Best practices for H2O management and savings for BUS operators

H2OBUS

D5.2 Evaluation of findings

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Table of Contents

List of Figures

List of Tables

Table of revisions

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List of abbreviation

Abbreviation	Long Version
BAT	Best Available Technology
CBA	Cost-Benefit Analysis
CP	Context Parameters
DQ	Design Question
DoW	Description of Work
EC	European Commission
KPI	Key Performance Indicators
LPI	Life Webtool indicators
LUCs	LIFEH2OBUS Case Studies
WP	Work Package
TE	Transferability Exercise
EV	Evaluation Category
WF	Water Footprint

EXECUTIVE SUMMARY

The LIFEH2OBUS project, funded under the European Union LIFE 2021 Environment programme, establishes the first comprehensive European best practice framework for water management in bus transport operations. Coordinated within a 42-month workplan and led in its evaluation activities (in WP5) by Sapienza University of Rome, the project responds to a long-overlooked sustainability challenge in public transport: the substantial volume of freshwater consumed annually for bus washing across Europe. While the sector has traditionally focused on alternative fuels and propulsion systems, LIFEH2OBUS addresses the environmental footprint of depot operations, where approximately 43 million cubic meters of freshwater are used each year for fleet cleaning. The project's overarching objective is to demonstrate and validate innovative water-saving technologies capable of reducing consumption by up to 84%, while ensuring operational reliability, economic feasibility, and transferability across diverse European contexts.

The evaluation considered all the three LIFEH2OBUS state-of-the-art washing solutions: basic wastewater reclamation; wastewater reclamation combined with rainwater harvesting; and waterless external waxing, at three bus depots operated by Arriva in Grugliasco (Italy), Budapest (Hungary), and Požega (Croatia), each representing different climatic, operational, and infrastructural conditions. Over a 12-month testing phase, field data were locally collected and sent to Sapienza. The evaluation compared a baseline "No-LIFEH2OBUS" scenario with a "LIFEH2OBUS" scenario in which the technologies were fully operational, allowing performance variations to be quantified through a structured Key Performance Indicator framework.

The evaluation methodology, defined in Deliverable 5.1 in its Measurement Plan and operationalized in Deliverable 5.2, is grounded in five Design Questions focusing on efficiency, achievement of targets, environmental impact, transferability, and alignment with LIFE programme indicators. The core analytical approach is comparative and scenario-based, measuring relative differences between pre-implementation and testing periods. Performance variations are calculated using standardized equations, while medians are employed to mitigate the influence of outliers, given the limited duration of testing and the exploratory nature of innovation deployment.

A distinctive methodological feature is the introduction of two complementary sub-scenarios. The LUC sub-scenario captures raw, field-based empirical data as recorded during the testing phase, reflecting real operational variability. The LIFE sub-scenario recalculates selected KPIs under harmonized assumptions using validated formulas aligned with the LIFE Web Tool, ensuring methodological consistency and comparability. This dual structure strengthens scientific robustness by separating empirical observation from model-based standardization, distinguishing short-term operational fluctuations from structural technological effects, and enhancing transparency, traceability, and reproducibility of results. It also supports both operational benchmarking for transport managers and policy-level environmental assessment.

Across the three case studies, the most significant outcome is the relevant reduction in water consumption per vehicle when calculated under standardized LIFE assumptions. In Grugliasco, water use decreased by approximately 85.5%, accompanied by comparable reductions in energy consumption and CO_2 emissions. Budapest demonstrated similarly strong cost efficiency, with washing operation costs reduced by over 90% and significant water and energy savings. These results confirm that substantial resource efficiency gains can be achieved without reducing washing frequency or compromising service standards. Operational KPIs indicate that depot productivity, reliability, and maintenance cycles remained stable, and in some cases improved, particularly in workshop turnaround times and washing duration.

Economic performance presents a mixed but generally positive picture. While operational washing costs and electricity consumption for washing decreased markedly, initial investment costs for installing reclamation systems must be considered in long-term cost-benefit analyses. Some increases in energy-related indicators observed in raw LUC data were attributed to transitional effects, system oversizing, or partial-load operation during early testing phases rather than intrinsic technological inefficiency. The standardized LIFE sub-scenario clarifies the structural energy-saving potential once systems operate under optimized conditions.

Environmental impacts extend beyond water and emissions. The introduction of filtration and reclamation systems generated additional hazardous and non-hazardous waste streams, reflecting a shift rather than an elimination of environmental burdens. Nonetheless, these waste volumes remain manageable and, within regulated frameworks such as Italy’s waste tracking system, contribute to improved environmental accountability in depot operations.

Social impacts reveal divergent perceptions. Passenger awareness, acceptance, attractiveness, and perceived travel comfort improved significantly, suggesting that cleaner buses and visible sustainability initiatives positively influence public perception. Conversely, staff comfort and acceptance declined in some contexts, likely due to increased operational complexity, adaptation challenges, or transitional stress during system introduction. These findings underscore the importance of workforce engagement, training, and change management in ensuring long-term technological adoption.

A central objective of the evaluation was the identification of the Best Available Technology (BAT) among the three tested solutions. Rather than selecting a single universally superior option, the methodology developed a performance matrix linking technologies to contextual parameters and overall efficiency scores. This matrix integrates environmental performance (water, energy, and emissions reduction), operational feasibility (maintenance stability, reliability, workforce impacts), and economic indicators (investment, operating costs, savings). By aggregating KPI variations across evaluation categories, the project identifies which technological configuration performs best under specific climatic, infrastructural, and organizational conditions. For instance, in contexts with high water tariffs and stable operational volumes, combined reclamation systems demonstrate strong economic and environmental returns. In settings with variable operational demand, system sizing and load optimization become decisive factors. The BAT concept is therefore contextual and dynamic, reflecting not only technical efficiency but also adaptability and long-term sustainability within each depot environment.

Complementing the BAT identification, the Transferability Exercise (TE) systematically assessed the potential exportation of LIFEH2OBUS solutions across other European contexts. Drawing on methodologies previously applied in European transport innovation projects and here totally updated to include for the very first time parameters and criteria associated to water saving in the bus sector, the TE engaged external experts, including academics, transport planners, and operators, who evaluated the tested technologies against a structured matrix of enabling factors and barriers. Context parameters such as fleet size, depot layout, climatic patterns, regulatory frameworks, and energy sourcing were considered alongside qualitative lessons learned from implementation. The exercise distinguished between technological transferability, organizational readiness, and financial viability, thereby moving beyond pure performance metrics to assess real-world scalability.

The TE findings confirm that water reclamation technologies are broadly transferable, particularly in medium-to-large depots with predictable washing cycles and access to technical maintenance capacity. However, successful transfer requires attention to system dimensioning, integration with existing maintenance workflows, and proactive engagement with staff to ensure acceptance and smooth operational adaptation. The structured analytical chain (from raw data collection to standardized recalculation, KPI aggregation, BAT scoring, and transferability assessment) provides a transparent decision-support framework for transport operators and policymakers.

Overall, Deliverable 5.2 demonstrates that LIFEH2OBUS successfully achieved its primary objective of substantial water reduction in bus washing operations while maintaining operational reliability and delivering measurable energy, emission, and cost benefits. The project provides a replicable evaluation methodology, robust performance evidence, and practical guidance to support widespread adoption of water-efficient technologies in the European public transport sector, contributing meaningfully to circular economy principles and sustainable mobility transition.

1. PROJECT DESCRIPTION

1.1 Context and overall objectives

LIFEH2OBUS builds for the first time a European best practice on water management for bus transport operators to reach the lowest possible water consumption; the best practice has been demonstrated during the project, supported by an innovative software system and proved to be flexible enough to adapt to different economic and geographical/climate contexts, to be shared and adopted as widely as possible. This is the first time a major public transportation project focuses on water management, which has been a neglected and underestimated topic in this sector for far too long in favour of alternatives mobility power sources considering that about 43 million m^3 of fresh water are consumed per year in Europe to clean buses, as estimated in the Description of Work (DoW) document. The idea was that of applying three different state-of-the-art solutions, namely: (i) simple wastewater reclamation; (ii) wastewater reclamation in combination with rainwater harvesting system; and (iii) external waxing without water and compare them at three different European locations (at Arriva depots), specifically in Italy, Croatia and Hungary. For one-year demonstration, main parameters have been gathered and monitored by means of the Intelligent Garage Management system, that was customized and implemented by Pluservice. Operational, environmental, climatic and economic data have been analysed and evaluated by University La Sapienza to provide a final matrix between location and techniques with a score of efficiency, pros and cons of their application and costs, accompanied by technical guidelines (these in WP6). The average project water saving that LIFEH2OBUS can bring was initially calculated as - 84% water consumption for fleet washing. LIFEH2OBUS will contribute to push the transport sector towards its sustainability and circularity, while providing the community with guidelines.

1.2 Workplan

The LIFEH2OBUS consortium has initially developed and structured a 42-month workplan for the successful design, deployment/operation, performance evaluation and validation as best practices of the technologies implemented through the project. The LIFEH2OBUS workplan is divided into seven work packages, the Gantt chart of the project is included therein.

The structure of the LIFEH2OBUS work plan strategy (Figure 1), which guarantees a solid concatenation of activities to unfold optimal results, foresees the three major following phases:

- Requirements, set-up and initialization phase (12 months duration): WP2 “Set-up” and WP3 “Technology Installation”, involves the following activities: (i) definition, design and perfectioning of technology requirements and P&IDs for all the Arriva’s depots included in the LIFEH2OBUS project; (ii) drafting of technical and administrative documents to start up and go through the procurement process, which comprehends provider choices for quotation and negotiation phase; (iii) undertake the legal and bureaucratic duties to collect the building and installation permits and preparing the construction sites areas and logistics to accommodate the technology supplies; (iv) design of the novel predictive maintenance algorithm and testing; and (v) start and finalize the installation of the novel solution, with all the various specifics, and conclude the phase with the preparation of the fleet to pave the way for the implementation phase to start. These include the first washing and waxing of the defined fleets.

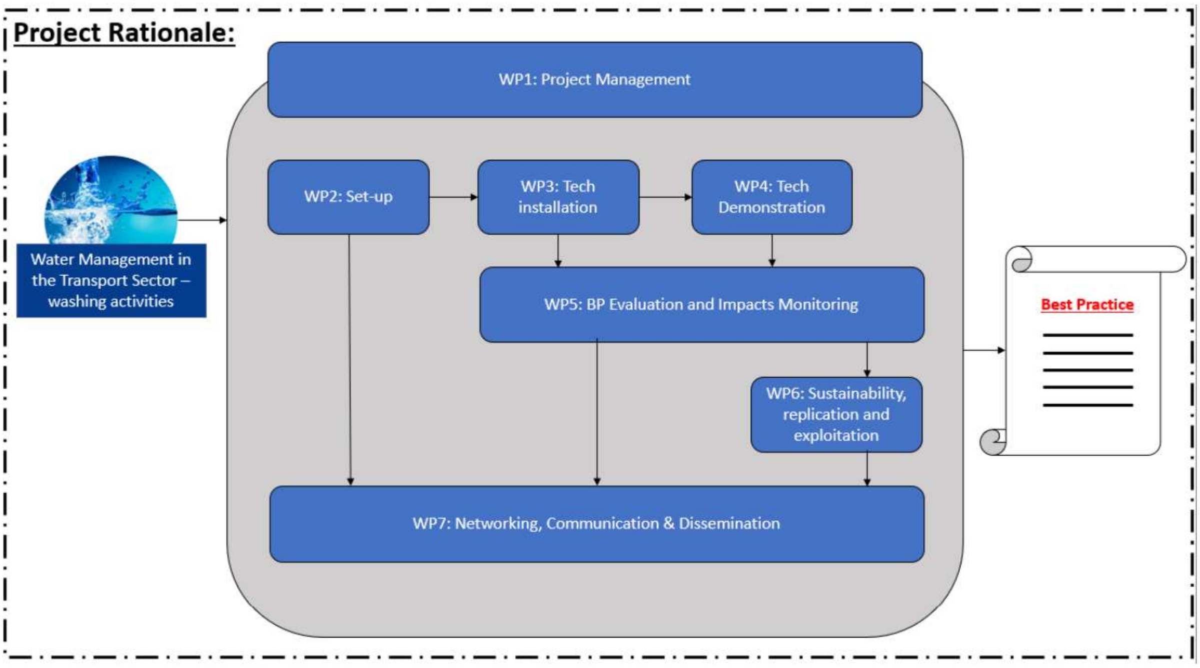

Figure 1 – LIFEH2OBUS rationale

- Implementation phase (13 months duration): WP4 “Technology demonstration” is due after the fleet preparation and includes the activities relative to: technology implementation and monitoring, which include the washing scheduling and overviewing for consumption performances in terms of water, energy and raw materials (wax). This is accompanied by the fleet monitoring, with all the relative parameters, previously defined thanks to La Sapienza. Each partner is responsible for the precise collection of data through this phase which will be essential for the evaluation of the technologies which to be carried in the third, following, phase. Pluservice dedicates its effort in extensively supporting the three Arriva’s depots, overviewing the correct functioning of the novel Intelligent Garage System Software (improved by the developed algorithm) and the comprehensive collection of the data, coordinating the partners and leading the way towards the filing of all the activities that will be crucial for the following evaluation phase.
- Overall evaluation and Best Practices phase: WP5 “Best Practice Evaluation and Impacts Monitoring” includes the overall analysis performed by Università La Sapienza, supported by

all the other partners of the consortium, allowing for the definition of the technologies to be implemented depending on the environment in which they are used. A comprehensive measurement plan including the introduction of KPI sets to measure the degree of target achievement. The exhaustive assessment and evaluation between LIFEH2OBUS and no-LIFEH2OBUS scenario will be performed together with a transferability exercise and an environmental analysis based on a Cost-Benefit assessment approach. Illustrative documents are prepared including a throughout review of project activities providing insights and suggestions to simplify the uptake of project results.

2. EVALUATION METHODOLOGY AND DELIVERABLE 5.2 RATIONALE

2.1 The evaluation methodology process

The evaluation process, once defined the methodological approach described in Del. 5.1 and there synthesized in the five main Design Questions (DQ), addresses in this phase its core, i.e. the study of performance variations due to the introduction of the three novel washing technologies in the three LIFEH2OBUS Case Studies (LUCs), at the Grugliasco, Andor and Požega bus depots. The performance variation is comparative and scenario-based, as it is grounded on the assessment of the operations prior the implementation of the three technologies (No-LIFEH2OBUS scenario) and those implemented during the 12-month test phase (LIFEH2OBUS scenario). The selection of KPIs associated with different evaluation categories, all fully described in Del. 5.1, enables this comparison and provide the basis for developing the WP6 Cost-Benefit Analysis (CBA) assessment and the WP5 Transferability Exercise (TE) further elaborated.

In this step, there are two issues each corresponding to a specific DQ, i.e. the:

- Efficiency issue: DQ1 – *Are LIFEH2OBUS scenario performance results able to show actual improvements in washing operations?*
- Achievement issue: DQ2 - *Can success be claimed for the LIFEH2OBUS project*?

For what concerns DQ1 - *Efficiency*, i.e. the quality of the three LUCs to generate environmental savings (with a specific focus on water and energy, consistently with the LIFEH2OBUS project' gist) and be operationally feasible, the methodology is developed to outline tangible results and their interpretation in the light of the development of the test at the three LUCs. DQ1's response is also specifically targeted to provide the basis for the development of the CBA in WP6.

In turn, to reply to DQ2 – *Achievement*, i.e. whether performance results are such that success can be claimed, the methodology is designed to elaborate results with a three-pronged task:

- on the one hand, to assess performance according to operational targets used to claim success, according to the experience developed in other EC-funded projects;
- on the other, to deliver facts and figures (the LIFEH2OBUS *knowledge*) to feed the TE and collect useful "intelligence" (as information of operational value for bus managers) to demonstrate the feasibility of the three washing technologies after the LIFEH2OBUS life, as defined in WP6
- and last but not least to progress with the LIFE program webtool task, i.e. to document the project's outcomes using its specific LPIs (i.e., Life KPI webtool), by providing the second reporting, known as the "Final Report Snapshot," and asses the LIFEH2OBUS further achievements in this field, according to the process explained in Del. 5.1. To be noted that

the present Deliverable 5.2 is twinned with Deliverable 5.3 - *Extract of the project data from the LIFE KPIwebtool.*

To conclude, all the data, results and findings presented in this deliverable are fully consistent with the five methodological DQs presented in Del. 5.1, thus providing a methodological framework for performance assessment easily replicable in similar research projects.

2.2 Deliverable 5.2 rationale

According to all of the above in mind, Deliverable 5.2 - Measurement Plan describes major activities developed within 5.3 - The Description of two Scenarios, 5.4. – Environmental Analysis and 5.5 – The Transferability Exercise. These tasks (highlighted in blue in Figure 2) belong to WP5 “Evaluation and Impact Monitoring”.

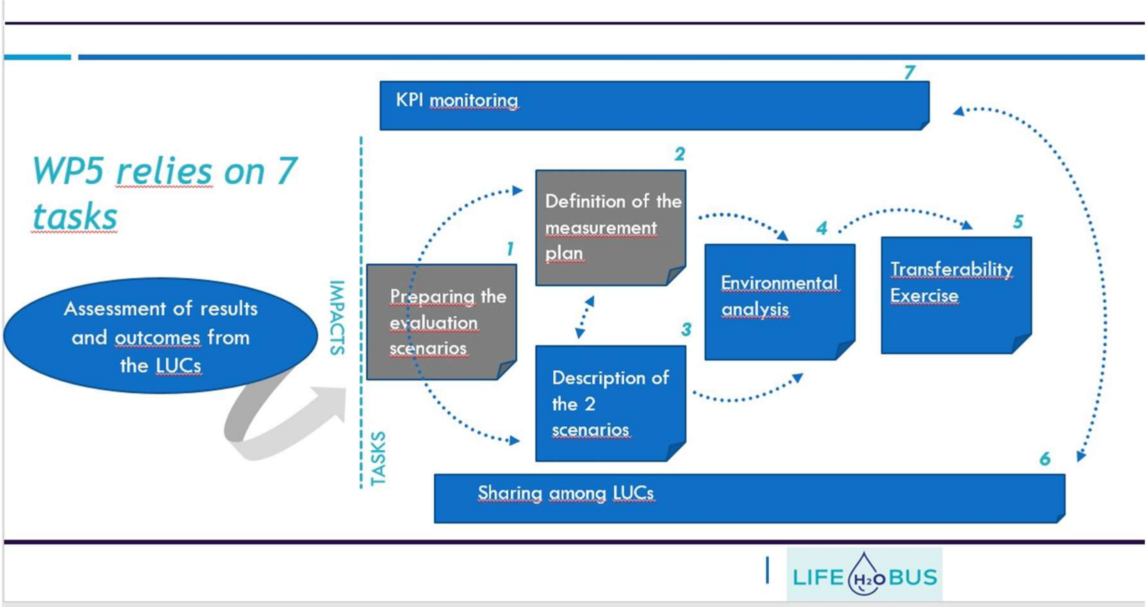

Figure 2 – LIFEH2OBUS WP5 Tasks

More specifically,

- Task 5.3 is designed to report the description of both No-LIFEH2OBUS and LIFEH2OBUS scenarios, with the former being a description of performance before the introduction of the three technologies and the latter that of the performance during the LIFEH2OBUS tests, with the goal to describe a full impact assessment of the LIFEH2OBUS technologies. Both scenarios are based on data collected through the KPIs and describe the performance variations occurred, thus giving rise to a comparative performance evaluation. The performance variations include also: i) a check to assess whether the LIFEH2OBUS performance met the performance target to claim success, and ii) a cross-case analysis aimed at defining the factors of success/failure (drivers or barriers) to transfer the three technologies results elsewhere according to the variations detected and create the basis to develop the above mentioned transferability exercise (Task 5.5). All of the above will be further described and coherent with the DoW content for Task 5.3, as well as with the DQs above mentioned.

- Task 5.4 focuses on the environmental project KPI (i.e., Water usage reduction; Energy saving; GHG emissions reduction) to assess the final effective environmental impact of LIFEH2OBUS. As for the previous task, also in this case the activities developed in this phase comply with the DQs earlier stated.
- T.5.5 develops the TE, in line with DQ2 and accordingly to data, facts and findings highlighted in the two previous tasks. More specifically, these are summarized, critically reviewed and eventually synthesized inform of key findings to place the LIFEH2OBUS experiences in the context of their transferability potential, to support a wider exploitation across Europe. To this end, the TE is developed according to a methodology already successfully applied in other EC-funded projects (namely CIVITAS and EBSF, EBSF_2” and ELIPTIC, all duly described further) and adapted to the LIFEH2OBUS concept and process. Participants in the TE expert volunteers (academicians, transport planners and managers, operators, etc.) recruited by Sapienza. This task complement the transferability assessment developed in WP6.

Again to remind, the methodology and the related activities above reported are coherent and go hand in hand with the complementing evaluation activities developed within the LIFE KPI webtool.

3. THE EVALUATION METHODOLOGY

The LIFEH2OBUS Evaluation Methodology in general, and more specifically the methodological criteria adopted specifically for Tasks 5.3 to 5.5 as in the DOW, coherently with the DQs above mentioned, address the following issues:

1. *Selection of the appropriate indicators*, i.e definition of performance variations between the no-LIFEH2OBUS and the LIFEH2OBUS scenarios, according to the Key Performance Indicators (KPIs) selected at each LUC, both at site level and cross-site.
2. *Impacts assessment*, i.e. identification, elaboration and interpretation of impacts due to the performance variations, in the light of potential performance targets associated with innovations
3. *LIFEH2OBUS technology potential*, i.e. identification of the performance analysis for the LIFEH2OBUS fleet, which combines the contribution of all washing technologies in reaching resources (water, energy) and pollution mitigation.
4. *Preparing for other tasks*, i.e. data collection to feed the CBA (developed in WP6) and the LIFE Webtool
5. *Transferability Exercise*, i.e. design of the procedure for the TE, including the TE matrix

all with the goal to identify the best available technology tested in the LUCs, according to three methodological pillars:

- the development a holistic, independent evaluation process based on a comprehensive project assessment framework;
- the identification of generic and specific learnings from the LUCs and
- the definition of directions, transferable from the LUCs to other European cities/contexts

This approach stems from previous fruitful experiences in past EC-funded projects in which performance assessments were central to claim the tested transit-related innovations' success and consistently reflects the evaluation framework consolidated in the scientific and gray literature[1] and now a reference in any assessment task, easily adapted to this project, thanks to the flexible procedures that connote this type of project.

As already stated in Del. 5.1., the methodological approach moves from the consideration that the three LIFEH2OBUS LUCs (Grugliasco, Andor and Požega) test three different innovative water-saving methodologies (Table 1), with different fleet size, vehicle types and operational requirements. Common

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[1] More specifically, the seminal EC-funded projects' evaluation guidelines have been considered: MAESTRO (TTR et al. 2003. Monitoring Assessment and Evaluation of Transport Policy Options in Europe); METEOR (Schelling, A. et al. 2004. METEOR Final Evaluation Guidelines; NEA et al. 2003. METEOR Assessment Framework and Evaluation Guidelines for Data Collection); MIRACLES (Musso, A. et al., ed. 2004. D 4.1 Evaluation report); EBSF (Karlsson, M.A., ed., 2010. EBSF Deliverable 4.2.1 - Assessment Framework); EBSF_2 (Cascajo, R. et al., ed., D 2.3 - Report on Evaluation Framework); ELIPTIC (Musso, A. et al., ed., 2016. D 3.1 Impacts evaluation plan); 3iBS and ZeEUs projects evaluation methodologies added additional contributions, especially for the cross-site data comparison.

goals, however, are to save water, reduce energy, mitigate emissions, improve operations, especially for maintenance, and the end-users' perception of the service.

Table 1 – Case studies and technologies tested (from Del. 5.1)

Technology LUCs	Basic Reclamation	Reclamation and Harvesting	Waxing
Grugliasco (IT)	X	X	X
Budapest (HU)	X		X
Požega (HR)	X	X	X

All of the above, adapted to LIFEH2OBUS specific activities, tasks and goals, give rise to five major evaluation categories (EVs), each associated to more impact areas suitable to investigate the performance variations due to the introduction of a given water-saving technology already presented in Del. 5.1 and now in Annex 1.

For what concerns Issue 1, the KPIs selection at each LUC right before the testing period covered a sufficient amount of KPIs to describe performance trends according to the five EVs, including those compulsory to provide data to process the required LPIs, according to the following consistency check:

- Eco3 and Ecs3 feed LPI 1 water reduction
- Ecs2 feeds core LPI2 energy reduction
- Eem1 feeds core LPI3 emission reduction
- Eco1-3, 5-6 feed core LPI6 cost savings.

It is to be reminded that, along with the KPIs, the methodology relied on specific Validation Objectives, i.e. quantitative variations (or Performance Targets) expected to achieve to claim the success of the newly installed technology at each LUC. The performance targets are quantitative (e.g. "84% water reduction) coherently with what already stated in the DoW.

3.1 Definition of the evaluation of the LIFEH2OBUS scenarios and calculation consistency

The LIFEH2OBUS scenario measures the three technologies' operations via a typical quantitative comparison based on the performance variations observed prior the implementation of the three technologies (No-LIFEH2OBUS) and during their operational testing life in the project (LIFEH2OBUS).

The No-LIFEH2OBUS scenario, i.e. to describe the situation without the implementation of the LIFEH2OBUS measure relies on the option "before", i.e. a reference or baseline according to data collected prior the implementation of the No-LIFEH2OBUS measures. In case of no data collection before the implementation of the technologies, the related values will be 0 or left blank (i.e. not available) and the assessment focuses only on the LIFEH2OBUS scenario. It is to be noted that due to the complexity of the installment of sensors and meters, resorting to "control" options resulted unfeasible. Consequently, the LIFEH2OBUS scenario is created according to the performance when the three washing technologies are operating, then acting as the test terms. Thus to recap, the scenarios performance assessment is, then, based on the comparison of a set of two "samples" among the following options:

- test vs before

Moreover, by having each KPI associated with a specific EV and Impact Area (IA), the LIFEH2OBUS performance variations will enable a full Impact Assessment.

The variation of KPIs between scenarios is calculated as the relative difference, following the equation (1):

$$KPI_{Var} = \left(\frac{KPI_2 - KPI_1}{KPI_1}\right) x100 \qquad (1)$$

with KPI_1 reporting the performance in the No-LIFEH2OBUS scenario (before) and KPI_2 the performance during the No-LIFEH2OBUS scenario. Aside from equation 1, performance trends have been also assessed in terms of median values to consider consistency or "typical behaviour" stemming from the datasets and cope with outliers. In other words, variations are used to assess the overall performance whereas medians describe the typical performance, in line with the quality of the LIFEH2OBUS performance values, i. e. those originated by the introduction of a novelty (the three technologies), over a limited period (the LIFEH2OBUS testing times), and resulting in non-consolidated (but reliable for the period in hand) and limited datasets.

For what concerns the energy and environment evaluation categories and impact areas, it is here to remind that KPIs Eco3 and Ecs3 feed LPI 1 water reduction, Ecs2 feeds core LPI2 energy reduction and Eem1 feeds core LPI3 emission reduction, respectively. This enables the building of two sub-scenarios, i.e the LUC scenario, where KPIs values correspond to data provided by the LUC manager, collected during the test according to directions provided in Del. 5.1., thus representing raw, field data. These KPIs have been further processed to give rise to a second data set, calculated with the equations already validated for the first snapshot of the LIFE web tool. More specifically, for this LIFE sub-scenario and the LPIs, energy performance has been calculated according to:

$$E_{tot} = W_i \cdot E_{ex} + W_s \cdot E_{wm} \qquad (2)$$

where
E_{tot} is the total energy used due to washing operations;
W_i is the industrial water usage;
E_{ex} is the external energy consumption due to abstraction, pumping, and distribution of the industrial water;
W_S is the total industrial water saved;
E_{wm} is the energy consumption of the water management system.

To be noted that in Eq (2) the total energy consumption is calculated in accordance with the explained methodology during the amendment, which includes both the on-site energy consumption of the water management system and the external energy consumption associated with abstraction, pumping, and distribution of industrial water to the site. In turn, emissions are calculated according to:

$$GHG_{tot} = E_{tot} \cdot EF_c \qquad (3)$$

where
GHG_{tot} are the emissions produced;
E_{tot} is the total energy used due to washing operations;
EF_c is the country's 2021 emission factor (not updated to align with the Grant Agreement and the first snapshot of the LIFE Web Tool).

The opportunity to have two sub-scenarios is clear: the LUC sub-scenario provides raw data to perform the before-vs during comparison according to what collected during the test period with units of measurement related to transport operations in sight of the transferability exercise and plan in this field where metrications based on vehicle or operational production are used. However, in the LUC sub-scenario, differences occurred between the “before” dataset and the “during” ones, all consistent with the exploratory nature of the LIFEH2OBUS project: typically, washing frequency and amount of water used per single washing operation varied in some LUCs from what set for the “before” scenario, thus making this before-vs-during comparison a reliable and quali-quantitative “snapshot” of the testing operations. Yet the goal of LIFEH2OBUS is to raise awareness and support bus operators in water saving, so it is necessary to provide additional data to create a full quantitative comparison based on the same assumptions (same amount of water and/or washing frequency) of the reference scenario and develop a full quantitative assessment, i.e. the LIFE sub-scenario. To this end, the data provided for the LUC sub-scenario have been recalculated for KPIs Eco3, Ecs3, Ecs2 and Eem1 according to the assumptions of the “before” scenario and the equations above reported, thus giving rise to the LIFE sub-scenario values. Eventually, the LIFE sub-scenario KPIs have been processed and metricated according to LIFE Web tool to give rise to the second LIFE Web Tool snapshot commented in Del. 5.3. The whole process is synthesized in Figure 3 and results fully elaborated and commented in Section 4.

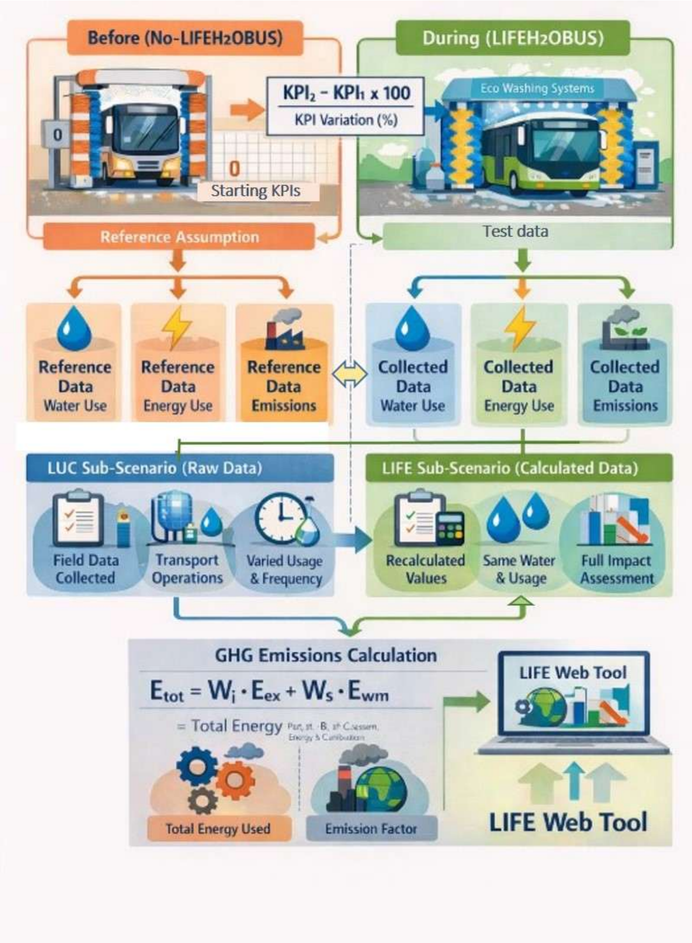

Figure 3 – LIFEH2OBUS Scenarios building process

It is to stress that the introduction of two sub-scenarios within the LIFEH2OBUS assessment framework is not only operationally convenient but methodologically necessary. Their coexistence strengthens the scientific robustness, transparency, and transferability of the project's impact evaluation. Therefore, to summarize, the scientific rationale for this dual structure thus relies on the following criteria:

- *Separation between empirical observation and model-based standardization* - The LUC sub-scenario represents empirical, field-based observation: it captures the KPIs exactly as recorded during the testing phase under real operational conditions. In contrast, the LIFE sub-scenario represents model-based standardization, where the same KPIs are recalculated under harmonized assumptions using validated equations. This separation is essential in experimental and quasi-experimental research, as it prevents the conflation of technological performance effects with operational variability. By distinguishing what happened in practice from what the technologies intrinsically deliver under equalized conditions, the framework ensures conceptual clarity and analytical rigor.

- *Distinction between snapshot performance and structural performance* - The LUC sub-scenario offers a reliable quali-quantitative snapshot of testing operations. It reflects the exploratory character of the LIFEH2OBUS project, where washing frequency and water volumes per operation may deviate from baseline assumptions. Such variability is informative, but it may obscure the structural impact of the technologies themselves. The LIFE sub-scenario addresses this issue by recalculating performance under standardized boundary conditions. Consequently, the analysis differentiates between short-term operational fluctuations and structural technological effects, ensuring that the final impact assessment reflects systemic improvements rather than temporary deviations.

- *Methodological consistency with the LIFE Web Tool* - The LIFE sub-scenario guarantees alignment with the validated calculation framework of the LIFE Web Tool. Energy performance is recalculated according to Eq. 2 and emissions are derived from Eq. 3. These equations integrate both on-site energy consumption and external energy associated with water abstraction and distribution, ensuring completeness of system boundaries. By recalculating KPIs according to these validated formulas, the LIFE sub-scenario ensures consistency, replicability, and compatibility with the tool's algorithmic structure. This step strengthens transparency and ensures that the second LIFE Web Tool snapshot is methodologically coherent with the first.

- *Statistical robustness under limited datasets* - The LIFEH2OBUS testing period generated datasets that are reliable but limited in duration. Novel technologies introduced over a short timeframe may produce non-consolidated patterns and occasional outliers. To address this, performance variations are calculated using relative differences, while medians are employed to describe typical behavior and mitigate outlier influence. The dual sub-scenario structure further enhances statistical robustness by distinguishing raw variability (LUC) from standardized recalculation (LIFE). This layered approach reduces statistical noise and improves the reliability of conclusions derived from constrained empirical samples.

- *Enhancement of transferability and scalability* - The LUC sub-scenario expresses KPIs in operational units aligned with transport practice (e.g., per vehicle or per washing operation), which supports benchmarking and transferability exercises across operators. It reflects the practical realities of bus depot operations. The LIFE sub-scenario, by contrast, provides a fully standardized quantitative assessment suitable for broader environmental evaluation and policy-level analysis. Together, they allow the project to speak simultaneously to operational stakeholders and to strategic decision-makers, thereby enhancing both practical applicability and scalability.

- *Transparency, traceability, and reproducibility of the analytical chain* - The dual sub-scenario structure creates a transparent analytical workflow: raw data collection (LUC), recalculation under standardized assumptions (LIFE), energy aggregation through Equation (2), emission calculation via Equation (3), and final metrication within the LIFE Web Tool. Each transformation step is explicit and traceable. This improves auditability, allows independent verification, and supports reproducibility. The structured progression from field measurement to standardized impact indicators ensures that no computational leap remains opaque.

As a last but not least methodological issue to consider, since one of the LIFEH2OBUS goals is to identify the best available technology (BAT), as stated in WP6, among those tested in the three LUCs (as stated in WP6), it is necessary not only to integrate the site-based assessment with a technology-based one, which is analysed in terms of efficiency. To this end, a final matrix linking overall achieved performance and tested techniques is developed to provide efficiency scores and identify the BAT. Calculation procedure and results are reported in Section 4.

Eventually, as usual, data from the questionnaires have been turned into percentages according to representativeness of the provided replies. The overall participants in the three LUCs resulted into to 222 sets of responses (as detailed here in Annex 3). To convert the Likert scale scores to univocal reference data have been calculated according to their Relative Frequency (RelFreq), according to the function reported in Eq. 4 for each single question, turned then into percentage:

$$\mathrm{RelFreq}(s) = \frac{f_s}{\sum_{k=1}^{10} f_k} \qquad (4)$$

where:

f_s is the frequency of responses with a given score g (e.g. 1),
$\sum_{k=1}^{10} f_k$ is the total frequency of all scores from 1 to 10, as in the responses' Likert scale.

It is here to be reminded that the text of the questionnaires is available in Annex 3 of Del. 5.1

3.2 Outline of context parameters

To improve the global knowledge on the test environment, a list of relevant Context Parameters (CPs) integrates the KPIs palette, to describe the context of application of the LUCS by simple indicators divided into four fields of application (Vehicles, Facilities, Energy, Weather) to report the general PT operational features. Therefore, CPs differ from KPIs as they are not targeted to describe specific performance of a given LUC, but the general conditions and operations of regular PT operations prior the LUCs application and also useful to provide operational features during the TE for participants not familiar with the LUCs environments.

The CPs set (Table 2) was filled in via a direct interview to the LUCs site manager, gray literature and, when possible, aerial analyses of the facilities during the construction of the infrastructure to accommodate the new water-based solutions at each garage. More specifically:

- the "Vehicles and "Tests"" data sets were provided by the LUCs site managers during the monthly LIFEH20BUS meetings,
- the "Facility" one was calculated through the ACME Planimeter web tool,
- the "Energy" and "Aerial view" ones were processed and calculated through the ACME Planimeter and Google Map web tools

- the “Weather” one was obtained by data provided from the national weather services of each LUCs’ area[2] and an international weather service[3], considering data for one year before the test period (No-LIFEH2OBUS reference) and the test periods (LIFEH2OBUS references). In any case, no national bulletins noted severe events specific to each LUC’s municipality in 2023-2025 beyond typical cold snaps and light snow (Požega and even less Grugliasco) and minimal accumulation (Budapest) in winter, whereas in winter, all the areas experienced warm, convective summers without major severe events and continental patterns held with July hottest. In additions, within the LIFEH20BUS meetings, LUCs site manager confirmed the absence of highly severe weather phenomena, able to generate potential service disruptions or any technological malfunctions during the two scenarios.

Table 2 – Context Parameters in the three LUCs

Context parameters in:					*Grugliasco*	*Budapest*	*Požega*
Vehicles	**1**	Fleet composition (vehicles in the depots)		Unit	70	140 (60*, 80**)	50
	2	Operational vehicles (observed empty slots)		Unit	15	35*, 60**	2
	3	Commercial speed (route)		km/h	70	50-70	70
	4	Vehicle length		m	12	12*, 18**	12
Facility	**5**	Depot surface (outdoor)		sqm	1663	38000	6960
	6	Depot surface (indoor)		sqm	3600	15700	3940
	7	Depot areas to accommodate LIFEH2OBUS technology		sqm	< 100	< 100	< 100
	8	Depot distance to the main city center (bee line)		km	6,5	4,5	1
Energy	**9**	Availability of energy from renewable sources in the depot (per type of source)			Yes, solar, point	Yes, solar, point	Yes, solar, diffused
Weather	**10**	Local temperature - Winter	°C	daily average (min-max)	0-7	0-3	-3-6
	11	Local temperature - Summer	°C	daily average	25-30	15-27	14-30
	12	Rain - Winter	mm	daily average	1-3	1-1.3	8.8-9.5
	13	Rain - Summer	mm	daily average	2-3	0.6-0.9	9-10
	14	Snow (max)	cm	daily	4	4.8	12
Test	**15**	Service disruption during the LIFEH2OBUS scenario			no	no	no
	16	LIFEH2OBUS 12-month scenario starting time			Jan 2024	Jan 2024	Nov 2024

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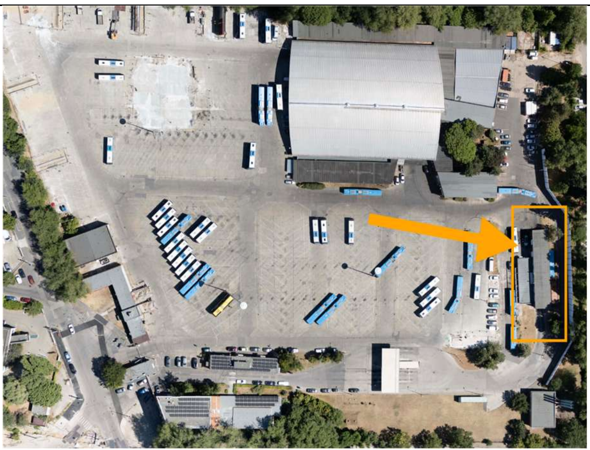
[2] For: Budapest, OMSZ at https://www.met.hu/en/eghajlat/magyarorszag_eghajlata/eghajlati_visszatekinto/elmult_honapok_idojarasa; Pozega, DHMZ at ttps://meteo.hr/podaci_e.php?section=podaci_vrijeme&prikaz=abc; Grugliasco, METEOAM at https://www.meteoam.it/it/meteo-citta/grugliasco; then, further navigation across the sites

3 Respectively, https://weatherspark.com/s/82172/3/Average-Winter-Weather-in-Po%C5%BEega-Croatia, https://weatherspark.com/s/84771/3/Average-Winter-Weather-in-Budapest-Hungary, https://weatherspark.com/s/55686/3/Average-Winter-Weather-in-Grugliasco-Italy

Cont. Table 2

Context parameters in:		
Aerial view	*Grugliasco*	
	Budapest	
	Požega	

4. PERFORMANCE ASSESSMENT BETWEEN THE TWO SCENARIOS

In this section, the LIFEH2OBUS performance variations among the two scenarios will be presented first per each LUC (site-specific) and then compared among the three LUCs (cross-case) within the LUC sub-scenario, and then according to LIFE sub-scenario (for the relevant KPIs, as explained in the previous Section, all in order to eventually build the final matrix between location and technologies, scoring efficiency, and highlighting pros and cons of their application, all to feed the TE and the CBA in WP6. The performance variation assessment, through KPIs, complements the LPIs evaluation described in Del. 5.3.

4.1 Site-specific evaluation

The LIFEH2OBUS performance variations at each LUC is described by Tables 3 to 11 where values are reported per each KPI according to the units of measurement stated in Annex 2 of Del. 5.1, and per evaluation category and impact areas (these reminded in Annex 1 of this document). Each table reports performance values prior to the project (column: Average No-LIFEH2OBUS), during the test phase (Average LIFEH2OBUS, including both LUC and LIFE subscenarios for the specific KPIs), their percentage variation between the two scenarios (column: Average variation, calculated according to eq. 1), their median during their test phase (column: Median LIFEH2OBUS) and their related percentage variation (column: Median variation). These are fed by data collected by the LUCs site managers and entered in the templates provided prior to the data gathering. Screenshots of the filled templates are available here in Annex 2.

4.1.1 Grugliasco site-specific performance trends

Results for the LIFEH20BUS scenarios are reported in Tables 3 (Evaluation category: Operations), 4 (Evaluation categories: Economic, Energy, and Environmental), and 5 (Evaluation category: People), and the impacts due to the introduction of the local water reclamation and harvesting system along with the waxing trial are elaborated as follows.

4.1.1.1 Operational impacts: workforce allocation, depot productivity and reliability

The operational KPIs (Table 3) show a generally stable depot system with a few noteworthy shifts. For what concerns the impacts on Staff, and starting from workforce-related indicators, the driving staff per vehicle (Ost1) decreases from an average of 1.099 to 1.07, corresponding to a -2.34% average change, while the median change is slightly stronger (-3.00%, median LIFEH2OBUS 1.066). This reduction may, per se, not directly relate to washing technology, but in this case it can be interpreted as a modest efficiency gain or reallocation of staff time that the introduction of a novelty in the local maintenance practice might generate. A similar pattern is observed in maintenance staff per vehicle (Ost3), decreasing from 0.084 to 0.078 with a

-6.65% average change (median change -4.64%). These reductions reflect improved depot stability and reduced secondary maintenance tasks related to cleaning processes, particularly since this type of water recirculating system is designed to reduce wear, residues, or water-related deterioration in local infrastructure.

In contrast, staff for water-based washing operations (Ost7.1) remains unchanged at 0.19 man/vehicle with 0% variation. This stability indicates that, despite the technological improvement, the depot did not reduce washing workforce. This is important: water-saving technologies often require monitoring, filter management, or operational supervision that offsets potential labour savings. Additionally, depot policies may retain staff levels for service quality reasons, even when processes become more efficient.

Some KPIs are effectively unchanged: management workload (Ost6) and staff workload (Ost8.1) remain constant, suggesting that the technology did not impose an additional burden at the overall management scale. However, the introduction of waxing operations as an additional feature is visible through Ost7.2 (washing staff wax) and Ost8.2 (staff workload wax), which were not present in the No-LIFEH2OBUS scenario. The LIFEH2OBUS scenario values (0.17 man/vehicle and 0.03 man-month/vehicle, respectively) indicate that LIFEH2OBUS may have expanded the scope of cleaning services rather than replacing existing water-based maintenance. This can be interpreted positively (improved vehicle appearance and protection) but also implies that the “water-saving” intervention may introduce additional tasks that must be accounted for when assessing overall operational efficiency. However, given the experience in Grugliasco, where, in the end, waxing did not meet the managers’ expectations, it can be concluded that the KPIs recorded a performance that over a longer time horizon and within consolidated operations could be different.

For what concerns impacts on Supply, results show that the depot productivity appears stable. The daily supply (Osu3) slightly increases from 66.4 to 66.68 places/vehicle, a small +0.41% average change, with no median change. This suggests that the technology did not disrupt depot output (and shows potential in marginally support vehicle readiness).

KPIs show stability when it comes to impacts on Service generated by the introduction of the new reclamation and harvesting system. Bus reliability (Ose4) stays at 99%, indicating that the depot maintained reliability despite introducing new technology. This is essential: introducing depot innovations can sometimes reduce reliability due to learning curves or equipment failures, but the stable reliability suggests a successful integration. One negative operational signal is the increase in not planned operations (Ose8) from 12 to 20.25 vehicles/month, a substantial +68.75% average increase (median change +41.67%). Unplanned operations can usually result from equipment issues, operational disruptions, or unexpected maintenance needs, or simply because of a new technology’s additional complexity per se; in this case it is possible to conclude that the test period coincided with other operational stressors generating this performance variation. Finally, washing time (Ose9) decreases from 0.76 to 0.743 (approximately -2.74% average change; median -3.10%), thus suggesting modest process acceleration: vehicles spend less time in washing, which improves the overall depot throughput. This is a not negligible result as even small reductions in washing time can translate into significant scheduling flexibility over a longer time span.

Table 3 –Operational KPI values at Grugliasco

KPI #	KPI Name	Unit of measurement	Average No LIFEH2OBUS	Average LIFEH2OBUS	Average variation	Median LIFEH2OBUS	Median variation
Ost1	Driving staff	man/vehicle	1.099	1.07	-2.34%	1.066	-3.00%
Ost3	Maintenance staff	man/vehicle	0.084	0.078	-6.65%	0.080	-4.64%
Ost6	Management workload	man-month /vehicle	0.000277	0.000277	-	0.000275	-
Ost7.1	Washing staff	man/vehicle	0.19	0.19	-	0.19	-
Ost7.2	Washing staff (wax)	man/vehicle	-	0.17	N/A	0.00	N/A
Ost8.1	Staff workload	man-month /vehicle	3.77	3.77	-	3.74	-
Ost8.2	Staff workload (wax)	man-month /vehicle	-	0.03	N/A	0.00	N/A
Osu3	Daily supply	places/vehicle	66.4	66.68	0.41%	66.4	0.00%
Oma2	Days in workshop (or MTTR)	h/action	7.96	6.99	-12.21%	7.42	-6.78%
Oma3.1	Maintenance of the bus components (or MTBW mean time between water-based washing)	days/washing	1.75	1.75	0.00%	1.75	0.00%
Oma3.2	Maintenance of the bus components (or MTBW-mean time between waxing)	days/washing	-	1.75	N/A	1.75	N/A
Oma9	Vehicles washing operations	events/travelled km	0.00091	0.00095	4.15%	0.00093	2.62%
Ose4	Bus Reliability	%	99	99	0.00%	99	0.00%
Ose8	Not planned operations	vehicles/month	12	20.25	68.75%	17	41.67%
Ose9	Washing time	% per vehicle	0.76	0.743	-2.74%	0.740	-3.10%
Osa1	Staff accidents	man/h	48	48	0.00%	48	0.00%

Likewise, positive results are achieved when considering the impacts on Maintenance: vehicle maintenance efficiency improves meaningfully in workshop time: days in workshop / MTTR (Oma2) decreases from 7.96 to 6.99, representing a -12.21% average reduction**,** with the median decreasing by -6.78%**.** This is a strong operational signal: although not entirely attributable to washing technology, the improvement indicates better depot turnaround time and potentially fewer disruptions. It may also imply that the tested technology reduces washing-related issues that otherwise cause downtime, such as water ingress problems, corrosion-related checks, or cleaning equipment faults. The KPI mean time between water-based washing (Oma3.1) remains unchanged at 1.75 days/washing**,** indicating that washing frequency did not change due to the technology. This is significant because it shows the depot maintained service standards: water saving did not come from reducing washing frequency but from optimizing water usage per wash. The additional KPI Oma3.2 (mean time between waxing) appears only after introduction, again showing that LIFEH2OBUS enabled additional treatments rather than lowering wash cycles. A key operational point concerns washing intensity: vehicles washing operations (Oma9) increases from 0.00091 to 0.00095 events/travelled km, a +4.15% average increase (median +2.62%), which suggests a slightly higher washing activity relative to production variation (distance travelled). This reflects improved ease of washing, improved washing capacity, and implies stronger emphasis on vehicle cleanliness due to the new water harvesting and reclamation system. Importantly, the increased washing activity occurs simultaneously with major reductions in water consumption (discussed later), highlighting the efficiency of the tested technology: the depot can wash slightly more without consuming more water.

Overall, operational KPIs suggest that LIFEH2OBUS delivered small-to-moderate improvements in efficiency and workshop turnaround, maintained reliability, slightly reduced washing time, and possibly increased washing intensity, all consistent with the magnitude and timespan of this LUC.

4.1.1.2 Energy, environmental and economic impacts: strong water and emission benefits, selective cost effects

The economic and environmental KPIs groups (Table 4) reveals the most significant impacts, with the core objective—water saving—being clearly achieved. For what concerns impacts associated with the Consumption area, in the LIFE sub-scenario Water consumption (Ecn13) drops from 300 L/vehicle to 44 L/vehicle, whereas in the LUC sub-scenario from 450 to 65.25 L/vehicle, both corresponding to an -85.5% reduction, and the median confirms the same -85.5% change. This is an exceptional performance improvement and strongly validates the tested technology's purpose. Importantly, as noted earlier, washing frequency did not decrease, meaning the savings represent true efficiency gains per wash. For the LIFE sub-scenario, closely related, energy consumption[4] (Ecn12) decreases from 69.34 MJ/vehicle to 10.29 MJ/vehicle,

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[4] It is here to be reminded that operationally, the differences between Ecn9 (total amount of electricity consumed for washing operations) and Ecn12 (energy consumed for washing operations) can be explained by their different system boundaries and calculation logic. Ecn9 typically represents the direct electrical consumption measured on-site, i.e., the actual electricity absorbed by pumps, treatment units, control panels, and auxiliaries during washing. It is therefore strongly influenced by real operating hours, load factor, start–stop cycles, and instantaneous power peaks. Ecn12, instead, generally reflects a broader or processed energy indicator. It may include not only on-site electricity but also indirectly calculated components (e.g., energy linked to water abstraction,

an -85.16% reduction. This suggests the new washing approach is far less energy-intensive. Energy savings in washing can result from reduced pumping requirements, lower heating needs, shorter cycles, or more efficient equipment. In performance assessment terms, this is important because energy and water savings often reinforce each other: less water use means less pumping and less treatment, leading to energy reduction. Conversely, if considering the data provided by the site manager during the test, giving rise to the LUC sub-scenario, Ecn 12 increases by 120% and this results can be explained by several factors. In this case energy values are provided directly by a meter meaning meaning that even modest increases in industrial water abstraction can significantly affect total energy (E_tot) and therefore the related KPI. Moreover, exploratory adjustments made by operators when installing novel systems or retrofitting those already operational may have temporarily increased energy demand while testing system performance boundaries. It is also to consider that calculations are based for a washing system designed to was approximately 30 per day, using 450 liters per vehicle for a total of 13.5 cubic meters; therefore, the recorded energy consumption refers to the constant treatment of 13.5 m^3 per day, whereas average washing operations involved 4 vehicles per day in the period from 1.1.2024 to 1.1.2025, which decreased to 3 if data until 31.12.2025 are considered (with a peak of 21 vehicles recorded on 4.4.2024). Thus LUC result leading to an increase in energy consumption may be explained by an oversized system running under partial-load conditions, thereby reducing operational efficiency.

Thus, the +120% increase observed for Ecn12 in the LUC sub-scenario can be, then, coherently explained by the combined effect of operational variability, the structure of the energy calculation framework, and transitional system conditions during the testing phase. Total energy consumption is calculated as in Eq. 2, meaning that variations in industrial water use and water management volumes directly affect both external and on-site energy components. During the test phase, deviations in treated water volumes likely affected W_i in Eq. 2, amplifying the external energy term. At the same time, the electrical absorption in this type of systems, in their inception phases, higher power peaks and longer operational cycles may, which increase total energy according to:

$$E_{tot} = \int P(t)dt \qquad (5)$$

where P(t) is the instantaneous power, with its increase or the same for duration of operations directly raises total energy consumption, even if a given underlying technology is more efficient. Furthermore, the system resulted to have been oversized relative to actual washing demand, operating under partial-load conditions and therefore below optimal efficiency. These combined factors explain the temporary increase in energy-related KPIs in the LUC scenario also in the face of decreased fresh water usage, whereas the LIFE sub-

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pumping, or distribution) derived from methodological equations such as in Eq. 2. Because of this, Ecn12 is volume-driven, while Ecn9 is operation-driven. Operationally, if washing frequency, treated volumes, or water recirculation rates change, the external energy term $W_i * E_{ex}$ may decrease significantly (reducing Ecn12), while on-site electricity may not decrease proportionally due to several factors as i) partial-load operations; ii) oversized equipment; iii) fixed baseline electrical demand; iv) longer but less intensive cycles. In short, Ecn9 reflects technical operation efficiency, whereas Ecn12 reflects system-level energy intensity per water volume.

scenario, by harmonizing assumptions and removing transitional effects, reveals the structural energy-saving potential of the tested washing technology.

These changes directly affect the environmental impacts, as the KPIs associated with the Emissions impact area demonstrate. CO_2 emissions (Eem1) fall from 4.27 g/vkm to 0.67 g/vkm, a reduction of -84.31%, again mirrored in the median, for the LIFE sub-scenario. This is a substantial environmental gain and could contribute to compliance targets, sustainability reporting, and improved public image of the operator. The contrast with the 43.33% increase for Eem 1 recorded for the LUC scenario stems from the consideration of the above mentioned combined factors (oversized equipment for the testing operations, sensitivity to water use variation leading to exploratory tunings and transitional operational dynamics). Thus, the increases for Ecn12 and Eem1 in this LUC sub-scenario do not indicate a technological deterioration or unfitness, but can be explained by a temporary increase in electrical absorptions, greater operational intensity, combined effect of the two energy terms in Eq 2, and eventually a non-optimized transition phase.

In Cost impacts terms, Table 4 shows mixed outcomes. Cost of washing operation (Eco33) decreases from 0.0774 to 0.0625 kEURO/vehicle, a -19.23% reduction (median -19.88%). This is a meaningful cost saving and indicates that operational costs of washing (labour, consumables, maintenance) were reduced even if staffing levels remained stable. In the long run, with the technology consolidation, savings may arise from less water handling, less equipment wear, or reduced cycle time. Similarly, electricity costs for washing (Eco36) decrease from 0.008 to 0.006 kEURO/vehicle, a **-**20.25% reduction, reinforcing the energy efficiency improvement. However, electricity costs for vehicles (Eco23) increase from 0.021 to 0.037 kEURO/vehicle, a +69.44% average change, while the median change is oddly reported as **-**8.28%**.** This discrepancy suggests variability, but from a performance assessment viewpoint, this KPI may not be directly attributable to washing technology, since it concerns vehicle electricity costs rather than depot washing electricity. It might reflect external energy price fluctuations, changes in vehicle technology, or accounting differences during the test period. The median suggests that typical electricity cost may not have worsened; rather, a few extreme months increased the average. Interestingly, water purchase price (Eco31) and cost of water (Eco34) remain unchanged (0% change). This indicates that water tariffs did not change, and therefore savings must come from reduced consumption rather than price effects. The KPI water saved (Eco35) appears only in LIFEH2OBUS with **0.**015 kEURO/vehicle, demonstrating monetised savings. Investment costs are also captured: Eco20 investment for the network is 0.47 kEURO/vehicle for the LIFEH2OBUS scenario, which must be considered when assessing net benefit. In other words, while the depot saves on operating costs and resource consumption, it incurred not negligible upfront investment. These values are the basis for the development of the CBA, within WP6.

Table 4 – Economic, Energy, and Environmental KPI values at Grugliasco

KPI #	KPI Name	Unit of measurement	Average No LIFEH2OBUS	Average LIFEH2OBUS	Average variation	Median LIFEH2OBUS	Median variation
Eco20	Investment for the network	kEURO/vehicle	-	0.47	N/A	0.47	N/A
Eco23	Electricity costs for vehicles	kEURO/vehicle	0.021	0.037	69.44%	0.020	-8.28%
Eco31	Water purchase	Euro/m^3	1	1	0.00%	1	0.00%
Eco33	Cost of washing operation	kEURO/vehicle	0.0774	0.0625	-19.23%	0.0620	-19.88%
Eco34	Cost of water	kEURO/vehicle	0.11	0.11	0.00%	0.11	0.00%
Eco36	Electricity costs for washing	kEURO/vehicle	0.008	0.006	-20.25%	0.006	-20.25%
Eco37	Wax purchase	Euro/kg	-	N/A [11kEURO for 10 times for 3 buses]	N/A	N/A [11kEURO for 10 times for 3 buses]	N/A
Ecn9	Electricity consumption	MJ/vehicle	326	313	-3.99%	313	-3.99%
Ecn12	Energy consumption	MJ/vehicle	69.34* 36**	10.29* 79.2**	-85.16%* 120%**	10.29* 79.2**	-85.16%* 120%**
Ecn13	Water consumption	L/vehicle	300* 450**	43.5* 65.25**	-85.5%	43.5* 65.25**	-85.5%
Eem1	CO_2 emissions	g/vkm	4.27* 5.4**	0.67* 7.7**	-84.31%* 43.33%**	0.67* 7.7**	-84.31%* 43.33%**
Ewa1	Hazardous waste	kg/month	0	25	-	25	-
Ewa2	Non-Hazardous waste	kg/month	0	4	-	4	-

* LIFE sub-scenario; ** LUC sub-scenario

Finally, for what concerns impacts on Waste generation and management, hazardous waste (Ewa1) increases from 0 to 25 kg/month, and non-hazardous waste (Ewa2) from 0 to 4 kg/month. This is an important side effect. Water-saving systems often rely on filtration, separation, chemical treatments, or residue capture that can generate waste (filters, sludge, concentrated contaminants). From a sustainability perspective, LIFEH2OBUS shifts some environmental burden from water consumption to waste management; it is also to consider that while water and CO2 savings are very positive, hazardous waste generation introduces regulatory and cost implications. However, results on waste are to be interpreted not just under a quantitative point of view, but in terms of optimization of waste disposal in transit operations, which is usually focused on highly-hazardous waste. In Italy this is particularly severe as hazardous waste processes have to be recorded by SISTRI (the Italian Waste Tracking System enforced by the Ministry of Environment to trace waste management). Consequently, in line with such national regulation, transit operators current practice is not to consider water used for washing as actual hazardous waste like tires, oils, lubricants, which need to be stoked in specific facilities (e.g. for waste engine oils, in underground tanks, so to have them regularly disposed by a provider specialized in waste management services and duly reported into SISTRI), thus underestimating their polluting potential.

4.1.1.3. People impacts: passenger perception improves, staff perception to be monitored

The KPIs assessing impacts on Passengers (Table 5) indicates a clear divergence: passengers respond positively, staff less so. Passenger awareness (Ppa1) increases from 68.13% to 72.50% (+6.42 points). Passenger acceptance (Ppa2) rises from 58.75% to 68.72% (+16.97 points), and attractiveness (Ppa3) increases from 60.63% to 74.74% (+23.29 points). Travel comfort (Ppa4) also improves (+15.03 points). These strong improvements suggest that the tested LIFEH2OBUS harvesting and reclamation system likely enhanced perceived cleanliness, comfort, and sustainability. This is in line with observed trends in literature where cleaner buses and environmentally friendly operations can influence passenger satisfaction and trust in the operator.

In contrast, for the Staff impact area, staff comfort (Pst1) declines sharply from 82.50% to 58.33% (-29.29 points), and staff acceptance (Pst2) drops from 88.13% to 75.14% (-14.73 points). Possible reasons include increased workload complexity, training issues, or contingent operational stress due other reasons as stated in section 4.1.1.1, where increase in unplanned operations may correlate with staff dissatisfaction. From a performance assessment standpoint, this human-factor dimension is critical: technology success depends on staff adoption. While environmental and passenger outcomes are highly positive, long-term sustainability requires addressing staff concerns through improved training, ergonomics, safety measures, and participatory implementation.

Table 5 - People KPI values at Grugliasco

KPI #	KPI Name	Unit of measurement	Average No LIFEH2OBUS	Average LIFEH2OBUS	Average variation
Ppa1	Passenger Awareness	%	68.13	72.50	6.42
Ppa2	Passenger Acceptance	%	58.75	68.72	16.97
Ppa3	Attractiveness	%	60.63	74.74	23.29
Ppa4	Travel Comfort	%	66.88	76.92	15.03
Pst1	Staff Comfort	%	82.50	58.33	-29.29
Pst2	Acceptance	%	88.13	75.14	-14.73

4.1.1.4. Overall performance interpretation for Grugliasco

Taken as a whole, the LIFEH2OBUS technology test in Grugliasco demonstrates a strong performance improvement in its primary target area: water saving if the LIFE sub-scenario is conisdered. The reduction of 85.5% in water consumption per vehicle is substantial and likely represents a best-practice result for depot washing efficiency. The accompanying energy and CO_2 reductions reinforce the sustainability case, while washing operation costs decreased by around 19–20%, indicating economic efficiency improvements as well.

In turn, the energy and emissions increase recorded for the LUC sub-scenario reflects typical inception problems and assumption variations described in Section 4.1.1.2. Operationally, the depot maintained reliability and output, reduced washing time, and improved workshop turnaround. However, the rise in unplanned operations and the decline in staff comfort/acceptance highlight that the intervention introduced new operational issues. Additionally, the relevance of hazardous waste suggests that the environmental benefit is not entirely "free" but comes with new waste-management responsibilities. In conclusion, the KPI variation indicates that LIFEH2OBUS delivers excellent resource and emission performance and improves passenger-perceived service quality, but it requires complementary measures in workforce management and operational stabilisation to ensure long-term adoption.

4.1.2 Budapest site-specific performance trends

The introduction of the LIFEH2OBUS water-reclamation technology and waxing at the Budapest bus depot demonstrates a clear and coherent performance improvement across operational efficiency (Table 6), economic and environmental sustainability (Table 7), and societal perception KPIs (Table 8).

4.1.2.1 Operational impacts: maintenance performance and workforce stability

From an operational standpoint (Table 6), the Budapest depot exhibits a high degree of stability following the water reclamation introduction. In terms of Staff impact area, Driving staff per vehicle (Ost1) decreases from 2.35 to 2.27 man/vehicle, corresponding to a -3.37% average change and median change. This reduction indicates a modest but consistent improvement in labour efficiency, potentially reflecting smoother depot operations and reduced indirect workload pressures rather than direct effects of washing technology. All washing-related workforce indicators remain unchanged. More specifically, Staff for washing operations (Ost4) and washing staff (Ost7.1) both show 0% variation, and management workload (Ost6) also remains constant. This indicates that in the LIFEH2OBUS scenario, the water reclamation system was integrated without requiring additional staffing or management resources and without displacing existing personnel. Such stability can be interpreted as a strong signal of organizational compatibility and liminal operational disruption. It is to be noted, however, that all of the above and the performance described in the next impact areas have been poorly affected by an actual waxing procedure, being wax diluted in the water during washing operations rather than being applied after.

More operational KPIs, within the Maintenance impact area, further reinforce this interpretation. Days in workshop / MTTR (Oma2) remains constant at 2.92**,** and both mean time between water-based washing (Oma3.1) and mean time between waxing (Oma3.2) remain unchanged at 1.75 days/washing. These results demonstrate that the technology did not interfere with the current practice (neither increased nor reduced maintenance intensity or washing activities). In performance terms, this confirms that efficiency gains stem from resource optimisation per washing event, rather than changes in operational patterns. A slight reduction is observed in vehicles washing operations per travelled kilometre (Oma9), decreasing by -1.38%

(average) and -1.40% (median). This marginal decline suggests a very small reduction in washing intensity, due to improved cleaning effectiveness per wash. Importantly, this reduction does not appear to negatively affect service quality or passenger perception (as further elaborated), indicating that washing effectiveness may have improved. Overall, operational KPIs reflect a smooth and non-disruptive implementation, with stable workloads, unchanged maintenance cycles, and minor efficiency gains.

Table 6- Operations KPI values at Budapest

KPI #	KPI Name	Unit of measurement	Average No LIFEH2OBUS	Average LIFEH2OBUS	Average variation	Median LIFEH2OBUS	Median variation
Ost1	Driving staff	man/vehicle	2.35	2.27	-3.37%	2.26	-3.74%
Ost4	Staff for washing operations	man/vehicle	0.01	0.01	0.00%	0.01	0.00%
Ost6	Management workload	man-month /vehicle	0.006	0.006	0.00%	0.006	0.00%
Ost7.1	Washing staff	man/vehicle	0.01	0.01	0.00%	0.01	0.00%
Oma2	Days in workshop (or MTTR)	h/action	2.92	2.92	0.00%	2.92	0.00%
Oma3.1	Maintenance of the bus components (or MTBW mean time between water-based washing)	days/washing	1.75	1.75	0.00%	1.75	0.00%
Oma3.2	Maintenance of the bus components (or MTBW- mean time between waxing)	days/washing	1.75	1.75	0.00%	1.75	0.00%
Oma9	Vehicles washing operations	events/travelled km	0.00215	0.00212	-1.38%	0.00212	-1.40%

4.1.2.2. Economic, energetic and environmental impacts: cost efficiency and highly-sustainable performance

The economic KPI set (Table 7) highlights substantial cost improvements, particularly in washing-related expenditure. Within the Cost impact area, Cost of washing operation (Eco33) drops dramatically from **0**.6 to 0.048 kEURO/vehicle, corresponding to a -91.96% average reduction and -91.75% median reduction. This is one of the strongest economic signals across all the LIFEH2OBUS depots and demonstrates the high financial effectiveness of the innovations introduce in this project. Water-related costs show consistent reductions. Water purchase price (Eco31) decreases by -49.79% (average) and -73.21% (median), while **cost of water** (Eco34) follows the same trend. These reductions reflect both lower consumption and more favourable procurement and tariff conditions during the test period**.** Water saved (Eco35) also decreases numerically, which may appear counterintuitive but reflects the accounting structure of the KPI: as water costs decline, the monetised "water saved" value is also reduced proportionally. Energy-related costs also improve significantly. Electricity costs for vehicles (Eco23) decrease by nearly -50%, and electricity purchase price (Eco30) drops by -35% (average) and -44% (median). While electricity costs for washing (Eco36) decrease only marginally (-0.88%), this likely reflects the already low baseline cost of washing electricity in at national level compared to water-related expenses. The investment cost (Eco20) for the LIFEH2OBUS scenario is relatively modest at 0.203 kEURO/vehicle, (substantially lower than in the Italian case). This lower capital magnitude, combined with very large operational savings, suggests a strong economic return on investment for the Budapest depot. Eventually, general operating costs (Eco1) increase slightly by +0.38%, but this variation is negligible and likely unrelated to the washing technology.

Still from Table 7, environmental performance improvements are clear, consistent, and substantial. For what concerns the Consumption impact area, in the LIFE sub-scenario Water consumption (Ecn13) decreases from 300 L/vehicle to 76 L/vehicle, i.e., a -74.73% reduction; likewise, in the LUC sub-scenario it passes from 1100 to 278 L/vehicles, thus with both sub-scenarios confirming that the technology achieved its core objective, and although slightly less pronounced than in Grugliasco, this reduction remains highly significant. Coherently, Energy performance mirrors water consumption trends. More specifically, energy consumption (Ecn12) decreases by -74.14% in the LIFE sub-scenario and by 22.69% in the LUC sub-scenario reflecting typical inception and tuning problems highlighted already for the Grugliasco case at overall energy consumption level; specifically, electricity consumption (Ecn9) decreases by -22.69% (average) and -29.76% (median). These reductions indicate that washing-related processes became significantly less energy intensive. As a result, in the LIFE sub-scenario, within the Emissions impact area, CO_2 emissions (Eem1**)** fall from 2.73 to 0.71 g/vkm, corresponding to a -74.14% reduction and by -25.28% in the LUC sub-scenario. These align closely with reductions in energy consumption trends and supports the contribution of LIFEH2OBUS to climate and emissions targets.

Likewise, for the Concentrations impact area, air quality indicators also improve. NOx concentrations (Eco2) decrease by over -21%, and PM_{10} concentrations (Eco3) decrease slightly (around -2%). While these pollutants are influenced by multiple factors beyond washing operations, the reductions suggest that improved depot processes and lower energy use contribute positively to local environmental conditions.

The Waste impact area shows the only negative environmental signal: the increase in hazardous waste (Ewa1), rising from 70 to 80 kg/month (+14.29%). This suggests that, as in Italy, the technology introduces additional waste streams, likely linked to filtration residues, detergents, and consumables. However, unlike Italy, non-hazardous waste remains unchanged. This indicates a manageable and contained trade-off, provided waste handling is properly managed.

Table 7 - Economic, Energy, and Environmental KPI values at Budapest

KPI #	KPI Name	Unit of measurement	Average No LIFEH2OBUS	Average LIFEH2OBUS	Average variation	Median LIFEH2OBUS	Median variation
Eco1	Operating cost (general)	kEURO/vehicle	14.4	14.5	0.38%	14.5	0.38%
Eco20	Investment for the network	kEURO/vehicle	-	0.20	N/A	0	N/A
Eco23	Electricity costs for vehicles	kEURO/vehicle	0.0319	0.0161	-49.43%	0.0156	-51.01%
Eco30	Electricity purchase	Euro/kWh	0.50	0.33	-35.21%	0.28	-44.28%
Eco31	Water purchase	Euro/m^3	5.38	2.70	-49.79%	1.44	-73.21%
Eco32	Detergents purchase	Euro/kg	1.25	1.58	26.67%	1.75	40.00%
Eco33	Cost of washing operation	kEURO/vehicle	0.6	0.0483	-91.96%	0.0495	-91.75%
Eco34	Cost of water	kEURO/vehicle	0.007	0.004	-49.79%	0.002	-73.21%
Eco35	Water saved	kEURO/vehicle	0.048	0.024	-49.79%	0.013104	-73.21%
Eco36	Electricity costs for washing	kEURO/vehicle	0.114	0.113	-0.88%	0.113	-0.88%
Eco37	Wax purchase	Euro/kg	-	0.125	N/A	0.125	N/A
Ecn9	Electricity consumption	MJ/vehicle	228.64	176.76	-22.69%	160.60	-29.76%
Ecn12	Energy consumption	MJ/vehicle	69.34* 67.25**	17.83* 51.99**	-74.14%* -22.69%**	17.83* 47.23**	-74.14%* -29.76%**
Ecn13	Water consumption	L/vehicle	300* 1100**	76* 278**	-74.73%	76* 278**	-74.73%
Eco2	NO_x concentrations	mg/m^3	56.3	44.17	-21.55%	43	-23.62%
Eco3	PM_{10} concentrations	g/m^3	16.3	15.95	-2.13%	16	-1.84%
Eem1	CO_2 emissions	g/vkm	2.73* 5.93**	0.71* 4.43**	-74.14%* -25.28%**	0.71* 4.43**	-74.14%* -25.28%**
Ewa1	Hazardous waste	kg/month	70	80	14.29%	80	14.29%
Ewa2	Non-Hazardous waste	kg/month	10	10	0.00%	10	0.00%

* LIFE sub-scenario; ** LUC sub-scenario

4.1.2.3. People impacts: the innovation receives a general positive reception

In the case of Budapest, local management only administered the post-questionnaire, as the LIFEH2OBUS testing was already underway, and they could not distribute an ante-questionnaire to other lines that operated their Arriva Hungary buses with standard (ante) washing operations. To estimate ante values virtual control set was created: i.e., the average of Italy and Croatia was used and adjusted for the relative differences in post values across all three depots. The People KPIs in Budapest (Table 8) show a strongly positive and balanced outcome. In the Passenger impact area when considering the virtual reference panel, perception improves markedly across all indicators: passenger awareness (Ppa1) increases by +49.41%, attractiveness (Ppa3) by +45.31%, acceptance (Ppa2) by +13.95%, and travel comfort (Ppa4) by +14.83%. These results suggest that passengers clearly perceived improvements in cleanliness, comfort, and service quality, and responded positively to the environmental innovation. Crucially, staff perception also improves, unlike in Italy. Staff comfort (Pst1) increases by +44.37**%**, and staff acceptance (Pst2) increases by +5.19%. This indicates that the technology was well received by depot staff, possibly due to perceived reduced physical effort, improved working conditions, and visible efficiency benefits. This alignment between technical performance and human acceptance significantly strengthens the sustainability of this water reclamation system. Last to note, although the ex ante values are calculated and not actually collected, the quality of the results lies in the high scores detected in the during phase, all largely exceeding the 50% of the positive evaluations (as in the value of column "Average LIFEH2OBUS" in Table 8).

Table 8- People KPI values at Budapest

KPI #	KPI Name	Unit of measurement	Average No LIFEH2OBUS	Average LIFEH2OBUS	Average change
Ppa1	Passenger Awareness	%	41.44	61.92	49.41%
Ppa2	Passenger Acceptance	%	48.27	55.00	13.95%
Ppa3	Attractiveness	%	45.27	65.78	45.31%
Ppa4	Travel Comfort	%	65.82	75.58	14.83%
Pst1	Staff Comfort	%	41.37	59.73	44.37%
Pst2	Acceptance	%	65.56	68.96	5.19%

4.1.2.4 Overall performance interpretation for Budapest

In summary, the Budapest LIFEH2OBUS implementation demonstrates a highly successful performance profile. The technology delivers substantial water, energy, cost, and emissions reductions while maintaining stable operations and improving both passenger and staff perception. Unlike the Italian case, there is no evidence of increased unplanned operations or declining staff acceptance. The main trade-off lies in increased hazardous waste generation, which appears moderate and manageable. Overall, the Hungarian depot illustrates a best-case implementation scenario for LIFEH2OBUS: strong environmental and economic benefits, low operational disruption, and broad stakeholder acceptance. These results suggest that the technology is well suited for replication in contexts with similar baseline conditions, cost structures, and organizational readiness.

4.1.3 Požega site-specific performance trends

The Požega LIFEH2OBUS scenario presents a specific performance profile since the operational (Table 9) and economic (Table 10) results reveal transitional adjustments within the depot system, while environmental benefits and strong improvements in passenger and staff perception are clear (Table 11). Overall, this case study experience highlights how the introduction of water-saving technology can act as a catalyst for broader organisational change, with both positive outcomes and short-term adaptations.

4.1.3.1 Operational impacts: maintenance staff, service performance and demand dynamics

Operational KPIs (Table 9) in Požega show substantial variation, indicating that the technology introduction coincided with a deeper reconfiguration of depot operations. For what concerns the Staff impact area, Driving staff per vehicle (Ost1) and drivers' workload (Ost2) both decrease by approximately -7%, suggesting improved labour efficiency. These reductions are consistent across average and median values and indicate a tangible optimisation of driving-related resources in the face of the introduction of the water harvesting and reclamation technology. In contrast, maintenance staff per vehicle (Ost3) increases by +12.37% (average) and +11.88% (median), which suggests that the new system required additional technical oversight and system monitoring. Unlike the Budapest case (where maintenance levels remained stable) Požega appears to have absorbed the technology through increased maintenance capacity, possibly reflecting local technical requirements. At the same time, washing-related staffing shows minor efficiency gains, since Staff for washing operations (Ost4) decreases slightly (around -1%), while management workload and general staff workload remain unchanged. As in the other case studies, the introduction of wax-related washing tasks (Ost7.2 and Ost8.2) represents an expansion of service scope rather than a substitution of existing processes, although as for Budapest, wax has been diluted in the washing water and not applied as a self-standing treatment.

From the Supply impact area perspective, daily supply (Osu3) increases significantly in average terms (+9.59%), indicating improved vehicle availability ad overall depot throughput. However, the median daily supply decreases (-3.81%), suggesting operational variability over time. This divergence between average and median values points to a system in transition, where some periods benefited strongly from the new setup while others experienced adjustments This is in line with the results of the KPIs associated with the Maintenance impact area where a critical operational signal emerges in maintenance turnaround. Days in workshop / MTTR (Oma2) increase dramatically from 32.42 to 51.59, corresponding to a +59.12% average increase and +34.54% median increase. This indicates stressors in maintenance efficiency. Such a result suggests that the depot faced significant challenges during the integration phase, due to exogenous factors but also because of new equipment learning curves, and corrective maintenance needs, thus contrasting sharply with Grugliasco and Budapest, where MTTR improved or remained stable. At the same time, vehicles washing operations per travelled kilometre (Oma9) decrease by nearly -70%, indicating a strong reduction in washing frequency if compared to the overall depot production, which reflects improved washing effectiveness per event (to be noted that a decreasing value for Oma 9, when introducing innovations in the transit sector specifically for any event affecting the fleet may also indicate capacity constraints arising from longer workshop times).

Table 9 - Operations KPI values at Požega

KPI #	KPI Name	Unit of measurement	Average No LIFEH2OBUS	Average LIFEH2OBUS	Average variation	Median LIFEH2OBUS	Median variation
Ost1	Driving staff	man/vehicle	0.98	0.91	-7.05%	0.93	-5.59%
Ost2	Drivers' workload	man-month/vehicle	0.98	0.91	-7.15%	0.93	-5.69%
Ost3	Maintenance staff	man/vehicle	0.336	0.377	12.37%	0.376	11.88%
Ost4	Staff for washing operations	man/vehicle/ day/month	0.010	0.0099	-0.89%	0.00990	-0.98%
Ost6	Management workload	man-month /vehicle	1.00	1.00	0.00%	1.00	0.00%
Ost7.1	Washing staff	man/vehicle	1.00	1.00	0.00%	1.00	0.00%
Ost7.2	Washing staff (wax)	man/vehicle	-	1.00	N/A	1.00	N/A
Ost8.1	Staff workload	man-month /vehicle	1.00	1.00	0.00%	1.00	0.00%
Ost8.2	Staff workload (wax)	man-month /vehicle	-	1.00	N/A	1.00	N/A
Osu3	Daily supply	places/vehicle	75.04	82.24	9.59%	72.18	-3.81%
Oma2	Days in workshop (or MTTR)	h/action	32.42	51.59	59.12%	43.62	34.54%
Oma9	Vehicles washing operations	events/ travelled km	0.001	0.00033	-69.95%	0.00036	-67.32%
Ose2	Bus frequency	events/h	2.57	2.50	-2.87%	2.64	2.54%
Ose9	Washing time	% per vehicle	-	0.12	-	0.13	-
Ode1	Passenger demand	Passkm	6,958,171.42	6,731,342.17	-3.26%	6,822,908.50	-1.94%

In the Service and Demand impact areas, KPIs present a mixed but generally resilient picture. For the former, bus frequency (Ose2) decreases slightly in average terms (-2.87%), while the median shows a small increase (+2.54%). This again points to a service temporal variability. Passenger demand (Ode1) decreases modestly by -3.26% (average) and -1.94% (median). Given the magnitude of operational restructuring and increased workshop times, this decrease is relatively limited and suggests that service quality remained broadly high to users during the transition. Importantly, the reduction in demand contrasts with improvements in passenger perception indicators (discussed later), implying that demand variation was influenced more by external factors than by user dissatisfaction.

4.1.3.2. Economic, energetic and environmental impacts: innovation strongly shapes the economic and sustainable features

The economic KPIs reveal sharp contrasts (Table 10): on the Cost impact area side, the results are very strong since Cost of washing operation (Eco33) decreases by -96.58% (average) and -99.09% (median), representing one of the most dramatic improvements across the three depots. For what concerns Water saved (Eco 35), since during the test it was reported higher water consumption due to increased washing frequency, technically no water could be saved and no comparison ex ante was possible, either as no baseline figures were available. Electricity costs for washing (Eco36) also decrease substantially (between -84% and -94%), confirming the high efficiency of the LIFEH2OBUS system in washing-related energy use.

The Consumption and Emissions impact areas KPIs further reinforce this outcome: water consumption (Ecn13) decreases from 300 L/vehicle to 120 L/vehicle, achieving 60% reduction in the LIFE sub-scenario and passes from 895 L/vehicle to 358 L/vehicles in the LUC sub-scenario, while energy consumption (Ecn12) decreases by -59.07% in the LIFE sub-scenario and by 26.28% in the LUC sub-scenario, mirrored exactly by CO_2 emissions (Eem1). These reductions are significant, though less extreme than in the other two case studies, and yet demonstrate that the implemented technology performs effectively even in very diverse operational contexts. It is to be stressed, however, that 90% water consumption reduction set as performance target was originally assumed as a general goal for the LIFEH2OBUS initial set of three depots, including a Netherlands facility, all similar in terms of operations. When the Dutch case study was substituted by the Croatian one, the original 90% assumption had to be maintained as a general reference, although the Požega facility markedly differed (types of vehicles and services operated). Nevertheless, for the 60% reduction achieved in Požega , success can be claimed, being this result fully consistent with local operations, showing the water saving potential of bus depots of such size. In turn, several economic indicators deteriorate, like General operating cost (Eco1) increasing sharply by +227%, and maintenance operational costs (Eco4) doing the same by +22.88%**.** These increases are consistent with the observed rise in maintenance staff and MTTR, suggesting that the depot absorbed the LIFEH2OBS technology through higher operating and maintenance efforts during the test period. All in all, even though the investment for the network (Eco20) decreases dramatically, the observed, short-term operational cost escalation represents a clear transitional burden. In this scenario, electricity purchase prices decline significantly (-37% to -42%), partially offsetting cost increases, while revenues per passenger show a small positive change. Within the Revenues impact area, the appearance of economic surplus (Ere1) under LIFEH2OBUS suggests that, despite higher operating costs, the depot achieved a positive financial balance during the test period. With the water consumption as a trigger, environmental performance is unequivocally positive. In addition to water, energy, and CO_2 reductions, Požega shows no increase in hazardous or non-hazardous waste, unlike Grugliasco and Budapest: this is a notable strength of the Croatian case, indicating that the water-saving technology was implemented without introducing new waste management burdens.

Table 10 - Economic, Energy, and Environmental KPI values at Požega

KPI #	KPI Name	Unit of measurement	Average No LIFEH2OBUS	Average LIFEH2OBUS	Average change	Median LIFEH2OBUS	Median change
Eco1	Operating cost (general)	kEURO/vehicle	0.50	1.63	227.42%	1.49	199.00%
Eco4	Maintenance operational costs	kEURO/vehicle	0.55	0.68	22.88%	0.67	21.22%
Eco17	Debt service coverage	kEURO/vehicle	-	0.04	N/A	0.05	N/A
Eco20	Investment for the network	kEURO/vehicle	1.10	0.003	-99.68%	0	-100.00%
Eco26	Electricity costs for facilities	kEURO/vehicle	-	26.53	-	20.57	-
Eco30	Electricity purchase	Euro/kWh	0.36	0.23	-37.35%	0.21	-41.53%
Eco31	Water purchase	Euro/m^3	2.64	2.73	3.41%	2.62	-0.85%
Eco32	Detergents purchase	Euro/kg	-	1.19	-	0	-
Eco33	Cost of washing operation	kEURO/vehicle	1.10	0.04	-96.58%	0.01	-99.09%
Eco34	Cost of water	kEURO/vehicle	-	0.36	-	0.36	-
Eco36	Electricity costs for washing	kEURO/vehicle	0.0575	0.0090	-84.36%	0.0037	-93.65%
Eco37	Wax purchase	Euro/kg	-	2.49	N/A	0	N/A
Ere1	Economic surplus	kEURO/vehkm	-	5.18	-	3.57	-
Ere3	Revenues per passenger	kEURO/passkm	0.00789	0.00807	2.36%	0.00793	0.59%
Ecn9	Electricity consumption	MJ/vehicle	119.68	118.08	-1.33%	103.52	-13.51%
Ecn12	Energy consumption	MJ/vehicle	69.34* 23.94**	28.38* 17.65**	-59.07%* -26.28%**	28.38* 16.5**	-59.07%* -30.98%**
Ecn13	Water consumption	L/vehicle	300* 895**	120* 358**	60%	120* 358**	60%
Eem1	CO_2 emissions	g/vkm	6.1* 13.37**	2.5* 9.80**	-59.07%* -26.69%**	2.5* 9.80**	-59.07%* -26.69%**
Ewa1	Hazardous waste	kg/month	0	0	0%	0	0%
Ewa2	Non-Hazardous waste	kg/month	0	0	0%	0	0%

* LIFE sub-scenario; ** LUC sub-scenario

4.1.3.3. People impacts: full acceptance and reception

The People impact areas KPIs show strong and consistent improvements across all indicators (Table 11**).** Passenger awareness, acceptance, attractiveness, and travel comfort all increase significantly, with attractiveness rising by +27.49% and awareness by +23.77%. These results suggest that users perceived tangible improvements in cleanliness, comfort, and overall service quality. Importantly, staff comfort and acceptance also improve substantially, with staff comfort increasing by +22.76% and acceptance by +8.23%. This contrasts with the Italian case and aligns more closely with the Hungarian experience, indicating that despite natural operational and maintenance challenges associated with the introduction of the harvesting and reclamation system, staff perceived long-term benefits or improved working conditions associated with the new technology.

Table 11- People KPI values at Požega

KPI #	KPI Name	Unit of measurement	Average No LIFEH2OBUS	Average LIFEH2OBUS	Average change
Ppa1	Passenger Awareness	%	62.10	76.86	23.77%
Ppa2	Passenger Acceptance	%	49.80	59.71	19.89%
Ppa3	Attractiveness	%	62.80	80.07	27.49%
Ppa4	Travel Comfort	%	70.80	79.87	12.81%
Pst1	Staff Comfort	%	72.54	89.05	22.76%
Pst2	Acceptance	%	83.93	90.83	8.23%

4.1.3.4 Overall performance interpretation for Požega

In summary, the Croatian LIFEH2OBUS implementation delivers strong environmental benefits, remarkable reductions in washing-related costs, and clear improvements in passenger and staff perception. However, these gains are accompanied by significant operational and maintenance challenges, including increased MTTR, higher maintenance staffing, and sharply rising general operating costs. The Požega case can therefore be interpreted as a high-impact but high-adjustment implementation. LIFEH2OBUS acts not only as a water-saving solution but as a driver of broader organisational change. While short-term efficiency losses are evident, particularly in maintenance performance, the positive human-factor outcomes and environmental gains suggest that, in the long run, with further optimisation and stabilisation, the transition toward a more balanced and sustainable long-term performance profile is fully achievable.

4.1.4 Cross-country comparison synthesis of LIFEH2OBUS performance in the three LUCs

The LIFEH2OBUS demonstrations in the three depots provide a valuable comparative perspective on how the same water-saving technology performs under different operational, economic, and organisational contexts. While all three case studies confirm the technical effectiveness of the solution in reducing water and energy consumption, the broader performance impacts vary significantly, revealing the importance of local conditions, implementation strategies, and organisational readiness. In synthesis, LIFEH2OBUS proves to be a technically robust and environmentally effective solution across all three depots. However, the quality of outcomes depends strongly on implementation context, with cross-cross evidences suggesting that technology alone is not sufficient. Learnt in terms of replicability and transferability criteria, successful "export" of LIFEH2OBUS requires complementary measures in staff engagement, maintenance planning, waste management, and change management. When these elements are aligned, the tested washing technologies can deliver not only water savings but a comprehensive improvement in depot sustainability and service quality. This is corroborated by the cross-case analysis of impacts reported as follows, based on the LIFE sub-scenario achievements, to align with the LIFE web tool results further described in Del. 5.3 and to adhere with the initial assumptions on water usage LIFEH2OBUS was grounded on. It is also here important to remind that that the LIFE sub-scenario represents normalized, assumption-controlled conditions, whereas LUC sub-scenario is based on raw, field-based, operational data, limited by the text environment experience.

4.1.4.1 Environmental impacts: a consistent and robust success

Across all three countries, the environmental objectives of LIFEH2OBUS are unequivocally achieved. Water consumption per vehicle decreases substantially in each case: by approximately 85.5% in Grugliasco**,** 74.7% in Budapest, and 60% in Požega for an average value of 73.4%**.** Although the magnitude of savings differs and the initial performance target was set at 84%, the direction is consistent, confirming that the technology reliably delivers water efficiency regardless of baseline conditions. Also, the percentage achieved in Grugliasco stress that at site level performance can progress beyond the initial PT. These water savings are closely mirrored by reductions in energy consumption and CO_2 emissions, reinforcing the systemic nature of the benefits. Italy and Hungary show the strongest emissions reductions (both above -74%), while Croatia records a still significant -59% reduction. This consistency demonstrates that LIFEH2OBUS contributes not only to water conservation but also to broader climate and energy goals, strengthening its policy relevance.

Environmental side effects, however, differ since Grugliasco and Budapest depots both experience the issue of hazardous waste, linked to filtration or residue management, whereas Croatia reports no increase in waste streams. This contrast highlights that environmental trade-offs are context-dependent and influenced by system configuration and waste-handling practices.

4.1.4.2. Operational impacts: stability versus transition stress

Operational impacts represent the clearest point of divergence among the three cases, as synthesized as follows.

- Budapest exhibits the most stable operational profile. Maintenance cycles, washing frequency, staffing levels, and workshop times remain unchanged, indicating a smooth integration of LIFEH2OBUS into existing processes. Thus efficiency gains are achieved without disrupting depot operations.
- Grugliasco shows a moderately positive but mixed operational response. Improvements are observed in workshop turnaround time and washing time, but these are offset by a substantial increase in unplanned operations which can be due also to exogenous factors. This suggests that, at least during its inception, while a harvesting and reclamation system can improve efficiency, it also introduces complexity or reliability challenges that require additional management attention in depots' retrofitting processes
- Požega experiences a typical operational transition when introducing innovation, since maintenance staff increase, workshop time rises sharply (+59%), and washing frequency drops significantly. The KPIs, then, suggest that the technology introduction might call for a broader structural or organisational changes, leading to short-term inefficiencies and adjustment costs, just limited to the early stage of the water saving implementation.

Taken together, these results suggest that LIFEH2OBUS performs best operationally when introduced into stable, well-prepared depot systems, while more constrained or restructured environments may experience transitional stress before benefits fully materialise.

4.1.4.3 Economic impacts: washing efficiency versus system-wide costs

In all three depots, washing-related costs decrease dramatically, confirming the economic efficiency of the technology at process level. Observed reductions in the cost of washing operations exceed -90% in Budapest and Požega and approach -20% in Grugliasco, reflect naturally local differences in baseline costs and accounting structures. However, the system-wide economic picture diverges and describes two typical situations when introducing novelties in the transit sector, useful for the Transferability exercise and plan development in WP6:

- Operators looking for technology's affordability (*economically-effortless scenario):* Budapest demonstrates the most favourable economic outcome, combining very large washing cost reductions with declining electricity and water prices, modest investment costs, and stable general operating costs. This results in a strong economic case and rapid potential payback.
- Operators managing technology's trade-offs (*adjustment scenario*): Grugliasco shows moderate cost savings, but benefits are partially offset by increased electricity costs in some periods and new waste-management requirements. Likewise, in Požega although washing cost savings are remarkable and energy prices reduced, general operating and maintenance costs increase sharply. All of the above indicate that the technology's benefits were outweighed in the short term by broader organisational or maintenance challenges.

The lesson learnt is then, that under the economic impact point of view, this comparison underscores that process-level savings do not automatically translate into system-level economic gains unless supported by stable operations and controlled maintenance demands, as further highlighted in the CBA.

4.1.4.4. People impacts: the decisive differentiator

Human perception KPIs reveal one of the most critical insights of the cross-country analysis: Passenger perception improves consistently and strongly in all three case studies. Awareness, attractiveness, acceptance, and travel comfort all increase, confirming that cleaner vehicles and sustainability messaging positively influence users regardless of operational context. This consistency suggests that LIFEH2OBUS delivers a clear customer-facing value proposition. Staff perception, however, diverges sharply:

- Budapest and Požega both record significant improvements in staff comfort and acceptance, indicating that staff perceived tangible benefits, such as improved working conditions or clearer long-term advantages.
- Grugliasco, by contrast, records a sharp decline in staff comfort and acceptance, aligning with the increase in unplanned operations.

This contrast highlights staff acceptance as a critical success factor. Where staff experience the technology as supportive and well-managed, overall performance is more stable. Where staff experience increased workload or uncertainty, operational risks increase even if technical performance is strong.

4.1.5 Efficiency score matrix to identify the Best Available Technology

To switch from a site-based assessment to a technology-based one, a specific methodology is proposed with the aim to identify the LIFEH2OBUS BAT. This methodology develops a standardized 0-10 efficiency score scale for bus washing techniques evaluated in the LIFEH2OBUS project, thus shifting focus from site-specific use cases (Grugliasco , Budapest and Požega) to technique-level performance. It aggregates KPI percentage variations between No-LIFEH2OBUS (baseline) and LIFEH2OBUS (test) scenarios across all applicable sites, emphasizing water savings (project target: ~84% reduction) while balancing energy, emissions, costs, and operations (for the same reasons highlighted in Section 4.1.4, efficiency is based on the results of the LIFE sub-scenario). Scores enable cross-context transferability, identifying best-available technologies for replication in European bus depots. The approach uses weighted averages of core KPIs, penalties for trade-offs, and normalization, drawing from document tables reporting average and median variations, through Eq. 1 values.

Basic reclamation (tested at all three sites) and reclamation with harvesting tested at Grugliasco and Budapest are considered, with waxing excluded for the reasons reported in the caveats section. Moving from core results for basic water-saving averages Grugliasco (-85.5% water), Budapest (-74.7%), Požega (-60%) and inputs derived from operational (Ops: staff allocation, MTTR, unplanned ops, wash time), economic (washing cost reductions), energy (Ecn12 total via Eq. 2), environmental (Ecn13 water, Eem1 CO2 via Eq. 3), and people evaluation categories, positive variations (negative % for reductions) drive scores. The Equation 5 used to provide raw scores (RS) is standard, with using linear weighted sum and reflecting priorities (P) in terms of savings (with water heaviest per DoW), i.e.:

$$RS = (0.4\times P_1)+(0.3\times P_2)+(0.3\times P_3)+(0.2\times P_4)+(0.1\times P_5) \qquad (5)$$

where:

P_1 – water saving in percentage (40%): Ecn13 average reduction (core LPI1); target benchmark ~84%.

P_2 – energy saving in percentage (30%): Ecn12 total consumption drop, including embedded water energy.

P_3 - emissions reduction in percentage (30%): Eem1 CO2eq reduction (core LPI3).

P_4 – cost reduction in percentage (20%): Washing operations savings (Eco1-3,5-6 aggregate).

P_5 – operational reduction in percentage (10%): Average of MTTR (Oma2), unplanned ops (Ose8), wash time (Ose9), staff (Ost1/3/7).

After calculating the raw score—which captures the weighted positive gains from key performance improvements like water and energy reductions—penalties are applied as a critical adjustment step to ensure a realistic, balanced assessment of each washing technique's viability. These penalties deduct 5 points for each identified major drawback, specifically defined as any KPI showing a worsening of more than 20% compared to the baseline No-LIFEH2OBUS scenario. The three primary drawbacks targeted are: a rise in waste production (e.g., from reclamation filters generating more solid residues), an increase in unplanned maintenance operations (e.g., unexpected downtime due to equipment teething issues), or an elongation of Mean Time To Repair (MTTR, reflecting higher workshop burdens from the new systems). This penalty is capped at a maximum of -15 points total, preventing it from completely undermining strong environmental gains while still flagging systemic issues that could hinder long-term adoption. To synthesize, criteria are reported as follows:

- Penalties apply post-raw: -5 points per major drawback (>20% rise in waste production, unplanned maintenance, or MTTR; max -15).
- Final score normalizes absolute gain:

  $$\min(10);\ \max\left(0,\left|\frac{|\text{Raw Score}|-\text{Penalties}}{10}\right)\right. \qquad (6)$$
- Thresholds: ≥8 (best-practice), 6-7.9 (viable), <5 (refine).

Once penalties are subtracted, the final efficiency score is normalized to a clear 0-10 scale using the eq. 6. Here, the absolute value of the raw score (always positive, as it represents net gains from negative percentage variations like -85% water reduction) is divided by 10 after penalty deduction, then bounded between 0 (complete failure, no meaningful improvements) and 10 (exceptional performance, exceeding project targets like ~84% water savings across all metrics). This normalization creates a quantitative rating:

- scores of 8 or higher signal a "best-practice" technique ready for wide transferability across European bus depots, as per LIFEH2OBUS's mission on replicable solutions;
- 5 to 7.9 indicates a "viable" option that works well but may need minor tweaks (small targeted, low-effort optimizations to push a washing technique from good to best-practice (≥8) without major redesign or reinvestment); and
- anything below 5 flags a technique requiring refinement or site-specific adaptations before scaling.

These enable to score the two technologies as follows:

a) Efficiency score for Basic Reclamation (all depots average):

- Water: Average % (-85.5 Grugliasco, -74.7 Budapest, -60 Požega) = -73.4%
- Energy: -72.8% (aligned reductions)
- Emissions: -72.5%
- Cost: -69.3% (strong Požega -96.6%)
- Operations: -1.2% (MTTR -10% avg, offset by +20-70% unplanned)
- RS= 0.4(−73.4) + 0.3(−72.8)+0.3(−72.5)+0.2(−69.3)+0.1(−1.2)=−65.350.4(−73.4)+0.3(−72.8)+0.3(−72.5)+0.2(−69.3)+0.1 (−1.2)=−65.35 (gain 65.35)
- Penalties: -10 (-5 waste rises all sites, -5 avg unplanned >20%)
- Adjusted: 55.35 → Final: 5.5/10 (moderate; water saving is solid but operations drag)

b) Efficiency score for Basic Reclamation and Harvesting (Grugliasco and Budapest average):

- Water: Avg(-85.5, -74.7) = -80.1%
- Energy: -79.7%
- Environmentals: -79.2%
- Cost: -55.6% (Budapest -92% boosts)
- Ops: -1.25% (stable staff, minor MTTR gain)
- RS: 0.4(−80.1)+0.3(−79.7)+0.3(−79.2)+0.2(−55.6)+0.1(−1.25)=−72.60.4(−80.1)+0.3(−79.7)+0.3(−79.2)+0.2 (−55.6)+0.1(−1.25)=−72.6 (gain 72.6)
- Penalties: -5 (waste only Budapest)
- Adjusted: 67.6 → Final: 6.8/10 (viable; harvesting enhances water and energy assessment)

The final efficiency scores (EF) are the reported in the following matrix:

	Water %	**Energy %**	**Emissions %**	**Cost %**	**Operations %**	**Raw Gain**	**Penalties**	**Final EF (0-10)**
Basic Reclamation	-73.4	-72.8	-72.5	-69.3	-1.2	65.4	-10	5.5
Reclamation + Harvesting	-80.1	-79.7	-79.2	-55.6	-1.3	72.6	-5	6.8

It is clear that reclamation and harvesting edges out for best available practice within LIFEH2OBUS KPIs, but weather must be factored in. Basic Reclamation as simple wastewater recycling without rainwater harvesting fits best in environments and operations where water scarcity or high costs make standalone recycling the priority, rather than relying on supplemental rainfall collection. In drier climates (e.g., continental summers like Grugliasco and Budapest with low rain: 0.6-3mm/day), harvesting can add minimal volume (Table 2: low summer rain), so basic reclamation delivers reliable ~73% water savings across sites without infrastructure for tanks. Its lower upfront costs (no harvesting extras) and strong cost reductions (-69% in average for washing oerationss) appeal to budget-constrained depots, like those emphasizing economic performance (Eco KPIs group) over max environmental gains. Požega's -96% cost drop shows this: economic wins outweigh moderate -60% water in high-rain but cost-sensitive spots. Conversely, reclamation and harvesting (6.8 score) shines in wetter areas (Požega 8-10mm/day rain) where harvesting boosts totals to -80%, but requires more capex and maintenance efforts, less ideal for dry zones where rain is unreliable. In other words, weather dictates effectiveness, but at the same time economics tip the scales.

4.2 A focus on the LIFEH2OBUS potential to save water: the Water Footprint Assessment Methodology

While section 4. 1 has quantified direct water savings and related energy and emission reductions at depot level through KPI/LPI-based scenario comparison, a further step is required to assess the broader and systemic implications of LIFEH2OBUS technologies along the entire water value chain; for this reason, a Water Footprint Assessment (WFA) methodology is here introduced to complement the previous analysis by capturing both direct and indirect water uses, thus providing a more comprehensive evaluation of the project’s actual contribution to sustainable water resource management. Therefore, this part complements the previous analyses (as planned in Task 5.3) by deepening the environmental potential and effects of the LIFEH2OBUS technologies (as in Task 5.4).

4.2.1 Rationale and scope for considering a multidimensional indicator

The Water Footprint (WF) is defined as “the volume of freshwater used to produce the product, measured over the full supply chain”[5] to assess the sustainability, efficiency and fairness of water use. The total water footprint within a geographically defined area, such as a region, nation, or watershed, is the sum of the relative water footprints of all processes carried out in that area.

A thorough assessment of the water footprint, therefore, encompasses all human activities involved in the supply and delivery of a given product or service. In this assessment, the bus washing cycle is, thus, evaluated as an integral component of the bus transport passenger service[6]. This comprehensive approach enables a

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[5] Hoekstra, A. Y., et al. The water footprint assessment manual: Setting the global standard, 2011, Routledge, London. pp. 92-103

[6] Hoekstra, A. Y., et al. The water footprint assessment manual: Setting the global standard, 2011, Routledge, London. pp. 92-103

detailed understanding of water consumption correlated to different operational dimensions within the service delivery framework. This evaluation is crucial for determining whether total water consumption exceeds the local freshwater system's capacity, beyond the data provided in the LIFEH2OBUS before-vs-during scenarios comparison.

The novelty of the WF lies in its measurement of water use relative to specific processes and in its assessment of the sustainability of these practices. Such a method enables downscaling and the attribution of sustainability targets to specific producers and consumers[7]. The use of the water footprint indicator has been demonstrated as an effective tool for promoting knowledge and awareness among diverse decision-makers, encouraging more responsible consumption practices[8]. Additionally, the water footprint serves as a relevant indicator for measuring progress towards SDG target 6.4, as this target encompasses both efficiency and sustainability components[9].

4.2.2 The Infrastructure Multiplier Effect and unitary calculations

The collection of water data enables the integration of a water footprint equation to measure and assess the impact of washing activities on water as a resource. To ensure the assessment captures the true social toll of water consumption, the framework incorporates a leakage factor (Lj) to account for infrastructural inefficiencies in municipal distribution. Since an average of 33% of abstracted water in the EU is lost before reaching end-users, with losses in specific regions like Italy and Croatia exceeding 40%[10], the WF methodology identifies an "infrastructure multiplier effect." Consequently, every litre saved at a bus depot prevents a significantly larger withdrawal at the environmental source, as the depot’s net demand must be met by a higher gross withdrawal at the municipal intake.

The Unitary Water Footprint (WF_{wj}) for a single vehicle wash at a specific location (*k*-th type), expressed in cubic metres per wash, is determined by Equation 7:

$$WF_{w_j} = \frac{\theta\cdot(1-r)}{1-L_j} \tag{7}$$

where θ is the total industrial water used per wash (m^3), r is the water consumption reduction factor representing the percentage of water reclaimed or harvested, and L_j is the location-specific infrastructure leakage rate. As done for other indicators, the water footprint is expanded to an all-inclusive depot-wide yearly figure (WF_{totj}):

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[7] Abd Kadir, N. H., et al. 2024. Assessment of water footprints in different sectors: utilization, safety and challenges, in: Bandh, S.A., Malla, F.A., (eds.) Current Directions in Water Scarcity Research, 8, 2024, Elsevier, Amsterdam, pp. 17-28.

[8] Gómez-LlanoS, E., et al.. Analysis of consumer awareness of sustainable water consumption by the water footprint concept. Science of the total environment, 721, 2020 137743; Berger, M., et al. . Advancing the water footprint into an instrument to support achieving the SDGs–recommendations from the “Water as a Global Resources” research initiative (GRoW). Water resources management, 35(4), 2021, pp. 1291-1298.

[9] Berger, M., et al. . Advancing the water footprint into an instrument to support achieving the SDGs–recommendations from the “Water as a Global Resources” research initiative (GRoW). Water resources management, 35(4), 2021, pp. 1291-1298. Hoekstra, A. Y., et al. Advancing water footprint assessment research: Challenges in monitoring progress towards sustainable development goal 6. Water, 9(6), 2017, 438.

[10] European Environment Agency, 2025. Water savings for a water-resilient Europe. [Online] Available at: https://www.eea.europa.eu/en/analysis/publications/water-savings-for-a-water-resilient-europe?activeTab=e076ddf8-dfa9-4e89-91a8-dd299a953b5c.

$$WF_{tot_j} = WF_{w_j} \cdot \mathrm{N} \cdot \mathrm{W} \quad (8)$$

where N is the number of buses washed at the depot, and W is the total number of bus washes in a year.

The acronym AWARE stands for Available WAter REmaining, which represents the remaining water per area in a watershed after the demands of humans and aquatic ecosystems have been met. It is designed to assess the potential impact of water scarcity on humans or ecosystems, positing that the less water remains available per area, the more likely another user will be denied access[11]. The AWARE method is considered one of the most suitable for assessing sustainable water resource management and provides Water Scarcity Footprint Characterisation Factors (WSF CFs) that reflect local climatic characteristics, including spatial and temporal variations in supply and demand. Several models have aimed to define WSF CFs using the withdrawal-to-availability (WTA) ratio[12] or the consumption-to-availability (CTA) ratio[13]. The WTA is based on human water abstraction but does not account for the amount of water returned to the same basin after abstraction, whereas CTA considers the water consumed and not returned. Therefore, CTA returns values more accurately than WTA, which may overestimate water scarcity[14] . The Available Minus Demand (AMD) concept, also termed AWARE, refers to absolute water scarcity; this quantification is not possible with either WTA or CTA and this inability may lead to overestimating or underestimating water scarcity, as one cubic metre of groundwater in an arid region is not equivalent to one cubic metre of water in an area with water abundance.

The definition of AMD and the resulting characterisation factor (CF) are illustrated in the following equations[15]:

$$AMD_{i,j} = \frac{A_{i,j} - (C_{i,j} + EWR_{i,j})}{Area_j} \quad (9)$$

$$CF_{i,j} = \frac{1/AMD_{i,j}}{1/AMD_{world\ avg}} = \frac{AMD_{world\ avg}}{AMD_{i,j}} \quad (10)$$

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[11] Ansorge, L., Beránková, T. LCA Water Footprint AWARE Characterization Factor Based on Local Specific Conditions. European Journal of Sustainable Development, 6(4), 2017 13.

[12] Pfister, S., and Bayer, P., 2014. Monthly water stress: spatially and temporally explicit consumptive water footprint of global crop production. Journal of Cleaner Production, 73, 2014, pp. 52-62;

[13] Berger, M., Van Der Ent, R., Eisner, S., Bach, V., and Finkbeiner, M. Water accounting and vulnerability evaluation (WAVE): considering atmospheric evaporation recycling and the risk of freshwater depletion in water foot printing. Environmental science & technology, 48(8), 2014, pp. 4521-4528; Boulay, A. M., Bulle, C., Bayart, J. B., Deschênes, L., Margni, M., Regional characterization of freshwater use in LCA: modeling direct impacts on human health. Environmental science & technology, 45(20), 2011, pp. 8948-8957; Hoekstra, A. Y., Mekonnen, M. M., Chapagain, A. K., Mathews, R. E., and Richter, B. D. Global monthly water scarcity: blue water footprints versus blue water availability. PloS one, 7(2), 2012, e32688.

[14] Pfister, S., Koehler, A., and Hellweg, S. Assessing the environmental impacts of freshwater consumption in LCA. Environmental science & technology, 43(11) 2009, pp., 4098-4104; Lee, J., Younos, T., 2018. Sustainability Strategies at the Water–Energy Nexus: Renewable Energy and Decentralized Infrastructure. Journal AWWA, 110(2), 2018, pp. 32–39. Ridoutt, B.G.; Pfister, S., . A new water footprint calculation method integrating consumptive and degradative water use into a single stand-alone weighted indicator. International Journal of Life Cycle Aassessment, 18, 2023, pp. 204–207.

[15] Boulay, A. M., Bare, J., Benini, L., Berger, M., Lathuillière, M. J., Manzardo, A., and Pfister, S. The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE). The International Journal of Life Cycle Assessment, 23(2), 2018, pp. 368-378

where $A_{i,j}$ represents water availability in the i-th month in region j (m^3/month), $C_{i,j}$ the human water consumption, $EWR_{i,j}$ the environmental water requirement, and $Area_j$ the surface area (sqkm). When $AMD_{i,j}$ is 10 times the world average, CF is set to a minimum of 0.1. When it is 100 times less than the world average, CF is given a maximum value of 100.

The importance of water varies significantly by location, consequently, characterisation factors are used as weights to allow accurate comparisons. AWARE was selected over the original Water Exploitation Index (WEI) as the latter was deemed too simplistic. While the EEA utilises WEI+, its limited adoption and availability outside the EU were a limiting factor for the transferability of these results beyond the project and the EU. Furthermore, while the other indicators, such as the Aqueduct indicator (developed by the World Resources Institute), are widely used by corporations, they are largely absent from scientific literature. AWARE suffers from none of these limitations and is the consensus method recommended by UNEP-SETAC. The characterised AWARE variants are:

$$WF_{AW_j} = \frac{\theta \cdot (1-r)}{1-L_j} \cdot \phi_j \tag{11}$$

$$WF_{AWtot_j} = WF_{AW_j} \cdot \mathrm{N} \cdot \mathrm{W} \tag{12}$$

where ϕ_j is the characterisation factor for water at location j.

4.2.2.1 Site-Specific Water Footprint Performance

The methodology above is then applied as follows to the three LUCs to estimate their local Water Footprint. More specifically in Grugliasco, the bus depot operates in a high-sensitivity region, where the AWARE factor is more than twice the European average[16]. The performance of the Rainwater Harvesting and Reclamation system was assessed thus using a local leakage rate (L_j) of 40%, according to EUREAU[17], and a characterisation factor for the non-irrigation/non-agricultural sector (ϕ_j) of 19.03 m^3 world-eq./m^3 as from the WULCA database[18]. All of the above provides the following figures:

- LUC No LIFEH2OBUS bus wash: 0.750 m^3/wash
- LUC No LIFEH2OBUS bus wash AWARE: 14.250 m^3 world-eq./wash
- LUC LIFEH2OBUS bus wash: 0.109 m^3/wash
- LUC LIFEH2OBUS bus wash AWARE: 2.066 m^3 world-eq./wash
- LIFE Standardised No LIFEH2OBUS bus wash: 0.5 m^3/wash
- LIFE Standardised No LIFEH2OBUS bus wash AWARE: 9.5 m^3 world-eq./wash
- LIFE Standardised LIFEH2OBUS bus wash: 0.073 m^3/wash
- LIFE Standardised LIFEH2OBUS bus wash AWARE: 1.378 m^3 world-eq./wash

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[16] As in data and publications from https://wulca-waterlca.org/publications/#elementor-toc__heading-anchor-3

[17] https://www.eureau.org/resources/publications/annual-reviews/6454-eureau-annual-report-2021-1/file

[18] https://wulca-waterlca.org/publications/#elementor-toc__heading-anchor-3

In turn, for what concerns Budapest, the Hungarian context evaluates the Water Reclamation system in an urban environment highly reliant on municipal water. The site-specific estimation utilises a local leakage factor (L_j) of 28% still according to EUREAU in 2021 (see footnote 17) and a scarcity weighting (ϕ_j) of 2.09 m^3 world-eq./m^3 as in WULCA in 2025 (see footnote 18).

- LUC No LIFEH2OBUS bus wash: 1.528 m^3/wash
- LUC No LIFEH2OBUS bus wash AWARE: 3.193 m^3 world-eq./wash
- LUC LIFEH2OBUS bus wash: 0.386 m^3/wash
- LUC LIFEH2OBUS bus wash AWARE: 0.807 m^3 world-eq./wash
- LIFE Standardised No LIFEH2OBUS bus wash: 0.417 m^3/wash
- LIFE Standardised No LIFEH2OBUS bus wash AWARE: 0.871 m^3 world-eq./wash
- LIFE Standardised LIFEH2OBUS bus wash: 0.105 m^3/wash
- LIFE Standardised LIFEH2OBUS bus wash AWARE: 0.220 m^3 world-eq./wash

Eventually, the Požega depot utilises the Rainwater Harvesting and Reclamation system to mitigate the impact of high local infrastructure leakage, recorded at approximately 49%. As for the other LUCs, given a local AWARE factor (ϕj) of 1.98 m3 world-eq./m3, the environmental impact of saved water is significantly amplified.

- LUC No LIFEH2OBUS bus wash: 1.755 m^3/wash
- LUC No LIFEH2OBUS bus wash AWARE: 3.475 m^3 world-eq./wash
- LUC LIFEH2OBUS bus wash: 0.702 m^3/wash
- LUC LIFEH2OBUS bus wash AWARE: 1.390 m^3 world-eq./wash
- LIFE Standardised No LIFEH2OBUS bus wash: 0.588 m^3/wash
- LIFE Standardised No LIFEH2OBUS bus wash AWARE: 1.165 m^3 world-eq./wash
- LIFE Standardised LIFEH2OBUS bus wash: 0.235 m^3/wash
- LIFE Standardised LIFEH2OBUS bus wash AWARE: 0.466 m^3 world-eq./wash

4.2.2.2 Comparative Water Footprint Estimation across the Three LUCs and Implications for the Identification of the Best Available Technology

The Water Footprint Estimation conducted across the three LIFEH2OBUS depots provides a harmonised and systemic basis for comparing the real contribution of the tested technologies to sustainable water resource management. Moving beyond the sole measurement of direct water withdrawal reductions presented in the first part of Section 4, the Water Footprint Assessment allows for an integrated interpretation of direct freshwater use, indirect water embedded in energy consumption, and operational boundary conditions. This broader perspective is essential not only for evaluating performance, but also for identifying the Best Available Technology (BAT) among the solutions tested.

Across all three LUCs, the LIFE sub-scenario, which standardises assumptions and removes transitional variability, confirms a strong structural reduction in freshwater footprint per vehicle. Grugliasco achieves the highest reduction (approximately –85.5%), effectively meeting and slightly exceeding the project's initial performance target. Budapest follows with a reduction close to –75%, while Požega demonstrates a comparable structural trend, albeit within a context characterised by smaller fleet size and operational adjustments during the testing phase. These reductions are not marginal improvements but represent a paradigm shift in depot washing practices. In conventional washing systems, freshwater withdrawal is linearly proportional to washing frequency. In contrast, LIFEH2OBUS technologies decouple washing intensity from freshwater abstraction by introducing water reclamation and, where applicable, harvesting systems. This structural decoupling is the core element that positions the tested solutions within the BAT domain.

Importantly, the reduction in direct water use is accompanied by consistent reductions in energy consumption and related CO_2 emissions under the harmonised conditions of the LIFE sub-scenario. This coherence confirms that the technologies do not simply shift environmental burdens from water to energy systems. On the contrary, the integration of reclamation processes reduces both abstraction volumes and associated pumping and treatment energy demand, reinforcing overall environmental efficiency. The Water Footprint Estimation therefore validates the systemic sustainability of the technologies rather than merely their localised performance.

Contextual parameters influence the magnitude and stability of the results. Climatic conditions affect harvesting potential; fleet size and washing demand influence system loading; local cost structures shape economic outcomes. However, the harmonised LIFE sub-scenario demonstrates that technological efficiency remains the dominant explanatory factor. Even in Požega, where maintenance KPIs revealed transitional stress during implementation, the structural water-saving potential remains evident once operational variability is normalised. Thus, from a BAT perspective, several dimensions must be considered beyond percentage reduction alone:

- Technical effectiveness – The combined reclamation and harvesting system tested in Grugliasco achieves the highest water reduction and demonstrates strong structural efficiency.
- Operational compatibility– Budapest shows the smoothest integration, with minimal operational disruption and strong workforce acceptance.
- Scalability and economic feasibility – The relatively lower investment per vehicle observed in Budapest, combined with high operational savings, indicates strong replicability under large-fleet conditions.
- Organisational adaptability – Požega illustrates that even in smaller depots, the technology can act as a catalyst for operational modernisation, though initial adjustments may be required.

When identifying the BAT, it is methodologically necessary to consider not only the absolute environmental gain but also robustness, replicability, cost-effectiveness, and stakeholder acceptance. In this sense, the BAT within LIFEH2OBUS should not be interpreted as a single rigid configuration, but rather as a technological approach based on closed-loop water reclamation, optionally integrated with harvesting systems where climatic conditions permit.

The Grugliasco configuration may be regarded as the most environmentally performant variant under optimal technical integration. The Budapest case demonstrates the strongest balance between environmental, economic, and organisational performance, suggesting high transferability in metropolitan contexts. Požega confirms that even under more limited operational scales, the core technological principle remains valid and capable of delivering structural water savings. Therefore, the BAT emerging from the LIFEH2OBUS comparative Water Footprint Estimation can be defined as a depot-based closed-loop water reclamation system, potentially integrated with rainwater harvesting where contextually suitable, capable of achieving structural freshwater reductions above 70–85% per washing cycle while maintaining operational stability and ensuring positive stakeholder acceptance. This definition aligns with European environmental policy principles, where BAT is characterised by technological maturity, demonstrated performance, environmental superiority, and feasibility under realistic operating conditions.

In conclusion, the comparative Water Footprint analysis confirms that LIFEH2OBUS technologies meet the core criteria for BAT candidacy. They achieve substantial and replicable reductions in freshwater abstraction, generate aligned energy and emission savings, maintain operational continuity, and (in most cases) enhance passenger perception. Differences among LUCs reflect contextual and managerial variables rather than intrinsic technological limitations. Consequently, the BAT identification is not site-exclusive but principle-based, grounded in the demonstrated ability of closed-loop water management systems to fundamentally transform resource efficiency in bus depot operations.

4.3 Caveats

Like any exploratory study, also in the case of LIFEH2OBUS there are some factors to consider for the results thus far reported and lead to two recurring research questions, the foremost being: “Would the outcomes have varied if tested on a larger scale or over an extended duration?” This is especially applicable to outcomes that did not meet fully expectations or debated, such as instances staff acceptance or amount of unplanned operations affecting results. However, based on prior experience, this may be more pertinent if the focus is just on economic concerns for smaller operations, as costly advances can ultimately prove prohibitive. Simultaneously, it is important to note that, despite being relatively small and of limited duration, the test fleets and activities in all LIFEH2OBUS scenarios align with standard experimental operations funded by European research initiatives centered on innovation. The second research question pertains to the fact that in certain KPIs, the No-LIFEH2OBUS scenario was "blank," meaning an actual comprehensive comparison with the pre-LIFEH2OBU situation was unattainable due to the absence of water and or energy-related specific meters and data. This was particularly evident when evaluating energy consumption and means that in this case the quality of the LIFEH2OBUS findings more than scenario-comparative is exploratory, consistently with the high level of innovation tested.

At the same time, it is to be considered the need to adopt a dual sub-scenario logic in the results assessment. In The LUC sub-scenario reflects raw, field-based data collected during the pilot phase and therefore captures real operational variability, including fluctuations in washing frequency, treated volumes, local conditions, and operator practices. As such, it provides a realistic snapshot of “system behavior” under exploratory conditions, but it may also incorporate natural, transitional inefficiencies, calibration adjustments, learning-curve effects, and possible partial-load operation of an oversized system, as already stressed. These factors can temporarily influence energy-related KPIs and explain divergences from expected performance trends. Conversely, the LIFE sub-scenario is based on recalculated and normalized data derived under normalized assumptions consistent with the reference (“before”) scenario and the LIFE Web Tool approach. In fact, while this improves quantitative comparability and enables a structured impact assessment aligned with the LIFE Web Tool methodology, it necessarily reduces sensitivity to real-world variability. Moreover, differences in system boundaries, volume-driven versus operation-driven indicators, limited monitoring duration, and the use of a fixed emission factor are all be acknowledged when interpreting results. Together, the two sub-scenarios provide complementary perspectives: one operational and empirical, the other normalized and assessment-oriented.

One more factor to consider is the role of waxing, which according to the depot managers did not achieved the expected results, and then being considered as a supplementary technique of the reclamation and harvesting processes. Yet the reasons which prompted the introduction of waxing in the LIFEH2OBUS were solid, and strongly rooted in environmental considerations based on the use of carnauba. Contrary to common belief, the waxing production process is also highly sustainable[19], but at a different scale from those based on saving water per se. The foliage of the Brazilian palm tree (Copenicia prunifera) yields carnauba wax which constitutes the foundation for this category of coating. Harvesting entails the collection of palm leaves, which are then sun-dried. A natural waxy layer develops on the leaves during the process. The coating is subsequently removed, usually by striking the leaves, following which the wax is refined and processed, all without necessitating the removal of trees. In the dry season, the crop thrives, serving as a vital resource for local communities by providing employment possibilities when rainfall is limited and agricultural activity decline. Carnauba wax is notable among natural waxes for its durability and sheen. Its natural origin confers a distinctive luminosity that synthetic waxes cannot replicate, and it is deemed safe for human use, including ingestion. Manufacturers enhance the pliability of the product for application to car surfaces by combining solvents and polymers. The carnauba wax undergoes a solidification process on the clear coat as the additional chemicals evaporate, facilitating buffing to attain a glossy finish.

One more factor to introduce waxing was its consolidated practice in the aviation sector, although I this field the driver is not saving water but contributing to reduce skin friction (drag) and improve commercial speed.

Thus, despite the potential environmental and operational benefits of wax technology[20], there is a significant dearth in research about the feasibility and economic viability of employing waxing technology to reduce water consumption in bus operations, and probably more consolidated waxing trials would have yield different directions.

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[19] W.F. Tinto, T.O. Elufioye, J. Roach. Waxes, in: Badal S., Delgoda R., R (Eds.), Pharmacognosy, Elsevier, Amsterdam (2017), pp. 443-455

[20] Pexa - Carcare & Shoppe. The Importance of waxing your car: why it's more than just a shine. https://www.linkedin.com/pulse/importance-waxing-your-car-why-its-more-than-just-shine-carclenx-2sckc/, 2023 (accessed 22 June 2024).

5. THE TRANSFERABILITY EXERCISE

Coherently with Task 5.5 mandate, performance results from the LIFEH2OBUS scenario have been further processed in form of key findings to place the LIFEH2OBUS experiences in the context of their transferability potential, to support a wider exploitation across Europe. To this end, a specific Transferability Exercise (TE) has been developed, according to a methodology already successfully applied in other EC-funded projects on the introduction of innovation in the bus sector, with a focus on depot operations (namely CIVITAS, EBSF, EBSF_2" and ELIPTIC) and adapted to the LIFEH2OBUS concepts and used to assess the possibility to transfer the LUCs tested technologies.

To describe the TE, the methodological background will be introduced (Section 5.1), its rationale within the LIFEH20BUS elaborated (Section 5.2), and its development and results fully reported (5.3) in order to provide background to the complementing Transferability Plan developed in WP6.

5.1. EC-funded projects on public transport methodology for the transferability exercises

Generally speaking, "Transferability" means the quality of being transferable or exchangeable, which, for the LUCs, becomes the possibility to implement elsewhere the positive results achieved during the project; scientific references generally present Transferability as the process to find out how applicable a best practice in question is in restructuring transport system in other geographical areas, which might also imply introducing new business models, service concepts and operational principles[21].

Thus, a clear vision of the findings achieved in the LIFEH2OBUS Scenario is, therefore, the prerequisite to perform the TE. Such findings were previously described in Section 4 and represent the knowledge base for this TE, i.e., an additional assessment where performance variations and outcomes from the LUCs are revised in light of the possibility to theoretically transfer the LIFEH2OBUS experiences elsewhere in Europe.

To this aim, the TE for the LUCs has been developed according to two intertwined steps:

1. the development of a methodology to perform the TE, further described along with
2. the development of the TE itself

which allow to draw conclusions on the possibility to transfer the LIFEH2OBUS experience to other European bus depots (described in the next sections).

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[21] Permala, A. et al. Multi-criteria evaluation method for freight logistics innovations, IET Intelligent Transportation Systems, 9(6), 2015, pp. 662-669,

5.1.1 The meaning of transferability

In the transport sector and more specifically within in the transit studies[22] the concepts of transferability and replicability easily overlap. If in other field studies the former means to export a given experience to a different domain or field and latter means to duplicate it in the same context, in transportation studies transferability means to replicate results obtained to demonstrators to different contexts according to the basic assumption behind that "what proved to be effective in a place may confirm to be useful again, in another place", with "place" meaning a city or an urban area. Yet, the translation of the concept into practice, however, is challenging since transferability is often mistaken for the selection of measure(s) that might fit a given situation, whereas it is actually a process that assesses the feasibility of implanting measures or technical solutions from an origin case study to a recipient or target case within the same range of operations (e.g. transit management, maintenance, operations planning, design, logistics, etc.). The scientific literature provides conclusive directions in this field. From state-of-the-art reviews, transferability clearly relies on a number of issues[23] , the first of which is to have a proper knowledge of the factors influencing origin or recipient contexts. These belong to three different areas: institutional domain (i.e., the regulatory tools authorizing the enforcement of a given measure), funding availability (i.e., the number of resources and personnel and the degree of technical know-how required to implement a given measure), and society (i.e., the conditions that make a community aware of the need to adopt a given measure; public involvement is essential since many studies on transferability are based largely on consultations[24]). The three factors constitute a kind of "environment," where theoretically, the transferability exercise can take place and where all mutual influences must be equally considered[25]. This is the reason why, in the LIFEH2OBUS TE, aside from the institutional domain lacking in the bus sector for what concerns water reuse, society and funding areas are represented by outcomes coming from the People and Economy evaluation categories and the technical feasibility is represented by the performance within the Energy, Operations, and Environment ones.

A second aspect to be considered is the scale of transferability. The European Commission–funded project TRANSPLUS (TRANSport Planning, Land Use, and Sustainability) developed the transferability scope for clusters of measures, that is, the vertical or horizontal transferability concepts. The former (vertical) implies the possibility of zooming a given measure in or out, while the latter (horizontal) means the opportunity to move such a measure without changing the scale[26]. Coherently with this concept, a number of projects (all funded by the European Commission) besides Transport Planning, Land Use, and Sustainability have progressively become the very test field for assessing the transferability of clusters of measures, and their

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[22] Starting from the pioneering paper: Macario, R., and C. F. Marques. Transferability of Sustainable Urban Mobility Measures. *Research in Transportation Economics*, Vol. 22, No. 1, 2008

[23] Marsden, G., and D. Stead. Policy Transfer and Learning in the Field of Transport: A Review of Concepts and Evidence. Transport Policy, Vol. 18, No. 3, May 2011, pp. 492–500; Macario, R., and C. F. Marques. Transferability of Sustainable Urban Mobility Measures. Research in Transportation Economics, Vol. 22, No. 1, 2008, pp. 146–156; Buchanan, C. Transferability of Best Practice in Transport Policy Delivery: Final Report. Scottish Executive, Edinburgh, United Kingdom, 2003; González-Hernández, B., et al. Development of a methodology to transfer road safety good practices in African Countries. Advances in Transportation Studies, Vol 55, 2021, pp.121-129.

[24] Buchanan, C. Transferability of Best Practice in Transport Policy Delivery: Final Report. Scottish Executive, Edinburgh, United Kingdom, 2003

[25] King, M. J. Case Studies of the Transfer of Road Safety Knowledge and Expertise from Western Countries to Thailand and Vietnam, Using an Ecological 'Road Safety Space' Model. Available at http://eprints.qut.edu.au /16191/.

[26] Macario, R., and C. F. Marques. Transferability of Sustainable Urban Mobility Measures. Research in Transportation Economics, Vol. 22, No. 1, 2008, pp. 146–156.

outcomes now constitute a reliable framework. Among these, LEDA (LEgal anD regulAtory measures for sustainable transport in cities) pioneered a transferability process for regulatory measures[27], and later the CIVITAS Initiative consolidated a transferability method based on a 10-step algorithm aimed at providing decision makers with a univocal process to transfer the CIVITAS experiences to more European urban areas[28], giving rise to multiple, successful applications of the TE methodology further described in several research projects on the introduction of innovations in the bus sector (namely, EBSF, EBSF2, ELIPTIC, 3iBS).

Moreover there is a third issue: within LIFEH2OBUS the conventional approach adopted in other field studies, i.e. to consider transferability as the mere possibility to export a given practice to a different domain or field is not fully applicable, being the LIFEH2OBUS approach exactly the reverse: i.e. to adopt (import) water harvesting and reclamation technologies (implemented in a large range of fields, from agriculture to commercial car wash) and waxing (from the aviation sector) in the bus sector.

It is clear, then, that there is no “original recipe” to start a TE, due to the great amount of variables to deal with. So far, many experiences have provided a wide palette of concepts for the transferability process, depending on different goals, contexts of application, measures/solutions to transfer, actors involved, etc. Therefore, it is also clear that with regard to the LUCs experiences/measures, outcomes cannot be just “moved” from one place to another and that there may be the need to transfer not only the technical knowledge but also some of the relations between institutions and contexts, which will be the core of the WP6 Transferability Plan. Examples of transferability of single technical measures abound, but in many cases they deal with simple recommendations of best practice to transfer; the literature on transferability of transportation policies is rather rich and consolidated results from TEs are available as well, although they mostly concern the transfer of a mix of measures or even policies from/to similar contexts.

Thus, the LIFEH2OBUS TE represents a strategic methodological choice that goes far beyond a simple technical replicability assessment (being this already included in the WP6 Replication Plan in Slovenia and the Netherlands). While replicability focuses on whether a technology can be reproduced elsewhere under similar technical conditions, transferability addresses a broader and more systemic research question: “*under which operational, economic, environmental and organizational conditions can the tested water-saving solutions generate comparable benefits?*” Given that LIFEH2OBUS has demonstrated three different water-saving technologies across depots with heterogeneous fleet sizes, weather patterns and operational structures, limiting the analysis to technical replication would have overlooked the decisive role of context parameters, governance settings and managerial capacity. Transferability, therefore, allows the project to integrate performance results, contextual variables, Cost-Benefit elements and societal perception into a structured framework that identifies drivers, barriers and enabling conditions. This is particularly important in public transport, where depot layouts, washing frequency, labour organization and regulatory frameworks vary significantly across Europe. By applying a methodology inspired by previous EU research initiatives and

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[27] Langazaam Verkeer (ed.). LEDA—Legal and Regulatory Measures for a Sustainable Transport in Cities. Best Practice—Transferability of Measures. European Commission, Graz, Austria, 1999.

[28] Hall, R., J. Piao, and M. McDonald. Transferability of Measures. Transportation Research Group, University of Southampton, England, 2008; CIVITAS MOBILIS. Final Transferability Report. Available at http://civitas.eu/downloadcenter.phtml?top=77&pro_id=2&rows=35.

adapting it to the LIFEH2OBUS framework, the TE transforms empirical findings into operational intelligence for bus operators and policy makers.

Eventually, LIFEH2OBUS marks the first time that a structured transferability methodology has been applied to water management in the public transport sector. Historically, transferability exercises in EU projects have focused on energy, electrification or ITS solutions, with water consumption remaining totally neglected. By introducing water into the transferability domain, LIFEH2OBUS expands the sustainability agenda of public transport beyond propulsion technologies, embedding circular resource management into strategic planning.

In conclusion, operating a TE rather than limiting the assessment to replicability ensures methodological robustness, policy relevance and scalability. It positions LIFEH2OBUS not only as a technical demonstration, but as a European best practice framework capable of guiding sustainable water management in diverse transport contexts.

5.2 The LIFEH2OBUS TE methodological approach and application

The TE is a well consolidated practice in the transportation studies literature both in terms of methodological process and calculation procedures, to which the LIFEH2OBUS TE strictly adheres as further described.

5.2.1 Building the TE for LIFEH2OBUS, the methodological approach

The major scientific reference when developing the TE within the bus sector studies is represented by the above mentioned CIVITAS Initiative transferability methodology, with its 10-step algorithm providing a full sequence of decisional operations designed to adapt successful urban transport measures across cities, ensuring feasibility and impact[29]. It encompasses a multi-core, structured sequence starting from the identification of the measure(s) to transfer (step 1) in the origin city or context which includes the analysis of its local conditions such as operations, infrastructure, etc (step 2). The identification of potential enablers or obstacles in the sight of the transfer (steps 3 and 4) leads to the first core activity of the TE methodology, i.e. the identification of the target city or context where to simulate the transfer according to given transfer objectives (step 5), a designed time plan and participants set for the TE in hand in the target contexts (step 6). The preparation of the information package and the TE test (templates) to be sent to the target participants (step 7) is usually developed in matricial form based on the performance achieved in the origin cities and represented by ex ante-vs-during KPI values variations. All of that is submitted to the participants who perform the TE accordingly (step 8) as the second core activity; in the third core activity, responses are then processed and evaluated (step 9) and eventually disseminated sharing lessons to foster sustainable

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[29] Macario, R., and C. F. Marques. Transferability of Sustainable Urban Mobility Measures. Research in Transportation Economics, Vol. 22, No. 1, 2008, pp. 146–156.

urban mobility transfer (step 10)[30]. Steps 1 to 5 create the "visioning" part of the TE, whereas the following ones creates the "assessing" one.

An advantage of the CIVITAS methodology is its flexibility, due to the very different nature of the innovations to transfer in the transportation fields which encompasses typically infrastructural, policy, regulatory, ITS-based, societal measures. To this end, the TE steps can be clustered or adapted (and even skipped) according to the case to transfer and its level of innovation.

In the case of LIFE2HOBUS, the TE strictly follows the sequence above described according to the following:

- Step 1 - *identification of the measure(s) to transfer in the origin city or context:* selection of the three water-saving systems at the three LIFEH2OBUS depots
- Step 2 - *the analysis of its local conditions*: finalization of the context parameters (CPs itemized in Table 2) to support the TE participants in their assessment
- Steps 3 and 4 - *identification of potential enablers or obstacles in the sight of the transfer*: no specific directions provided here, to avoid bias in the assessment
- Step 5 - *identification of the target city or context where to simulate the transfer according to given transfer objectives*: identification of key context areas as transport planning, research, management, environmental care, strictly associated with the target to reduce fresh water consumption by the average percentages presented in section 4.
- Step 6 – *identification of designed time plan and participants set in the target contexts*: selection of a panel of 10 high-profile experts from the expertise areas identified in Step 5
- Steps 7 and 8 - *preparation of the information package and the TE test and its submission:* creation of the *Transferability Kit*, submitted to the TE participants, including the TE explanation, the CP and KPIs tables, the Complementarity Matrix to perform the assessment (duly elaborated in section 5.2.2), ready to fill in.
- Step 9 - *responses process and evaluation*: data process and elaboration, finalized by M42 by the Sapienza team (as reported in section 5.2.2).
- Step 10 – *dissemination*: presentation of results, as LIFEH2OBUS after-life activities (at the moment identified the WCTRS 2028 as potential event on this purpose).

For what concerns step 3, since the LIFEH2OBUS water-saving technologies are highly innovative, with no specific elements of comparison in the transit sector and a dearth of regulations and literature in this field, it has been decided to avoid stressing any drivers or barriers resulting from the project and leave the respondents to freely assess the transferability on the basis of their expertise and data provided. The selection of participants in Step 6 was carried out considering not only the level of expertise required but also the past participation in similar activities and/or EC-funded projects. From the initial selection of 10

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[30] Permala, A. et al. Multi-criteria evaluation method for freight logistics innovations, IET Intelligent Transportation Systems, 9(6), 2015, pp. 662-669; Macario, R., and C. F. Marques. Transferability of Sustainable Urban Mobility Measures. Research in Transportation Economics, Vol. 22, No. 1, 2008, pp. 146–156.

participants, 8[31] provided a completed TE, thus eligible for the data process in Step 9. The collection of 8 expert assessments is extremely positive as usually in the TE, the ratio target city/context - origin city/context is 1.

5.2.2 Performing the LIFEH2OBUS TE

The TE started with the preparation of the Transferability Kit (described here in Annex 4), sent to the TE participant at the beginning to M41, to be returned by the end of the same month. Each participant was previously contacted via conf calls and explained the gist of the TE along with its deadline; Sapienza offered support if need be, but the participants completed the TE autonomously and by the due deadline. The views and opinions expressed by the respondents were solely their own and did reflect their personal expertise and professional judgment. They did not (necessarily) represent, and should not be construed as reflecting, the official position, policy, or views of the organizations, institutions, or employers with which the TE participants are affiliated.

The Kit was designed as an interactive questionnaire to invite respondents to imagine adopting the LIFEH2OBUS' three solutions—basic water reclamation, reclamation with harvesting, and waxing—in bus garages or, more in general, transportation facilities where wash water is currently wasted. In the explanatory conf calls they were explained that such facilities could include other types of transit and paratransit vehicles (such as trams, minivans for school or shuttle services, taxis, etc.), so to include all the types of services and operations. To this end, this TE is considered to be applicable to any multimodal transit facility, and overcome the simplification of replicating/importing the technologies between similar, monomodal origin/target contexts. In the TE first section, participants had to identify the top priority or "vision" for adopting these technologies, among for options, each corresponding to the LIFEH2OBUS evaluation categories and impact areas relevant KPIS as in Figure 4.

Priority	KPI Name
Quality of the bus service ***(LIFEH2OBUS impact area: Ecn - consumption)***	Energy consumption
	Water consumption
Productivity of the system ***(LIFEH2OBUS(impact areas: Ost – Staff, Oma- Maintenance)***	Driving staff
	Washing staff
	Washing workload
	Vehicle washing operations
	Washing time
Urban environment care ***(LIFEH2OBUS impact area: Ewa – Waste; Eem-Emissions)***	Hazardous waste
	Non-hazardous waste
	CO2 eq. emissions
Customer satisfaction and attractiveness of bus services ***(LIFEH2OBUS impact areas: Ppa – Passengers; Pdr- Drivers)***	Passenger awareness
	Passenger acceptance
	Attractiveness
	Travel comfort
	Staff comfort
	Staff acceptance

Figure 4 – LIFEH2OBUS "visioning" for the TE

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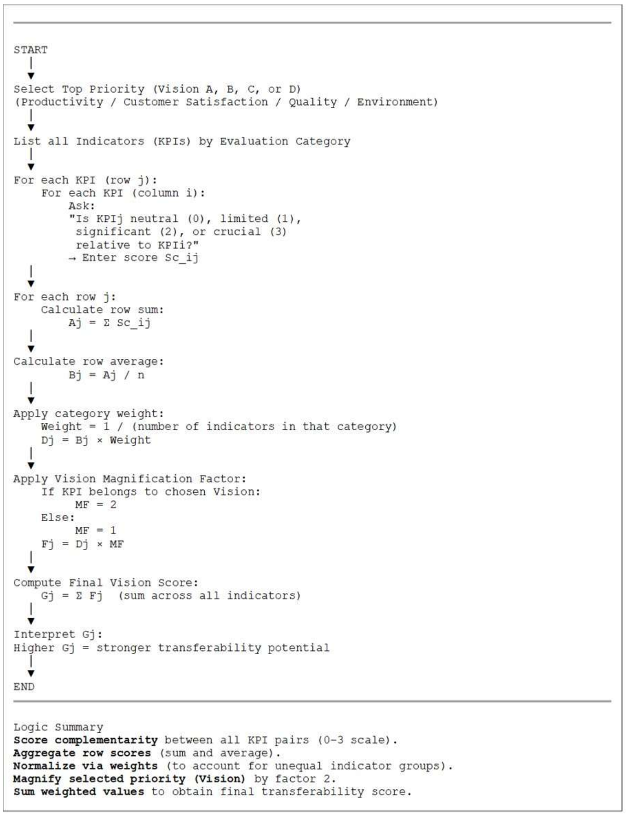
[31] These are: Dr Veronica Sgarra, ASSTRA (Italian public transport operators association); Dr. Aida Abdullah, UITP (public transport operators associations); Prof. Nadia Giuffrida, Polytechnic of Bari, School of Engineering; Prof. Maria Eugenia Lopez Lambas, Polytechnic of Madrid, School of Engineering; Dr. Kathleen Jacobi, Transport Infrastructure Ireland; Dr. Alvin Benjamin Owusu, Nais Solutions; Dr. Mahnaz Babapour TTS Italia (Italian ITS-providers associations for public transport); Prof. Andrea Pierelli (Laboratoire Ampère - Université de Lyon - INSA Lyon - École Centrale de Lyon)

This section correspond to the “visioning” part of the TE methodology as respondents has to reply to a very basic question: “*imagine that you want to adopt these water saving technologies…..what would be the reason or priority that would theoretically prompt the transfer and adopt these LIFEH2OBUS water-saving technologies?*”, by ticking on one of the motivation/vision above mentioned. The second section shifts to the “assessment” part of the TE technology: respondents evaluate potential drivers and barriers for the transfer using the set of KPIs associated with the LIFEH2OBUS evaluation category (for which a glossary was also provided) via a complementarity matrix, further elaborated. This complementarity matrix is designed to encourage participants to rate how strongly each KPI influences the others. To fill the complementarity matrix in, actual KPIs data from LUCs illustrating real-world impacts are provided. To facilitate the KPIs comprehension, identifying codes have been removed and names simplified, as in the case of Ost4 Staff for washing operations (man/vehicle/day/month) which has been renamed as Washing Workload.

Once completed, the TEs were sent back to Sapienza, to be collected and checked for consistency and completeness to assess their suitability for the next step, the data processing. This included the data transfer to a spreadsheet for calculations and the data process described in the next section.

5.2.3 Calculation procedure LIFEH2OBUS TE

The calculation procedure is based on an algorithm described in Figure 5 (corresponding to Step 9 described in section 5.2.1) and here elaborated.



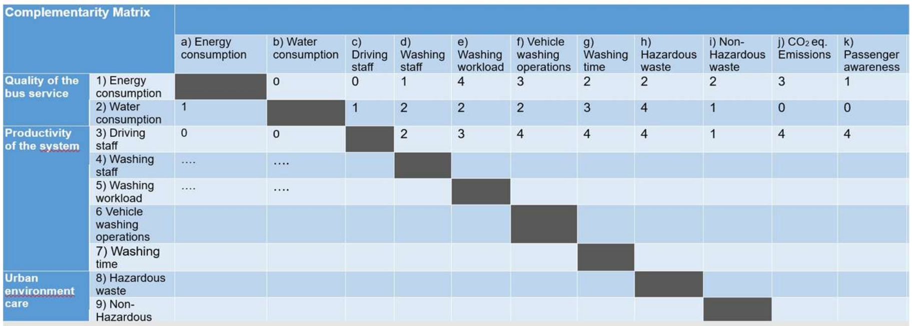
```
START
  |
  ▼
Select Top Priority (Vision A, B, C, or D)
(Productivity / Customer Satisfaction / Quality / Environment)
  |
  ▼
List all Indicators (KPIs) by Evaluation Category
  |
  ▼
For each KPI (row j):
    For each KPI (column i):
        Ask:
        "Is KPIj neutral (0), limited (1),
         significant (2), or crucial (3)
         relative to KPIi?"
        → Enter score Sc_ij
  |
  ▼
For each row j:
    Calculate row sum:
        Aj = Σ Sc_ij
  |
  ▼
Calculate row average:
        Bj = Aj / n
  |
  ▼
Apply category weight:
    Weight = 1 / (number of indicators in that category)
    Dj = Bj × Weight
  |
  ▼
Apply Vision Magnification Factor:
    If KPI belongs to chosen Vision:
         MF = 2
    Else:
         MF = 1
    Fj = Dj × MF
  |
  ▼
Compute Final Vision Score:
    Gj = Σ Fj  (sum across all indicators)
  |
  ▼
Interpret Gj:
Higher Gj = stronger transferability potential
  |
  ▼
END
```

Logic Summary
Score complementarity between all KPI pairs (0–3 scale).
Aggregate row scores (sum and average).
Normalize via weights (to account for unequal indicator groups).
Magnify selected priority (Vision) by factor 2.
Sum weighted values to obtain final transferability score.

Figure 5 – Algorithm used for the TE in LIFEH2OBUS

Starting from the first part of the TE questionnaire, as said, respondents, were called on for “visioning.” To create the scenarios for transferring the LIFEH2OBUS measures, before filling in the complementarity matrix, they had to state which top priority could theoretically trigger the transferability process to the target context (bus depot or any other transit facility). They did so by choosing from among Vision A top priority: productivity of the system; Vision B top priority: customer satisfaction and attractiveness of bus services; Vision C top priority: quality of the bus service; and Vision D top priority: urban environment. Each vision corresponded to a set of KPIs associated with a given KPI representing a given impact area or evaluation category (Figure 4) that can be interpreted as the fields of interest that could prompt the transferability assessment.

For the visions, the KPIs were considered in regard to their degree of complementarity in the matrix provided (Figure 6 and Annex 5) using the following rating scale was used: 0, neutral; 1, limited; 2, significant; and 3, crucial.



Complementarity Matrix		a) Energy consumption	b) Water consumption	c) Driving staff	d) Washing staff	e) Washing workload	f) Vehicle washing operations	g) Washing time	h) Hazardous waste	i) Non-Hazardous waste	j) CO_2 eq. Emissions	k) Passenger awareness
Quality of the bus service	1) Energy consumption	■	0	0	1	4	3	2	2	2	3	1
	2) Water consumption	1	■	1	2	2	2	3	4	1	0	0
Productivity of the system	3) Driving staff	0	0	■	2	3	4	4	4	1	4	4
	4) Washing staff	….	….		■							
	5) Washing workload	….	….			■						
	6 Vehicle washing operations						■					
	7) Washing time							■				
Urban environment care	8) Hazardous waste								■			
	9) Non-Hazardous									■		

Figure 6 – An example of the TE complementarity matrix

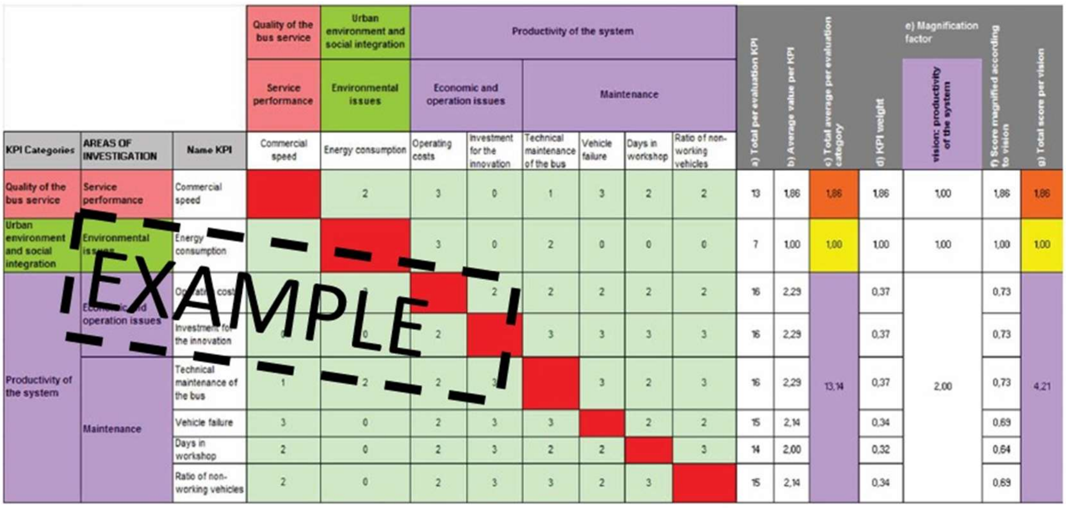
In other words, the panel of respondents had to score how important the performance achieved in the LUCs was to them, to simulate a successful transfer of the LIFEH2OBUS technologies to their contexts. To do this, scores were given by the respondents in replying to a very simple question: *“Will the x-KPI performance in the row be: a) Neutral (as neither relevant nor negligible); b) Limited (of little relevance); c) Significant (substantial) d) Crucial (decisive) in relation to the y-KPIs’ performance in the columns to transfer the LIFEH2OBUS experience successfully, according to the chosen top priority?”* Row by row, this question is reiterated for each pair of KPIs. Doing so allows them to be scored in relation to mutual complementarity in seeking to accomplish the vision.

For each row it is possible to calculate the sum of scores Aj as follows:

$$A_j = \sum_{i=1}^{n} Sc_{ij} \qquad (13)$$

where Sc is the score provided in each cell, with i-row = 1...n, and j-column = 1...m, to be reported in the column a) in Figure 7 (here as an example for calculation) and its average value Bj, to be reported in the column b) in Figure 7, calculated as:

$$B_j = \frac{1}{n} A_j \qquad (14)$$



			Quality of the bus service	Urban environment and social integration	Productivity of the system										
			Service performance	Environmental issues	Economic and operation issues		Maintenance								
														e) Magnification factor		
KPI Categories	AREAS OF INVESTIGATION	Name KPI	Commercial speed	Energy consumption	Operating costs	Investment for the innovation	Technical maintenance of the bus	Vehicle failure	Days in workshop	Ratio of non-working vehicles	a) Total per evaluation KPI	b) Average value per KPI	c) Total average per evaluation category	d) KPI weight	vision: productivity of the system	f) Score magnified according to vision	g) Total score per vision
Quality of the bus service	Service performance	Commercial speed	🟥	2	3	0	1	3	2	2	13	1,86	1,86	1,86	1,00	1,86	1,86
Urban environment and social integration	Environmental issues	Energy consumption		🟥	3	0	2	0	0	0	7	1,00	1,00	1,00	1,00	1,00	1,00
Productivity of the system	Economic and operation issues	Operating costs	[illegible]	2	🟥	2	2	2	2	2	16	2,29	13,14	0,37	2,00	0,73	4,21
		Investment for the innovation	0	0	2	🟥	3	3	3	3	16	2,29		0,37		0,73	
	Maintenance	Technical maintenance of the bus	1	2	2	3	🟥	3	2	3	16	2,29		0,37		0,73	
		Vehicle failure	3	0	2	3	3	🟥	2	2	15	2,14		0,34		0,69	
		Days in workshop	2	0	2	3	2	2	🟥	3	14	2,00		0,32		0,64	
		Ratio of non-working vehicles	2	0	2	3	3	2	3	🟥	15	2,14		0,34		0,69	

Figure 7 – An example of the complementarity matrix calculation

Since a different number of KPIs belongs to each Evaluation Category, scores must be homogenized according to a weight given to each evaluation category, as follows:

- Productivity of the system (n KPIs) each row weight: 1/n
- Customer satisfaction and attractiveness of bus services (m KPIs) each row weight: 1/m
- Quality of the bus service (x KPIs) each row weight: 1/x
- Urban environment (y KPIs) each row weight: 1/y.

Results C (Indicator average value x Indicator weight) are reported in the column d in Figure 7, being calculated as:

$$C = \sum_{j=1}^{m} B_j \qquad (15)$$

Once the KPIs are weighted, the “vision” can be taken further by hypothesizing what would happen by privileging one goal/vision over the others, according to the preference already stated by the respondent; the difference with the previous steps of the assessment is that, thus far, the respondent had to provide the scores considering the chosen vision as a goal, without forgetting the results of the Indicators achieved also in the other evaluation areas; now the assessment becomes “single-focused”, as the underlying leading question is: “*What would happen if the chosen vision were considered strong enough to apply the measure(s), in spite of the advantages from other areas*?”. This question is needed because in the target context the reasons for implementing the LIFEH2OBUS technologies may differ from those of the origin LUCs, or they may not have the same priority, so it is important to assess whether the requirements may be met, also in case of diverging visions.

Values Dj can be then re-calculated according to the Respondent's chosen vision which is magnified by 2, whereas the others are magnified by 1. Such magnification factors are reported in column e) in Figure 7. The recalculation of each Indicator according to such magnified factors Fj, is calculated as:

$$F_j = MF_j \times D_j \tag{16}$$

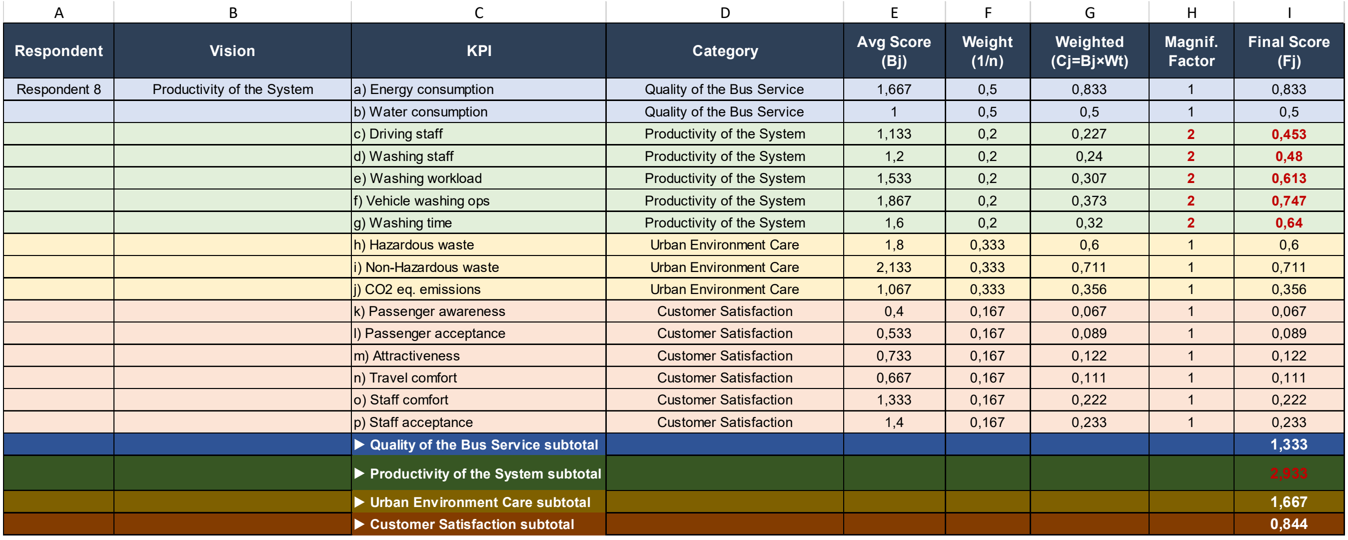
(where *Dj* is: $\mathrm{D_j} = \mathrm{B_j} \times \frac{1}{\mathrm{m}}$) in column f) in Figure 1. Then, the sum of all the Indicators resulting scores per each vision chosen and Evaluation Category leads to the final Total Score for the Gj vision calculated as:

$$G_j = \sum_{j=1}^{m} F_j \tag{17}$$

as in column g) in Figure 7, where calculations have been made according to a "dummy" respondent's chosen vision A – top priority: Productivity of the system, as an example.

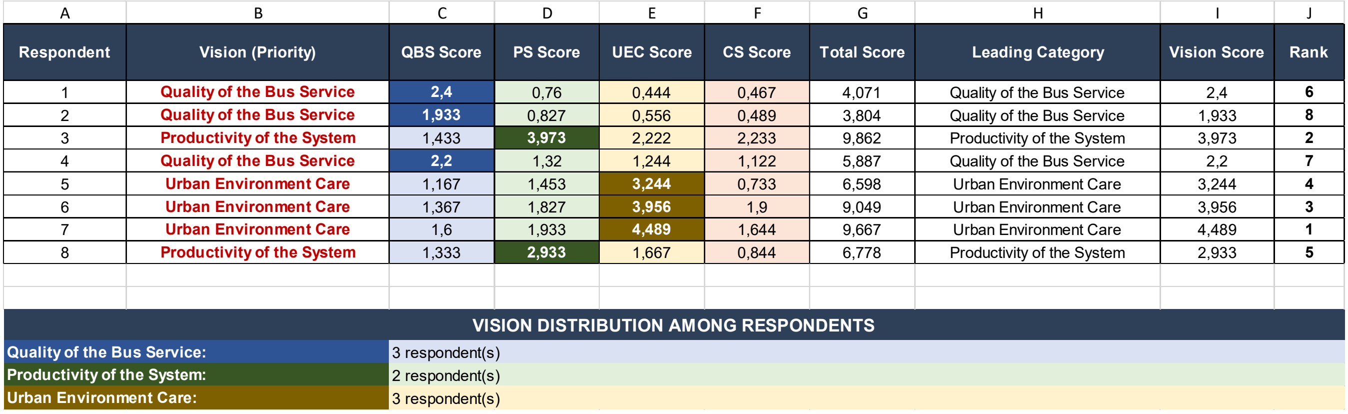
5.2.3.1 Computational chain adopted

The methodology transforms the raw 16×16 complementarity matrix entries into a scalar category score for each respondent through a four-step chain. Understanding this chain is essential for reading both the specific performance results at the 'KPI Detail' level (which shows every intermediate value, as in Figure 8, with all results for all the respondents available in Annex 5) and their 'Summary' and 'Cross-Case Comparison' final values (which present the final aggregated results in columns C–J in Figure 9 and C–G in Figure 10, respectively).



A	B	C	D	E	F	G	H	I
Respondent	**Vision**	**KPI**	**Category**	**Avg Score (Bj)**	**Weight (1/n)**	**Weighted (Cj=Bj×Wt)**	**Magnif. Factor**	**Final Score (Fj)**
Respondent 8	Productivity of the System	a) Energy consumption	Quality of the Bus Service	1,667	0,5	0,833	1	0,833
		b) Water consumption	Quality of the Bus Service	1	0,5	0,5	1	0,5
		c) Driving staff	Productivity of the System	1,133	0,2	0,227	**2**	**0,453**
		d) Washing staff	Productivity of the System	1,2	0,2	0,24	**2**	**0,48**
		e) Washing workload	Productivity of the System	1,533	0,2	0,307	**2**	**0,613**
		f) Vehicle washing ops	Productivity of the System	1,867	0,2	0,373	**2**	**0,747**
		g) Washing time	Productivity of the System	1,6	0,2	0,32	**2**	**0,64**
		h) Hazardous waste	Urban Environment Care	1,8	0,333	0,6	1	0,6
		i) Non-Hazardous waste	Urban Environment Care	2,133	0,333	0,711	1	0,711
		j) CO2 eq. emissions	Urban Environment Care	1,067	0,333	0,356	1	0,356
		k) Passenger awareness	Customer Satisfaction	0,4	0,167	0,067	1	0,067
		l) Passenger acceptance	Customer Satisfaction	0,533	0,167	0,089	1	0,089
		m) Attractiveness	Customer Satisfaction	0,733	0,167	0,122	1	0,122
		n) Travel comfort	Customer Satisfaction	0,667	0,167	0,111	1	0,111
		o) Staff comfort	Customer Satisfaction	1,333	0,167	0,222	1	0,222
		p) Staff acceptance	Customer Satisfaction	1,4	0,167	0,233	1	0,233
		▶ Quality of the Bus Service subtotal						**1,333**
		▶ Productivity of the System subtotal						**2,933**
		▶ Urban Environment Care subtotal						**1,667**
		▶ Customer Satisfaction subtotal						**0,844**

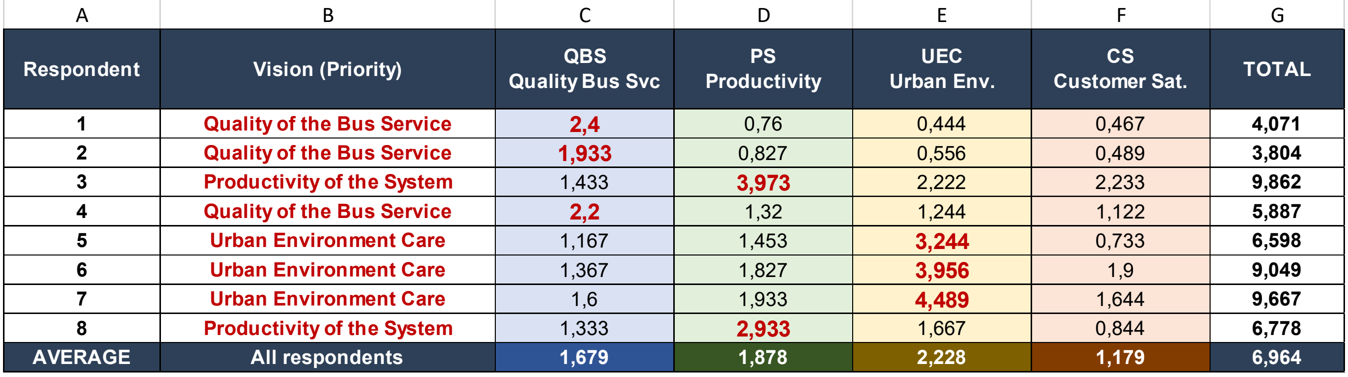
Figure 8 – Calculation at 'KPI Detail' level



A	B	C	D	E	F	G	H	I	J
Respondent	**Vision (Priority)**	**QBS Score**	**PS Score**	**UEC Score**	**CS Score**	**Total Score**	**Leading Category**	**Vision Score**	**Rank**
1	**Quality of the Bus Service**	**2,4**	0,76	0,444	0,467	4,071	Quality of the Bus Service	2,4	**6**
2	**Quality of the Bus Service**	**1,933**	0,827	0,556	0,489	3,804	Quality of the Bus Service	1,933	**8**
3	**Productivity of the System**	1,433	**3,973**	2,222	2,233	9,862	Productivity of the System	3,973	**2**
4	**Quality of the Bus Service**	**2,2**	1,32	1,244	1,122	5,887	Quality of the Bus Service	2,2	**7**
5	**Urban Environment Care**	1,167	1,453	**3,244**	0,733	6,598	Urban Environment Care	3,244	**4**
6	**Urban Environment Care**	1,367	1,827	**3,956**	1,9	9,049	Urban Environment Care	3,956	**3**
7	**Urban Environment Care**	1,6	1,933	**4,489**	1,644	9,667	Urban Environment Care	4,489	**1**
8	**Productivity of the System**	1,333	**2,933**	1,667	0,844	6,778	Productivity of the System	2,933	**5**

VISION DISTRIBUTION AMONG RESPONDENTS	
Quality of the Bus Service:	3 respondent(s)
Productivity of the System:	2 respondent(s)
Urban Environment Care:	3 respondent(s)

Figure 9 – Calculation at 'Summary' level



A	B	C	D	E	F	G
Respondent	**Vision (Priority)**	**QBS Quality Bus Svc**	**PS Productivity**	**UEC Urban Env.**	**CS Customer Sat.**	**TOTAL**
1	**Quality of the Bus Service**	**2,4**	0,76	0,444	0,467	**4,071**
2	**Quality of the Bus Service**	**1,933**	0,827	0,556	0,489	**3,804**
3	**Productivity of the System**	1,433	**3,973**	2,222	2,233	**9,862**
4	**Quality of the Bus Service**	**2,2**	1,32	1,244	1,122	**5,887**
5	**Urban Environment Care**	1,167	1,453	**3,244**	0,733	**6,598**
6	**Urban Environment Care**	1,367	1,827	**3,956**	1,9	**9,049**
7	**Urban Environment Care**	1,6	1,933	**4,489**	1,644	**9,667**
8	**Productivity of the System**	1,333	**2,933**	1,667	0,844	**6,778**
AVERAGE	**All respondents**	**1,679**	**1,878**	**2,228**	**1,179**	**6,964**

Figure 10 – Calculation at 'Cross-site' level

Thus, Equations 13 to 17 generates the following 4-step computational chain (as in the algorithm in Figure 5):

Step 1 — Average Score per KPI (Bj): For each KPI row i in respondent r's matrix, Bj is the arithmetic mean of all off-diagonal entries, that is, the sum of the fifteen scores assigned to i-KPI in relation to every other KPI, divided by 15. This value captures how centrally each indicator is perceived within the overall performance system. Thus, according to Eq. 14:

$$Bj = \Sigma\,(\text{complementarity scores in } i\text{-row, excluding diagonal}) \;/\; 15$$

Bj is visible in column E of the 'KPI Detail' sheet (Figure 8) and is the primary metric used throughout the descriptive statistics presented in Section 5.3.1

Step 2 — Weighted Score (Cj): Each Bj is normalised by dividing it by the number of KPIs in its category (n_cat). This weight (shown in column F of the 'KPI Detail' Table, in Figure 8), ensures that categories with more KPIs do not mechanically dominate the aggregate. As described in the comment for Eq. 15, here applied, the weights are: Quality of the Bus Service (QBS): 1/2 = 0.500; Productivity of the System (PS): 1/5 = 0.200; Urban Environment (UE): 1/3 = 0.333; Customer satisfaction and attractiveness of bus services (CS): 1/6 = 0.167. Then, column G in the 'KPI Detail' sheet in Figure 8 reports:

$$\mathrm{Cj} = \mathrm{Bj} \times (1 / \mathrm{n\_cat})$$

The inverse-size weighting means that a PS KPI scoring $Bj = 1.8$ yields $Cj = 0.36$, while a QBS KPI scoring the same $Bj = 1.8$ yields $Cj = 0.90$, a consequence of QBS containing only two indicators. This structural asymmetry is one of the most consequential features of the methodology and is discussed further in Section 5.3.2

Step 3 — Magnification and Final Score (Fj): The Magnification Factor (MF) encodes each respondent's strategic priority. KPIs belonging to the declared vision category receive $MF = 2$, doubling their weighted score; all others receive $MF = 1$. In Figure 8 column H of the 'KPI Detail' sheet records MF, and column I the resulting Fj, as in Eq. 16, *i.e. :*

$$Fj = Cj \times MF \qquad \text{(MF = 2 if KPI category = vision, else MF = 1)}$$

The MF mechanism is the methodological device that makes each respondent's vision category always emerge as the top-scoring domain, provided the respondent's raw assessments are at least internally consistent. It also means the vision score (column I of the 'Summary' sheet, in Figure 9) is the single most design-sensitive figure in the entire output.

Step 4 — Category Score and Summary Columns C–J (Figure 9): By applying Eq. 17, the category score (Gj) is the sum of all Fj values for KPIs within a given category. This is what appears in columns C through F of both the 'Summary' and the 'Cross-Case Comparison' sheets in Figures 9 and 10, as:

$$Gj = \Sigma\, Fj \quad \text{(summed across all KPIs in that category).}$$

Column G (Total) is the sum of the four category scores: Gj_QBS + Gj_PS + Gj_UEC + Gj_CS. Column H (Leading Category, in Figure 9) identifies the category with the highest Gj (by design this always matches the respondent's declared vision), providing an internal consistency check. Column I (Vision Score) in Figure 9 reproduces the Gj for the vision category to enable direct cross-respondent comparison regardless of which category was chosen. Column J (Rank) still in Figure 9 orders all eight respondents by total score (column G). To be noted that the Cross-Case Comparison sheet (Figure 10) adds no new calculations. Its value is entirely comparative: reading columns C–G horizontally across all respondents reveals pattern-level findings, typically vision consistency, category dominance hierarchies, and outlier behaviour, that would otherwise require manual cross-referencing across eight separate rows in the KPI Detail sheet (Figure 8).

5.3 LIFEH2OBUS TE results

Through the equations and the computational chain above reported, the process of this TE data provides several level of findings, all elaborated in this section. It is to be here reminded that, each respondent duly completed the LIFEH2OBUS 16×16 complementarity matrix, scoring every pair of KPIs on a scale from 0 (neutral) to 3 (crucial) as requested, having prior stated a priority vision, i.e. the evaluation category they considered most strategically relevant. As anticipated, calculations results are reported here in Annex 5.

5.3.1 Descriptive statistics and findings per specific KPIs

Table 12 presents the full KPI-level descriptive statistics, drawn from the 'KPI Detail' spreadsheet (Figure 8) above commented. For each indicator, Mean Bj and its standard deviation are computed across all eight respondents. Mean Fj is the average final score, already incorporating the weighting and magnification effects. The classification in the last column follows the joint criterion of mean level and dispersion: 'Strong Driver' requires mean $Bj \geq 1.5$, whereas an asterisk (*) flags indicators where standard deviation exceeds 0.55, thus signalling that the classification is univocal across the panel; this enables to identify actual drivers and elements of uncertainty.

Table 12- Identification of Drivers

KPI	Cat	Mean Bj	Std Bj	Min Bj	Max Bj	Mean Fj	Classification
a) Energy consumption	QBS	1.183	0.420	0.333	1.667	0.746	**Moderate Driver**
b) Water consumption	QBS	1.358	0.309	1.000	1.867	0.933	**Moderate Driver**
c) Driving staff	PS	0.858	0.649	0.000	2.067	0.252	**Weak / Uncertain**
d) Washing staff	PS	1.383	0.583	0.400	2.200	0.358	**Moderate Driver***
e) Washing workload	PS	**1.500**	0.320	0.867	1.933	0.380	**Strong Driver**
f) Vehicle washing ops	PS	**1.800**	0.399	1.067	2.200	0.455	**Strong Driver**
g) Washing time	PS	**1.692**	0.504	0.733	2.267	0.433	**Strong Driver**
h) Hazardous waste	UEC	**1.517**	0.656	0.533	2.467	0.736	**Strong Driver***
i) Non-Hazardous waste	UEC	1.417	0.665	0.200	2.267	0.703	**Moderate Driver***
j) CO2 eq. emissions	UEC	**1.558**	0.780	0.533	2.600	0.789	**Strong Driver***
k) Passenger awareness	CS	1.050	0.800	0.267	2.333	0.175	**Moderate Driver***
l) Passenger acceptance	CS	1.200	0.698	0.467	2.333	0.200	**Moderate Driver***
m) Attractiveness	CS	1.217	0.733	0.333	2.467	0.203	**Moderate Driver***
n) Travel comfort	CS	1.050	0.675	0.200	2.200	0.175	**Moderate Driver***
o) Staff comfort	CS	1.267	0.632	0.200	2.400	0.211	**Moderate Driver***
p) Staff acceptance	CS	1.292	0.588	0.333	2.200	0.215	**Moderate Driver***

Key: QBS –Quality of the Bus Service; PS – Productivity of the System; UEC-Urban Environment Care; CS- Customer Satisfaction

5.3.1.1 Strong and moderate drivers

Five KPIs achieve a mean Bj of 1.5 or above. Vehicle washing operations (mean Bj = 1.800) is the highest-scoring indicator in the dataset, with the second-lowest standard deviation among strong drivers (0.399). Every respondent, regardless of vision, rates this KPI above 1.0 (the hallmark of a universal driver). Washing time (mean Bj = 1.692) is nearly as consistent and ranks among the top three for all three vision groups; together, these two indicators associated with the Productivity of the System form the clear foundation of any transferability argument. CO_2 equivalent emissions (mean Bj = 1.558) is the single most contested strong driver: it carries the widest standard deviation of all sixteen KPIs (0.780) and the widest individual range (min = 0.533 for Respondent 1 a transit stakeholder, max = 2.600 for Respondent 3, an academician, with the highest individual Bj score in the entire dataset). For Urban Environment-vision respondents it is decisive, whereas for those opting for the Quality of the Bus Service vision it is near-peripheral. Hazardous waste (1.517) shows a comparable though less extreme profile. Eventually, Washing workload (1.500) is the most statistically stable of the five strong drivers (std = 0.320), suggesting broadly shared recognition of its importance.

When it comes to moderate drivers, ten KPIs sit between 1.0 and 1.5. Water consumption (mean Bj = 1.358) is the most analytically distinctive of this group: its standard deviation of 0.309 is the lowest of all sixteen KPIs and no respondent rates it below 1.000. This narrow range signals a genuinely shared concern across all stakeholder orientations, making it the safest and most reliable anchor point in any cross-vision transfer communication. Yet, water consumption does not reach the status of full driver. The six Customer Satisfaction indicators (rows k through p in Table 12, mean Bj 1.050–1.292) all fall in the moderate range, but without exception carry high standard deviations (0.588 to 0.800). This dispersion pattern reveals that Customer Satisfaction indicators function as conditional rather than universal drivers: Respondent 3, whose vision was Productivity of the Service, assigns Customer Satisfaction Bj values of 2.133 to 2.400 throughout, while Respondent 1 assigns values of 0.200 to 0.733. The Customer Satisfaction group amplifies for respondents with a passenger- or workforce-oriented lens and nearly disappears for those focused on operational efficiency.

5.3.1.2 Weak and uncertain indicators

Driving staff (row c in Table 12) is the only KPI below the 1.0 threshold (mean Bj = 0.858) and the only one that qualifies as weak across all three vision groups. Its range, from 0.000 (Respondent 1) to 2.067 (Respondent 3), is the second-widest in the dataset, confirming that its relevance is entirely context-dependent. In the context of a bus washing system, most respondents see driving staff requirements as peripheral; for a productivity-focused transit operator managing labour costs tightly, however, it can become significant. This KPI should be treated as a conditional indicator: present it only when the recipient's profile explicitly supports its inclusion.

All in all, no KPI falls below mean Bj = 0.5, meaning no absolute barrier exists in this dataset. The nearest to a structural barrier is the Customer Satisfaction category as a group, not because its individual items scores are zero, but because their high variability and the absence of any Customer Satisfaction -vision respondent result in systematically suppressed final scores across the panel.

5.3.2 Summary and cross-case comparison aggregated statistics

Results are first summarized in Tables 12 where the individual Respondents Scores by Priority are reported, reproducing the 'Summary' Table 9 in full, with column letters annotated, showing the final category scores (columns C–F), total (G), leading category (H), vision score (I), and rank (J) for each respondent.

Wide gaps between a respondent's vision score and their non-vision scores signal a focused, vision-coherent assessment; narrower gaps, visible for Respondent 3 (a transit operator) and Respondent 8 (an academician), indicate broader engagement across all categories. Reading the Table 13 as a whole, the most immediate observation is the pronounced spread of total scores, which range from 3.804 (Respondent 2, a consultant) to 9.862 (Respondent 4, an academician), a difference that reflects both the varying intensity of individual matrix assessments and the structural influence of the chosen vision category. The three respondents who declared Urban Environment Care as their priority, Respondents 6 to 8 (one consultant and two academicians, respectively) occupy three of the top four positions in the ranking. Respondent 8 in particular stands out, achieving the highest vision score in the entire panel (4.489 on Urban Environment Care) and the highest total (9.667), a result driven by consistently strong complementarity scores across all environmental KPIs, each doubled by the magnification mechanism. Respondent 7 follows with a vision score of 3.956 and a total of 9.049, and Respondent 6, while scoring more modestly on her non-vision categories, still records a Urban Environment Care score of 3.244 that places her in the upper half of the ranking.

The two Productivity-vision respondents tell a more differentiated story. Respondent 4 achieves the highest absolute total in the dataset (9.862), but what makes this result particularly notable is that it is not built on vision amplification alone. His non-vision category scores (1.433 for Quality of the Bus Service, 2.222 for Urban Environment Care, and 2.233 for Customer Satisfaction) are all among the highest recorded by any respondent in those respective columns, revealing an assessor who perceives strong interdependencies across the entire KPI system rather than concentrating his scores selectively on the Productivity of the System domain. Respondent 5 (a transit stakeholder), by contrast, shows a more focused profile: her Productivity of the System vision score of 2.933 is well ahead of her other category scores, the lowest of which (Customer Satisfaction at 0.844) indicates that she assigned little complementarity to passenger-facing dimensions.

Table 13- Individual Respondent Scores by Category (vision category in red/bold per respondent)

(A) Respondent	(B) Vision	(C) QBS	(D) PS	(E) UEC	(F) CS	(G) Total	(H) Leading Cat.	(I) Vision Score	(J) Rank
1	**Quality of the Bus Service**	**2.400**	0.760	0.444	0.467	**4.071**	*Quality of the Bus Service*	**2.400**	**#6**
2	**Quality of the Bus Service**	**1.933**	0.827	0.556	0.489	**3.804**	*Quality of the Bus Service*	**1.933**	**#8**
3	**Quality of the Bus Service**	**2.200**	1.320	1.244	1.122	**5.887**	*Quality of the Bus Service*	**2.200**	**#7**
4	**Productivity of the System**	1.433	**3.973**	2.222	2.233	**9.862**	*Productivity of the System*	**3.973**	**#2**
5	**Productivity of the System**	1.333	**2.933**	1.667	0.844	**6.778**	*Productivity of the System*	**2.933**	**#5**
6	**Urban Environment Care**	1.167	1.453	**3.244**	0.733	**6.598**	*Urban Environment Care*	**3.244**	**#4**
7	**Urban Environment Care**	1.367	1.827	**3.956**	1.900	**9.049**	*Urban Environment Care*	**3.956**	**#3**
8	**Urban Environment Care**	1.600	1.933	**4.489**	1.644	**9.667**	*Urban Environment Care*	**4.489**	**#1**
Key: QBS –Quality of the Bus Service; PS – Productivity of the System; UEC-Urban Environment Care; CS- Customer Satisfaction									

The three Quality of the Bus Service respondents, Respondents 1 to 3 (a transit stakeholder, a consultant and a transit operator, respectively) occupy the bottom three positions in the ranking, with totals of 4.071, 3.804, and 5.887 respectively. This outcome is not primarily a reflection of scoring conservatism but of a structural constraint: Quality of the Bus Service contains only two KPIs, meaning that even under full MF = 2 amplification the maximum achievable vision score is bounded by a mathematically lower ceiling than Productivity of the System or Urban Environment Care. Respondent 3 is the notable exception within this group, recording non-vision scores that are substantially higher than those of other two, particularly 1.320 on Productivity of the System, 1.244 on or Urban Environment Care, and 1.122 on Customer Satisfaction, suggesting a more integrative reading of the KPI system that partially compensates for the Quality of the Bus Service structural disadvantage. Customer Satisfaction, visible in column F across all rows, is consistently the weakest category for every respondent except Respondent 4, a direct consequence of no respondent having declared it as their vision and all six Customer Satisfaction indicators therefore remaining unamplified throughout the exercise.

Table 14 compresses the eight individual profiles into a single panel-level picture. Urban Environment Care ranks first with the highest mean score (2.228) but also the widest spread (std = 1.431, range 0.444–4.489), confirming that Urban Environment Care is both the most rewarded and the most polarising domain: it soars when vision-amplified and recedes sharply otherwise. Productivity of the System ranks second (mean 1.878) with moderate variability, reflecting genuine cross-respondent recognition of this vision KPIs. Quality of the Bus Service ranks third despite three vision declarations, a consequence of its two-KPI structural ceiling[32]. Customer Satisfaction ranks last (mean 1.179), penalised by zero vision declarations and the lowest per-KPI weight in the framework.

Table 14 - Category-Level Aggregate Statistics

Category	# Vision	Mean Score	Std Dev	Min	Max	KPI count	Panel Rank
Quality of the Bus Service	3	**1.679**	0.419	1.167	2.400	2	**#3**
Productivity of the System	2	**1.878**	1.022	0.760	3.973	5	**#2**
Urban Environment Care	3	**2.228**	1.431	0.444	4.489	3	**#1**
Customer Satisfaction	0	**1.179**	0.627	0.467	2.233	6	**#4**

Eventually, Table 15 makes the cross-respondent comparison immediate. Reading each column top-to-bottom, the vision effect is unmistakable: every respondent's highest score sits in their declared vision column, coloured in red. The “Average” row at the bottom exposes the category hierarchy at panel level: Urban Environment Care leads (2.228), Productivity of the System follows (1.878), Quality of the Bus Service third (1.679), Customer Satisfaction last (1.179). Column G reveals a trimodal distribution, a top cluster near 9–10, a middle cluster around 6–7, and a bottom cluster below 5, grouping respondents by both scoring intensity and vision structure.

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[32] Structural asymmetry insight: QBS respondents face a mathematical ceiling of approximately 2.40 even under maximum raw scoring and full MF amplification (2 KPIs × 0.500 weight × 2 MF × max Bj ~1.2). PS respondents can reach ~4.0 (5 KPIs × 0.200 × 2 × ~2.0), and UEC respondents ~4.5 (3 KPIs × 0.333 × 2 × ~2.3). Analysts should weight rank positions accordingly, recognising that column J conflates scoring intensity with category structure.

Table 15 Category Scores by Respondent with Panel Average (vision categories in red/bold; average row in grey)

Respondent	(B) Vision	(C) QBS	(D) PS	(E) UEC	(F) CS	(G) TOTAL
1	*Quality of the Bus Service*	**2.400**	0.760	0.444	0.467	**4.071**
2	*Quality of the Bus Service*	**1.933**	0.827	0.556	0.489	**3.804**
3	*Quality of the Bus Service*	**2.200**	1.320	1.244	1.122	**5.887**
4	*Productivity of the System*	1.433	**3.973**	2.222	2.233	**9.862**
5	*Productivity of the System*	1.333	**2.933**	1.667	0.844	**6.778**
6	*Urban Environment Care*	1.167	1.453	**3.244**	0.733	**6.598**
7	*Urban Environment Care*	1.367	1.827	**3.956**	1.900	**9.049**
8	*Urban Environment Care*	1.600	1.933	**4.489**	1.644	**9.667**
AVERAGE	*All respondents*	**1.679**	**1.878**	**2.228**	**1.179**	**6.964**

Key: QBS –Quality of the Bus Service; PS – Productivity of the System; UEC-Urban Environment Care; CS- Customer Satisfaction

5.3.3 Cross-vision analysis: Universal vs. context-specific drivers

A critical dimension of the transferability analysis is whether KPIs function as universal drivers, relevant regardless of the respondent's vision, or as context-specific drivers that are significant only when aligned with a particular evaluation priority. This question is answered by comparing mean Bj scores across the three vision groups (Quality of the Bus Service; Productivity of the System; Urban Environment Care) in the 'Cross-Case Comparison' analysis (Figure 10, Tables 13-15)

Oma 9 Vehicle washing operations (noted as f in the above mentioned Tables) and Ose 9 Washing time (likewise noted as g) are the only two KPIs that consistently rank among the top performers across all three vision groups. For Quality of the Bus Service-oriented respondents, Vehicle washing operations is the highest-ranked KPI (group mean $Bj = 1.556$); for Productivity of the System-oriented respondents, it ties with Washing time (1.900 each); for those Urban Environment Care -oriented, it ranks third at 1.978. This cross-vision consistency, visible in the high Productivity of the System scores recorded even by “non- Productivity of the System –vision” respondents in column D of Table 15, is the strongest available evidence of universal relevance.

Eem1 CO_2 equivalent emissions illustrates the opposite profile. Among Urban Environment Care respondents, it is the top-ranking KPI (group mean $Bj = 2.156$); among Productivity of the System respondents it ranks lower; among Quality of the Bus Service respondents it does not reach the top five. A parallel pattern holds for Ewa1 Hazardous waste, which appears among the top performers for Productivity of the System; Urban Environment Care respondents but is marginal for Quality of the Bus Service -oriented ones. These KPIs are powerful but vision-contingent: they function as drivers only in the right strategic context.

The Customer Satisfaction indicators cluster at the lower end of the performance ranking across all three vision groups — a consistent finding that reinforces the marginalisation of column F already noted at the category level. Ppa1 Passenger awareness (noted as k in the above mentioned Tables) is the most contested KPI in the dataset (std = 0.800) yet remains in the bottom half of the ranking for every vision group. This dual characteristic, high variability combined with low group means, identifies it as the purest example of a conditional indicator that may become relevant in a future Customer Satisfaction-vision assessment but currently provides no stable transferability signal.

Ost 1 Driving staff (noted as c) is the only KPI that appears in the bottom three for all three vision groups, making it the closest approximation to a universal weak performer. Its behaviour mirrors what already described in the literature[33] on innovations in the bus sector, as an element of uncertainty: a performance dimension whose inconsistent results in the baseline exercise do not constitute a persuasive case for transfer, even when general intent to transfer exists.

5.3.4 Transferring potential

All of the above is consistent with the results from Section 5.3. and the merged interpretation (i.e. KPI-level statistics together category-level cross-case comparison) generates four functional groups according to their role in facilitating or impeding the transferability of the LIFEH2OBUS bus washing system innovations; these groups are:

- *Universal Drivers:* Both Oma9 Vehicle washing operations and Ose 9 Washing time qualify as universal drivers. Their high mean Bj values, moderate standard deviations, and cross-vision consistency make them the most reliable foundations on which any transferability case can be built. Improvements in these two KPIs will resonate with recipients regardless of their primary strategic orientation. Ecn 13 Water consumption can be here interpreted as approaching this status: its exceptional stability (std = 0.309, minimum Bj = 1.000) marks it as the safest anchor point for cross-vision evaluation, even though its mean is moderate rather than strong.

- *Vision-Activated Drivers:* Eem1 CO2 equivalent emissions, Ewa1 Hazardous waste, and Ewa2 Non-hazardous waste are powerful drivers for Urban Environment Care-vision respondents but comparatively modest for others. Ost 7.1. Washing staff and Ost 4 Washing workload function as strong drivers for Productivity of the System-oriented recipients. The six Customer Satisfaction indicators become meaningful only when the recipient context explicitly prioritises passenger or workforce experience. This mean that when importing the washing technologies, these KPIs need a selective focus, tailoring emphasis according to the declared or inferred strategic priorities of the target depot.

- *Conditional and Uncertain performance:* Ost 1 Driving staff is the only indicator that cannot be reliably positioned as a driver for any vision group. Its binary relevance, insignificant in contract-based cleaning contexts, potentially important for publicly regulated transit operators, means it should appear in transfer documentation only where the recipient's labour model explicitly supports its inclusion.

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[33] Musso, A., Corazza, M.V. Visioning the Bus System of the Future: Stakeholders Perspective. Transportation Research Record: Journal of the Transportation Research Board, 2533, 2015, pp. 109–117.

- *Absence of Absolute Barriers:* No KPI scores below 0.5 on mean *Bj,* being this the conventional threshold for an absolute barrier. This finding is itself analytically meaningful: all sixteen indicators are seen as at least conditionally relevant by at least some respondents, suggesting a well-constructed and contextually coherent KPI framework. The relative barriers (indicators that suppress rather than promote transferability motivation) are collectively the Customer Satisaction category indicators, whose combination of moderate mean scores, high variability, and structural under-weighting (*MF* = 1 across the respondents' board) results in the lowest category totals in the dataset.

5.4 Conclusions and implications for transfer

The complementarity matrix analysis confirms that the bus washing system innovation has a credible transferability case, anchored on two universal performance dimensions: Vehicle washing operations and Washing time. These KPIs should form the core of any transferability narrative as they provide a robust, vision-independent justification for adoption that will resonate across all recipient profiles.

A secondary tier of vision-activated drivers (most prominently CO_2-equivalent emissions, Hazardous waste, and the Washing staff and workload indicators) provides additional motivation for environmentally or productivity-oriented recipients. The structural formula underpinning the 'Summary' spreadsheet (columns C–J in Figure 9, and also in the results from Tables in Section 5.3.2) shows precisely how the magnification mechanism amplifies these dimensions for aligned respondents; in the transfer package for WP 6 this logic should be used intentionally, tailoring the emphasis of their evidence base to the declared vision of the target institution.

Customer Satisfaction, while not a structural barrier, plays a supporting rather than leading role in this panel's transferability logic. Its indicators carry the greatest potential to rise in relevance as sustainability and passenger-experience mandates deepen across European transit systems, but at present they neither drive nor block adoption.

Reading the 'Cross-Case Comparison' column by column (Table 15) shows a trimodal distribution of total scores and a consistent pattern in which UEC-vision respondents occupy the top positions, a finding that owes as much to the three-KPI Urban Environment Care pool and the 0.333 weight per indicator as it does to the intensity of those respondents' environmental assessments. In sight of WP6 Transferability Plan, all rank positions with this structural asymmetry in mind need to be considered: the methodology is designed to be decision-facilitating rather than purely descriptive, and its outputs are most useful when read alongside the intermediate KPI-level values in the 'KPI Detail' (from Figure 9 on) that produced them.

Overall, the respondent panel is coherent, internally consistent, and vision-aligned. The diversity of visions (three Quality of the Bus Service, two Productivity of the System, three Urban Environment Care) provides adequate coverage of the analytical space, and the universal drivers identified offer a stable foundation for cross-context transfer regardless of which vision a future recipient declares.

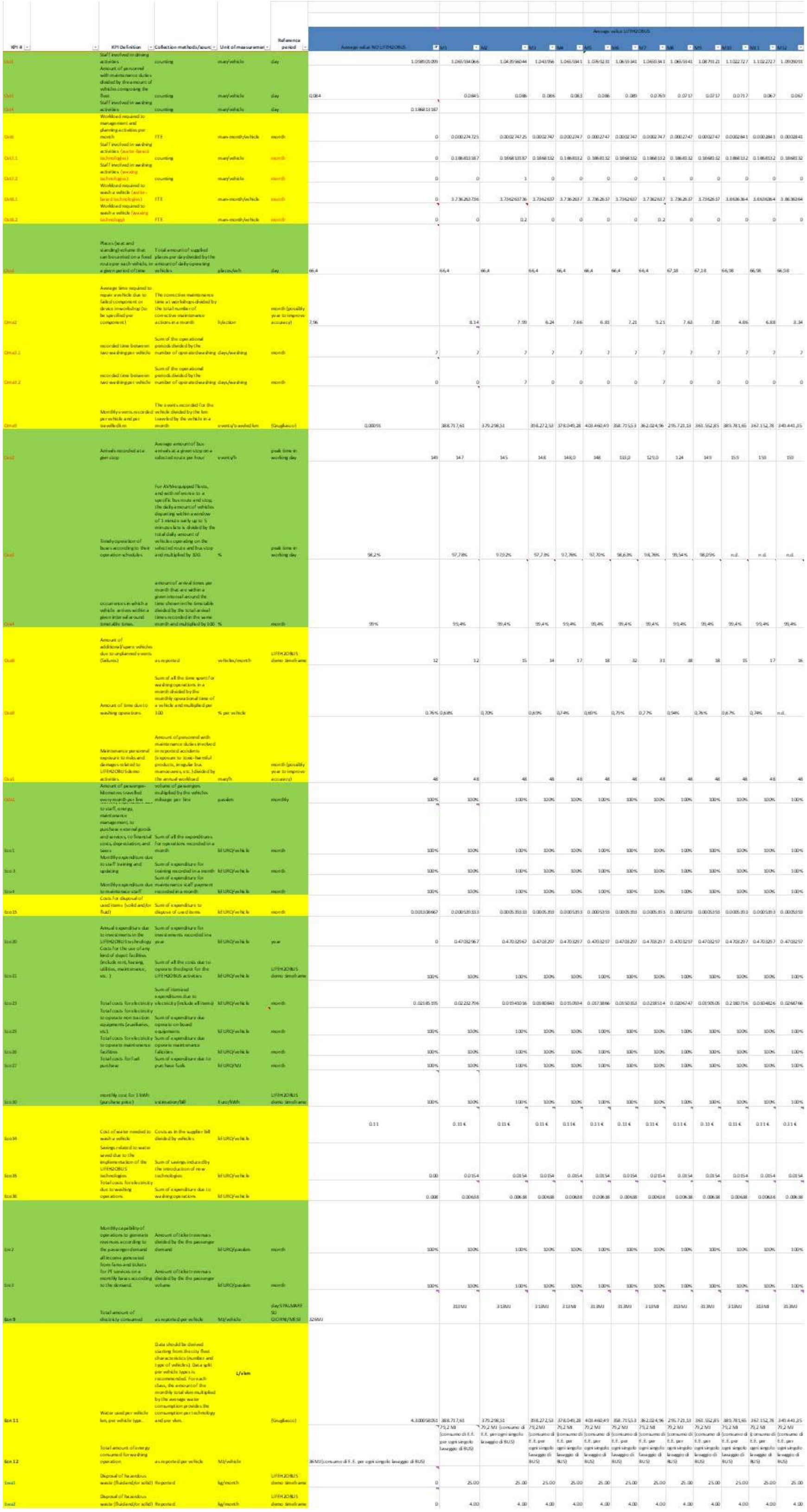
Annex 1 – Assessment criteria

Main Evaluation Categories and Impact Areas

Evaluation Category	Impact Area	Performance to investigate due to implementation of the LUCs technologies
Operations	Staff	Changes in the amount of personnel
	Supply	Changes in the operating fleet
	Maintenance	Changes in the workload due to maintenance operations
	Service	Changes in the service workload
	Safety	Changes in the amount of risky events
	Demand	Changes in the amount of passengers
	IT	Changes in the data process
Economy	Costs	Changes in the amount of expenditures
	Revenues	Changes in the amount of incomes
	Incentives	Amount of subsidies granted
Energy	Consumption	Quantity of energy used to operate the new technology
	Supply	Need of energy to operate the new technology
Environment	Noise	Changes in the noise emission/perception
	Emissions	Changes in the amount of pollutants emitted by the fleet
	Waste	Changes in the amount of waste matter/products
People	Passengers	Changes in the passengers' overall perception
	Staff	Changes in the drivers' overall perception

Annex 2 – Data Provision

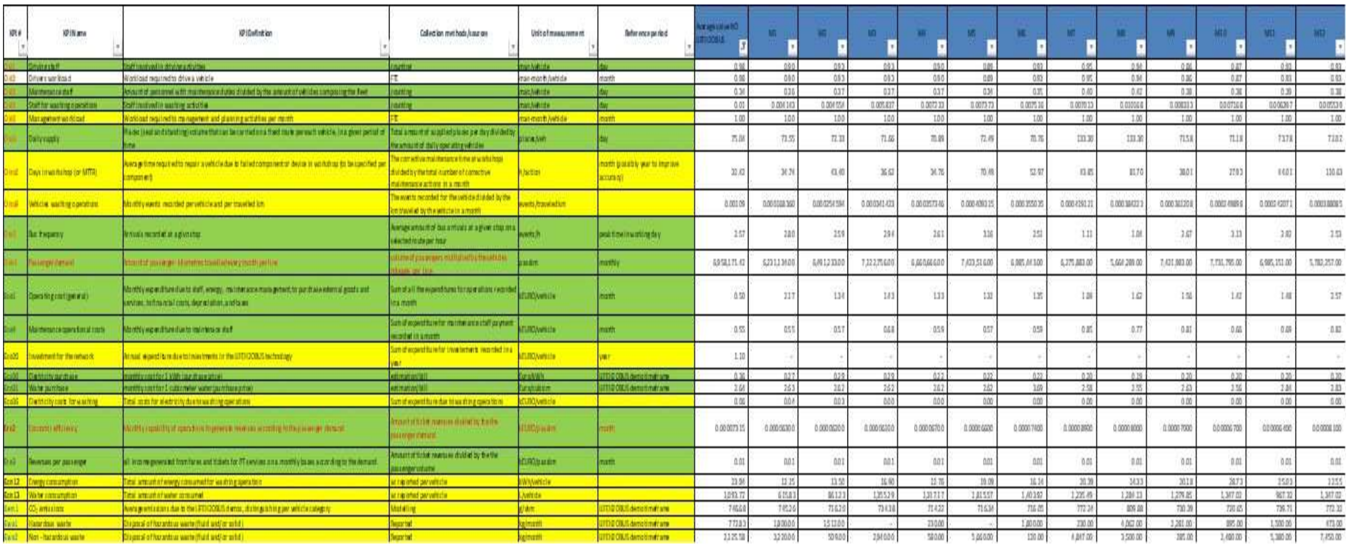
Grugliasco data collection



Budapest data collection

Evaluation Category	Impact area	KPI #	KPI Name	KPI Definition	Collection methods/sources	Unit of measurement	Reference period		Average value LIFEH2OBUS											
								Average value NO LIFEH2OBUS	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Operations	Staff	Ost1	Driving staff	Staff involved in driving activities	counting	man/vehicle	day	2.35	2.304878	2.323171	2.347561	2.323171	2.25	2.231707	2.243902	2.182927	2.25	2.27439	2.27439	2.243902
		Ost3	Maintenance staff	Amount of personnel with maintenance duties divided by the amount of vehicles composing the fleet	counting	man/vehicle	day	0.182926829	0.1829268	0.182927	0.182927	0.182927	0.182927	0.182927	0.182927	0.182927	0.182927	0.182927	0.182927	0.182927
		Ost4	Staff for washing operations	Staff involved in washing activities	counting	man/vehicle	day	0.012195122	0.0121951	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195
		Ost6	Management workload	Workload required to management and planning activities per month	FTE	man-month/vehicle	month	0.006097561	0.0060976	0.006098	0.006098	0.006098	0.006098	0.006098	0.006098	0.006098	0.006098	0.006098	0.006098	0.006098
		Ost7.1	Washing staff	Staff involved in washing activities (water-based technologies)	counting	man/vehicle	month	0.012195122	0.0121951	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195
		Ost8.1	Staff workload	Workload required to wash a vehicle (water-based technologies)	FTE	man-month/vehicle	month	0.012195122	0.0121951	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195	0.012195
	Supply	Osu3	Daily supply	Places (seat and standing) volume that can be carried on a fixed route per each vehicle, in a given period of time	Total amount of supplied places per day divided by the amount of daily operating vehicles	places/veh	day	110	110	110	110	110	110	110	110	110	110	110	110	110
	Maintenance	Oma2	Days in workshop (or MTTR)	Average time required to repair a vehicle due to failed component or device in workshop (to be specified per component)	The corrective maintenance time at workshops divided by the total number of corrective maintenance actions in a month	h/action	month (possibly year to improve accuracy)	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92
		Oma3.1	Maintenance of the bus components (or MTBW mean time between water-based washing)	recorded time between two washing per vehicle	Sum of the operational periods divided by the number of operated washing	days/washing	month	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13
		Oma3.2	Maintenance of the bus components (or MTBW mean time between waxing)	recorded time between two washing per vehicle	Sum of the operational periods divided by the number of operated washing	days/washing	month	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13	8.13
		Oma9	Vehicles washing operations	Monthly events recorded per vehicle and per travelled km	The events recorded for the vehicle divided by the km traveled by the vehicle in a month	events/traveled km		2.15	2.12	2.14	2.09	2.15	2.11	2.12	2.1	2.14	2.09	2.1	2.12	2.13
	Service	Ose3	Bus Punctuality	Timely operation of buses according to their operation schedules	For AVM-equipped fleets, and with reference to a specific bus route and stop, the daily amount of vehicles departing within a window of 1 minute early up to 5 minutes late is divided by the total daily amount of vehicles operating on the selected route and bus stop and multiplied by 100.	%	peak time in working day	95	95	95	95	95	95	95	95	95	95	95	95	95
		Ose4	Bus Reliability	occurrences in which a vehicle arrives within a given interval around timetable times.	amount of arrival times per month that are within a given interval around the time shown in the timetable divided by the total arrival times recorded in the same month and multiplied by 100	%	month	95	95	95	95	95	95	95	95	95	95	95	95	95
		Ose8	Not planned operations	Amount of additional/spare vehicles due to unplanned events (failures)	as reported	vehicles/month	LIFEH2OBUS demo timeframe	14	14	14	14	14	14	14	14	14	14	14	14	14
		Ose9	Washing time	Amount of time due to washing operations	Sum of all the time spent for washing operations in a month divided by the monthly operational time of a vehicle and multiplied per 100	% per vehicle		2	2	2	2	2	2	2	2	2	2	2	2	2
Economy	Costs	Eco1	Operating cost (general)	Monthly expenditure due to staff, energy, maintenance management, to purchase external goods and services, to financial costs, depreciation, and taxes	Sum of all the expenditures for operations recorded in a month	kEURO/vehicle	month	14.4444425	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
		Eco23	Electricty costs for vehicles	Total costs for electricity	Sum of itemized expenditures due to electricity (include all items)	kEURO/vehicle	month	0.031914878	0.0296598	0.024631	0.021898	0.018828	0.015129	0.009527	0.009527	0.009527	0.009315	0.011326	0.016143	0.018154
		Eco30	Electricity purchase	monthly cost for 1 kWh (purchase price)	estimation/bill	Euro/kWh	LIFEH2OBUS demo timeframe	0.5025	0.355	0.365	0.3725	0.386075	0.46805	0.28	0.28	0.28	0.28	0.28	0.28	0.28
		Eco31	Water purchase	monthly cost for 1 cubicmeter water (purchase price)	estimation/bill	Euro/cubicm	LIFEH2OBUS demo timeframe	5.375	4.6134	5.35575	5.130625	5.7641	1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.44
		Eco32	Detergents purchase	monthly cost for 1 kg (purchase price)	estimation/bill	Euro/kg	LIFEH2OBUS demo timeframe	1.25	1.35	1.35	1.35	1.35	1.35	1.75	1.75	1.75	1.75	1.75	1.75	1.75
		Eco33	Cost of washing operation	Sum of all costs incurred to wash a vehicle	Sum of expenditure due to staff, water, detergents, power, etc.	kEURO/vehicle		0.006	0.053	0.054	0.05	0.048	0.043	0.044	0.04	0.044	0.051	0.049	0.051	0.052
		Eco34	Cost of water	Cost of water needed to wash a vehicle	Costs as in the supplier bill divided by vehicles	kEURO/vehicle		0.0069875	0.0059974	0.006962	0.00667	0.007493	0.001872	0.001872	0.001872	0.001872	0.001872	0.001872	0.001872	0.001872
		Eco35	Water saved	Savings related to water saved due to the implementation of the LIFEH2OBUS technologies	Sum of savings induced by the introduction of new technologies	kEURO/vehicle		0.0489125	0.0419819	0.048737	0.046689	0.052453	0.013104	0.013104	0.013104	0.013104	0.013104	0.013104	0.013104	0.013104
		Eco36	Electricity costs for washing	Total costs for electricity due to washing operations	Sum of expenditure due to washing operations	kEURO/vehicle		0.114	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113
	Consumption	Ecn 9	Electricty consumption	Total amount of electricty consumed	as reported per vehicle	MJ/vehicle	day	228.6439024	300.77561	242.9341	211.6317	175.5659	116.3634	122.4878	122.4878	122.4878	119.7659	145.6244	207.5488	233.4073
		Ecn 12	Energy consumption	Total amount of energy consumed for washing operation	as reported per vehicle	MJ/vehicle		67.2482066	88.463415	71.45122	62.24462	51.63702	34.22453	36.02582	36.02582	36.02582	35.22525	42.8307	61.04376	68.64921
		Ecn 13	Water consumption	Total amount of water consumed	as reported per vehicle	L/vehicle		2800	950	900	780	700	639	620	540	525	570	600	600	670
Environment	Concentrations	Eco2	NOx concentrations	Average hourly (or peak/off-peak) of NOx concentrations	data from monitoring station	mg/m³	peak/off peak hours (average working day)	56.3	79	54	50	41	31							
		Eco3	PM_{10} concentrations	Average hourly (or peak/off-peak) of PM_{10} concentrations	data from monitoring station	µg/m³	peak/off peak hours (average working day)	16.3	16	16	17	16	15.6							
	Waste	Ewa1	Hazardous waste	Disposal of hazardous waste (fluid and/or solid)	Reported	kg/month	LIFEH2OBUS demo timeframe	70	80	80	80	80	80	80	80	80	80	80	80	80
		Ewa2	Non - hazardous waste	Disposal of hazardous waste (fluid and/or solid)	Reported	kg/month	LIFEH2OBUS demo timeframe	10	10	10	10	10	10	10	10	10	10	10	10	10

Pozega data collection



ANNEX 3 – Participants in the LUC to the questionnaires

Depot	Ante Passenger	Post Passenger	Ante Driver	Post Driver	Total number of respondents
Croatia	50	51	21	21*	122
Hungary	N/A**	30	N/A	25	55
Italy	8	26	4	7	45
Total number of respondents	58	107	25	53	222

*Same respondents as in the ante case, so they do not contribute to the total.

Annex 4 – The transferability KIT

LIFEH2OBUS
Best practices for H2O management and savings for BUS operators
Transferability Exercise
“Visioning & Assessing”

Dear Respondent,

Thank you for participating in this Transferability Exercise!

This document includes Part 1, Sections 1 and 2 which constitute the Transferability Exercise, and Part 2 with Tables 1 and 2 where performance variations according to the project’s main KPIs and context parameters are presented, for your knowledge.

Are you ready? Just reply to Questions 1 and 2…..Let’s start!

Part 1

Section 1 – Visioning

First, imagine that you want to transfer one or all these three *LIFEH2OBUS* water-saving technologies:

- ✓ water basic reclamation
- ✓ water basic reclamation and harvesting
- ✓ waxing.

in a bus garage where water for bus washing operations is simply wasted after each washing operations. So the question is:

1) ***“What would be the reason or priority that would theoretically prompt the transfer and adopt these LIFEH2OBUS water-saving technologies?”***

Please, tick the most appropriate from the list below:

	Top Priority:	*Tick here please (one option, only)*
I would like to transfer the LIFEH2OBUS water-saving technologies because I want to improve:	a)Productivity of the system	
	b)Customer satisfaction and attractiveness of bus services	
	c)Quality of the bus service	
	d)Urban environment	

Section 2 – Assessing

Thank you for letting us know about the transfer prompting reason, now imagine that you want to analyse pros and cons of transferring the three *LIFEH2OBUS* water-saving technologies. In other words, please theoretically assess what would be the performance's drivers and barriers to adopt these LIFEH2OBUS water-saving technologies.

Before replying we suggest to have a look at Part 2, at the end of this document, and check Table 1 with the actual performance variations achieved during the LIFEH2OBUS project, along with the local context parameters.

To identify pros and cons, please fill in the Complementarity Matrix at page 4, and consider the KPIs reported as proxy of performance, as explained in this glossary:

Glossary

Priority	KPI Name	KPI definition
Quality of the bus service	Energy consumption	Energy consumed per washing operation
	Water consumption	Energy consumed per washing operation
Productivity of the system	Driving staff	Drivers engaged in parking the bus in the washing lane
	Washing staff	Depot personnel engaged washing operations
	Washing workload	Staff for washing operations
	Vehicle washing operations	Washing frequency per operations
	Washing time	Time for washing a single vehicle
Urban environment care	Hazardous waste	Ordinary waste generated during washing operation
	Non-hazardous waste	Harmful waste generated during washing operation
	CO2 eq. emissions	Pollution generated during washing operations
Customer satisfaction and attractiveness of bus services	Passenger awareness	Passengers aware of the need to save water
	Passenger acceptance	Passengers accepting the introduction of novel washing technology
	Attractiveness	Passengers finding the travel experience attractive
	Travel comfort	Passengers finding the travel experience comfortable
	Staff comfort	Depot staff finding the washing experience comfortable
	Staff acceptance	Depot staff accepting the introduction of novel washing technology

Ok, now consider the KPIs in terms of complementarity each of them has against the others in transferring the three LIFEH2OBUS technologies, so as to fill in each row of the Complementarity Matrix below.

You can do that by answering this simple question:

2) ***"Will the x-KPI performance in the row be:***
   - ✓ ***Neutral (as neither relevant nor negligible)***
   - ✓ ***Limited (of little relevance)***
   - ✓ ***Significant (substantial)***
   - ✓ ***Crucial (decisive)***

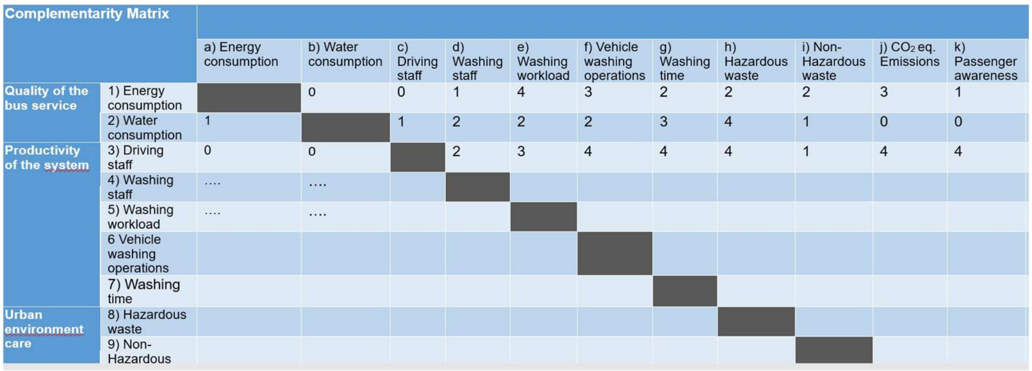
   in relation to the y-KPIs' performance in the columns to transfer the LIFEH2OBUS experience successfully, according to the chosen top priority?"

Please use only the following rating scale:
0 – Neutral;
1 – Limited;
2 – Significant;
3 – Crucial
and score each KPI of each row against all of those in the column.

Rows are numbered 1), 2), 3)…9). Columns are numbered a), b), c),…..k).

Taking KPI 1 "Energy consumption" as an example in Figure 1 and starting from row 1, the question is: "will energy consumption performance be neutral, limited, significant or crucial in relation to water consumption performance to transfer the LIFEH2OBUS experience successfully, according to the chosen top priority?". Since, as in this picture, KPI 1 "Energy consumption" has been scored *Neutral* against "Water consumption", 0 was entered. The KPI1 scoring has to be repeated for all the KPIs from 1b, 1c….to 1p in the columns, so as to have cells in row 1 from 1b to 1p all scored. Then, pass to row 2 and repeat filling in all cells 2a, 2c,2d….2p. Complete, please for all the rows.

Figure 1



Complementarity Matrix		a) Energy consumption	b) Water consumption	c) Driving staff	d) Washing staff	e) Washing workload	f) Vehicle washing operations	g) Washing time	h) Hazardous waste	i) Non-Hazardous waste	j) CO_2 eq. Emissions	k) Passenger awareness
Quality of the bus service	1) Energy consumption	■	0	0	1	4	3	2	2	2	3	1
	2) Water consumption	1	■	1	2	2	2	3	4	1	0	0
Productivity of the system	3) Driving staff	0	0	■	2	3	4	4	4	1	4	4
	4) Washing staff	….	….		■							
	5) Washing workload	….	….			■						
	6 Vehicle washing operations						■					
	7) Washing time							■				
Urban environment care	8) Hazardous waste								■			
	9) Non-Hazardous									■		

The assessment may be not symmetrical: for example, the score given to cell 1b (i.e. 0) can differ from the score given to cell 2a (i.e. 1).

Now please, fill in:

Complementarity Matrix

		a) Energy consumption	b) Water consumption	c) Driving staff	d) Washing staff	e) Washing workload	f) Vehicle washing operations	g) Washing time	h) Hazardous waste	i) Non-Hazardous waste	j) CO_2 eq. Emissions	k) Passenger awareness	l) Passenger acceptance	m) Attractiveness	n) Travel comfort	o) Staff comfort	p) Staff acceptance
Quality of the bus service	1) Energy consumption	■															
	2) Water consumption		■														
Productivity of the system	3) Driving staff			■													
	4) Washing staff				■												
	5) Washing workload					■											
	6) Vehicle washing operations						■										
	7) Washing time							■									
Urban environment care	8) Hazardous waste								■								
	9) Non-Hazardous waste									■							
	10) CO2 eq. emissions										■						
Customer satisfaction and attractiveness of bus services	11) Passenger awareness											■					
	12) Passenger acceptance												■				
	13) Attractiveness													■			
	14) Travel comfort														■		
	15) Staff comfort															■	
	16) Staff acceptance																■

Done? Thank you so much!!!! Please, now save and send back this file to this email address: mariavittoria.corazza@uniroma1.it by Dec. 19!

Again, we appreciated a lot your valuable time and effort!

Part 2

KPIs variation before-vs-during the LIFEH2OBUS test are reported in Table 1

Table 1

Priority	KPI Name	KPI definition	Average no technology 1)	Average with technology 2)	Unit of Measurement	Percent Change
Quality of the bus service	Energy consumption	Energy consumed per washing operation	42.40	49.61	MJ/vehicle	17.00
	Water consumption	Energy consumed per washing operation	815	225.51	L/vehicle	-72.33
Productivity of the system	Driving staff	Drivers engaged in parking the bus in the washing lane	1.48	1.42	man/vehicle	-4.05
	Washing staff	Depot personnel engaged washing operations	0.51	0.51	man/vehicle	0
	Washing workload	Staff for washing operations	0.07093	0.07070	man/vehicle/day/ month	-0.33
	Vehicle washing operations	Washing frequency per operations	0.00067	0.00068	events/ travelled km	1.49
	Washing time	Time for washing a single vehicle	1.38	0.95	% per vehicle	-31.12
Urban environment care	Hazardous waste	Ordinary waste generated during washing operation	0.21	0.4	kg/vehicle	90.48
	Non-Hazardous waste	Harmful waste generated during washing operation	0.03	0.06	Kg/vehicle	100
	CO2 eq. Emissions	Pollution generated during washing operations	24.62	26.18	kg CO_2 eq./ vehicle	6.36
Customer satisfaction and attractiveness of bus services	Passenger Awareness	Passengers aware of the need to save water	55.61	73.16	%	31.58
	Passenger Acceptance	Passengers accepting the introduction of novel washing technology	50.09	66.53	%	32.81
	Attractiveness	Passengers finding the travel experience attractive	56.63	74.77	%	32.04
	Travel Comfort	Passengers finding the travel experience comfortable	68.75	77.05	%	12.08
	Staff comfort	Depot staff finding the washing experience comfortable	57.75	73.39	%	27.07
	Staff acceptance	Depot staff accepting the introduction of novel washing technology	75.08	78.92	%	5.12

1) Value assumed prior to the LIFEH2OBUS project
2) Value recorded during the LIFEH2OBUS project (12-month average value)

In Table 2 the Context Parameters with the three bus garages main operational features are presented.

Table 2

		Context parameters in bus garage			1 Italy	2 Hungary	3 Croatia
Vehicles	1	Fleet composition (vehicles in the depots)	Unit		70	140 (60*, 80**)	50
	2	Operational vehicles (observed empty slots)	Unit		15	35*, 60**	2
	3	Commercial speed (route)	km/h		70	50-70	70
	4	Vehicle length	m		12	12*, 18**	12
Facility	5	Depot surface (outdoor)	sqm		1663	38000	6960
	6	Depot surface (indoor)	sqm		3600	15700	3940
	7	Depot areas to accommodate LIFEH2OBUS technology	sqm		< 100	< 100	< 100
	8	Depot distance to the main city center (bee line)	km		6,5	4,5	1
Energy	9	Availability of energy from renewable sources in the depot (per type of source)			Yes, solar, point	no	Yes, solar, diffused
Weather	10	Local temperature - Winter	°C	daily average (min-max)	0-7	0-3	-3-6
	11	Local temperature - Summer	°C	daily average	25-30	15-27	14-30
	12	Rain - Winter	mm	daily average	1-3	1-1.3	8.8-9.5
	13	Rain - Summer	mm	daily average	2-3	0.6-0.9	9-10
	14	Snow (max)	cm	daily	4	4.8	12
	15	Service disruption during the LIFEH2OBUS scenario			no	no	no
Test	16	LIFEH2OBUS scenario Starting time			Jan 2024	Jan 2024	Nov 2024

To be noted:

- during the 12-month test, no weather extreme phenomena occurred and operations at the garage were regular
- technologies were installed within the bus garage areas, with no external surface requirements

Find more on LIFEH2OBUS at: https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE21-ENV-IT-LIFEH2OBUS-101074151/best-practices-for-h2o-management-and-savings-for-bus-operators

Annex 5 – Responses to the TE

Respondent: UITP – Priority: Quality of the bus service

Respondent	Vision	KPI	Category	Avg Score (Bj)	Weight (1/n)	Weighted (Cj=Bj×Wt)	Magnif. Factor	Final Score (Fj)
Respondent 1	Quality of the Bus Service	a) Energy consumption	Quality of the Bus Service	1,4	0,5	0,7	**2**	**1,4**
		b) Water consumption	Quality of the Bus Service	1	0,5	0,5	**2**	**1**
		c) Driving staff	Productivity of the System	0	0,2	0	1	0
		d) Washing staff	Productivity of the System	0,4	0,2	0,08	1	0,08
		e) Washing workload	Productivity of the System	0,867	0,2	0,173	1	0,173
		f) Vehicle washing ops	Productivity of the System	1,4	0,2	0,28	1	0,28
		g) Washing time	Productivity of the System	1,133	0,2	0,227	1	0,227
		h) Hazardous waste	Urban Environment Care	0,533	0,333	0,178	1	0,178
		i) Non-Hazardous waste	Urban Environment Care	0,2	0,333	0,067	1	0,067
		j) CO2 eq. emissions	Urban Environment Care	0,6	0,333	0,2	1	0,2
		k) Passenger awareness	Customer Satisfaction	0,333	0,167	0,056	1	0,056
		l) Passenger acceptance	Customer Satisfaction	0,667	0,167	0,111	1	0,111
		m) Attractiveness	Customer Satisfaction	0,533	0,167	0,089	1	0,089
		n) Travel comfort	Customer Satisfaction	0,733	0,167	0,122	1	0,122
		o) Staff comfort	Customer Satisfaction	0,2	0,167	0,033	1	0,033
		p) Staff acceptance	Customer Satisfaction	0,333	0,167	0,056	1	0,056
		▶ Quality of the Bus Service subtotal						**2,4**
		▶ Productivity of the System subtotal						**0,76**
		▶ Urban Environment Care subtotal						**0,444**
		▶ Customer Satisfaction subtotal						**0,467**

Respondent: NAIS Solutions – Priority: Quality of the bus service

Respondent	Vision	KPI	Category	Avg Score (Bj)	Weight (1/n)	Weighted (Cj=Bj×Wt)	Magnif. Factor	Final Score (Fj)
Respondent 2	Quality of the Bus Service	a) Energy consumption	Quality of the Bus Service	0,733	0,5	0,367	**2**	**0,733**
		b) Water consumption	Quality of the Bus Service	1,2	0,5	0,6	**2**	**1,2**
		c) Driving staff	Productivity of the System	0,2	0,2	0,04	1	0,04
		d) Washing staff	Productivity of the System	1	0,2	0,2	1	0,2
		e) Washing workload	Productivity of the System	1,133	0,2	0,227	1	0,227
		f) Vehicle washing ops	Productivity of the System	1,067	0,2	0,213	1	0,213
		g) Washing time	Productivity of the System	0,733	0,2	0,147	1	0,147
		h) Hazardous waste	Urban Environment Care	0,533	0,333	0,178	1	0,178
		i) Non-Hazardous waste	Urban Environment Care	0,6	0,333	0,2	1	0,2
		j) CO2 eq. emissions	Urban Environment Care	0,533	0,333	0,178	1	0,178
		k) Passenger awareness	Customer Satisfaction	0,267	0,167	0,044	1	0,044
		l) Passenger acceptance	Customer Satisfaction	0,467	0,167	0,078	1	0,078
		m) Attractiveness	Customer Satisfaction	0,333	0,167	0,056	1	0,056
		n) Travel comfort	Customer Satisfaction	0,2	0,167	0,033	1	0,033
		o) Staff comfort	Customer Satisfaction	0,667	0,167	0,111	1	0,111
		p) Staff acceptance	Customer Satisfaction	1	0,167	0,167	1	0,167
		▶ Quality of the Bus Service subtotal						**1,933**
		▶ Productivity of the System subtotal						**0,827**
		▶ Urban Environment Care subtotal						**0,556**
		▶ Customer Satisfaction subtotal						**0,489**

Respondent: Laboratoire Ampère - Université de Lyon – Priority: Productivity of the System

Respondent	Vision	KPI	Category	Avg Score (Bj)	Weight (1/n)	Weighted (Cj=Bj×Wt)	Magnif. Factor	Final Score (Fj)
Respondent 3	Productivity of the System	a) Energy consumption	Quality of the Bus Service	1,2	0,5	0,6	1	0,6
		b) Water consumption	Quality of the Bus Service	1,667	0,5	0,833	1	0,833
		c) Driving staff	Productivity of the System	2,067	0,2	0,413	**2**	**0,827**
		d) Washing staff	Productivity of the System	2,067	0,2	0,413	**2**	**0,827**
		e) Washing workload	Productivity of the System	1,667	0,2	0,333	**2**	**0,667**
		f) Vehicle washing ops	Productivity of the System	1,933	0,2	0,387	**2**	**0,773**
		g) Washing time	Productivity of the System	2,2	0,2	0,44	**2**	**0,88**
		h) Hazardous waste	Urban Environment Care	2,467	0,333	0,822	1	0,822
		i) Non-Hazardous waste	Urban Environment Care	1,6	0,333	0,533	1	0,533
		j) CO2 eq. emissions	Urban Environment Care	2,6	0,333	0,867	1	0,867
		k) Passenger awareness	Customer Satisfaction	2,333	0,167	0,389	1	0,389
		l) Passenger acceptance	Customer Satisfaction	2,133	0,167	0,356	1	0,356
		m) Attractiveness	Customer Satisfaction	2,133	0,167	0,356	1	0,356
		n) Travel comfort	Customer Satisfaction	2,2	0,167	0,367	1	0,367
		o) Staff comfort	Customer Satisfaction	2,4	0,167	0,4	1	0,4
		p) Staff acceptance	Customer Satisfaction	2,2	0,167	0,367	1	0,367
		▶ Quality of the Bus Service subtotal						**1,433**
		▶ Productivity of the System subtotal						**3,973**
		▶ Urban Environment Care subtotal						**2,222**
		▶ Customer Satisfaction subtotal						**2,233**

Respondent: Transport Infrastructure Ireland – Priority: Quality of the bus service

Respondent	Vision	KPI	Category	Avg Score (Bj)	Weight (1/n)	Weighted (Cj=Bj×Wt)	Magnif. Factor	Final Score (Fj)
Respondent 4	Quality of the Bus Service	a) Energy consumption	Quality of the Bus Service	0,333	0,5	0,167	**2**	**0,333**
		b) Water consumption	Quality of the Bus Service	1,867	0,5	0,933	**2**	**1,867**
		c) Driving staff	Productivity of the System	0,2	0,2	0,04	1	0,04
		d) Washing staff	Productivity of the System	0,867	0,2	0,173	1	0,173
		e) Washing workload	Productivity of the System	1,533	0,2	0,307	1	0,307
		f) Vehicle washing ops	Productivity of the System	2,2	0,2	0,44	1	0,44
		g) Washing time	Productivity of the System	1,8	0,2	0,36	1	0,36
		h) Hazardous waste	Urban Environment Care	1,267	0,333	0,422	1	0,422
		i) Non-Hazardous waste	Urban Environment Care	1,267	0,333	0,422	1	0,422
		j) CO2 eq. emissions	Urban Environment Care	1,2	0,333	0,4	1	0,4
		k) Passenger awareness	Customer Satisfaction	1	0,167	0,167	1	0,167
		l) Passenger acceptance	Customer Satisfaction	1,4	0,167	0,233	1	0,233
		m) Attractiveness	Customer Satisfaction	1,533	0,167	0,256	1	0,256
		n) Travel comfort	Customer Satisfaction	0,8	0,167	0,133	1	0,133
		o) Staff comfort	Customer Satisfaction	1,067	0,167	0,178	1	0,178
		p) Staff acceptance	Customer Satisfaction	0,933	0,167	0,156	1	0,156
		▶ Quality of the Bus Service subtotal						**2,2**
		▶ Productivity of the System subtotal						**1,32**
		▶ Urban Environment Care subtotal						**1,244**
		▶ Customer Satisfaction subtotal						**1,122**

Respondent: TTS Italia – Priority: Urban Environment

Respondent	Vision	KPI	Category	Avg Score (Bj)	Weight (1/n)	Weighted (Cj=Bj×Wt)	Magnif. Factor	Final Score (Fj)
Respondent 5	Urban Environment Care	a) Energy consumption	Quality of the Bus Service	1,133	0,5	0,567	1	0,567
		b) Water consumption	Quality of the Bus Service	1,2	0,5	0,6	1	0,6
		c) Driving staff	Productivity of the System	0,867	0,2	0,173	1	0,173
		d) Washing staff	Productivity of the System	1,6	0,2	0,32	1	0,32
		e) Washing workload	Productivity of the System	1,6	0,2	0,32	1	0,32
		f) Vehicle washing ops	Productivity of the System	1,533	0,2	0,307	1	0,307
		g) Washing time	Productivity of the System	1,667	0,2	0,333	1	0,333
		h) Hazardous waste	Urban Environment Care	1,6	0,333	0,533	**2**	**1,067**
		i) Non-Hazardous waste	Urban Environment Care	1,6	0,333	0,533	**2**	**1,067**
		j) CO2 eq. emissions	Urban Environment Care	1,667	0,333	0,556	**2**	**1,111**
		k) Passenger awareness	Customer Satisfaction	0,4	0,167	0,067	1	0,067
		l) Passenger acceptance	Customer Satisfaction	0,6	0,167	0,1	1	0,1
		m) Attractiveness	Customer Satisfaction	0,667	0,167	0,111	1	0,111
		n) Travel comfort	Customer Satisfaction	0,4	0,167	0,067	1	0,067
		o) Staff comfort	Customer Satisfaction	1,333	0,167	0,222	1	0,222
		p) Staff acceptance	Customer Satisfaction	1	0,167	0,167	1	0,167
		▶ Quality of the Bus Service subtotal						**1,167**
		▶ Productivity of the System subtotal						**1,453**
		▶ Urban Environment Care subtotal						**3,244**
		▶ Customer Satisfaction subtotal						**0,733**

Respondent: Polytechnic of Madrid – Priority: Urban Environment

Respondent	Vision	KPI	Category	Avg Score (Bj)	Weight (1/n)	Weighted (Cj=Bj×Wt)	Magnif. Factor	Final Score (Fj)
Respondent 6	Urban Environment Care	a) Energy consumption	Quality of the Bus Service	1,467	0,5	0,733	1	0,733
		b) Water consumption	Quality of the Bus Service	1,267	0,5	0,633	1	0,633
		c) Driving staff	Productivity of the System	1,2	0,2	0,24	1	0,24
		d) Washing staff	Productivity of the System	1,733	0,2	0,347	1	0,347
		e) Washing workload	Productivity of the System	1,733	0,2	0,347	1	0,347
		f) Vehicle washing ops	Productivity of the System	2,2	0,2	0,44	1	0,44
		g) Washing time	Productivity of the System	2,267	0,2	0,453	1	0,453
		h) Hazardous waste	Urban Environment Care	1,8	0,333	0,6	**2**	**1,2**
		i) Non-Hazardous waste	Urban Environment Care	1,667	0,333	0,556	**2**	**1,111**
		j) CO2 eq. emissions	Urban Environment Care	2,467	0,333	0,822	**2**	**1,644**
		k) Passenger awareness	Customer Satisfaction	2,2	0,167	0,367	1	0,367
		l) Passenger acceptance	Customer Satisfaction	2,333	0,167	0,389	1	0,389
		m) Attractiveness	Customer Satisfaction	2,467	0,167	0,411	1	0,411
		n) Travel comfort	Customer Satisfaction	1,8	0,167	0,3	1	0,3
		o) Staff comfort	Customer Satisfaction	1,267	0,167	0,211	1	0,211
		p) Staff acceptance	Customer Satisfaction	1,333	0,167	0,222	1	0,222
		▶ Quality of the Bus Service subtotal						**1,367**
		▶ Productivity of the System subtotal						**1,827**
		▶ Urban Environment Care subtotal						**3,956**
		▶ Customer Satisfaction subtotal						**1,9**

Respondent: Polytechnic of Bari – Priority: Urban Environment

Respondent	Vision	KPI	Category	Avg Score (Bj)	Weight (1/n)	Weighted (Cj=Bj×Wt)	Magnif. Factor	Final Score (Fj)
Respondent 7	Urban Environment Care	a) Energy consumption	Quality of the Bus Service	1,533	0,5	0,767	1	0,767
		b) Water consumption	Quality of the Bus Service	1,667	0,5	0,833	1	0,833
		c) Driving staff	Productivity of the System	1,2	0,2	0,24	1	0,24
		d) Washing staff	Productivity of the System	2,2	0,2	0,44	1	0,44
		e) Washing workload	Productivity of the System	1,933	0,2	0,387	1	0,387
		f) Vehicle washing ops	Productivity of the System	2,2	0,2	0,44	1	0,44
		g) Washing time	Productivity of the System	2,133	0,2	0,427	1	0,427
		h) Hazardous waste	Urban Environment Care	2,133	0,333	0,711	**2**	**1,422**
		i) Non-Hazardous waste	Urban Environment Care	2,267	0,333	0,756	**2**	**1,511**
		j) CO2 eq. emissions	Urban Environment Care	2,333	0,333	0,778	**2**	**1,556**
		k) Passenger awareness	Customer Satisfaction	1,467	0,167	0,244	1	0,244
		l) Passenger acceptance	Customer Satisfaction	1,467	0,167	0,244	1	0,244
		m) Attractiveness	Customer Satisfaction	1,333	0,167	0,222	1	0,222
		n) Travel comfort	Customer Satisfaction	1,6	0,167	0,267	1	0,267
		o) Staff comfort	Customer Satisfaction	1,867	0,167	0,311	1	0,311
		p) Staff acceptance	Customer Satisfaction	2,133	0,167	0,356	1	0,356
		▶ Quality of the Bus Service subtotal						**1,6**
		▶ Productivity of the System subtotal						**1,933**
		▶ Urban Environment Care subtotal						**4,489**
		▶ Customer Satisfaction subtotal						**1,644**

Respondent: ASSTRA – Priority: Productivity of the System

Respondent	Vision	KPI	Category	Avg Score (Bj)	Weight (1/n)	Weighted (Cj=Bj×Wt)	Magnif. Factor	Final Score (Fj)
Respondent 8	Productivity of the System	a) Energy consumption	Quality of the Bus Service	1,667	0,5	0,833	1	0,833
		b) Water consumption	Quality of the Bus Service	1	0,5	0,5	1	0,5
		c) Driving staff	Productivity of the System	1,133	0,2	0,227	**2**	**0,453**
		d) Washing staff	Productivity of the System	1,2	0,2	0,24	**2**	**0,48**
		e) Washing workload	Productivity of the System	1,533	0,2	0,307	**2**	**0,613**
		f) Vehicle washing ops	Productivity of the System	1,867	0,2	0,373	**2**	**0,747**
		g) Washing time	Productivity of the System	1,6	0,2	0,32	**2**	**0,64**
		h) Hazardous waste	Urban Environment Care	1,8	0,333	0,6	1	0,6
		i) Non-Hazardous waste	Urban Environment Care	2,133	0,333	0,711	1	0,711
		j) CO2 eq. emissions	Urban Environment Care	1,067	0,333	0,356	1	0,356
		k) Passenger awareness	Customer Satisfaction	0,4	0,167	0,067	1	0,067
		l) Passenger acceptance	Customer Satisfaction	0,533	0,167	0,089	1	0,089
		m) Attractiveness	Customer Satisfaction	0,733	0,167	0,122	1	0,122
		n) Travel comfort	Customer Satisfaction	0,667	0,167	0,111	1	0,111
		o) Staff comfort	Customer Satisfaction	1,333	0,167	0,222	1	0,222
		p) Staff acceptance	Customer Satisfaction	1,4	0,167	0,233	1	0,233
		▶ Quality of the Bus Service subtotal						**1,333**
		▶ Productivity of the System subtotal						**2,933**
		▶ Urban Environment Care subtotal						**1,667**
		▶ Customer Satisfaction subtotal						**0,844**

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