accuracy of timekeeping for public bus
	Replacement of old vehicles with more efficient vehicles *(EVs)* **and an increase of use of public services** *(buses, e-bikes)*	Decrease in energy consumption	Energy performance indicators	Energy consumption
				Vehicle fuel efficiency
Environmental indicators	**Use of high performance green vehicles** *(EVs, electric and biogas buses)*	Reduce the CO_2 emissions	Emissions indicator	CO_2, HC, NOx, PM emission by travelled distance
			Use of cleaner vehicles	Total number of recharges per year (EV)
				Total kWh recharged in the EV charging stations (EV) Total Kg of biogas used by biogas buses

Table 5: KPIs agreed for evaluating sustainable mobility actions (from D7.2, D7.3)

These KPIs are dealt with in more detail within the next sections of this deliverable, specifically for each of the lighthouse cities: Vitoria-Gasteiz, Tartu and Sonderborg.

Agreed KPIs will be calculated preferably from direct measures (real sensors, dataloggers, etc.). However, depending on the availability of measurement equipment, in some cases estimations will be used.

In the specific case of traffic congestion reduction, the effects of the interventions will be measured at city level (impacts evaluation) and won't be included in the current protocol, which is focused on the mobility interventions at demo site level.

For each of the relevant KPIs a baseline will be calculated and used as a reference for comparison with the value observed after the physical implementation of the interventions.

The methodology followed will consist in adapting the Measurement & Verification (M&V) option A of the IPMVP for the mobility interventions deployed in the three LH cities.

The M&V Plan will include the specific measurements, collecting sources and adjustments for each particular scenario, taking into account the interventions that will be performed, and also the available sensors that will gather the measurements for the evaluation. The M&V Plan will be structured as follows:

- Formulation of mobility-related general objectives
- Selected IPMVP Option and Measurement Boundary
- Baseline design
- Post-intervention measurements and collecting sources
- Analysis
- Reporting Period

3.3 SmartEnCity evaluation approach

As stated in D7.3, there is no unified verification protocol to guide the evaluation process to quantify and validate the improvements achieved with urban mobility interventions in the specific terms of SmartEnCity project general objectives. Therefore, an ad-hoc protocol will be defined, based on IPMVP principles (this protocol is commonly used for building retrofitting).

When applied to building retrofitting, IPMVP offers four different Measurement and Verification options:

- Option A. Retrofit Isolation with Key Parameter Measurement
- Option B. Retrofit Isolation with All Parameter Measurement
- Option C. Whole Facility Measurement
- Option D. Calibrated Simulation

The choice among these options involves many considerations including the location of the measurement boundary. If only the performance of the intervention itself is of concern, a retrofit-isolation technique may be more suitable.

For the mobility scenario only option A can really be applied , given that it is impossible to measure the city as a whole and isolate the effects of the mobility actions from other possible interferences, and it is not possible either to measure all different parameters that might affect the formulation of mobility-related general objectives within reasonable cost constraints.

Option A is the Partially Measured Retrofit Isolation, in which savings are determined by partial field measurement of the energy use of the element(s) to which the formulation of each mobility-related general objective was applied, separate from the energy use of the rest of the system. The monitored parameters are followed on a continuous basis or a high rate, and the rest of variables are fixed as stipulations.

We will use available statistics (such as average fuel consumption, vehicles adoption rates or emissions per litre of fuel) in order to make the stipulations as accurate as possible to the real values.

The measurement boundary for the evaluation will be the set of vehicles deployed within SmartEnCity interventions, and the network of charging stations (electric and biogas). To determine the EV adoption rate, local (city-level) statistics will be used.

3.3.1 Baseline design

The mobility baseline period chosen should be one year. This is suitable since some of the parameters, such as vehicle purchases statistics are released on a yearly basis, and vehicle monitored data for distances and energy can be aggregated along this period.

Regarding the scope of the baseline in terms of energy savings, an equivalent number and typology of internal combustion vehicles will be chosen as reference for the ones introduced by the mobility interventions.

Scope of the Intervention	Baseline
# E-bikes	# gasoline / diesel vehicles
# Electric vehicles	# (gasoline / diesel vehicles)
# Biogas buses	# diesel buses
# Last mile delivery EVs	# (gasoline / diesel last mile delivery vehicles)
# Bike-hubs	# Current existing infrastructure for conventional bikes
# New charging points	# Current existing charging points (previous to SmartEnCity project)
# New biogas stations	# Diesel stations previously devoted to old diesel buses refuelling

Table 6: Baseline scope

The schedule of the project does not accommodate for the time needed to gather baseline data for a full year, so already available statistical information about internal combustion vehicles energy usage, CO_2 emissions or the current charging infrastructure will be used to provide a baseline.

Additionally, historic values from freight delivery services and public buses actual timekeeping along one year previous to the interventions implementation will be used as far as possible.

Decrease of energy consumption in urban transport

Given the fact that FEV are more efficient than ICEs, it is foreseen to save several MW worth of energy during the lifetime of the project.

One year would be the ideal time slot required to set up the baseline. However, there's not enough time to accommodate such time period, during which we should be measuring the energy consumption of an equivalent fleet of ICE vehicles. We will estimate it from:

- The travelled distance of the vehicles of the intervention, assuming the ICE vehicles would be used to provide an equivalent service.
- In the case of Vitoria-Gasteiz a remarkable number of bikes are expected to be deployed. We can consider they will be substituting ICEs, but also public transport, and walking. The travelled distance by bikes may be registered through an app with a smartphone. Some assumptions will have to be made in order to estimate the energy consumption saved through the use of bikes.
- The average fuel consumption per distance travelled for the vehicle type (car, bus, diesel or gasoline)
- The energetic value of a litre of fuel: of 8.79 kWh per litre of gasoline and a value of 9.98 kWh per litre of diesel.

Therefore, the baseline for energy consumption of vehicles is[1]:

$$
\begin{aligned}
&Baseline\ for\ energy\ consumption \\
&= Total\ km\ travelled\ by\ buses \cdot 0.6762 \frac{l\ diesel}{km} \cdot 9.98 \frac{kWh}{l\ diesel} \\
&+ Total\ km\ travelled\ by\ electric\ cars\ \cdot (0.47\ gasoline\ car\ ratio \\
&\cdot 8.79 \frac{kWh}{l\ gasoline} \cdot 0.055 \frac{l\ gasoline}{km} + 0.51\ diesel\ car\ ratio\ \cdot 9.98 \frac{kWh}{l\ diesel} \\
&\cdot 0.047\ \frac{l\ diesel}{km})
\end{aligned}
$$

Reduction of CO_2 emissions in urban transport

CO_2 emissions cannot be measured directly, but they can be estimated from the burnt fuel or the distance travelled per vehicle type, either as a factor of the distance, or as a factor of the burnt fuel, which is in direct relation with the distance.

Using information about emissions provided by the US Energy Information Administration, the Atmospheric Chemistry and Physics Journal and the UK Vehicle emission curves for the National Transport Model, assuming modern ICE vehicles fitted with particle filters (since the intervention vehicles would be replacing newly acquired vehicles), we can calculate the baseline CO_2 emissions as:

$$
\begin{aligned}
&Baselilne\ for\ CO2\ emissions \\
&= Total\ km\ travelled\ by\ buses\ \cdot 0.6762\ \frac{l\ diesel}{km} \cdot \frac{2.68\ Kg\ \mathrm{CO2}}{l\ diesel} \\
&+ Total\ km\ travelled\ by\ electric\ cars\ \cdot (0.47\ gasoline\ car\ ratio \cdot \frac{2.35\ Kg\ CO2}{l\ gasoline} \\
&\cdot 0.055\ \frac{l\ gasoline}{km} + 0.51\ diesel\ car\ ratio \cdot \frac{2.68\ Kg\ CO2}{l\ diesel} \cdot \frac{0.047\ l\ diesel}{km})
\end{aligned}
$$

[1] Sources: Instituto para la Diversificación y Ahorro de Energía for average new car fuel consumption, US Energy Information Administration for energetic values of a litre of fuel

Increase the efficiency of public transport

Public transport efficiency can be assessed from transport planning tools -or from timekeeping historic values, registered along one year previous to the implementation of the new buses fleets. In the case of biogas/electricity technology, no changes in timekeeping are to be expected if only the technology changes, but not the performance or the routes planning of the buses. However, less traffic congestion may have a positive effect on buses punctuality, and an improved buses service will attract more passengers that will leave their private cars at home, thus reducing traffic congestion.

Indicators assessing the punctuality of the old buses will be calculated in those cases where it makes sense. They will be based on the deviations from the theoretical arrival and departure times. Data from the transport planning tool deployed in Tartu will be used for this purpose.

Increase the efficiency of freight delivery

The only city deploying last mile delivery actions is Vitoria-Gasteiz. Last mile delivery efficiency would be ideally assessed from delivery delays historic values, registered along one year previous to the implementation of the new freight delivery fleets. These data would be retrieved (as far as possible) from similar fleets, providing similar services.

If there were no registers of delivery delays from historic values, estimations would be made to calculate a reasonable baseline. The ultimate target is to have a reference against which we can compare the improved performance thanks to the freight delivery intervention.

According to a recent study on last mile delivery solutions for Vitoria-Gasteiz[2] in the short to medium term, a logistics delivery system has been proposed, based on banning the entrance of delivery vehicles further to a set of non-attended reception points (packstations). Traffic congestion and CO_2 emissions would be reduced as a result of this procedure.

3.3.2 Post-intervention design

Key parameters to be monitored during the intervention are the same that constitute the baseline, although the information will come or will be derived from the installed monitoring devices. At this stage the monitoring equipment specifications are not fixed in general for any of the LH cities. These specifications depend to a great extent on the final mobility actions to be deployed. More information on this will be provided in D7.7 Mobility action monitoring program.

- **Energy expenditure:** Sensors installed in the electric vehicles for battery levels and recharges, as well as sensors in the charging stations will provide the energy expenditure information required, so we will measure real data rather than estimations. Given that some electric vehicle models may not provide energy expenditure information, the reported expenditure per distance will be used along with the travelled distance to provide estimation (as a worst case scenario).
- Biogas consumption by buses will be measured with specific on-board equipment as far as possible. Otherwise, estimations will be used.

[2] Definición de un nuevo modelo logístico de distribución urbana (Definition of a new logistic model for urban distribution). Developed by DHL for Vitoria-Gasteiz.

- **CO_2 emissions:** Given that it is hard to get accurate measures for CO_2 emissions on vehicles, particularly for electric vehicles (as the emission takes place where the energy is generated and unrelated to the electric vehicle location), we will use the consumed kWh and multiply it by the factor of CO_2 emissions per generated Kilowatt of the particular electric generation mix in each country. In Spain this factor is 0.203 Kg/KWs, which may be also valid for Denmark.

- **Electric vehicle recharges**: Number and KWh recharged yearly. This information will be measured directly in the charging stations

- **Biogas bus refuelling**: Number of refuelling times and litres refuelled yearly. This information will be measured directly in the biogas stations.

- **Timekeeping** registers from biogas buses and freight delivery vehicles

Next sections present the monitoring plans for the mobility actions of the three lighthouse cities: Vitoria-Gasteiz, Tartu and Sonderborg.

4 Vitoria-Gasteiz mobility action monitoring

This section describes the monitoring plan for the mobility actions of Vitoria Gasteiz.

Sustainable mobility related measures have been redefined and the new ones have been approved under an amendment signed on June 2018. The new actions fall under two categories:

- Action 1: 100% electric bus line
- Action 2: Last mile logistics fleet

The list of sustainable mobility actions is shown in the table below:

	Year II	Year III	Year IV
100% electric bus line	---	*Tenders, purchase of the e-buses (13) and the associated infrastructure (before summer); start of the works (before the end of the year)*	*End of the works; system deployed and running.* *MONITORING*
Last mile logistics fleet	*3 EVs*	*23 EVs*	*MONITORING*

Table 7: Deployment of mobility actions in Vitoria-Gasteiz city

Action 01: 100% electric bus line

13 new high-capacity 100% electric buses and their charging infrastructure will be deployed in the city of Vitoria-Gasteiz. They will be included in the city BRT (Bus Rapid Transit) that will fully electrify the current "line 2", which is the most crowded one. The 13 new e-buses include 7 articulated and 6 conventional-sized ones. The charging infrastructure will be composed by four ultra-fast CP pantographs on the street, together with slow charging infrastructure in the public transport company garage (devoted to night charging).

The awarded company/ies will be required to include both performance and energy consumption monitoring devices in each e-bus.

These data will be integrated within the SmartEnCity ICT platform as to monitor charging performance in real-time until the end of the project.

Action 02: Last mile logistics fleet

26 new Electric Vehicles will be purchased and they will be devoted to different types of freight logistics. Three different models of EVs will be acquired:

- 8 electric light trucks
- 7 electric light vans
- 11 electric cargo-bikes

A hub for last mile delivery to supply EVs to self-employment in the daily delivery will be created. Hub location is in an unused supermarket parking and the following services will be covered:

Courier:

A collaboration agreement will be established with a last-mile state-owned courier company from Vitoria-Gasteiz city to identify new business niches through the implementation of electric vehicles and software. Some of the clients are now being reached on foot and others by means of conventional ICE vehicles. An analysis of the specific needs of the vehicle and software will be carried out to obtain an optimum operative that allows enlarging the niche market, and thus reaching new clients.

Touristic routes around the city:

A new concept of sustainable and interactive EV driving tour will be implemented. An eco-tour will show every corner of the city with a virtual guide, with EVs that have room for up to 4 people.

There will be 4 types of tours depending on the length of the journey: city tour (2 hours), gastro & culture tour (4 hours), all in one (6 hours), the green tour (3 hours and a half).

Urban freight delivery:

Cooperation agreements will be carried out with companies in order to replace existing ICE vehicles with EV ones. Their operation will be optimized through the implementation of a new software.

Final consumer delivery of supermarket goods:

A collaboration project will be carried out with a supermarket brand that has more than 20 stores in Vitoria-Gasteiz. The vehicles currently being used for distribution (ICE vans) will be replaced with EVs and the delivery process will be optimized through the implementation of a new software design that will deal with the management, allocation and optimization of routes.

4.1 Collection of KPIs & city indicators applicable for the mobility action evaluation

Using as base of information deliverable *D7.3 - Evaluation protocols* and the update on the mobility protocol made on section 3 (and also D7.4 if city indicators apply) this section includes for Vitoria-Gasteiz the specific KPIs that will be used for the evaluation of the mobility actions. For each KPI the variables to be measured need to be defined. These measurements will come from sensors (monitoring equipment) or from other sources, which are also determined in order to ensure all the required inputs are taken into account.

The set of relevant KPIs has been classified according to the related Actions and distributed in Table 8, Table 9 and Table 10.

Indicator name	Description	Unit	Data source
EV identification data	Model (light truck, light van, cargo bike) Service: courier, touristic route, etc.	---	Companies providing the service
Distance driven per charging process	Distance driven between two charging processes as a way to know how often drivers recharge and if they use the full battery range	Km	monitoring
Routes	Distance driven while performing the different services	Km	monitoring
Speed	Real-time value of the vehicle speed. This is useful to know which is the specific speed in different areas of the city and will help identify which areas can be adequate for electric mobility; which ones are more densely populated, etc.	Km/h	monitoring
BSoC	Battery state of charge.	% (A.h)	monitoring
Aux SoC	Auxiliaries state of charge	%	monitoring
Electricity consumption	Both from the battery and also from the auxiliary systems	kWh	monitoring
Electricity recovered from regenerative breaking	Some vehicles may offer the possibility of recovering energy from regenerative breaking	%	monitoring
Outdoor temperature	This can be useful to check the influence of outside temperature on battery electricity consumption	Celsius degrees	monitoring
Maintenance record	Information on typical breakdowns and maintenance records	-----	Records
Accuracy of timekeeping	This would apply to those vehicles performing a delivery service	Time	Surveys
Emissions saved / travelled distance	CO_2, HC, NOx, PM emissions saved can be estimated from the travelled distance	Pollutant tonnes	Estimation

Table 8: KPIs for the evaluation of EVs performance in Vitoria-Gasteiz city

Indicator name	Description	Unit	Data source
e-bus identification data	e-bus number, line	----	Public information

GPS position, speed	Actual speed and GPS position of e-buses	coordinates	Monitoring
Travelled distance	Travel distance is needed to estimate emissions	km	Monitoring
Electricity consumption of the motor	Instantaneous electricity consumption of the e-bus electric motor	kWh	Monitoring
BSoC	Battery state of charge.	% (A.h)	Monitoring
Aux SoC	Auxiliaries state of charge	%	Monitoring
Electricity consumption	Both from the battery and also from the auxiliary systems	kWh	Monitoring
Electricity recovered from regenerative breaking	Instantaneous value for this KPI may be registered in the first place. Then, a cumulative value may be provided	%	Monitoring
Emissions saved / travelled distance	CO_2, HC, NOx, PM emissions saved can be estimated from the travelled distance	Pollutant tonnes	Estimation
Average annual energy economic savings	Calculation of average economic savings that can be derived from the technology (electric vehicle), fuel, maintenance costs, etc. We are comparing conventional buses against electric ones.	Euros	Estimation / calculation
Number of trips per month/year	This can be calculated from the number of trips per day, which is a fixed number.	#	Calculation
Average occupancy	This is useful to know the actual impact on citizens	#	Estimation
Accuracy of timekeeping	This is useful to assess the impact of the time spent for charging	minutes	Monitoring
Average time to complete the route	This is useful to compare performance of e-buses against performance of conventional ones	minutes	Monitoring
Vehicle fuel efficiency	Vehicle fuel efficiency = Distance travelled / kW consumed	km/kW	Calculation from Annual distance driven & annual electricity consumption

Table 9: KPIs for the evaluation of e-buses performance in Vitoria-Gasteiz city

Indicator name	Description	Unit	Data source
CP identification data	Public / private charging point. Location	-----	Database
Number of charging processes /day/year/month	Number of charging processes performed every year	#	Monitoring
Average charging time	Average time to perform a charging process	hours	Monitoring
Preferred charging time	Identify the preferred (most common) time of the day to start charging the EV	hour	Monitoring
Amount of kW recharged per day/month/year	Amount of kW recharged. This must be done at least annually.	kW	Monitoring
Maintenance record	Information on typical breakdowns and maintenance records	-----	Records

Table 10: KPIs for the evaluation of charging points' performance in Vitoria-Gasteiz city

Further to the KPIs already listed, there's a set of indicators (from D7.4) that are meant for evaluating the impacts at city level. These are listed in Table 11 below:

Indicator name	Description
Energy savings in the city due to sustainable mobility actions	This indicator will be calculated from the specific KPIs that relate to energy savings.
Lower emissions of CO2 in the city due to sustainable mobility actions	This indicator will be calculated from the specific KPIs that relate to CO2 reduction.
New sustainable vehicles (EV) in the city due to SmartEnCity project	This indicator will be calculated from the number of new electric vehicles classified by categories (cars, buses, trucks)
Increase of the number of EV charging infrastructures in the city (only public or public & private infrastructure) due to the project	This indicator will be calculate from the number of public EV charging stations
Increase in the use of EV charging infrastructures due to the project	This indicator will be calculated from: • Total number of recharges per year • Total kWh recharged in the EV charging stations

Business generated during the project linked with the sustainable mobility actions	This indicator will be calculated through the revenues or the companies involved in the mobility actions due to the project.
Number of jobs created due to district renovation, mobility actions and citizen engagement actions	This indicator will be calculated from the total number of jobs created and the further link with the city unemployment rate.
Employment profile created due to mobility actions	This indicator will be calculated by means of a supply chain assessment or questionnaire that will be distributed among actors involved with mobility actions
New companies created or new services offered by companies due to mobility actions during the whole project	This indicator will be calculated by means of a supply chain assessment or questionnaire that will be distributed to actors involved with mobility actions
Acquisition of training skills due to mobility actions during the whole project	This indicator will be calculated through a questionnaire that will be distributed to actors involved with mobility actions

Table 11: Indicators applicable to the mobility actions evaluation for Vitoria-Gasteiz

Logistic KPIs, aimed at **reducing traffic congestion**, will be calculated from available sources. These KPIs are:

- Traffic flow by vehicle type (peak and off-peak)
- Flow (at a specific reference point)
- Average vehicle speed (peak / off-peak)
- Average time for a reference distance
- Average occupancy

4.2 Non-KPI related monitoring requirements

This section deals with other sources of information that will complement the data obtained directly from the monitoring equipment, to calculate many of the KPIs included in the tables from the previous section.

Very often, KPIs must be obtained from data bases, historical records, statistics, that are combined with actual values registered with monitoring equipment. These sources are described next:

Weather conditions (more specifically, outdoor temperature): It is well known that electric vehicles with Li-ion batteries when driven in cold weather experience a drastic power loss and a restriction of regenerative braking at temperatures below 5–10 °C. Both factors greatly reduce cruise range. Though weather conditions in Vitoria-Gasteiz are not very extreme, outdoor temperature is likely to have some effect on the performance or EVs and it has been considered as a useful KPI.

To collect this KPI, there are two possibilities: to install a weather station or to make use of existing weather services. In the case of Spain, AEMET is the meteorological state service (https://opendata.aemet.es/), whose information is available on multi-platform programming languages based on REST API. In the specific case of Vitoria, the weather station collecting the real data for this service is “Foronda-Txokiza” located on the coordinates 42° 52' 55" N; 2° 44' 6" W, having both instantaneous and historical data available to query.

Maintenance records: historical records of typical breakdowns and the related costs

Average annual economic savings: historical records

4.3 Monitoring equipment and other sources of information

After clarifying the monitoring needs from the KPI calculation and additional data perspectives, the next step is to define the monitoring equipment and its location, in order to measure all the variables. This section focuses on the recommendations about sensors and meters and their placement for the measurement of the variables stated before, including all specifications of the physical systems when available (data sheets of equipment could go into an annex at the end of the document). The LH cities may determine more specifications about the monitoring systems during tendering and commissioning processes. It is also important to note that the variables measured with the meters are integrated in the data collection approach (see D7.9).

In terms of monitoring, two levels of data are identified: monitoring equipment, which refers to hardware equipment, and other sources that provide information.

Variable	Definition	Meter	Location
Speed, acceleration, braking, engine revolutions, electricity consumption, state of charge of the battery	These variables are the basic ones that provide a proper assessment of driving performance. They are usually available through the vehicles CAN bus	Assistance system for efficient driving	Inside the bus
Charging time, kW recharged in each charging process	These are the basic variables required to monitor the charging process	SCADA system	
CO, NO_x emissions	CO and NOx emissions sensors will provide a fair assessment of the actual pollution in the area.	CO, NOx sensors	Integrated in the assistance system for efficient driving
Number of passengers	This variable measures the occupancy rates. The installed system will allow more than 95% reliability	Passenger counter system	Inside the bus
Abrupt turn while driving	Unexpected and abrupt turning of the vehicle	Accelerometer	Integrated in the assistance system for efficient driving

Table 12: Monitoring equipment for Vitoria-Gasteiz

For the **electric buses** there will be two main monitoring systems:

- Assistance system for efficient driving: to monitor the buses driving performance
- SCADA system: to monitor the charging process of the buses

The assistance system for efficient driving will be connected to the CAN bus and will be able to store, process and send all the relevant variables which are related to the driving process every 10 seconds. These data will be downloaded at the central control system, in real time, to allow their analysis and the definition of real time guidelines that can lead to a more efficient driving process in terms of electricity consumption.

The assistance system for efficient driving will be able to generate real time alarms, and on-line monitoring of the vehicles will be possible from the central control system. Drivers will be informed about potential driving-related incidents, and adequate recommendations will be provided. The ultimate goal is to achieve environmental benefits, reduce maintenance service and increase the comfort of passengers thanks to an improved driving experience.

The central control system will have specific software to analyse the registered data. Different indicators will be calculated to assess the efficiency of the driving process (electricity consumption of different buses lines, drivers, vehicles, etc.) Moreover, this central control system will be integrated with the Tracking and Monitoring System and thus it will be possible to relate relevant parameters (e.g. routes, demands, types of services, etc.) to the actual costs.

The SCADA system will be able to control the whole charging infrastructure. Different screens will show the different charging stations with the related monitored information and generated alarms.

Variable	Definition	Meter	Location
Outdoor temperature	This variable is useful to assess the performance of electric batteries under different outdoor temperatures.	Weather station	Fixed locations in the city

Table 13: Other sources of information for Vitoria-Gasteiz

5 Tartu mobility action monitoring

This section describes the monitoring plan for the mobility actions of Tartu.

Sustainable mobility related measures have been redefined and the new ones have been approved under an amendment signed on June 2018. The new actions fall under four categories:

- Action 1: Public charging
- Action 2: E-bike rental system
- Action 3: Biogas buses
- Action 4: Reuse of EV batteries
- Action 5: Public transport planning tool
- Action 6: Bike-share system

The list of sustainable mobility actions is shown in the table below:

	Year I	Year II	Year III	Year IV	Year V
Public charging			*5CP*		
E-bike rental system			*75*	*75*	*150*
Biogas buses				*60BB*	
Bike-share system				*450*	
Public transport planning tool			*1 PT*		
Reuse of EV batteries			*1CP*		

Table 14: Deployment of mobility actions in Tartu city

Action 1: Public recharging

5 new 50kW fast charging points have been installed in public locations to cover the demand generated by the future new EVs that are going to be introduced (rentals, taxis and private use).

Action 2: E-bike rental system

An innovative e-bike rental system will be developed by the City of Tartu. This solution avoids the need to dock bikes for parking, by using GPS technology in combination with ICT solutions, making use of the project's City information infrastructure. There will be 300 e-bikes available for rental. Bikes will be booked and unlocked from the distance by using the web application or mobile app. It is possible to get the required information from the e-bike in real time. Thanks to the batteries, the bike is able to stay in connection with stations and server for a long time, giving a wide autonomy. All smartness is integrated into the bike.

Additionally, IT solutions will help to create user profiles in a way that each user can determine how much support from the electric motor he or she needs when cycling. The user profile is saved and each time when the user is identified, the e-bike automatically sets it according to the user profile.

Action 3: Bikeshare

A bike sharing business model has already been developed and a related analysis was carried out in 2014. Bike sharing is mainly addressed to people who need to travel 2-5 km and it is a great alternative to driving a car. The analysis showed that the potential number of bike share users could be up to 224,000 annually (65 parking locations, 450 bikes).

Action 4: Biogas buses

The City of Tartu will request during the fourth year of the project 60 brand new biogas buses to serve the public transportation network. This means that from 2019 onwards, 100% of public transportation buses will run on biogas. The annual capacity of the regular public transportation service is currently 3.6 million line kilometres.

Action 5: Reuse of EV batteries

EV batteries that are not useful for EVs anymore, but still can deliver 70-80% of their original output, will be used for storing energy.

As a first application they will be used to provide stability to the power grid through demand response and frequency regulation.

Once scaled up they could take consumers off the grid altogether or see active interaction between electric vehicles and the grid (i.e. vehicle-to-grid system design with bi-directional grids and real-time pricing).

The EV taxis of the private company OÜ Takso will be partially recharged based on renewable energy that is produced on-site with PV panels and stored in used EV batteries. OÜ Takso will install the recharging point (for reusing the EV batteries) and 300 m^2 of PV panels (aiming to generate 50kW of solar energy) during the third year of the project.

Action 6: Public transport planning tool

Based on a prototype developed in the Smart City Lab, the transport plan will also include advancing a transport web application that will have the following aims – providing means for citizens to plan their everyday movement, notifying citizens of any changes in transport schedules/plans, involving citizens in improving transport arrangements and to make public transport more efficient and need-based. The application will thereby include in minimum next functionalities:

- The current schedule and bus lines
- Trip-planning based on the current schedule
- Giving feedback on the schedule and travel opportunities

5.1 Collection of KPIs & city indicators applicable for the mobility action evaluation

This section provides the specific KPIs that will be used to evaluate the mobility actions of Tartu. *D73 - Evaluation protocols* and the update on the mobility protocol are used as base of information. For each KPI the variables to be measured need to be defined. These measures will ideally come from sensors (monitoring equipment) or from other sources, which are also determined in order to ensure all the required inputs are taken into account.

Specific KPIs for Tartu:

Indicator name	Description	Unit	Data source
CP identification data	Public / private charging point. Location	-----	Database
Total number of recharges per year /day/year/month	Number of charging processes performed every year	#	Monitoring
Average charging time	Average time to perform a charging process	hours	Monitoring
Preferred charging time	Identify the preferred (most common) time of the day to start charging the EV	hours	Monitoring
Amount of kW recharged per day/month/year	Amount of kW recharged. This must be done at least annually.	kW	Monitoring
Maintenance record	Information on typical breakdowns and maintenance records	-----	Records

Table 15: KPIs for the evaluation of charging points' performance in Tartu city

Indicator name	Description	Unit	Data source
Annual number of users	Number of users that make use of the e-bike rental system every year	#	Monitoring
Amount of kW recharged per day/month/year	Amount of kW recharged. This must be done at least annually.	kW	Monitoring
Average annual distance driven	Average distance driven by the e-bikes every year. This KPI can provide an estimation of the emissions saved by using e-bikes instead of conventional ICE vehicles	km	Monitoring / estimation

Table 16: KPIs for the evaluation of the e-bike rental system in Tartu city

Indicator name	Description	Unit	Data source
Annual number of users	Number of users that make use of the bike share service every year	#	Monitoring
Annual distance driven	As a way to estimate the emissions saved by using bikes instead of conventional ICE vehicles	km	Monitoring/Estimation

Table 17: KPIs for the evaluation of the bike share system in Tartu city

Indicator name	Description	Unit	Data source
Annual distance travelled	This KPI will be used to estimate CO_2 emissions saved as a result of substituting conventional buses with biogas ones. Biogas buses are carbon-neutral because the carbon in biogas comes from plant matter that fixed this carbon from atmospheric CO_2.	km	Estimation (bus routes are fixed)
Average vehicle speed	Average vehicle speed (peak / off-peak)	Km/hour	Monitoring / estimation
Energy consumption	Biogas consumed per travelled distance	kg (m3)	Monitoring / estimation
Vehicle fuel efficiency	Vehicle fuel efficiency = Distance travelled / fuel consumed	km/m3	Calculation from Annual distance travelled & annual biogas refuelled
Emissions saved / travelled distance	CO_2, HC, NOx, PM emissions saved can be estimated from the travelled distance	Pollutant tonnes	Estimation

Table 18: KPIs for the evaluation of the biogas buses in Tartu city

Indicator name	Description	Unit	Data source
Renewable energy coming from PV that is stored in the batteries	Amount of renewable energy (from PV) that is stored in the reused batteries	kW	Monitoring
Energy used for recharging purposes	Amount of energy recharged	kW	Monitoring

Table 19: KPIs for the evaluation of reused batteries in Tartu city

Indicator name	Description	Unit	Data source
Accuracy of timekeeping for public bus	This KPI aims to assess the efficiency of public biogas buses in terms of timely arrivals and departures		

Table 20: KPIs for the evaluation of public transport planning tool in Tartu city

Further to the KPIs already listed, there's a set of indicators (from D7.4) that are meant for evaluating the impacts at city level. The set of indicators that apply to the mobility actions evaluation are listed in Table 20 below

Indicator name	Description
Energy savings in the city due to sustainable mobility actions	This indicator will be calculated from the specific KPIs that relate to energy savings.
Lower emissions of CO_2 in the city due to sustainable mobility actions	This indicator will be calculated from the specific KPIs that relate to CO_2 reduction.
New sustainable vehicles (EVs and biogas) in the city due to SmartEnCity project	This indicator will be calculated from the number of new electric and biogas vehicles classified by categories (cars, buses, trucks)
Increase of the number of EV charging infrastructures in the city (only public or public & private infrastructure) due to the project	This indicator will be calculated from the number of public EV charging stations
Increase in the use of EV charging infrastructures due to the project	This indicator will be calculated from: • Total number of recharges per year • Total kWh recharged in the EV charging stations
Number of jobs created due to district renovation, mobility actions and citizen engagement actions	This indicator will be calculated from the total number of jobs created in relation to mobility actions.

Employment profile created due to mobility actions	This indicator will be calculated by means of a questionnaire that will be distributed among actors involved with mobility actions.
New companies created or new services offered by companies due to mobility actions during the whole project	This indicator will be calculated by means of a questionnaire that will be distributed to actors involved with mobility actions
Acquisition of training skills due to mobility actions during the whole project	This indicator will be calculated through a questionnaire that will be distributed to actors involved with mobility actions

Table 20: Indicators applicable to the mobility actions evaluation

Logistic KPIs, aimed at **reducing traffic congestion**, will be calculated from available sources. These KPIs are:

- Flow (at a specific reference point)
- Average vehicle speed (peak / off-peak)
- Average time for a reference distance
- Average occupancy

5.2 Non-KPI related monitoring requirements

This section includes other sources of information that complement the monitoring equipment used to register measures used to calculate the KPIs from section 5.1.

Some KPIs must be obtained from data bases, historical records, statistics, etc. Monitored data will be obtained from the SmartEnCity CIOP (gathered from sensors, vehicles, equipment etc.).

5.3 Monitoring equipment and other sources of information

This subsection contains the explanation of the monitoring equipment and other sources of information, including all specifications of the physical systems when available (data sheets of equipment could go into an annex at the end of the document). Recommendations should be provided about sensors and meters and their placement for the measurement of the variables stated before. These descriptions should match with the variables identified in previous sections 5.1 and 5.2.

In terms of monitoring, two levels of data are identified: monitoring equipment, which refers to hardware equipment, and other sources that provide information.

Variable	Definition	Meter	Location
Total number of recharges per year /day/year/month Average charging time Preferred charging time Amount of kW recharged per day/month/year Maintenance record	These variables characterize the performance of EV-chargers	Data logger	Inside the charger
Annual number of users Amount of kW recharged per day/month/year Average annual distance driven	These variables characterize the performance of e-bike rental system	Data logger	Inside the e-bike/e-bike rental management system
Annual number of users Annual distance driven	These variables characterize the performance of bike-share system	Data logger	Inside the bike/bike rental management system
Annual distance travelled Average vehicle speed Energy consumption Vehicle fuel efficiency Emissions saved / travelled distance	These variables characterize the performance of biogas buses	GPS data logger combined with CIOP	Inside the bus
Renewable energy coming from PV that is stored in the batteries Energy used for recharging purposes	These variables characterize the performance of EV-battery re-use system	Data logger	Inside the equipment
Accuracy of timekeeping for public bus	This variable characterize the performance of public transport planning tool	GPS data logger	Inside the bus

Table 21: Monitoring equipment for Tartu

Variable	Definition	Meter	Location
Lower emissions of CO_2 in the city due to sustainable mobility actions New sustainable vehicles (EV) in the city due to SmartEnCity project New sustainable vehicles (biogas buses) in the city due to SmartEnCity project Increase of the number of EV charging infrastructures in the city (only public or public & private infrastructure) due to the project Increase in the use of EV charging infrastructures due to the project Number of jobs created due to district renovation, mobility actions and citizen engagement actions Employment profile created due to mobility actions New companies created or new services offered by companies due to mobility actions during the whole project Acquisition of training skills due to mobility actions during the whole project	These variables help to evaluate mobility activities	Data from specific meters + Different KPI´s + interviews + statistics	CIOP

Table 22: Other sources of information for Tartu

6 Sonderborg mobility action monitoring

This section describes the monitoring plan for the mobility actions of Sonderborg.

Sustainable mobility related measures have been redefined and the new ones have been approved under an amendment signed on June 2018. The new actions fall under three categories:

- Action 1: Biogas buses
- Action 2: Electric vehicles
- Action 3: Intelligent recharging points

The list of sustainable mobility actions is shown in the table below:

	Year I	Year II	Year III	Year IV	Year V	Year VI
Biogas buses		*44 BB*				
Intelligent recharging points				*30 CP*		

Table 23: Deployment of mobility actions in Sonderborg city

Action 1: Biogas buses

Biogas buses for 6 bus lines with 44 buses in the Municipality of Sonderborg have been implemented in 2017. Biogas filling stations for buses at Ragebol outside of Sonderborg town are in operation since 2017 – placed in the Sonderborg 100% RES Smart Community Local RES-supply Zone.

Action 2: Charging points

28 intelligent "Evergreen" chargers and 2 normal chargers will be installed for charging electric vehicles. Charging of electric vehicles will be carried out according to wind electricity production delivered to the Danish grid, which has a 40% wind electricity penetration.

6.1 Collection of KPIs & city indicators applicable for the mobility action evaluation

Using as a base of information deliverable D7.3 and the update on the mobility protocol made on section 3 (and also D7.4 if city indicators apply) this section includes the specific KPIs that will be used for the evaluation of the mobility actions in Sonderborg city.

Then for each KPI, it will be necessary to define needed variables that have to be measured to calculate them, and also the frequency for such calculations and data gathering.

Indicator name	Description	Unit	Data source
Accuracy of timekeeping for public bus	This KPI aims to assess the efficiency of public biogas buses in terms of timely arrivals and departures. From June 2017 onwards there is real life tracking of the biogas buses, however our ICT platform will not be up and running until 2019. The real time tracking shows in real time whether the buses are on time or delayed.		Site for the live tracking: http://www.rejseplanen.dk/bin/help.exe/mn?L=vs_dot.vs_livemap&tpl=fullscreenmap&custom=sydtrafik_Regionen&view=dsb
Annual distance travelled	This KPI will be used to estimate CO_2 emissions saved as a result of substituting conventional buses with biogas ones. Biogas buses are carbon-neutral because the carbon in biogas comes from plant matter that fixed this carbon from atmospheric CO_2.	km	Estimation (bus routes are fixed)
Energy consumption	Biogas consumed per travelled distance	litres	Estimation
Vehicle fuel efficiency	Vehicle fuel efficiency = Distance travelled / fuel consumed When comparing biogas against diesel, 1 mio liter of diesel oil was used by the busses in 2015, this equals 2,16 mio km based on the standard diesel buses energy efficiency factor (2.16 by TI). The energy used is 0,46 l diesel per km - equal to 0,46 x 38,6 MJ/km = 17,8 MJ/km	km/litres	Calculation from Annual distance driven & annual biogas refuelled
Emissions saved / travelled distance	CO_2, HC, NOx, PM emissions saved can be estimated from the travelled distance	Pollutant tonnes	Standard calculations

Table 24: KPIs for the evaluation of the biogas buses in Sonderborg city

Indicator name	Description	Unit	Data source
CP identification data	Public / private charging point. Location	-----	Database
Total number of recharges per year /day/year/month	Number of charging processes performed every year Only data on public recharges exist, none from private electrical cars charges in private homes. Total number of EV-charges in 2015 was 242 chargings on the CLEVER and EON public charging stations in Sonderborg	#	Monitoring
Amount of kW recharged per day/month/year	Amount of kW recharged. This must be done at least annually.	kW	Monitoring

Table 25: KPIs for the evaluation of charging points' performance in Sonderborg city

Further to the KPIs already listed, there's a set of indicators (from D7.4) that are meant for evaluating the impacts at city level. These are listed in Table 26 below:

Indicator name	Description
Lower emissions of CO_2 in the city due to sustainable mobility actions	This indicator will be calculated from the specific KPIs that relate to CO_2 reduction.
New sustainable vehicles (EV) in the city due to SmartEnCity project	This indicator will be calculated from the number of new electric vehicles classified by categories (cars, buses, trucks)
New sustainable vehicles (biogas buses) in the city due to SmartEnCity project	This indicator will be calculated from the number of new biogas buses in the project.
Increase of the number of EV charging infrastructures in the city (only public or public & private infrastructure) due to the project	This indicator will be calculate from the number of public EV charging stations
Increase in the use of EV charging infrastructures due to the project	This indicator will be calculated from the kWh recharged in the EV charging stations

Table 26: Indicators applicable to the mobility actions evaluation for Sonderborg

Note that logistic KPIs as traffic flow, average vehicle speed, average time for a reference distance, aimed at assessing the **traffic congestion reduction**, will not be feasible in the case of Sonderborg.

Average occupancy will be calculated for biogas buses, from collected data.

6.2 Non-KPI related monitoring requirements

This subsection is devoted to include other sources of information, that would complement the data registered with the monitoring equipment to calculate some of the KPIs included in section 6.1.

Often, KPIs must be obtained from data bases, historical records, statistics, that are combined with the actual values registered with the monitoring equipment.

Up to now there is no availability of information linked to this non-KPI related monitoring equipment for Sonderborg.

6.3 Monitoring equipment and other sources of information

At this stage, Sonderborg is still redefining some of their mobility actions and not much information is available regarding the monitoring equipment they will be using.

The information from this section will be provided in future related deliverables.

7 Commissioning plan guidelines

This section contains some general guidelines to accomplish the commissioning of monitoring equipment. There should be a commissioning plan for the whole actuations (initially to be included within D7.5/D7.10/D7.11 Supervision of interventions in LH projects documents). This section covers aspects related at least to the part concerning the monitoring systems and equipment.

After the definition of the equipment, one important aspect to be taken into consideration is the commissioning of the equipment. In this way, D7.6 and D7.8 already provide an explanation about the commissioning process for the monitoring system. As the monitoring equipment is similar to the one in both previous deliverables, it does not make sense to repeat the same description of the procedure. Hence, this section summarizes the six stages as in D7.8, while more details are available in D7.6.

- Design
  - This phase is established for the collection of the monitoring requirements, what has been done in D7.6, D7.7 and D7.8. Moreover, the planning is also detailed.
- Initial setup
  - Once the equipment is delivered, initial calibrations are necessary in order to ensure proper measurements.
- Installation
  - Physical deployment of the devices in the monitoring location.
- Commissioning & set up
  - After installing, the test of the data gathering and fine-tuning process is carried out. Besides, continuous monitoring is left along some days to assure communication continuity.
- Maintenance & data collection
  - Devices may break or miss calibration. Therefore, maintenance is the phase where the staff is in charge of keeping the quality. Moreover, the data collection is running in order to store the information in the persistent databases and applying data quality methodologies.
- Decommissioning
  - Last but not least, although out of scope of SmartEnCity, the final stage is dismantling, if necessary, of the equipment.

8 Deviations to the plan

This deliverable was originally due on month 18 (July 2017), but due to several changes that have been implemented in the mobility measures from the three LH cities as a consequence of the "cascade funding" implications, it was decided and agreed with the P.O. to postpone it till month 34 (November 2018). In the case of Vitoria and Tartu several changes have been implemented and approved via amendment, and therefore there's some information that can be shared and has been included in the current document. In the case of Sonderborg there are still big uncertainties that don't allow sharing much information for the time being. This information will be provided in future related deliverables.

Apart from that, no delays are foreseen on the submission of this deliverable according to the new timeline and deadline within Amendment Reference No AMD-691883-29 for the Grant Agreement number 691883.

9 Outputs for other WPs

This document provides output mainly for activities and deliverables under WP7 although it also has a reflection on the activities carried out on the LH cities, as there is where the final implementations take place.

The evaluation scheme that has been drawn through the different documents delivered previously on WP7, has its continuation on D7.6, D7.7 and D7.8 monitoring programs.

The evaluation scheme started to be deployed in D7.1 and D7.2 with the definition of a strategy of evaluation consisting of a set of objectives to be reached and KPIs for their evaluation. This strategy has been validated by the local partners participating on the interventions and depicted on the evaluation plan delivered in D7.3 jointly with D7.4, where the procedures for the evaluation of the baseline and final performance of the interventions were described. For the mobility aspects an updated version of the evaluation protocol has been included in this same document D7.7.

The baseline evaluation of each LH city was included as part of D3.2, D4.2 and D5.2 respectively by applying the protocols described in D7.3 and D7.4. In parallel, the monitoring programs deliverables for the district retrofitting and integrated infrastructures actions and the data collection approach deliverable have been defined. Those documents jointly show how the data gathering and collection from the different sources (dwellings, buildings, district, vehicles, etc.) will be done to allow a final evaluation of the final performance. The final evaluation will be done under task T7.5 and the results of this assessment included on Deliverable D7.13.

Also, a final report including the detailed information of all monitoring elements and the data collection process will be done at the end of the project (D7.12). This document will be the most updated version of the information included in this deliverable.

Figure 1 below shows the process described before of the evaluation scheme in parallel to the corresponding tasks/deliverables associated:

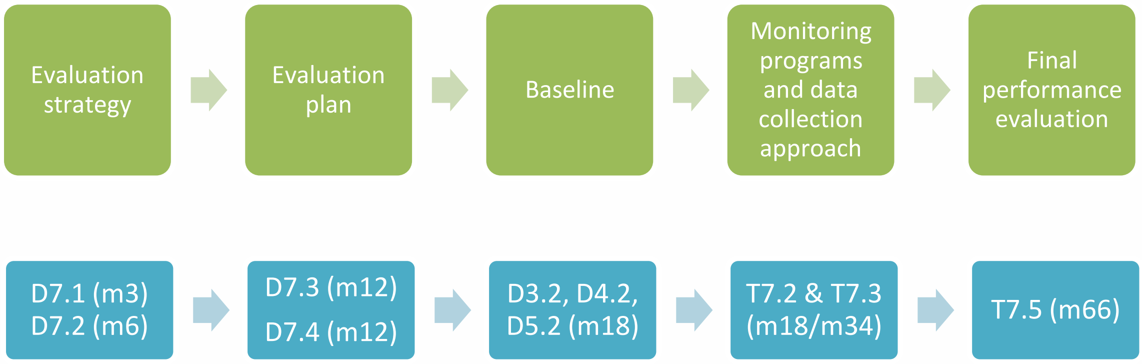

Figure 1: Deliverable D7.7 in the framework of the evaluation scheme

In parallel a follow-up process is done to check periodically the advances of the actuations, and the implementation of the different measures, as well as the data collection process. This will be contemplated on internal periodic reports and also on the supervision of the interventions deliverables (D7.5, D7.10 and D7.11).