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NextETRUCK

Efficient and affordable Zero Emission logistics through **NEXT** generation **E**lectric **TRUCK**s

HORIZON Innovation Actions ¦ Project Number: 101056740

D8.1
Evaluation plan

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Legal disclaimer

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ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
BEV	Battery Electric Vehicle
CAN Bus	Controller Area Network
CAPEX	Capital Expenditure
DT	Digital Twin
EC	European Commission
FOTs	Field Operational Tests
ICE	Internal Combustion Engine
KPI	Key Performance Indicator
MCV	Medium-duty Commercial Vehicle
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
SoA	State of Art
SoC	State of Charge
TCO	Total Cost of Ownership
UC	Use Case
WTW	Well-to-Wheel
ZEV	Zero Emission Vehicle

EXECUTIVE SUMMARY

NextETRUCK has developed an evaluation plan to ensure that the individual components, functions, and overall systems of the project architecture meet the specified requirements and specifications. The plan adheres to accepted validation methodology best practices and draw upon recommendations from previous support projects such as CONVERGE and FESTA. By following this approach, the project aimed to propose a comprehensive evaluation framework for NextETRUCK.

The Evaluation Plan outlines the approach and process for validation and impact assessment. (The verification step is already covered in WPs 4 and 5). It defines a set of research hypotheses and the associated goals for the various innovation elements of the project to establish the basis for evaluation. Key aspects of the Evaluation Plan include the definition of ***Key Performance Indicators (KPIs)***. In D8.1, KPIs were identified that will be measured during the demonstration and digital twin operations. A set of 26 KPIs has been defined that cover areas such as the vehicle & charging, the digital tools, the driver/fleet operator and the market/TCO. These KPIs will encompass both quantitative and qualitative measures derived from objective data, subjective evaluations, and inputs such as vehicle data, questionnaires, and driver interviews.

A significant part of the Evaluation Plan is the ***validation plan***. NextETRUCK utilises data from real-life demonstrations and simulations (digital twin model) as part of the validation process. This plan guides Task 8.2 and ensures the assessment of the project systems.

D8.1 addresses the ***impact assessment*** activities through a dedicated plan. This plan will guide Task 8.3 and outline the approach for evaluating the overall impact of NextETRUCK. It considers various factors and implications resulting from the project's implementation.

By implementing these components within the Evaluation Plan, the project aims to comprehensively assess the performance, validate the system, and determine the impact of NextETRUCK.

1 INTRODUCTION

1.1 About NextETRUCK

NextETRUCK is a 3-year Horizon Europe project that develops ZEV concepts tailored for regional medium freight haulage, running from 1 July 2022 until 31 December 2025.

The project aims at playing a pioneering role in the decarbonisation of vehicle fleets, demonstrating next-generation e-mobility concepts. It also contributes to the development of zero-emission vehicles and ecosystems that are holistic, innovative, affordable, competitive, and synergetic.

NextETRUCK is expected to build concepts tailored for regional medium freight haulage with at least a 10% increase in energy efficiency compared to existing highest-end benchmark electric vehicles. In addition, it shall prepare concept and infrastructure demonstrators for fast charging and offer new business models to increase end-user acceptance and foster the market uptake of the project solutions.

The project's consortium consists of 19 partners from 8 countries: The Netherlands, Belgium, Germany, Spain, Greece, Australia, Turkey, United Kingdom[1]. The project's coordinator is TNO (Netherlands Organization for Applied Scientific Research).

NextETRUCK shall conduct demonstrations in Istanbul, Barcelona, and Utrecht.

1.1.1 WP8 Evaluation, Impact Assessment and upscaling strategy

WP8 main objectives are the validation of the project vehicles and charging solution, the exploitation of the outcomes, considering recommendations for future legislative frameworks, a thorough market and cost benefit analysis as well as environmental assessment, and the preparation of the business plan for the commercialisation of the e-vehicles and the assessment of the project impact.

More specifically, the objectives of WP8 are: a. Validation of the practical applicability of the project vehicles, chargers and subsystems, and its functionality and user acceptance. b. Assessment of the scaleup potential of the NextETRUCK technology for the European market of mid-size trucks by: analysis of market and operational conditions; demonstration of the economic viability for a variety of use cases; (comparative) life cycle assessment. c. Preparation of the exploitation measures of individual partners. d. Elaboration and preliminary validation of a business plan concepts and development of an Exploitation Agreement for the project outcomes.

[1] The UK participants in this project are co-funded by the UK.

1.2 Purpose of the deliverable

This document describes the approach and process for validation and impact assessment for the NextETRUCK project vehicles and charging system. In D8.1, a common framework for the evaluation of the project systems is defined, including:

- Evaluation criteria and performance indicators;
- Data analysis tools and methods, a preliminary approach to be further elaborated in WP7;
- Methodological principals for the evaluation (in real and simulated conditions) and the impact assessment tasks;
- Relation with other project tasks that deal with the data management, validation and the impact assessment, especially with all tasks in WP7.

1.3 Intended audience

This deliverable is available to the public.

1.4 Structure of the deliverable and its relation with other work packages/deliverables

Following the introduction to the project and Task 8.1 (*Sections 1*), *Section 2* of this deliverable provides an overview of the evaluation methodology. *Section 3* is describing the method to assess the proposed KPIs. *Section 4* is dedicated to the management of the data and the tools to be used for the collection of information. The evaluation plan of the project outcomes and the plan for the impact assessment (related to fleet upscale, market, environment and costs) are addressed in *Sections 5 and 6* respectively. The deliverable ends up with a summary of Conclusions (*Sections 7*).

This deliverable is linked to the following WPs and Tasks:

- WP2: Use case and preliminary KPIs definition in D2.1 and the data collection list in the test catalogue in D2.5.
- WP3: The connection of the vehicles with the IoT platform (T3.4) which will be the hub of the collected data to be forwarded to Task 7.4.
- WP7: all four tasks of this WP are strongly related to the content of this report. Key partners of WP7 are also involved in WP8 in order to define the validation requirements of the real-world piloting at an early stage. Item of D8.1, such as the data collection plan and processing, will be further elaborated in D7.4.
- WP8: the remaining three tasks will use this document as a guide for progressing both the validation and the impact assessment tasks.

2 EVALUATION FRAMEWORK

2.1 Introduction

In terms of the evaluation methodology, there are two types of evaluations commonly found in the literature: ex-ante evaluation (a priori assessment) and ex-post evaluation (a posteriori assessment). NextETRUCK focuses on ex-post evaluation, which measures the actual benefits of the system and is discussed in this deliverable.

The ex-post evaluation methodology comprises six stages based on CONVERGE (1998). First, identify the final users of the services, typically private/public fleet operators or individuals. Then, select the most relevant Key Performance Indicators (KPIs) that are meaningful and applicable to the identified final users. It follows the definition the methodology for collecting and analyzing the data. Data can be collected through direct measurements, simulations, or questionnaires. Statistical analyses are necessary to ensure representative results from the sample. Then, determine the data requirements for calculating the KPIs. Multiple data sources must be considered, including fleet information, traffic/weather management centers, fleet management centers, and local sensors.

The methodology continues with the preparation of the necessary analysis and monitoring tools. These tools should be prepared in advance, prior to the implementation works, to identify any additional tasks required during installations. If additional data is needed, it should be incorporated during the installations and not afterward. Monitoring the performance of the demonstration is crucial to detecting potential malfunctions and low user participation, which could impact the evaluation results.

The above steps have been updated by the FESTA project, which received funding from the FP7 calls under Challenge 6: ICT for Mobility, Environment Sustainability, and Energy of the Information and Communication Technologies Priority. The project aimed to support Field Operational Tests (FOTs) by providing a handbook of good practices covering various aspects such as FOT timeline and administration, integration of acquired data, and estimation of socio-economic benefits.

The evaluation steps proposed by FESTA in 2008 were further updated in the second FESTA project in 2011. The current evaluation steps in an FOT, as proposed by FESTA, are as follows:

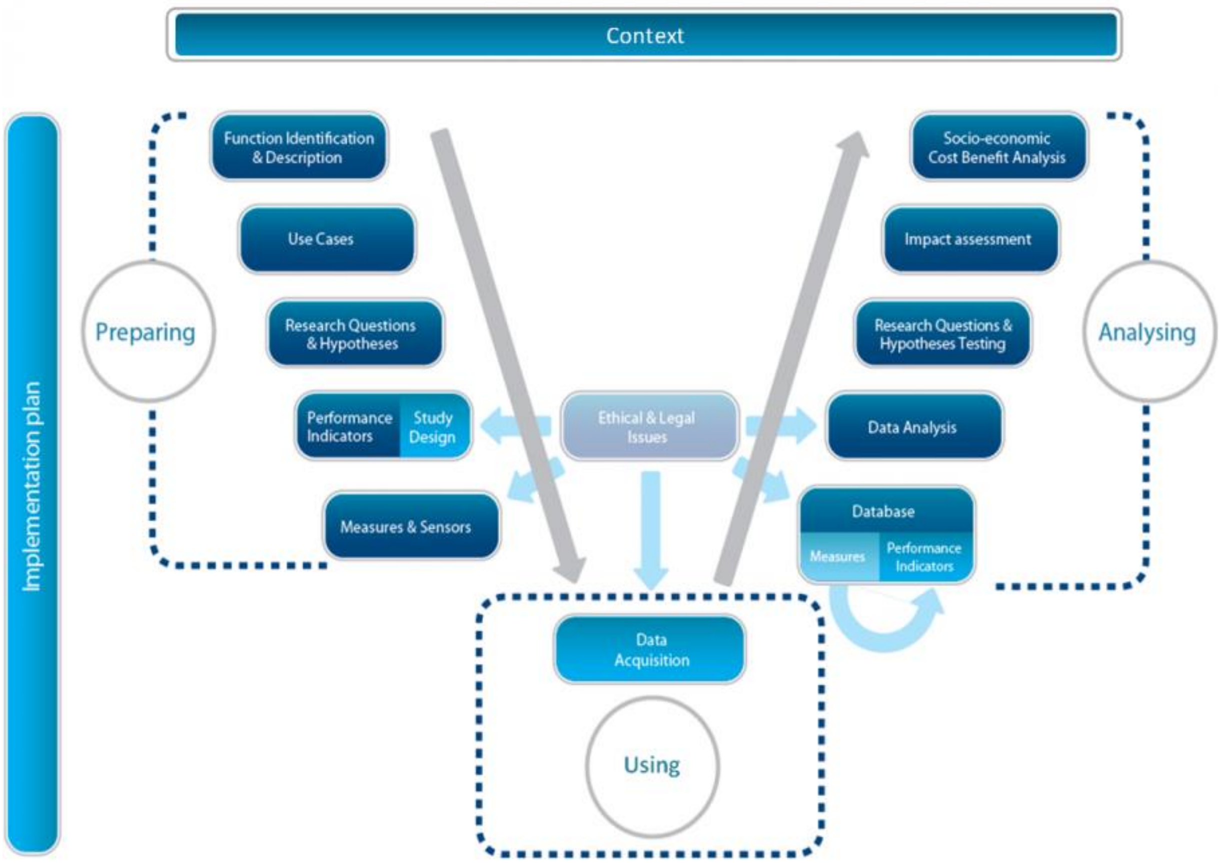


Figure 1: Evaluation methodology proposed by the FESTA handbook

Source: FESTA Handbook for Developing and Assessing Field Operational Tests (update 2021)

The V-scheme illustration depicts the different stages of the evaluation process. The left side represents the preparation activities for setting up the test, the bottom part represents data acquisition during system usage, and the right side represents data analysis and result interpretation.

The preparation phase follows a research-oriented approach. Firstly, the functions to be tested are defined, and use cases are described, outlining the specific situations where the system is expected to perform. Research questions related to the use cases are also identified, which should be statistically testable and assess the system's performance within those scenarios. Secondly, hypotheses, performance indicators (qualitative or quantitative), measures, and sensors are defined. These hypotheses aim to address the research questions by directly measuring or indirectly estimating/calculating the relevant indicators.

The analysis phase involves estimating indicator values to either accept or reject the hypotheses and provide answers to the research questions. The results are often scaled up to evaluate the socio-economic impacts of the system if it were to be deployed on a larger scale.

According to Gay (1996), a good hypothesis is one that "clearly and concisely states the expected relationship (or difference) between two variables and defines those variables in operational, measurable terms." It is essential to state and define hypotheses clearly because they must be testable, meaning that data collection and analysis should support or not support the hypotheses (Gay, 1996).

2.2 Relevant projects review

In this sub-section a number of related EC funded projects, concerning the efficiency of trucks and the evaluation method applied for the assessment of their impact, have been reviewed and discussed.

2.2.1 CONVENIENT

The CONVENIENT project aimed to achieve a 30% reduction in fuel consumption for long-haul heavy trucks by developing innovative energy-saving technologies and solutions. The project took a holistic approach to vehicle energy management, considering the truck, semi-trailer, driver, and overall mission.

Sub Project A4's main objective was to evaluate the proposed technologies' enhancement in terms of fuel efficiency at the complete vehicle level. This involved defining assessment criteria and identifying suitable reference missions for simulation activities. The criteria aimed to enable the use of simulation tools like PERFECTS and AVL Cruise to simulate fuel consumption for the entire heavy-duty vehicle (truck-semitrailer combination). The simulations would validate the fuel-saving solutions during subsequent testing phases of the CONVENIENT project. The assessment criteria prioritised realistic operational conditions to assess fuel efficiency, potential CO_2 emission reductions, and a detailed investigation of the high-voltage battery's energetic balance in the electric hybrid system.

AVL's contribution involved developing and providing vehicle models that simulated the longitudinal driving dynamics of the vehicles and depicted all energy flows, including mechanical, thermal, and electrical energy. Access to and control over all energy flows were crucial for evaluating optimal fuel-saving strategies. Specific technologies evaluated for different truck applications included a Hybrid Electric Vehicle for Iveco Truck, "on-demand" operation strategies and holistic energy management for VOLVO truck with E-Auxiliaries, and low voltage recuperation and smart board net control for DAF truck.

2.2.2 CORE

The primary goal of the CORE project was to demonstrate a significant reduction in CO_2 emissions by improving powertrain efficiency in long-haul applications, with the aim of implementing the technologies in production around 2020. The project focused on enhancing engine concepts with turbocharger systems, variable valve actuation, reduced friction, and after-treatment systems for low-temperature ranges. Hybridization and natural gas were also utilised as additional approaches.

To evaluate the results, tests were conducted using both EURO VI legislation cycles and real-life driving cycles. The development efforts covered various aspects, including component redesign, improved performance, control strategy enhancements, and implementation of components for complete engine system tests.

The final assessment took place in Sub-Project A4, where a vehicle simulation tool was used to estimate the efficiency benefits of CORE technologies on overall vehicle performance. The most promising technologies were integrated into compatible vehicle packages. The simulation models of the base vehicles were validated by comparing them with real vehicle measurements over representative cycles. These models were then expanded to include the most promising technology packages, and further simulations were conducted. The results indicated that the relative benefits of each CORE technology varied depending on the specific vehicle application and its duty cycle.

2.2.3 eCoMOVE

The eCoMove project aimed to minimise fuel wastage in road transport by addressing three main causes of avoidable energy use: uninformed trip planning and route choice, non-ecological driving performance, and inefficient traffic management and control. To tackle these inefficiencies, the project sought solutions that would support drivers, fleet managers, and traffic managers in adopting energy-efficient practices.

eCoMove utilised performance indicators related to the environment, mobility, and driver behavior. These indicators would validate whether the system reduced CO_2 emissions and fuel consumption, improved traffic efficiency, and positively influenced driver behavior. The validation approach of the eCoMove project followed a structured methodology comprising three main phases: definition, evaluation, and impact assessment. During the definition phase, the validation framework, objectives, applications to be tested, and test sites were established. The evaluation phase involved data acquisition, logging, and analysis of performance indicators and impacts. The impact assessment was conducted for each eCoMove application individually and for the combined eCoMove system. Throughout the process, legal and ethical aspects were taken into consideration.

The validation of the eCoMove project's success criteria employed various test methods, including field trials, traffic network studies, driver studies, and simulations at the validation sites. The criteria focused on determining whether the system was built correctly rather than assessing the effectiveness of the built system.

2.2.4 CO-GISTCS

The primary goal of the CO-GISTICS project was to implement, validate, and establish five cooperative logistics services aimed at enhancing energy efficiency: CO_2 Footprint Estimation and Monitoring, Cargo Transport Optimization, Intelligent Truck Parking and Delivery Area Management, Eco-Drive Support, and Priority and Speed Advice. These services were tested and validated in seven European cities and logistics hubs with the objective of reducing fuel consumption, CO2 emissions, and pollution.

The project's Evaluation Framework focused on identifying KPIs for evaluating the Field Operational Tests (FOTs) and categorizing them accordingly. The evaluation criteria and performance indicators were defined considering the needs of stakeholders and the underlying business models to determine the necessary data to be collected during the pilot operations. The evaluation criteria encompassed assessing network efficiency, environmental impact, economic sustainability, traffic network management, and specific metrics related to drivers and goods. The CO-GISTICS evaluation framework outlined different measurement types to evaluate the designated KPIs.

2.2.5 OptiTruck

The objective of the optiTruck project was to enhance the fuel efficiency of commercial trucks through the development and validation of optimization processes. This was accomplished by implementing and testing these processes on a prototype truck. Within the project, Work Package 7 was responsible for designing the evaluation methodology and creating comprehensive plans for demonstration and validation activities.

The validation framework outlined the chosen validation method, test plan, and data collection measurements necessary to evaluate the KPIs that have been selected. The task utilised these KPI values to assess the success of the system during both simulated and real-life demonstrations. The optiTruck KPIs were organised into categories based on their specific areas of focus, such as fuel consumption performance and acceptance by drivers and fleet operators. Each KPI required specific measurements to be collected, which involved sensor data logging or calculations based on sensor inputs. Objective validation was also performed through driving surveys. The plan covered data flows, data acquisition, quality considerations, and the tools used to calculate the KPIs. The validation process for the systems involved both simulated testing using advanced vehicle simulations and testing in real-life environments.

2.2.6 Key Takeaways

The NextETRUCK evaluation plan methodology will follow a series of steps, drawing from the principles of CONVERGE and FESTA. The planned steps are as follows:

- Definition of the evaluation framework: This involves specifying procedures for collaboration among project partners, test sites, and external providers.
- Determination of evaluation criteria and performance indicators: The selected KPIs will be categorised into four groups: vehicle & charging, the digital tools, the driver/fleet operator and the market/TCO.
- Compilation of assessment tools: A list of tools, such as sensor data, CAN-Bus data, and questionnaires, will be identified for the evaluation process.
- Data analysis methodology: Both quantitative and qualitative methods will be employed for data analysis.

- Analysis of User Requirements: User requirements will be thoroughly examined and analysed.
- Building of demonstrators: Prototype systems/models will be developed to showcase the project concept.
- Validation of the demonstrators: The demonstrators will undergo a validation process (in real and simulated environment).
- Impact assessment: A three stage impact assessment will take place concerning the up-scaling of the project outcomes on a city/urban and peri-urban level, the market up-take and the environmental and cost impact.
- Development of an exploitation plan (T8.4): A plan will be established to ensure the effective use and exploitation of the project results and outcomes.

Similar to the other projects, NextETRUCK will employ evaluation testing through simulations, as some tests may not be feasible (e.g. weather, traffic, mission parameters) to conduct in real-life settings.

2.3 Research hypotheses and project goals

This section sets a number of research hypothesis and the projects goals associated to them, in order to reach the final outcome as initially described though the project objectives in the DoA.

Table 1. Project hypotheses and list of goals to meet the NextETRUCK objectives

id	Hypothesis description	NextETRUCK goals
1	NextETRUCK vehicle range is more than the baseline vehicle	Achieving 10% longer range per energy consumption in comparison with the state-of-the-art similar EVs …
2	NextETRUCK vehicles load is almost equal to the ICE trucks for similar missions	... and for at least 90% loaded case in comparison to the ICE trucks for similar missions
3	The range of the NextETRUCK vehicles is similar with and without using cabin heating	For all use cases, achieving at least 95% of the ZEV truck operation range while heating is used, compared to no heating
4	Multi-parameter modelling of the EV performance can be achieved by high-fidelity DT models	Realization of the High-fidelity Digital Twin ensuring advanced and multi-parameter modelling of the electrical vehicle reliability and energy-use
5	New algorithms and tools can contribute to the fleet management of electric trucks	Realization of algorithms and tools for fleet-level management of electric vehicles
6	Digital tools can assist fleet managers and contribute to the improvement of processes and operations	Realization of the digital tool for the ZEV virtual validation, seamless integration to the ecosystem and operational optimization by fleet managers

id	Hypothesis description	NextETRUCK goals
7	NextETRUCK vehicles will have a lower TCO than existing modern trucks	20% TCO reduction of ZEV is achieved when compared with a modern e-truck
8	NextETRUCK vehicles will have a lower TCO than existing modern ICE trucks	TCO parity with ICE 2020 trucks
9	Improved charging efficiency	Up to 4% more average efficiency increase is achieved at WBG-based power modules.
10	Improved thermal efficiency	Vehicle thermal efficiency is improved by 15%.
11	Efficient e-powertrain design can be made by means of a digital tool	Complete e-powertrain design tool is realised and validated
12	NextETRUCK charging infrastructure has a lower TCO than existing similar examples	15% TCO reduction for the fleet charging infrastructure
13	NextETRUCK vehicles can be used in more than one transport shifts	Double shift operation for the fleet operator (thus, improving the TCO by minimizing the investment in rolling stock and the charging time) is made possible
14	Charging experience is improved	Improved charging experience and CO_2 reduction due to eco-charging management tool
15	CO_2 reduction is demonstrated through charging management	Improved charging experience and CO_2 reduction due to eco-charging management tool
16	Goods distribution vehicle can achieve a reference range of 200 km per day (FORD demo vehicle)	Goods distribution e-truck in Istanbul with FORD as OEM is successfully in operation for a daily range of more than 200km, for at least 6 months
17	Goods distribution vehicle meets user needs (FORD demo vehicle)	Goods distribution e-truck in Istanbul with FORD as OEM is successfully in operation for a daily range of more than 200km, for at least 6 months
18	ZEV refuse vehicle can achieve a sufficient range to perform a usual daily mission (IRIZAR demo vehicle)	ZEV refuse truck in Barcelona with IRIZAR as OEM is successfully in operation for a daily range to collect refuse and waste, for at least 6 months
19	ZEV refuse vehicle meets user needs (IRIZAR demo vehicle)	ZEV refuse truck in Barcelona with IRIZAR as OEM is successfully in operation for a daily range to collect refuse and waste, for at least 6 months
20	Vehicle that performs back to base logistics can achieve a reference range of 200 km per day (TEVVA demo vehicle)	Back to base logistics e-truck for express transport in Utrecht with TEVVA as OEM is successfully in operation for a daily

id	Hypothesis description	NextETRUCK goals
		range of more than 200km, for at least 6 months
21	Back to base logistics vehicle meets user needs (TEVVA demo vehicle)	Back to base logistics e-truck for express transport in Utrecht with TEVVA as OEM is successfully in operation for a daily range of more than 200km, for at least 6 months
22	NextETRUCK will lead to an increased market penetration of this vehicle sector	15% increase in the average e-Medium-duty Commercial Vehicles (MCVs) market penetration
23	NextETRUCK outcomes can be launched using new bussiness models	New proposed business models are taken up by Reference Group stakeholders
24	NextETRUCK vehicles meet user needs in terms of driving and mission	The NextETRUCK overall system is compatible with the driving/mission tasks
25	NextETRUCK vehicles meet user needs in terms of usability	High usability of the NextETRUCK overall system
26	NextETRUCK vehicle demonstrates reduced emissions	NextETRUCK demonstrates a reduction in operational CO_2 emission relative to BEV and ICE baseline vehicles.
27	NextETRUCK has similar to ICE truck operation time	The operating hour of NextEtruck are similar to ICE truck (95% parity)
28	The charging rate of the NextETRUCK will not deviate from the predicted one	The charging rate of the NextEtruck is as close as possible to the predicted by the MCS system in the range from 20% to 80% SoC (90% parity)
29	The charging time for a full charge is similar to current e-trucks on the market	The charging time for a full charge is similar to current e-trucks on the market
30	NextETRUCK vehicles lead to a competitive driving time / charging time ratio	The ratio of driving time / charging time will at least be equal or more than the current e-trucks on the market
31	NextETRUCK vehicles will be competitive in terms of average speed in comparison to current e-trucks on the market	The driving speed will at least be similar or higher than the current e-trucks on the market
32	NextETRUCK vehicles lead to a competitive total cost of charging / total kms driven	The total cost of charging / the kms driven should be less than the current e-trucks on the market

2.4 Use cases

NextETRUCK has defined three UCs in the DoA which have further been elaborated in D2.1 (for more information please see D2.1). However, considering that not all KPIs can be answered during these three UCs (because of e.g. weather or traffic conditions not reaching the set thresholds during real-life testing), additional UCs have to be considered that will be simulated with the use of the DT in T8.3. The list of the UCs, as defined at this stage of the project and is still a subject of amendments during the validation phase, is described in the table below.

Table 2. Real-life and virtual UCs for the assessment of the project objectives

id	Use Case title	Test environment	Use Case details	Linked to Hypothesis and goals (id)
1	Distribution Logistics	Real	Tested in Turkey with the FORD demonstrator	1-3, 7-10, 12-17, 24-32
2	Voluminous waste collection	Real	Tested in Barcelona with the IRIZAR demonstrator	1-3, 7-10, 12-15, 18, 19, 24-32
3	Back-to-base logistics	Real	Tested in Utrecht with the TEVVA demonstrator	1-3, 7-10, 20, 12-15, 21, 24-32
4	Transportation of refrigerated goods	Simulated	Using the DT model and the real-life UCs scenarios varying the cargo compartments parameters	4, 11, 22, 24, 25, 30-32
5	Driving under extreme weather conditions	Simulated	Using the DT model and the real-life UCs scenarios varying the weather parameters	4-6, 11, 24, 25, 30, 31
6	Driving under highly congested road segments	Simulated	Using the DT model and the real-life UCs scenarios varying the road type and traffic parameters	4-6, 11, 24, 25, 30, 31
7	Operating an e-truck fleet	Simulated	Using the DT model and the real-life UCs scenarios varying the vehicle number and the transport mission	5-8, 13, 15, 24-26, 30-32

3 KPI DEFINITION

3.1 Introduction

The KPIs (Key Performance Indicators) presented here are indicators that can be either quantitative or qualitative. They are derived from predetermined measurements and expressed as percentages, indices, rates, or other values. These indicators are monitored at regular or irregular intervals and can be compared to one or more criteria. The definition of the criteria depends on the specific field of research and the intended goals. To validate the initial assumptions during project development, appropriate evaluation criteria must be used. These criteria can include baselines, different experimental conditions, absolute values, and so on.

It is important to note that KPIs require a denominator (such as time, distance, or trip) to ensure comparability. For qualitative KPIs, the "denominator" is represented by the time and circumstances in which the data are acquired (e.g., before and after implementing a specific technology proposed in the project). It is also worth mentioning that KPIs cannot be considered uniform due to variations in the nature of collected data (qualitative/quantitative), the data acquisition process, and the type of data considered, leading to diverse types of KPIs (Nilsson et al., 2000).

Table 3 provides a comprehensive list of KPIs that are useful for assessing the performance of NextETRUCK systems at each UC. This list has been validated against the requirements outlined in D2.1 to ensure that all requirements related to the system's tangible impact will be evaluated using the indicators generated from WP2 and WP8. The KPIs have been sorted out based on generic categories such as e-Truck (ET), Digital Twin models (DT), Charging Infrastructure/Efficiency (CI) and User Acceptance (UA).

The last six KPIs of the table (KPI-20 to 25) have been included in the evaluation process as suggested by the 2Zero partnership.

Table 3. List of KPIs and their link to the project Hypothesis and Goals

KPI id	KPI title	Link to Hypothesis and Goal	Category classification
KPI-1a	Efficiency Increase & Payload Capacity Distance: *Driven per Absolut Energy Consumption*	1	ET
KPI-1b	Efficiency Increase & Payload Capacity Distance: *Load per mission*	2	ET
KPI-2	Thermal management system efficiency	3	ET
KPI-3	Realization of the High-fidelity Digital Twin	4	DT
KPI-4	Realization of fleet management system	5	DT
KPI-5	Digital Twin realization and tools for ZEV virtual validation	6	DT

KPI id	KPI title	Link to Hypothesis and Goal	Category classification
KPI-6a	TCO reduction of ZEV: *vs modern e-trucks*	7	UA
KPI-6b	TCO reduction of ZEV: *parity with ICE 2020 trucks*	8	UA
KPI-7	Charger efficiency	9	ET, CI
KPI-8	Vehicle thermal efficiency	10	ET
KPI-9	e-powertrain design	11	DT
KPI-10	TCO reduction of charging	12	UA
KPI-11	Double shift fleet operation	13	DT
KPI-12a	Charging experience: *user perspective*	14	UA
KPI-12b	Charging experience: *CO_2 reduction*	15	DT
KPI-13a	Realisation of UC1: *200 km per day*	16	ET
KPI-13b	Realisation of UC1: *vehicles meet user needs*	17	UA
KPI-14a	Realisation of UC2: *200 km per day*	18	ET
KPI-14b	Realisation of UC2: *vehicles meet user needs*	19	UA
KPI-15a	Realisation of UC3: *200 km per day*	20	ET
KPI-15b	Realisation of UC3: *vehicles meet user needs*	21	UA
KPI-16	Market penetration increase	22	UA
KPI-17	Business models adoption	23	UA
KPI-18	The NextETRUCK overall system is compatible with the driving/mission tasks	24	UA
KPI-19	High usability of the NextETRUCK overall system	25	UA
KPI-20	Reduction in operational CO_2 emission	26	ET
KPI-21	Operating hours	27	ET
KPI-22	Charging rate	28	ET, CI
KPI-23	Charging time	29	ET, CI
KPI-24	Driving to charging time	30	ET, CI
KPI-25	Average driving speed	31	ET
KPI-26	Charging cost per km	32	ET, CI

3.2 KPIs description and assessment

This section presents a structured approach for comprehensive evaluation, encompassing KPI description, assessment methods, parameters, and details necessary to address each KPI, as well as potential risks and challenges during the evaluation phase. By following this methodology, stakeholders can ensure a thorough and meaningful analysis of the performance of the NextETRUCK systems. The steps followed are described below:

KPI Description: The methodology begins by clearly defining the KPIs relevant to the evaluation of novel electric trucks. Each KPI is described, outlining its purpose and relevance to the performance goals. This step ensures a shared understanding of the specific metrics to be assessed, facilitating consistency and accuracy throughout the evaluation process.

KPI Assessment Method: Once the KPIs are defined, the next stage involves establishing appropriate assessment methods. This step outlines the procedures, tools, and techniques to be employed in measuring and evaluating the identified KPIs. Whether it involves data collection, simulations, or real-world testing, the assessment method should be selected to provide reliable and meaningful results.

Parameters and Details: To effectively answer each KPI, it is essential to determine the parameters and their associated details required for evaluation. This involves specifying the relevant measurements/data that contribute to the assessment of each KPI.

Risks and Challenges: Recognizing the risks and challenges that may arise during the evaluation phase is a crucial aspect of the methodology. Identifying potential obstacles, such as data limitations, technical constraints, or resource constraints, allows for proactive mitigation strategies.

3.2.1 Efficiency Increase & Payload Capacity

Description

In pursuit of Outcome 1 *[Provide innovative, competitive and affordable zero tailpipe emissions vehicles architectures for regional medium freight transport and distribution full electric N2 and/or N3 category vehicles (VECTO vehicle group 1, 2 or 3, i.e. with Gross Vehicle Weight >7.5 t), with prototype(s) fully validated for a zero-emission driving range of at least 200 km under driving conditions comparable to VECTO regional and urban delivery mission profiles, with strong synergies of urban and suburban operations.*], which entails developing a specialised concept for regional medium freight haulage (N2 & N3), NextETRUCK aims to achieve a minimum 10% increase in energy efficiency compared to existing SoA EVs (Statement of the Art Electric Vehicles) within the same size category and operating under similar mission profiles. To assess progress towards this objective, specific quantitative Key Performance Indicators (KPIs) have been identified.

- **KPI-1a** Distance Driven per Energy Consumption (absolute and relative): Achieve 10% longer range per energy consumption in comparison with the state-of-the-art similar EVs.
- **KPI-1b** Load per mission: Achieve at least 90% loaded case in comparison to the ICE trucks for similar missions.

Methodology

KPI-1a Distance Driven per Energy Consumption (absolute and relative)

Compare energy consumption in [kWh/km] and its corresponding percentage energy consumption reduction compared to the baseline vehicle for different weather, traffic conditions and the same payload.

Calculations:

- Equation absolute numbers:

$$E_{ConNextETRUCK}\left[\frac{kWh}{km}\right] = \frac{(E_{NextETRUCK}\,[kWh])}{(L[km])}$$

  Equation absolute numbers unit metric: kWh/km

- Equation relative numbers:

$$\rho E[\%] = \frac{E_{ConBT}\left[\frac{kWh}{km}\right] - E_{ConNextETRUCK}\left[\frac{kWh}{km}\right]}{E_{ConBT}\left[\frac{kWh}{km}\right]} * 100\%$$

  Equation relative numbers unit metric: %

- $E_{NextETRUCK}$ = Absolute energy consumption [kWh]
- L = Distance [km]
- ρE[%] - relative energy consumption
- E_{conBT} [kWh/km]- energy consumption baseline truck
- $E_{conNextETRUCK}$ [kWh/km]- energy consumption NextETRUCK

KPI-1b Load per mission

Compare KPI-1a for the resulting 3 vehicles with the 3 baseline e-Trucks, when carrying, 90% of the payload, the 3 defined ICE trucks are carrying right now

$$W_{ratio} = \left(\frac{W_{BaseTruck}}{W_{NextETRUCK}}\right) * 100\%$$

- $W_{NextETRUCK}$ = loading capacity NextETRUCK [kg]
- $W_{BaseTruck}$ = loading capacity Base Truck [kg]

Ratio unit metric: %

Data requirements

Attribute	Unit	Specific data requirements	Note
Absolute energy consumption	kWh		
Distance	km		
Payload	kg		
Temperature (weather)	°C		
Weather conditions			
Traffic conditions			
Energy consumption baseline vehicle	kWh/km	Data gather in the same condition as NextETRUCK	
Loading capacity NextETRUCK	kg		
Loading capacity Base Truck	kg		

Risks / Challenges

Risk	Impact	Mitigation
Missing data	Not accurate estimation of the KPIs	Simulation via the DTs

3.2.2 Thermal management system efficiency

Description

KPI-2 considers the impact of the implemented thermal efficiency measures on the operational range of the NextETRUCK vehicles across use cases. It aims to ensure that the range reduction caused by heating remains minimal, allowing the NextETRUCK to perform effectively and meet the demands of various operating conditions.
The KPI is formulated as follow:
KPI-2: For all use cases, achieving at least 95% of the ZEV truck operation range while heating is used, compared to no heating.

Methodology

As there is no commitment from OEM to implement the measures we need to follow two approaches.

1. Directly measures.
2. Simulation (supported by AIT).

$$Opr.Range.ratio = \frac{Driving\ range\ with\ thermal\ eff.}{Driving\ range\ without\ thermal\ eff.}$$

Data requirements

Attribute	Unit	Specific data requirements	Note
Driving range with thermal eff.	km		
Driving range without thermal eff.	km		
Absolute energy consumption	kWh		
Distance	km		
Payload	kg		
Temperature (weather)	°C	Temperatures outside the cabin	
Temperature (inside cabin)	°C		
Temperature (set temp. inside cabin)	°C	Temperature of the cabin should be set to 23°C. The outside temperature should range between 5°C and 35°C	
Electric energy heating elements	W	Electric energy (heating elements) used to maintain cabin comfort, as consumed from the battery	
Weather conditions			
Traffic conditions			
loading capacity NextETRUCK	kg		

Risks / Challenges

Risk	Impact	Mitigation
Thermal efficiency measures will not be implemented by OEM.	No data from demonstration	Simulation
Thermal efficiency measures are designee only for one truck (in one use case)	No data from other use cases	Simulation
Energy from the heading elements not available	Unclear energy consumption by the heating elements	
Cabin set Temperature not available	Unclear energy consumption by the heating elements	

3.2.3 Realization of fleet management system

Description

The project aims to create an accessible and user-friendly fleet decarbonization strategy tool that operates through a web-based platform. This tool will assist fleet operators across Europe in making informed decisions regarding the adoption of zero-emission trucks and charging infrastructure. By utilizing the strategy tool, fleet operators will gain a comprehensive understanding of the suitability of zero-emission trucks, along with the potential environmental and cost savings over their lifecycle, as compared to alternative technologies.

In addition to the fleet decarbonization strategy tool, a charging strategy tool will also be developed. This tool will incorporate a map feature, allowing fleet managers to input their depot locations and typical routes. Using this information, the tool will estimate the state of charge (SoC) of the battery for each route. It will identify routes that would require top-up recharges along the way, including the locations of public charge points displayed on the map. The tool will also determine routes that can be managed with an overnight depot charge, eliminating the need for intermediate recharges.

KPI-4 *Realization of fleet management system* addresses whether the proposed tools have been successfully developed and implemented.

Methodology

The following steps will be considered:

- **Tools description**: Specify the algorithms and interface that will be used by the fleet owners.
- **Data Collection**: Gather data from the fleet management tool, electric trucks, and associated systems. This includes information on energy consumption, charging patterns, vehicle performance, maintenance records, operational costs, and user feedback.
- **Performance Evaluation**: Assess how effectively it helps optimize energy usage, manage charging infrastructure, improve vehicle utilization, reduce costs, and enhance overall fleet operations. Compare the actual performance against benchmarks or without using the tools.
- **User Feedback and Satisfaction**: Conduct interviews, or user feedback sessions to gather insights from fleet operators and managers who have utilised the tool. Assess their satisfaction levels, identify areas of improvement, and determine if the tool meets their needs and expectations.

This KPI will mainly be assessed by means of simulation in order to evaluate the benefits of the tool at a fleet level and not only per individual vehicle.

Data requirements

Attribute	Unit	Specific data requirements	Note
Energy usage	kW		
Charging time	min		
Charging stops	#		
Vehicle average speed	km/h		
Vehicle maintenance breaks	hours		
Operational cost	€	Charging costs, maintenance costs, costs because of deadtime during charging, etc	
Baseline data		As above when not using the fleet management tool	

Risks / Challenges

Risk	Impact	Mitigation
Baseline data not available from the collaborating partners in the UCs	Inaccurate estimation of the successful realisation of the tool	Collect data through external fleet owners or unions such as IRU
The missions for both UCs and simulations are not complex enough to require an advanced management tool	Not accessing the real value of the tool	If necessary, add an additional UC during T8.3 that require e.g. more frequent public charging

3.2.4 Digital Twin realization and tools for ZEV virtual validation

In this section, a group of three KPIs are elaborated in order to obtain the Objective-2 (Advanced vehicle Digital Twin, as well as digital tools for fleet management and virtual integration of ZEV).

Description

- **KPI-3:** Realization of the High-fidelity Digital Twin ensuring advanced and multi-parameter modelling of the electrical vehicle reliability and energy-use.
- **KPI-4:** Realization of algorithms and tools for fleet-level management of electric vehicles.
- **KPI-5:** Realization of the digital tool for the ZEV virtual validation, seamless integration to the ecosystem and operational optimization by fleet managers.

A ZEV digital twin concept at different DT levels (shown in the table below) need to be developed that is capable of:

- Performing rapid impact assessment of the new ZEV powertrain architectures that are realized by the developed technologies and innovations through the project, where, by this means, achieving significant shortening of the ZEV development stage when deploying equivalent or similar ZEVs to various use cases,
- In comparison to the existing ZEV fleets that lack the connectedness synergy between the vehicle, infrastructure and the fleet ecosystem, reducing the energy and system costs by means of deducing eco-driving scenarios with the physical-to-digital feedback system, that is updated by the vehicle-, fleet- and ecosystem-level data, as well as optimally generated mission profiles with respect to live traffic data and prediction uncertainty,
- Reducing the operational costs of ZEVs through holistic eco-strategies for logistic hub interactions, fleet management, charging, routing and driving, leading to more affordable ZEV fleet operations.

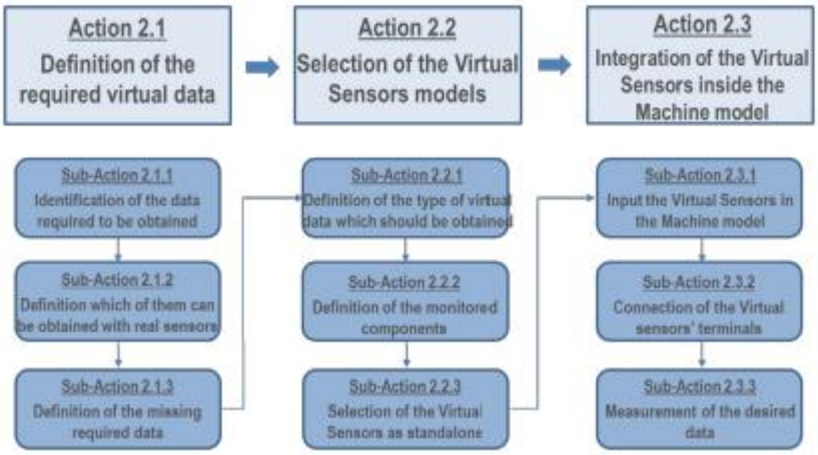
Table 4. Different DT levels of the digital twin concept

Digital Twin Level	Digital Twin Description	DT Developer
Sub-system/ component level	Battery DT characterising aging	TNO
	Battery DT for charge time estimation	TNO
	HiFi/MED-Fi of the e-powertrain, its component thermal model and eco-driving control	VUB
	Model for the vehicle cabin and the HVAC system	AIT
	Vehicle cooling system model	AVLD
Vehicle level	Vehicle DT characterising energy consumption	AVL-AT
	Traffic flow info, routing & content	NNG
	Digital twin for multi-level control system optimization	TEC
Fleet level	Charge management platform	PANION
	Logistics planner & mission assignment	CERTH
	Modular IoT & fleet management	DATIK

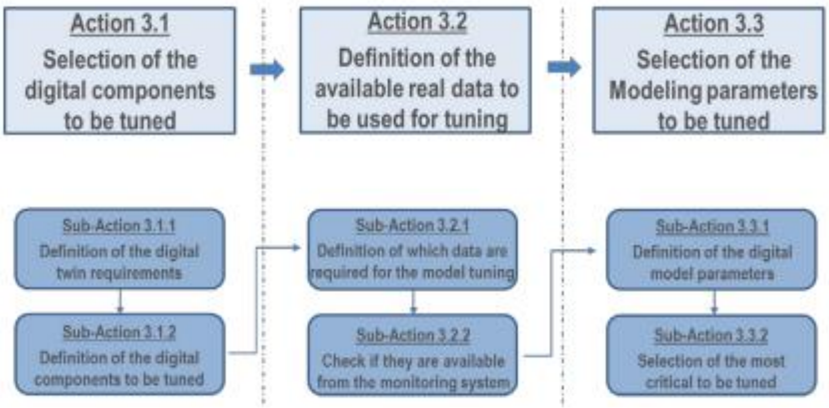
(Note: a module description can be found in D2.4)

Methodology including three phases has been prepared for DT realization.

- *The first phase*: Modelling of dynamic behaviour of different systems toward DT models in T4.1. Each element could be modelled as: black box (masked/protected model), grey box (parameterised model), or white box (fully opened model).
- *The second phase*: Modelling of virtual sensors aiming to monitor and gather data during the simulation. Following actions are foreseen.



- *The third phase*: Definition of the modelling parameters aiming to online updating based on real gathered data. Following actions are foreseen.



Tools for ZEV virtual validation

The figure below shows a workflow overview of the main steps required to generate and run a digital twin based on the AVL software suite. First, a SysML (Systems Modelling Language) based tool, which is often integrated with a requirement tool, generates a system architecture. This is often generated as an XMI file (based on the OMG standard) and contains information on what components are in a system and how they are wired together. A file importer is used to generate industry standard SSP (System Structure and Parameterization) files for import into the model execution tool. Next the models are created in CRUISETM, which has over 100 pre-built 0-D and 1-D model components, tailored to the mobility industry, to allow quick generation of working components and systems. These can be exported as industry standard FMI files, both to preserve intellectual property (IP) around the parameterization, but also for use in any simulation execution environments that support it. The parameter management is handled by CRETATM which allows easy storage and versioning of parameter sets with hundreds of thousands of entries. Simulation execution is handled by Model.CONNECT. All the previous three components (System Architecture, Models and Model Parameterization) are combined in this tool for execution.

Test execution is handled via CAMEOTM which handles all test types, which we have broadly separated into two categories: manual tests and automated tests. Manual tests are designed to mimic a testbed or chassis dynamometer. Cycles can be run, and parameters manually or automatically changed, to scope out the behaviour of the modelled systems. Automated tests are designed to run a predetermined sequence of tests, with the aim of understanding system behaviour and optimizing their performance. This could involve anything from individual component dimensioning to full controller tuning. Real-world tests – automated and manual testing in the physical world is handled in much the same way, with the advantage that any tests performed in simulation can be run in the real world with very little modification. Post processing is handled by CONCERTOTM which is a data analytics platform for visualizing and comparing different datasets. There are many toolboxes built in that allow automation of data manipulation tasks and preparation of data for storage and reporting.

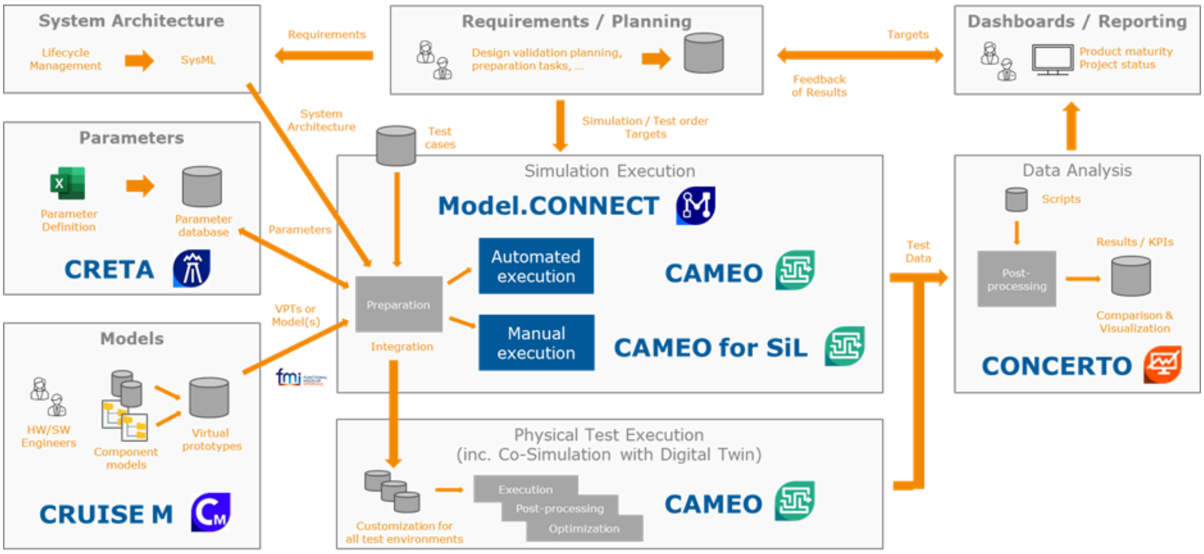


Figure 2: Main steps required to generate and run a digital twin

Risks / Challenges

Risk	Impact	Mitigation
Lack of data availability of Models on component, vehicle and fleet level from WP3	DT will be at upper level, not providing much detail	Similar baseline models from previous projects could be updated and used.
Implementing/integrating the proposed enhanced control loops at vehicle level due to technical or accessibility reasons	The DT will not be able to simulated UCs scenarios with the expected data response	Simplify the proposed controls loops and algorithms and/or find an intermediate solution to assure access to necessary minimum data.
Reduced scalability of the designed component models	Limited usage of the DT	Define properly in WP2 the parameters and vehicle types expected to be covered by the digital twin.

Risk	Impact	Mitigation
Insufficient data to obtain sound results and clear impacts to the defined KPIs	High	The KPIs and the assessment plan will be defined in collaboration with WP2 to ensure that the data generated will drive to a clear identification of the potential benefits. The use of digital twin models' simulation will complement the real-world developments.

3.2.5 TCO reduction of ZEV

Description

This KPI concerns the reduction of the total cost of ownership (TCO) of the NextETRUCK vehicle against the baseline cases of the earlier generation battery electric vehicle (BEV) and internal combustion engine vehicle (ICE) equivalents.

The general project-wide definition of **KPI-6** is:
KPI-6: 20% TCO reduction of ZEV is achieved in addition to parity with ICE 2020 trucks.

For the purpose of evaluation, this KPI has been further refined to two measurable sub-KPIs:
KPI-6a: 20% TCO reduction of ZEV is achieved when compared with a modern e-truck.
KPI-6b: TCO parity with ICE 2020 trucks.

TCO will be considered to include both the innovations to the physical design of the NextETRUCK vehicles with each OEM, and the fleet-level management and efficiency innovations including eco-routing, eco-charging etc. TCO will be calculated separately for each use case.

Methodology

Calculation of the TCO for both the NextETRUCK design and the two baseline cases will require an estimation of the capital expenditures (CAPEX) and operational expenditures (OPEX) over the total expected vehicle lifetime for each given vehicle use case.

The CAPEX and OPEX can be broadly defined by the following equations:

$$CAPEX = \sum Retail\ Cost_{Vehicle} - \sum Residual\ Value_{Vehicle} + \sum Retail\ Cost_{Charger}$$

$$OPEX = \sum Lifetime\ Charge\ Costs + \sum Lifetime\ Maintenance\ Costs_{Veh} + \sum Vehicle\ Taxes + \sum Lifetime\ Maintenance\ Costs_{Ch}$$

A calculation of the above costs at the early lifetime stage of a vehicle demonstrator will require some estimation to extrapolate measured vehicle and charger performance to the full hardware lifetime and to scale costs up to fleet-level use cases and missions.

Data requirements

Performance of all aspects of the NextETRUCK demonstrators in each use case must be captured for the extrapolation to typical annual and whole-life costs for the vehicle operation. Equivalent operational data for both BEV and ICE baseline vehicles must also be available for comparison of costs, however, data from an identical duty cycle to the measured NextETRUCK performance will be difficult to obtain. Intelligence can be applied to the data analysis exercise to target or isolate specific sections of the duty cycle from the baseline vehicle, so that they match the duty cycle sections from the NextETRUCK vehicle. This way we can enable a fairer comparison of performance data between vehicles, which in turn feeds the TCO calculations.

The specifics of how each aspect of the TCO calculation will be calculated will be adapted to ensure that a reasonable estimate of TCO is created with the available data.

Attribute	Unit	Specific data requirements	Note
NextETRUCK, BEV baseline & ICE baseline vehicle cost	€/unit	Cost of vehicle (including battery for both BEV, any physical design changes from NextETRUCK project).	
NextETRUCK, BEV baseline & ICE baseline vehicle residual value	€/unit	Residual cost of vehicle including battery for both BEV options.	
NextETRUCK & BEV baseline charger cost	€/unit	Cost of NextETRUCK and baseline charger hardware.	
Annual operational energy demand per UC: NextETRUCK, BEV and ICE baselines	KWh/year, litre/year	Assumed annual energy required for each NextETRUCK vehicle to fulfil each UC.	Should include impacts of: annual km, external conditions, vehicle performance, routing software, fleet management for NextETRUCK.
Vehicle lifetime	years	Intended vehicle lifetime per UC.	Defined by each UC.
Charge efficiency	%	Efficiency of NextETRUCK charger at each UC.	

Attribute	Unit	Specific data requirements	Note
Managed recharge/refuel unit cost per UC: NextETRUCK, BEV and ICE baselines	€/kWh, €/litre	Cost of grid-side energy demand of NextETRUCK & BEV vehicle charging per UC. Cost of refuelling ICE baseline per UC.	Includes both local electricity costs over time and charge management cost optimization for NextETRUCK
Annual vehicle maintenance cost per UC: NextETRUCK, BEV and ICE baselines	€/year	Likely cost of both short-term and longer-term vehicle maintenance required for each UC.	Includes impact of IoT predictive maintenance for NextETRUCK.
Local taxes per UC: NextETRUCK, BEV and ICE baselines	€/year	Relevant annual taxes, subsidies or other costs for each UC.	
Annual charger maintenance cost per UC: NextETRUCK, BEV baseline	€/year	Likely cost of charger maintenance required for each UC.	

Risks / Challenges

The level of detail and accuracy possible for the TCO calculation will depend on the vehicle performance and cost data available to the project.

Risk	Impact	Mitigation
Demonstrator data does not cover full typical yearly conditions for performance estimation.	Accuracy of estimated yearly energy demand is reduced.	Extrapolate average yearly energy performance from existing data and digital twin simulation using year-round conditions.
Baseline vehicles for BEV and ICE baseline cases not available for measurement, neither during the trial nor historic data	Comparison of measured performance data not possible.	Simulation of baseline vehicles if available, or use of industry average performance data.
Historic or trial data from baseline vehicles available, but energy consumption from exact equivalent duty cycle not available	Direct comparison for like duty cycles not entirely possible.	Closest possible estimate made with available data. Intelligence applied to data analysis to isolate and target specific sections of baseline duty cycle that match as

Risk	Impact	Mitigation
		close as possible duty cycle sections from NextETRUCK use case pilots.
Local data from each UC not available for maintenance costs, taxes/subsidies etc.	Accuracy of vehicle operational costs reduced	Estimation made using average publicly available values in Europe

3.2.6 Charger efficiency

Description

KPI-7 focuses on the attainment of up to a 4% increase in average efficiency by leveraging WBG-based power modules within the NextETRUCK project. This KPI is crucial for achieving Outcome 4, which involves demonstrating fast-charging concepts that align with established regulations and business practices, specifically at load/unload points, to enable efficient operations.

The formulation of KPI-7 is as follows:
KPI-7: Up to 4% more average efficiency increase is achieved at WBG-based power modules.

Methodology

To evaluate the effectiveness of WBG-based power modules, the following approaches will be undertaken:

1. Laboratory measurement: Direct measurements will be conducted to assess the efficiency gains achieved through the implementation of WBG-based power modules. (Supported by JEMA measurements and data)
2. Demonstration measurement: This involves capturing real-time data from the charger during the demonstration.

η_{WBG} = WBG charger efficiency [%]
E_{ch} = Energy to the charger in 1 charging cycle [kWh]
E_{bat} = Energy from the charger in 1 charging cycle [kWh]
η_{ref} = Reference “Si” charger efficiency [%]

$$\eta_{WBG} = \frac{E_{bat}}{E_{ch}} * 100\%$$

$$4\% \geq \frac{(\eta_{WBG} - \eta_{ref})}{\eta_{WBG}}$$

Data requirements

Attribute	Unit	Specific data requirements	Note
Energy to the charger	kWh	Energy going to the charger	
Energy from the charge	kWh		
Temperature (weather)	°C		
Reference “Si” charger efficiency	%	Reference charger of the same power used on the same vehicle	

Risks / Challenges

Risk	Impact	Mitigation
Missing reference charger data	4% improvement will be not visible	Look up SoA of chargers
Missing energy information during the demonstration	Not possible to determine the charger efficiency during the demonstration operation	Use only data from the laboratory measurement

3.2.7 Vehicle thermal efficiency

Description

KPI-8 focuses on improving thermal efficiency to achieve Outcome 1 and 2 providing innovative and competitive ZE vehicle architectures with a zero-emission driving range of at least 200 km under driving conditions comparable to VECTO regional and urban delivery mission profiles. To be able to achieve this the KPI was formulated as follows:
KPI 8: Vehicle thermal efficiency is improved by 15%.

Methodology

As there is no commitment from OEM to implement the measures we need to take 2 approaches.

1. Directly measures. Measure the required energy for heating on the NextETRUCK with the improving thermal efficiency and on a truck without the thermal improvement.
2. Simulation (supported by AIT). Simulate the required energy for heating with and without thermal efficiency measures

To gather the needed data the data should be gathered from the baseline truck and the NextETRUCK should be gathered at similar time/conditions.

Electric energy (heating elements) and thermal energy (temperatures outside and inside the cabin, and set temperature) are used to maintain cabin comfort, as consumed from the battery

$$\eta_{Vth} = \frac{E_{heating\_with\_imp}}{E_{heating\_without\_imp}}$$

$$15\% \approx \frac{(\eta_{Vth} - \eta_{ref})}{\eta_{Vth}}$$

Data requirements

Attribute	Unit	Specific data requirements	Note
Driving range with thermal eff.	km		
Driving range without thermal eff.	km		
Absolute energy consumption	kWh		
Distance	kW		
Payload	kg		
Temperature (weather)	°C	temperatures outside the cabin	
Temperature (inside cabin)	°C		
Temperature (set temp. inside cabin)	°C	The temperature of the cabin should be set to 23°C. The outside temperature should range between 5°C and 35°C	
Energy consumed by a standard cabin vehicle to maintain indoor comfort	W	Electric energy (heating elements) used to maintain cabin comfort, as consumed from the battery	
Weather conditions			
Traffic conditions			
loading capacity NextETRUCK	[kg]		

Risks / Challenges

Risk	Impact	Mitigation
Thermal efficiency measures will not be implemented by OEM.	No data from demonstration	Simulation
Thermal efficiency measures are designee only for one truck (in one use case)	No data from other use cases	Simulation
Energy from the heading elements not available	Unclear energy consumption by the heating elements	

Risk	Impact	Mitigation
Cabin set Temperature not available	Unclear energy consumption by the heating elements	

3.2.8 e-powertrain design

Description

KPI-9: Complete e-powertrain design tool is realised and validated.

In order to ensure the correct Design decisions, it is important to take a holistic view, hence the combination of the validated digital twins shall be applied within a generic co-design optimization tool/framework (Figure 3). A potential result view is shown in Figure 4 assuming the digital twins would be available. For this figure, just dummy values were used to give a potential impression of the decision-making options.

Methodology

- Based on validated Digital twins as intended to be built according to the “Big Picture” (Figure 2 in D 2.4 "Definition of System Interaction and logical Architecture”) and summarised in the inner part of Figure x, systematic design space investigations shall be enabled. The space of possible design parameters will be big and multidimensional with many interactions to be expected. Therefore, advanced Design of Experiment techniques like “Active DoE” in AVL CAMEO shall be used to see the influence of the change in the design parameters on the TCO. For the Vehicle OEM, parameters such as Battery size, Energy density, Vehicle curb weight, E-motor and Transmission parameters, as well as thermal management parameters and on-board charger parameters will be relevant to the optimization.
- In the consortium having also the charging station suppliers and the logistic partners available as members, also the consideration of the interaction to the charging process might show some potential to be leveraged.
- Since the consortium has charging station suppliers as well as logistics partners, interactions with the charging process may also be a fruitful target for optimization.
- Last but not least, the economic boundary conditions will have an influence, which might not be possible to actively change, but should be understood and incorporated into KPIs, so their influence on costs can be optimised.

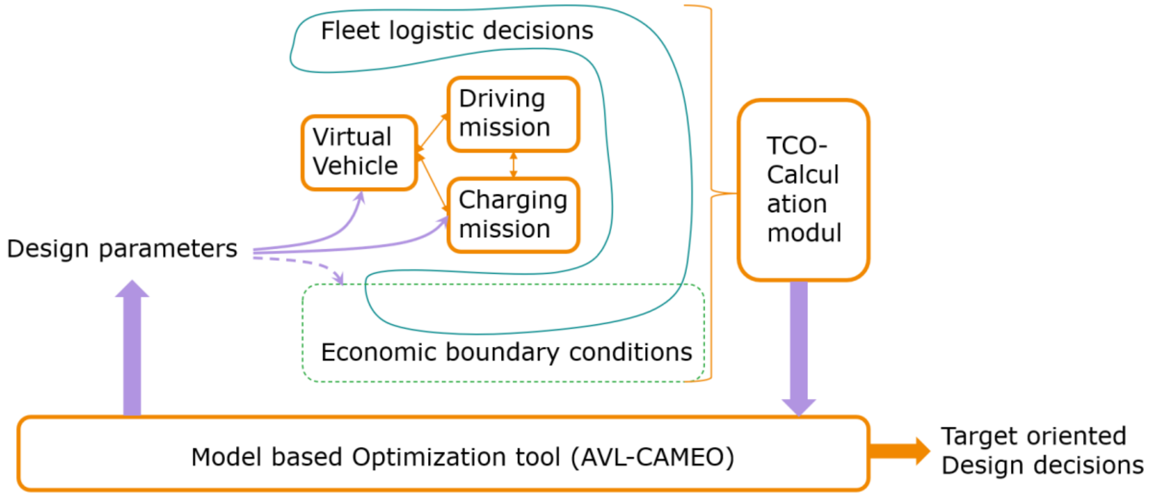


Figure 3: Generic co-design optimization tool/framework

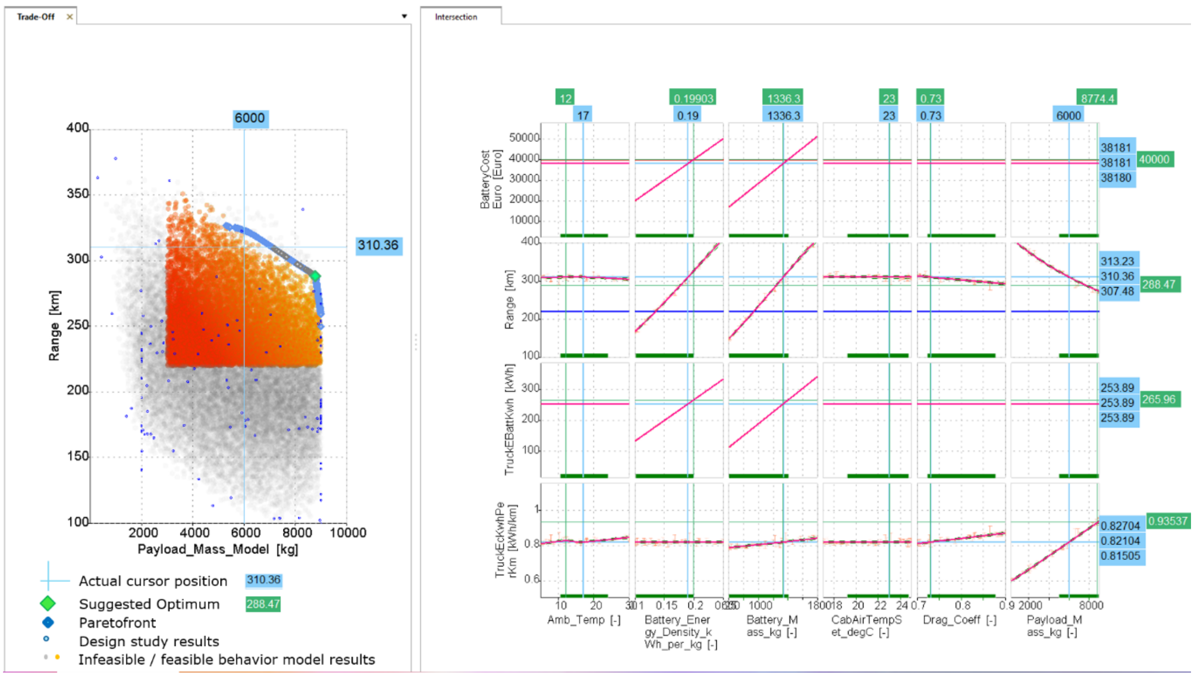


Figure 4: Model based decisions based on trade off views and behaviour models

In Figure 4 there is shown a trade-off graph on the left side, interacting with behaviour models identified out of a design study: varying in this simplified example Ambient Air temperature, available Energy density of the battery, Battery mass designed in, Cabin air temperature, Air drag coefficient and payload. The dependency of Battery cost, Range in a reference cycle, and the related Energy consumption in kWh/km were identified by ca. 120 Simulation calculations in this 6-dimensional space by “Active DoE”

The design optimization requested was using a multi objective target:

- Maximise Range (at least 220 km)

- Maximise Payload (at least 3000 kg)

Constrains

- Battery cost less than 40000 Euro
- Ambient Temperature: 12 °C
- Cabin Temperature: 23 °C

Finally, one can see for example, that applying 0.199 kWh/kg Battery (a 266 kWh Battery weighing 1336kg) will lead to a range of 288 km with 8774 kg Payload.

For further investigations one can easily change the input conditions to see the consequences: As example the actual cursor position is set to a payload of 6000 kg and having available 0.19 kWh/kg Battery and ambient temperature of 17 °C leading to a range of 310 km.

Data requirements

Attribute	Unit	Specific data requirements	Note
Designed Vehicle masses E-Motor-Power Battery Energy density	kg		Drive train parameters and possible design options (tbd. In detail)
			Charging Process parameters

Risks / Challenges

Risk	Impact	Mitigation
Validation of DGT would show significant deviations	Optionally wrong decisions	Fine tune DGTs with field data

3.2.9 TCO reduction of charging

Description

KPI-10: 15% TCO reduction for the fleet charging infrastructure.

This KPI is closely related to KPI-6, as both KPIs are related to the total cost of ownership of the NextETRUCK innovations. This KPI is defined to include the TCO impacts specific to the charging infrastructure, including:

- Charging hardware design and efficiency improvements
- Charge infrastructure planning and management tools
- Possibility of double shifting facilitated by high power charge
- Any additional impacts on number of chargers/vehicles e.g. through load capacity increase

As with the TCO of the vehicle or fleet, a reduction will be calculated with reference to a baseline charger.

Methodology
Similarly to KPI-6, calculation of the TCO for both the NextETRUCK charging infrastructure and the baseline BEV infrastructure will require an estimation of the capital expenditures (CAPEX) and operational expenditures (OPEX) over the total expected hardware lifetime.

Data requirements

Attribute	Unit	Specific data requirements	Note
NextETRUCK & BEV baseline charger cost	€/unit	Cost of NextETRUCK and baseline charger hardware.	
Charger units required: NextETRUCK and baseline	No. units	Number of charger units required per UC, NextETRUCK and baseline.	Including NextETRUCK impacts on chargers needed, e.g. planning outputs.
Annual operational energy demand per UC: NextETRUCK, BEV baselines	KWh/year,	Assumed annual energy required for each NextETRUCK vehicle to fulfil each UC.	Should include impacts of: annual km, external conditions, vehicle performance, routing software, fleet management for NextETRUCK.
Vehicle lifetime	years	Intended vehicle lifetime per UC.	Defined by each UC.
Charge efficiency: NextETRUCK & BEV baseline	%	Efficiency of NextETRUCK & baseline charger at each UC.	
Managed recharge/refuel unit cost per UC: NextETRUCK, BEV baseline	€/kWh	Cost of grid-side energy demand of NextETRUCK & BEV vehicle charging per UC.	Includes both local electricity costs over time and charge management cost optimization for NextETRUCK
Annual charger maintenance cost per UC: NextETRUCK, BEV baseline	€/year	Likely cost of charger maintenance required for each UC.	

Risks / Challenges

This KPI shares its risks and mitigations with KPI-6, as detailed in the section above.

3.2.10 Double shift fleet operation

Description

KPI-11 *Double shift operation* for the fleet operator aims to answer the scenario of using the NextETRUCK vehicles for more than one shift, thus, improving the TCO by minimizing the investment in rolling stock. The main constrain for the double shift usage is the recharging time for a sufficient recharge of the e-truck to successfully perform the next mission within the time window as set by the customer.

Methodology

The proposed method consists of the following steps:

1. Collection of relevant data about the electric truck fleet and its operations. This may include information on vehicle usage patterns, charging requirements, driver schedules, and any existing operational constraints.
2. Analysis of the operational aspects of the electric truck fleet to understand its current performance and identify areas for improvement. Assess factors such as vehicle availability, charging infrastructure availability, driver availability, route planning, and operational constraints related to regulations and driver hours.
3. Evaluation of the existing charging infrastructure to determine its capacity and compatibility with double shift operations. Assess the availability of charging stations, their power capacity, charging times, and any potential limitations that may impact the feasibility of double shift operations.
4. Examination of the battery performance of the e-trucks to ensure they can sustain double shift operations. Analysis of factors such as battery range, degradation over time, charging cycles, and the need for additional charging during the double shift period.
5. Performing a financial analysis of the cost and benefit to assess the financial implications of implementing double shift fleet operations. Consider factors such as increased vehicle utilization, potential savings in driver wages, maintenance costs, and energy consumption. Compare the projected benefits with the additional costs associated with implementing the double shift operation.

Data requirements

Attribute	Unit	Specific data requirements	Note
Energy usage	kW		
Charging time	min		
Charging stops	#		
Vehicle average speed	km/h		

Attribute	Unit	Specific data requirements	Note
Vehicle maintenance breaks	hours		
Operational cost	€	Charging costs, maintenance costs, costs because of deadtime during charging, drivers wage, etc	
Baseline data		As above when the e-truck not used more than one time per day	

Risks / Challenges

Risk	Impact	Mitigation
The missions for both UCs and simulations are not complex enough to require double shift	Not accessing the KPI accurately	If necessary, add an additional UC during T8.3 that require e.g. two or more missions per day

3.2.11 Charging experience

Description

KPI-12: Improved charging experience and CO_2 reduction due to eco-charging management tool. This KPI has been further divided into two quantitative and qualitative sub-KPIs:

- *KPI-12a: Improved charging experience due to eco-charging management tool.*
- *KPI-12b: CO_2 reduction due to eco-charging management tool.*

Methodology

KPI-12a: Improved charging experience

This KPI will be evaluated via qualitative assessment of online surveying of the relevant stakeholders at each use case location (vehicle users, fleet managers, as appropriate at each demonstrator) to compare the user experience of the managed charging against experience with unmanaged charging.

In the ideal case, this will involve a short test period where the NextETRUCK charge management system is disabled to allow users to experience the difference in charging operation with the same vehicle and charger.

Risks / Challenges

Risk	Impact	Mitigation
Charge management system cannot be disabled for test period	Direct comparison of managed vs unmanaged charging not possible for NextETRUCK vehicle and charger.	Collection of qualitative experiences with the NextETRUCK charging system still completed. Comparative unmanaged charging relies on users'

Risk	Impact	Mitigation
		previous experience with EV charging.
Users are not able or willing to complete the surveys	Missing part of results of assessment.	Alternative users of the vehicle are surveyed if multiple users are available. Assessment is completed with a limited set of the use cases if alternative users not available.
Users cannot complete the survey as designed in English	Missing part of results of assessment.	Survey is translated into local languages for each use case with the help of project partners.

KPI-12b: CO_2 reduction

The live eco-charging management tool to be developed in Task 6.4 must demonstrate reduced carbon emissions for a given recharging energy demand vs the use of an unmanaged charger. The carbon emissions from each charging session can be calculated by assessing the power drawn from the grid at each moment during the charging session and the local grid carbon intensity during this period.

If it is possible to allow the physical vehicle demonstrators to run a short test period of unmanaged charging, a directly measured comparison can be made of the average carbon emission per kWh drawn from the grid during managed charging and unmanaged charging. However, it is expected that the local grid carbon intensity will vary from day to day, meaning that measurements taken on different days may show variation in emissions not related to the effectiveness of the charging management system. It is therefore preferable to assess this KPI via simulation, where for a fixed energy demand and grid intensity profile, the PANION charging system can supply a managed and unmanaged charging profile, and the associated carbon intensity of each charge session can be calculated.

As the PANION charging management system will calculate carbon emissions as part of the management process, the easiest method to measure this outcome would be as a direct output of their system. If this is not possible, charging intensity can be estimated using publicly available grid intensity data.

Data requirements

Attribute	Unit	Specific data requirements	Note
Unmanaged charging carbon emissions	$kgCO_2$/kWh charged	Average carbon emission per kWh charged over the test period.	Can be obtained via measurement or simulation, with simulation preferred for comparability.

Attribute	Unit	Specific data requirements	Note
Managed charging carbon emissions	$kgCO_2/kWh$ charged	Average carbon emission per kWh charged over the test period.	Can be obtained via measurement or simulation, with simulation preferred for comparability.

Risks / Challenges

Risk	Impact	Mitigation
PANION system is not able to output carbon emissions data for comparison	Emissions as calculated by the management system cannot be verified	Manual calculation of emission per charge cycle based on charging profile and local grid carbon intensity.
Local grid carbon intensity data not available for all use cases.	Accuracy of carbon emission estimate reduced.	Use of national-level or Europe-wide average grid intensity data.

3.2.12 Realisation of UC1

Description

KPI-13 aims to fulfil Outcome 1 of project, which involves providing fully electric N2 and/or N3 category vehicles for regional medium freight transport and distribution. These vehicles, belonging to VECTO vehicle groups 1, 2, or 3 with a Gross Vehicle Weight exceeding 7.5 tons, will be equipped with prototypes that are fully validated for a zero-emission driving range of at least 200 km. The driving conditions will be comparable to VECTO regional and urban delivery mission profiles, emphasizing the integration of urban and suburban operations.

The KPI is formulated as follows:
KPI 13: Goods distribution e-truck in Istanbul, with FORD as the OEM, is successfully in operation for a daily range of more than 200 km for a minimum period of 6 months.

This KPI has been further divided into two quantitative and qualitative sub-KPIs:
KPI 13-a: The vehicle can achieve a reference range of 200 km per day.
KPI 13-b: The NextETRUCK vehicles meet user needs.

KPI 13-a: Vehicle can achieve a reference range of 200 km per day

Methodology

The average daily distance covered by the vehicle during a usual working schedule in 6 months should be >200 km without recharging the vehicle.

Data requirements

Attribute	Unit	Specific data requirements	Note
Absolute energy consumption	kWh		
Distance	km		
Payload	kg		
Temperature (weather)	°C		
Weather conditions			
Traffic conditions			
loading capacity NextETRUCK	kg		
energy consumption NextETRUCK	kWh/km		
SoC	%		

Risks / Challenges

Risk	Impact	Mitigation
The demonstrator does not achieve 200 km usage	Missing operation range in real driving conditions	Estimate the maximum possible range with the same usage by extrapolating from the remaining SoC after UC is completed.

KPI-13-b: User needs analysis

Methodology

First, we identify the user needs for this project. To assess if the user needs are met within this project, qualitative data will be gathered by conducting interviews with different stakeholders. Each of the three pilots has different applications of medium duty trucks, we need to analyse the context of the pilot and conduct a stakeholder analysis to create an understanding of how and who are involved in operating the vehicles. Semi-structured interviews will be held by CENEX Nederland with the most relevant stakeholders. The interview guide will be tailored to the involvement of the stakeholder in the operational processes. The interviews will be summarised in a paragraph per identified user need, all relating information across all interviews is summarised. A cross-case analysis will be conducted to understand the differences in results among the three pilots. The methodology will therefore include the following steps:

1. Identification of user needs
2. Context analysis
3. Stakeholder analysis
4. Interview guide
5. Conducting the interviews
6. Analysis of results

In case too many stakeholders are involved; the interview could be replaced by either a survey or a focus group workshop.

Risks / Challenges

Risk	Impact	Mitigation
Stakeholders not able or willing to be interviewed	Missing part of results of assessment	Interview similar stakeholders from other levels, or interview stakeholders that are closely related to the operations missing
Recording interviews may withhold stakeholders from being completely honest	Biased results	Best to interview face-to-face to make the stakeholder more comfortable
Stakeholders who may not speak English	Unable to be interviewed by CENEX Nederland	Ask local partners to help

3.2.13 Realisation of UC2

Description

Similarly to KPI-13, **KPI-14** aims to fulfil Outcome 1 of the NextETRUCK project, which involves providing fully electric N2 and/or N3 category vehicles for regional medium freight transport and distribution. These vehicles, belonging to VECTO vehicle groups 1, 2, or 3 with a Gross Vehicle Weight exceeding 7.5 tons, will be equipped with prototypes that are fully validated for a zero-emission driving range of at least 200 km. The driving conditions will be comparable to VECTO regional and urban delivery mission profiles, emphasizing the integration of urban and suburban operations.

The KPI is formulated as follows:
KPI 14: ZEV refuse truck in Barcelona, with IRIZAR as the OEM, is successfully in operation for a daily range of more than 200 km for a minimum period of 6 months.

This KPI has been further divided into two quantitative and qualitative sub-KPIs:
KPI 14-a: The vehicle can achieve a reference range of 200 km per day.
KPI 14-b: The NextETRUCK vehicles meet user needs.

KPI 14-a: Vehicle can achieve a reference range of 200 km per day

Methodology

The average daily distance covered by the vehicle during a usual working schedule in 6 months should be >200 km without recharging the vehicle

Data requirements

Attribute	Unit	Specific data requirements	Note
Absolute energy consumption	kWh		

Attribute	Unit	Specific data requirements	Note
Distance	km		
Payload	kg		
Temperature (weather)	°C		
Weather conditions			
Traffic conditions			
loading capacity NextETRUCK	kg		
energy consumption NextETRUCK	kWh/km		
SoC	%		

Risks / Challenges

Risk	Impact	Mitigation
The demonstrator does not achieve 200 km usage	Missing operation range in real driving conditions	Estimate the maximum possible range with the same usage by extrapolating from the remaining SoC after UC is completed.

KPI-14-b: User needs analysis

Methodology

First, we identify the user needs for this project. To assess if the user needs are met within this project, qualitative data will be gathered by conducting interviews with different stakeholders. Each of the three pilots has different applications of medium duty trucks, we need to analyse the context of the pilot and conduct a stakeholder analysis to create an understanding of how and who are involved in operating the vehicles. Semi-structured interviews will be held by CENEX Nederland with the most relevant stakeholders. The interview guide will be tailored to the involvement of the stakeholder in the operational processes. The interviews will be summarised in a paragraph per identified user need, all relating information across all interviews is summarised. A cross-case analysis will be conducted to understand the differences in results among the three pilots. The methodology will therefore include the following steps:

1. Identification of user needs
2. Context analysis
3. Stakeholder analysis
4. Interview guide
5. Conducting the interviews
6. Analysis of results

In case too many stakeholders are involved; the interview could be replaced by either a survey or a focus group workshop.

Risks / Challenges

Risk	Impact	Mitigation
Stakeholders not able or willing to be interviewed	Missing part of results of assessment	Interview similar stakeholders from other levels, or interview stakeholders that are closely related to the operations missing
Recording interviews may withhold stakeholders from being completely honest	Biased results	Best to interview face-to-face to make the stakeholder more comfortable
Stakeholders who may not speak English	Unable to be interviewed by CENEX Nederland	Ask local partners to help

3.2.14 Realisation of UC3

Description

Similarly to KPI-13 and KPI-14, The **KPI-15** aims to fulfill Outcome 1 of the NextETRUCK project, which involves providing fully electric N2 and/or N3 category vehicles for regional medium freight transport and distribution. These vehicles, belonging to VECTO vehicle groups 1, 2, or 3 with a Gross Vehicle Weight exceeding 7.5 tons, will be equipped with prototypes that are fully validated for a zero-emission driving range of at least 200 km. The driving conditions will be comparable to VECTO regional and urban delivery mission profiles, emphasizing the integration of urban and suburban operations.

The KPI is formulated as follows:
KPI 15: Back to base logistics e-truck for express transport in Utrecht with TEVVA as OEM is successfully in operation for a daily range of more than 200km, for at least 6 months.

This KPI has been further divided into two quantitative and qualitative sub-KPIs:
KPI 15-a: Vehicle can achieve a reference range of 200 km per day
KPI 15-b: NextETRUCK vehicles meet user needs

KPI 15-a: Vehicle can achieve a reference range of 200 km per day

Methodology

The average daily distance covered by the vehicle during a usual working schedule in 6 months should be >200 km without recharging the vehicle

Data requirements

Attribute	Unit	Specific data requirements	Note
Absolute energy consumption	kWh		
Distance	km		

Attribute	Unit	Specific data requirements	Note
Payload	kg		
Temperature (weather)	°C		
Weather conditions			
Traffic conditions			
loading capacity NextETRUCK	kg		
energy consumption NextETRUCK	kWh/km		
SoC	%		

Risks / Challenges

Risk	Impact	Mitigation
The demonstrator does not achieve 200 km usage	Missing operation range in real driving conditions	Estimate the maximum possible range with the same usage by extrapolating from the remaining SoC after UC is completed.

KPI-15-b: User needs analysis

Methodology

First, we identify the user needs for this project. To assess if the user needs are met within this project, qualitative data will be gathered by conducting interviews with different stakeholders. Each of the three pilots has different applications of medium duty trucks, we need to analyse the context of the pilot and conduct a stakeholder analysis to create an understanding of how and who are involved in operating the vehicles. Semi-structured interviews will be held by CENEX Nederland with the most relevant stakeholders. The interview guide will be tailored to the involvement of the stakeholder in the operational processes. The interviews will be summarised in a paragraph per identified user need, all relating information across all interviews is summarised. A cross-case analysis will be conducted to understand the differences in results among the three pilots. The methodology will therefore include the following steps:

1. Identification of user needs
2. Context analysis
3. Stakeholder analysis
4. Interview guide
5. Conducting the interviews
6. Analysis of results

In case too many stakeholders are involved; the interview could be replaced by either a survey or a focus group workshop.

Risks / Challenges

Risk	Impact	Mitigation
Stakeholders not able or willing to be interviewed	Missing part of results of assessment	Interview similar stakeholders from other levels, or interview stakeholders that are closely related to the operations missing
Recording interviews may withhold stakeholders from being completely honest	Biased results	Best to interview face-to-face to make the stakeholder more comfortable
Stakeholders who may not speak English	Unable to be interviewed by CENEX Nederland	Ask local partners to help

3.2.15 Market penetration increase

Description

KPI-16 *Market penetration increase* will answer whether the NextETRUCK vehicles contributes to a 15% increase in the average e-Medium-duty Commercial Vehicles (MCVs) market penetration.

Methodology

Estimating the market penetration of a e-truck involves a systematic analysis of various factors and market dynamics. While the exact method may vary based on specific circumstances, here is a general approach to estimate market penetration:

- **Define the Target Market**: Clearly define the target market segment for the e-truck. Consider factors such as geographical location, industry verticals, customer profiles, and any specific requirements or regulations that may impact market penetration.
- **Market Research**: Conduct market research to gather information on the target market segment. Analyse industry reports, market trends, competitor analysis, and customer preferences. Identify key market influencers, such as fleet operators, logistics providers, or government entities, and gather insights into their purchasing behaviour and decision-making processes.
- **Total Addressable Market** (TAM): Estimate the total addressable market for the e-truck by determining the total number of potential customers or fleet operators in the target market. This can be based on factors such as the number of existing trucks in operation, fleet size, market demand, and growth projections.
- **Market Share Analysis**: Assess the market share of the e-truck's industry in the target market. This can be obtained through industry reports, market surveys, or publicly available data.

- **Differentiation and Value Proposition**: Determine the unique selling points and value proposition of the NextETRUCK vehicles compared to the current trucks. Identify the features, benefits, and advantages that set the NextETRUCK vehicles apart in terms of performance, cost-effectiveness, sustainability, technology, or other key factors. Assess the potential market appeal and competitive advantage of these differentiators.

KPI-16 is strongly related to KPI-6a & b, KPI-10 and KPI-11 and in order to be answered the four related KPIs should be considered.

The market penetration increase can be calculated by comparing the market penetration rates with and without the NextETRUCK vehicles:

$$Market\ Penetration\ Rate\ =\ (Number\ of\ Customers\ /\ Total\ Addressable\ Market)\ *\ 100$$

This equation calculates the market penetration rate by dividing the number of customers by the total addressable market size and multiplying by 100 to express it as a percentage. It provides a measure of how much of the potential market has been captured.

Data requirements

Attribute	Unit	Specific data requirements	Note
Number of customers	#		
Number of potential customers representing the total market of this vehicle segment	#		
Baseline data	#	As above when not considering the NextETRUCK vehicles on the market	

Risks / Challenges

Risk	Impact	Mitigation
Market data not available from the collaborating partners in the UCs	Inaccurate estimation of the market penetration increase	Collect data through external e-truck stakeholders, fleet owners or unions such as IRU. If necessary, acquire dedicated market sales reports

3.2.16 Business models adoption

Description

KPI-17 *Business models adoption* refers to new proposed models by the consortium which are taken up by the Reference Group stakeholders. Such models can be:

- Performance-based Incentives and Subsidies
- Pay-per-Use or Subscription Models
- Shared Mobility and Collaborative Logistics
- Energy-as-a-Service (EaaS)
- Vehicle-to-Grid (V2G) Services
- Battery Leasing

Methodology

Customer surveys and feedback should take place when drafting the business models in T8.3. Surveys or interviews will take place with potential customers or industry experts to gather insights into their awareness, interest, and perception of the e-trucks. Assess their likelihood of adopting the e-truck based on factors such as price, performance, reliability, serviceability, and brand reputation. Based on their feedback, the appropriate business models will be communicated to them that meet their wants and needs. The predominant models will be considered as the ones to answer the KPI.

Risks / Challenges

Risk	Impact	Mitigation
The models are too ambitious for the market status and customer perception	The stakeholders will be sceptical and cautious whether to consider them as potential future business solutions	Simplify the models in a way the e-truck potential customers can realise the benefits through the implementation of such models

3.2.17 The NextETRUCK overall system is compatible with the driving/mission tasks

Description

KPI-18: The NextETRUCK overall system is compatible with the driving/mission tasks

Methodology

First, we identify the user needs for this project. To assess if the user needs are met within this project, qualitative data will be gathered by conducting interviews with different stakeholders. Each of the three pilots has different applications of medium duty trucks, we need to analyse the context of the pilot and conduct a stakeholder analysis to create an understanding of how and who are involved in operating the vehicles. Semi-structured interviews will be held by CENEX Nederland with the most relevant stakeholders. The interview guide will be tailored to the involvement of the stakeholder in the operational processes. The interviews will be summarised in a paragraph per identified user need, all relating information across all interviews is summarised. A cross-case analysis will be conducted to understand the differences in results among the three pilots. The methodology will therefore include the following steps:

1. Identification of user needs
2. Context analysis
3. Stakeholder analysis
4. Interview guide
5. Conducting the interviews
6. Analysis of results

In case too many stakeholders are involved; the interview could be replaced by either a survey or a focus group workshop.

Risks / Challenges

Risk	Impact	Mitigation
Stakeholders not able or willing to be interviewed	Missing part of results of assessment	Interview similar stakeholders from other levels, or interview stakeholders that are closely related to the operations missing
Recording interviews may withhold stakeholders from being completely honest	Biased results	Best to interview face-to-face to make the stakeholder more comfortable
Stakeholders who may not speak English	Unable to be interviewed by CENEX Nederland	Ask local partners to help

3.2.18 High usability of the NextETRUCK overall system

Description

KPI-19: High usability of the NextETRUCK overall system

Methodology

First, we identify the user needs for this project. To assess if the user needs are met within this project, qualitative data will be gathered by conducting interviews with different stakeholders. Each of the three pilots has different applications of medium duty trucks, we need to analyse the context of the pilot and conduct a stakeholder analysis to create an understanding of how and who are involved in operating the vehicles. Semi-structured interviews will be held by CENEX Nederland with the most relevant stakeholders. The interview guide will be tailored to the involvement of the stakeholder in the operational processes. The interviews will be summarised in a paragraph per identified user need, all relating information across all interviews is summarised. A cross-case analysis will be conducted to understand the differences in results among the three pilots. The methodology will therefore include the following steps:

1. Identification of user needs
2. Context analysis
3. Stakeholder analysis
4. Interview guide
5. Conducting the interviews
6. Analysis of results

In case too many stakeholders are involved; the interview could be replaced by either a survey or a focus group workshop.

Risks / Challenges

Risk	Impact	Mitigation
Stakeholders not able or willing to be interviewed	Missing part of results of assessment	Interview similar stakeholders from other levels, or interview stakeholders that are closely related to the operations missing
Recording interviews may withhold stakeholders from being completely honest	Biased results	Best to interview face-to-face to make the stakeholder more comfortable
Stakeholders who may not speak English	Unable to be interviewed by CENEX Nederland	Ask local partners to help

3.2.19 Reduction in operational CO_2 emission

Description

KPI-20: NextETRUCK demonstrates a reduction in operational CO_2 emission relative to BEV and ICE baseline vehicles.

CO_2 emission reductions are expected through several mechanisms in the NextETRUCK operation. This KPI aims to ensure that a reduction relative to baseline emissions is achieved with the combination of approaches (vehicle design, charger design, eco-features) deployed on the project.

Methodology

Tailpipe and well-to-wheel (WTW) greenhouse gas emission savings will be calculated for each NextETRUCK vehicle use case using the observed energy usage during the 6-month demonstration period, with supporting data from Digital Twin simulation if required. Relevant emission factors will be applied to the observed energy usage for each vehicle's recharging events. A comparison of emissions for the baseline vehicles completing an equivalent use case will be calculated using the best available data: with priority given to measured performance of a physical baseline vehicle running the equivalent use case mission if available within the project, either during the pilot or historic data. Intelligence can be applied to the data analysis exercise to target or isolate specific sections of the duty cycle from the baseline vehicle, so that they match the duty cycle sections from the NextETRUCK vehicle. This way we can enable a fairer comparison of performance data between vehicles, which in turn feeds the TCO calculations.

A best estimation of baseline emissions will otherwise be calculated through simulation, measurement of baseline performance on other missions or use of industry energy average consumption values as available per use case.

The tailpipe air quality emissions savings of the NextETRUCK relative to the ICE vehicle baseline will be calculated using the widely industry recognised tool COPERT, using the average speed, payload and gradient from the duty cycles, plus the diesel engine size from the baseline ICE vehicle.

Data requirements

Attribute	Unit	Specific data requirements	Note
Energy consumption from NextETRUCK demonstrators	kWh	Energy consumption for equivalent each use case duty cycle	
Measured charge efficiency	%	Average charge efficiency of each NextETRUCK demonstrator UC	
WTW emission factors for EV charging	$kgCO_2/kWh$	Average figures for NextETRUCK managed charging from PANION and baseline EV charger system.	Managed charging emission may be extracted direct from PANION system
Baseline BEV vehicle energy consumption	kWh	Energy consumption for equivalent duty cycle to NextETRUCK vehicles in each UC	Obtained through measurement or simulation
Baseline ICE vehicle energy consumption	litres	Energy consumption for equivalent duty cycle to	Obtained through measurement or simulation

Attribute	Unit	Specific data requirements	Note
		NextETRUCK vehicles in each UC	
WTW emission factors for diesel baseline	kgCO_2/litre	Average WTW CO2 emission per litre of diesel	
Air quality emissions	Grams NOx and PM per km	Duty cycle average speed, payload and gradient, plus diesel engine size	These are the inputs required by the COPERT tool

Risks / Challenges

Risk	Impact	Mitigation
Inaccuracy in estimated yearly energy demand	Inaccuracy in CO_2 and air quality emissions estimates	As detailed in KPI-6, best data available will be used, with historical data or industry averages used as backup where relevant
Local grid carbon intensity or emission factors not available	Localised estimate of emissions not possible.	Estimation made using average publicly available values in Europe
Historic or trial data from baseline vehicles available, but energy consumption from exact equivalent duty cycle not available	Direct comparison for like duty cycles not entirely possible.	Closest possible estimate made with available data. Intelligence applied to data analysis to isolate and target specific sections of baseline duty cycle that match as close as possible duty cycle sections from NextETRUCK use case pilots

3.2.20 Operating hours

Description

As the charging in most of the case should be done in the nigh and during breaks the operational time of the NextETRUCK should be comparable with operation time of ICE vehicle.

KPI-21: Operational hours per day

Methodology

Consider the average operational time of the NextETRUCK and compare it to average operation time of an ICE truck under similar conditions

$$\mathrm{OHpD} = t_{op}/24$$

Data requirements

Attribute	Unit	Specific data requirements	Note
Operational hours per day [OHpD]	h/day		
Total operating time/day	H		
Weather		Weather conditions	
Load per day	t/day	Transported goods per day	
Reference truck data in the same period on the same route			

Risks / Challenges

Risk	Impact	Mitigation
No reference data	Inaccuracy to the comparison of the operational hours	Access data though fleet manager via interviews

3.2.21 Charging rate

Description

The charging rate (**KPI-22**) of the NextETRUCK will be as close as possible to the predicted by the charging system in the range from 20% to 80% state of charge.

Methodology

Measure the time the vehicle is charging and the energy charge in that time, paying attention to the selected charging method.

$$CR = Ec/Tc$$

where:

- CR = Charging rate
- Ec = Energy of charging
- Tc = Time of charging

Data requirements

Attribute	Unit	Specific data requirements	Note
Charging rate	kWh/min		
Energy charge	kWh		
Charging time	Min		
Weather		Average yearly conditions	

Risks / Challenges
No risks have been identified for this KPI.

3.2.22 Charging time

Description
KPI-23 specifies the charging time required for a full recharge of the battery.

Methodology
Depending on the selected charging method, we will measure the charging time from 20% SoC to 80% state of charge. For overnight charging the charging to 100% state of charge can be performed.

Data requirements

Attribute	Unit	Specific data requirements	Note
charging time,	min		
Battery SoC, Charger power, Weather	%	From 20% - 80% SoC, overnight charging up to 100%	
Weather		Yearly average conditions	

Risks / Challenges
No risks have been identified for this KPI.

3.2.23 Driving time to charge time

Description
KPI-24 is defined as the ratio of the time the vehicle operates after a full charge (80% SoC) to the time required for the recharging of the battery up to 80% SoC.

Methodology
Calculate the ratio of total time spent on driving/operating and on charging, and consider the load carried during that time.

Ratio of driving time to charge time

$$\text{RDtC} = \frac{t_{driving}}{t_{charging}}$$

where:

- tdr = time of driving/operating
- tch = time of recharging

Data requirements

Attribute	Unit	Specific data requirements	Note
Driving time	min		
Charge time	min	Total time spend on charging	Consider how to include influence of overnight charging and the different type of charging (kW provided by the charger)

Risks / Challenges

Risk	Impact	Mitigation
Overnight charging may blur the outcome	Very high charging time	Consider time spend on charging only during work time 9-5

3.2.24 Average driving speed

Description

KPI-25 estimates the average driving speed of the vehicle during a mission from one charge to another. The high torque of the electric motor should allow the driver to achieve comparable average speed with an ICE vehicle and in some cases even higher. A higher speed will have impact to narrowing somehow the delivery time window.

Methodology

We measure the average speed achieved by the vehicle during operation and we compare it to similar use case of an ICE vehicle. The speed can be measured by:

- The vehicle itself (speedometer)
- The GPS unit
- Calculated from the distance travelled / the time to cover the distance

Data requirements

Attribute	Unit	Specific data requirements	Note
Vehicle speed	Km/h		
Load	kg		
Number of stops	#		

Attribute	Unit	Specific data requirements	Note
Traffic conditions		Average traffic conditions, traffic flow	
Weather		Yearly average conditions	

Risks / Challenges

Risk	Impact	Mitigation
Conditions are not similar in order to draw a conclusion based on several missions	Less accuracy of the speed estimation	In not possible to assess an accurate result, a simulated indication can be derived through the DT

3.2.25 Charging cost per km

Description

KPI-26 is defining the ration of the cost for charging to the distance covered for this charge. Of course, the charging cost depends of various parameters such as the type of charging, the owner of the charger, the day time of charger, etc.

Methodology

Calculate the ratio of total cost spent on charging and the kilometres driven with that charge. In NextETRUCK, the typical charge as planned in the UCs will only be considered. It will be a combination of slow, overnight charging and fast charging to max 180 kW with the chargers owned by the fleet operators.

$$\text{CPK} = \text{total costs of charging} / \text{total km covered}$$

Data requirements

Attribute	Unit	Specific data requirements	Note
Total costs of charging	€		
Total km covered	km		
Load	kg	Average UC transport mission	

Risks / Challenges

No risks have been identified for this KPI.

4 DATA TOOLS AND MANAGEMENT

4.1 Data flow and processes

Both the on-board and cloud logged data will be stored for analysis. During a test, the on-board data will be recorded in the vehicle data logger. To transfer the data, a USB stick or cable connection or wireless connection will be used, depending on the file size, and it will be sent to the central OEM server. In contrast, the cloud logged data will be directly stored in a dedicated area in the cloud.
Access to the logged data is restricted to OEMs and the evaluation team for the on-board data, in compliance with privacy rules. However, the cloud data will be more widely available to the consortium. To ensure data security, a backup copy will be saved on a separate server.

The data flow follows these steps:

- Data is transferred from the vehicle/chargers and the cloud to a secure storage area.
- A backup of all files is saved in a different location.
- Data is processed for analysis and aggregation. Synchronization and cleaning procedures are performed if necessary. In cases of missing data, efforts will be made to fill in the gaps if feasible.
- The dataset is prepared for analysis, and aggregated results are reported.
- Key Performance Indicators (KPIs) are calculated using the defined methodology.
- Both processed and analysed data are stored and backed up as described above.

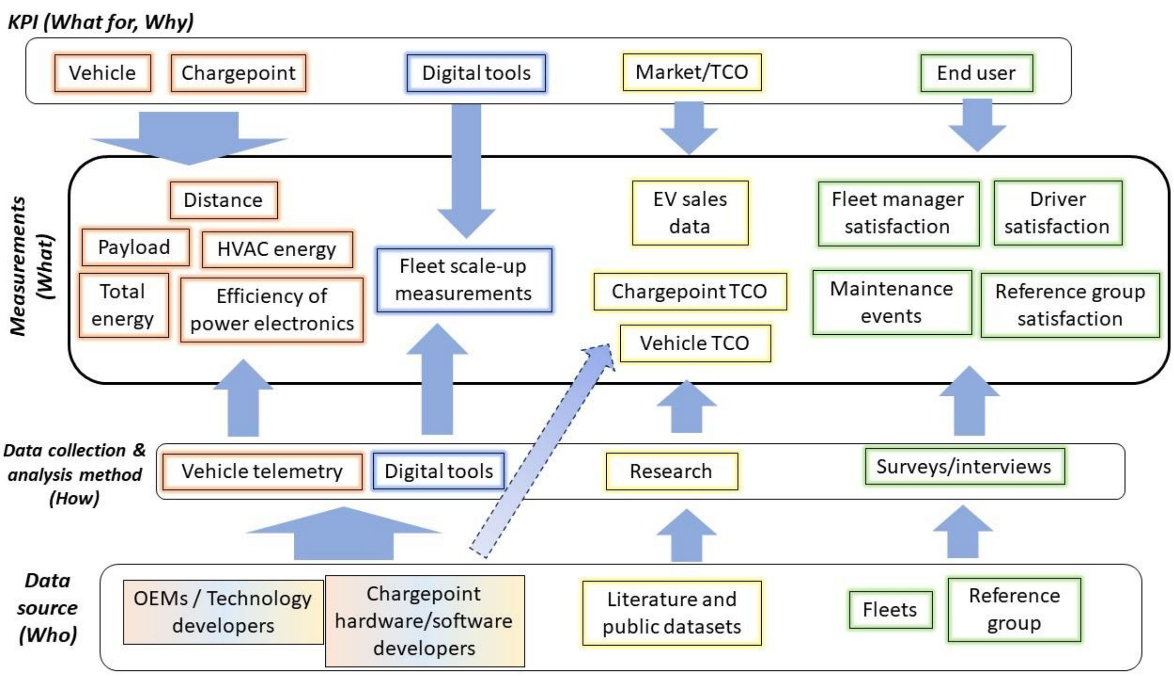


Figure 5: Data flow process

The diagram above shows the data elements to be collected and analysed during the project. The colour codes are aligned with the four KPI groups:

- In orange, the 'Vehicle & Charge point' related KPIs. These want to capture the performance of the design innovations compared to the baseline technologies. They are primarily measured via telemetry systems.
- In blue, the 'Digital tools' related KPIs. They want to capture the simulated performance of a large fleet of electric vehicles across a variety of missions, locations and ambient conditions, by scaling up the behaviour of the three pilot vehicles and using their data to recalibrate themselves and increase their accuracy.
- In yellow, the 'Market/TCO' related KPIs. These capture the business case improvements to a fleet user due to the innovations adopted within the project. They will be measured using a combination of literature and/or public datasets, plus first-hand data from the OEMs and technology developers participating in the project.
- In green, the 'End user' related KPIs. They will capture the satisfaction of various users of the innovations developed within the project,

OEMs and technology developers expand three colours because they will need to provide info across several KPI categories. The way of reading this is:

1. Why do we need to measure parameters? **First level**
2. What do we need to measure? **Second level**
3. Who will provide the data? **Fourth level**
4. How will it be collected and analysed? **Third level**

4.2 Data collection for KPI monitoring

Measurements refer to values assigned to objects or events. They can be generated by multiple sensors or sources, and certain KPIs may utilise the same measurement multiple times to evaluate the extent of the KPIs. Measurements can be categorised into the following types:

- *Direct Measurements*: These are measurements obtained directly from a specific sensor or source without any additional calculations or interpretations.
- *Indirect Measurements*: These measurements are derived or calculated based on other measurements or through mathematical transformations or algorithms.
- *Self-Reported Measurements*: These measurements are obtained through self-reporting by individuals or users, typically involving subjective assessments or perceptions.
- *Situational Variables*: These measurements capture specific contextual factors or conditions that may influence the interpretation or analysis of other measurements.

By distinguishing between these types of measurements, it becomes possible to better understand and utilise the various aspects of data collection and analysis in relation to the evaluation of objects, events, or performance indicators.

4.2.1 Direct Measurements

A Direct Measurement is logged directly from a sensor and it is logged into a system without a processing phase before saving the data (conversions from a unity of measurement to another or signal manipulation are not considered as processing). How the sensor arrives at its output is not relevant for the classification according to the FESTA Consortium.

For several direct measurements, two data sources form GPS and CAN-Bus are available. In this case, data from two or more sources can be used for a cross-check of results.

4.2.2 Indirect Measurements

Indirect measurements are derived from the combination of direct measurements and are not directly logged from a sensor. The literature lacks a standardised method for calculating indirect measurements, resulting in different estimation approaches being found in previous studies.

4.2.3 Self-Reported Measurements

Self-reported measurements are derived from the subjective opinions and experiences of individuals who utilise the provided system/service. These measurements are obtained through questionnaires, rating scales, interviews, or similar methods. The reported data typically have a lower frequency rate, usually collected before, during, and at the end of the service period. In vehicle-related studies, these measurements are utilised to evaluate driver behaviour and user acceptance.

4.2.4 Situational Variables

To conduct a comprehensive analysis, it is important to consider the correlation between estimated KPIs and non-constant influencing parameters that depend on the specific situation or conditions. While the validation tests have a predefined framework in terms of time and repetitions, it is anticipated that situational parameters will be observed and could potentially have a significant impact. Factors such as dense traffic volume or rainy weather may come into play and should be taken into account during the analysis process.

4.2.5 Baseline data

Baseline data refers to the initial set of measurements and observations collected as a reference point for evaluating and comparing the performance of project introduced technologies. This data serves as a benchmark against which subsequent measurements and evaluations are compared to assess the vehicle's performance improvements or deviations.

Accurate and reliable baseline data is crucial for ensuring the validity and effectiveness of subsequent validation processes, as it forms the foundation for the performance assessments. In NextETRUCK two sets of baseline data will be used: one concerning the performance of similar ICE trucks and the other of the most resent medium size e-trucks. For the ICE and e-truck baseline data, FORD and IRIZAR will provide reference values from their current models on the market.

4.3 Data acquisition

The primary objective of data collection is to assess the KPIs, which require a combination of subjective and objective data. The data will be collected through logged data and personal surveys. Objective data will include background data, in-vehicle data, sensor data, real-time observations, and cloud data. Subjective data will encompass factors such as driving load, interface with the system, effectiveness of information and stress generation. This subjective data will be collected through written surveys administered to test drivers before, during, and after the driving tasks.

Data will be generated during three different evaluation/validation tasks:

- Real-life demos in T7.2.
- Simulation processes in T8.2.

The format of the data does not need to adhere to specific rules since the analysis of the data for each task will be conducted independently. There is no requirement to merge, for example, real-life data with simulation data. As a result, the format of the log files may vary depending on the analysis tools used in each task.

4.4 Sensors and report instruments

Telemetry data will be collected from each vehicle to record signals such as the battery voltage and current, battery state of charge, vehicle speed and location, acceleration and braking rates, and battery charging power. The exact method of collecting this telemetry data is to be determined. If there are existing telematics systems which collect this data, CENEX will interface with these systems to collect the existing data. If no such system exists, then CENEX will configure CAN bus data loggers to collect and remotely transmit the data.

In either case, the raw data will be collected and stored on CENEX's data processing workstation which is physically located in CENEX's UK office. This data will then be automatically processed to produce summary aggregate data which can be used to produce reports.

Reported information consists of participants' opinions regarding the functionality of the systems. This data is crucial for evaluating the subjective KPIs. Typically, these measurements are obtained through questionnaires, rating scales, interviews, focus groups, or other similar methods. In addition to subjective assessments, reported measurements can also include data related to costs and revenues. These financial aspects may be collected by the driver or an operator during the test period, providing valuable insights into the economic implications of the system.

4.5 Monitoring tools

As part of the data collection process, CENEX will set up systems to detect missing data, faulty loggers and invalid data. These checks will comprise both systems already in place as part of our existing suit of data collection and processing software, and custom checks specific to this project. We will receive email alerts if there is a problem so we can investigate and organise a solution to the issue.

Check we will perform, and actions taken include:

- Identifying patterns of usage and flagging if data has not been received for an unusually long time, which might indicate a non-functional logger. Action can be taken to verify a faulty logger (as opposed to the vehicle not being used, e.g. due to maintenance) and to repair or replace the logger as necessary.
- Ensuring that all signals are present and received at the expected rate. Any deviations may point to a faulty connection to a specific CAN bus, or a potential logger malfunction.
- Validating the values of data received to ensure they are within sensible limits. Telemetry systems often produce spurious data, e.g. a default very high or low value or an invalid identifier if a sensor or not working, that signal is not applicable at that time, or is simply producing junk data at the start or end of a session. Cenex's data processing pipeline identifies such invalid data and either automatically removes it or highlights it as suspicions so that such data does not find its way into the final analysis.

4.6 Analysis tools

T7.4 and T8.2 have the objective of developing methods and tools to acquire the performance indicators. The data analysis tools will be provided to determine the values of both measured and estimated performance indicators. These tools include customised versions of commercial software packages tailored to meet the requirements of the project, as well as self-developed tools utilizing widely recognised analysis software. Custom made programs will be developed in Python and MATLAB. These tools and programs should offer robust capabilities for data analysis, manipulation, and simulation, enabling us to derive meaningful insights from the collected data.

Also, through AVL, the *AVL CONCERTO 5*™ software will be available to certain partners. It is a holistic, open and adaptive data analytics solution. It is a generic data processing platform for visualizing, analyzing and reporting many measured and simulated data types.

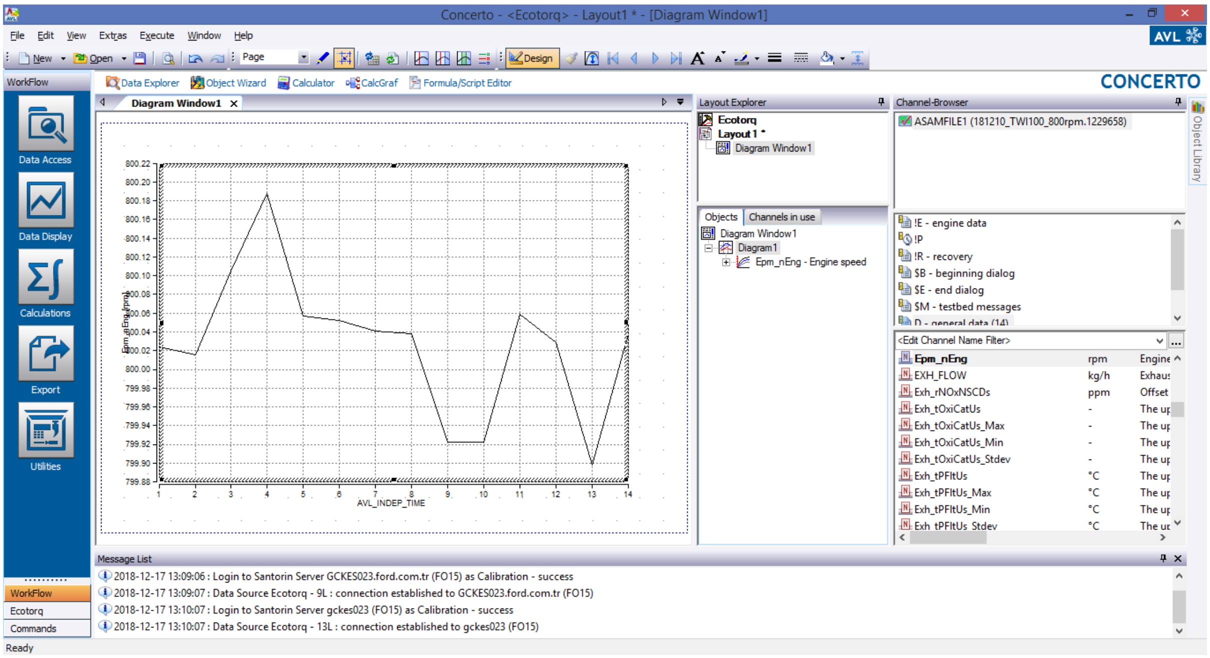


Figure 6: AVL Concerto Interface

4.7 Ethics

NextETRUCK is a project that prioritises user engagement and recognises the crucial role of humans in achieving successful outcomes. The project aims to encompass a range of users from diverse backgrounds, encompassing various mission patterns and preferences. Its overarching goal is to explore the sustainability and acceptance of e-truck driving and enhance the overall driver/fleet owner experience in an urban/peri-urban ecosystem involving different stakeholders.

Concerns regarding the utilization of tools, services, and technologies in transportation can be summarised as follows (adapted from opinion 13 of the European Group on Ethics, EGE):

- *Limited understanding and integration*: Many individuals struggle to comprehend and incorporate technologies into their daily transportation routines, resulting in a lack of familiarity and ease of use.
- *Lack of transparency among involved parties*: The work conducted by various entities, including IT systems and control centers, service providers, and vendors, is not sufficiently transparent. This opacity affects the relationship between driver and user, encompassing both commercial and socio-economic aspects.
- *Privacy and confidentiality challenges*: Preserving privacy and confidentiality becomes challenging when third parties express a strong interest in accessing electronically recorded and stored personal and transportation usage data.
- *Security of shared data*: Ensuring the security of shared personal information, location data, and service usage data poses difficulties, given the potential risks associated with unauthorised access or breaches.

Hence, the Consortium must commit to the following guidelines:

- *Protection of personal identification data*: Personal identification data encompasses sensitive information concerning an individual's identity and private life. Therefore, it is imperative to handle this data with utmost care and confidentiality.
- *Interoperability for enhanced data circulation*: The utilization of interoperable services, tools, and architectures enables the seamless flow of personal travel data across local, national, and professional boundaries, thereby imparting a distinct European dimension to such data.

To ensure ethical considerations are upheld during the evaluations conducted in NextETRUCK, the principles outlined in the European Convention of Human Rights, the Convention of the Council of Europe for the protection of individuals regarding automatic processing of personal data, European Directive 95/46/EC for personal data protection, and General Data Protection Regulation (GDPR) 2016/679 must be strictly adhered to. Users will primarily participate in surveys (WP7 and WP8) and user tests (WP7), while additional involvement may include workshops and events.

Data collection during the demonstrations will occur in 3 cities across Europe during pre-demonstration and the actual demonstrations. Informed Consent mechanisms will be discussed in D7.1, with detailed explanations and templates provided. It is essential to emphasise that all users/drivers and stakeholders (such as operators, truck drivers, etc.) recruited by the project will have the opportunity to provide Informed Consent. If necessary, a guardian or legal representative can provide consent on their behalf, in compliance with GDPR regulations. Users of all types will be informed of their involvement in research tests and will receive information regarding the handling of their personal and performance data by the project.

The data collected at all 3 sites will result in substantial research data. Collection of personally identifiable information will adhere to relevant European and national legislation and Directives specific to the country where data collection occurs. Such data will be stored centrally in an anonymised and secure manner, following established standards and in accordance with the General Data Protection Regulation [Regulation (EU) 2016/679 of the European Parliament].

5 VALIDATION PLAN

In the project, TNO with support of CENEX will perform the validation for the 3 UC of NextETRUCK to ensure the trucks are built to specifications and perform according to the project requirements. This validation process involves a systematic assessment of the data, aiming to identify potential issues and ensure compliance with the requirements.

During the NextETRUCK validation process, factors such as driving range, acceleration, load capacity, energy efficiency, charging efficiency, user acceptance, and safety features will be evaluated based on the set KPIs. This chapter outlines a validation plan that provides a structured framework for conducting the assessments, ensuring high-quality and reliable NextETRUCK outcomes. The successful implementation of the electric truck within the project instils confidence in its performance.

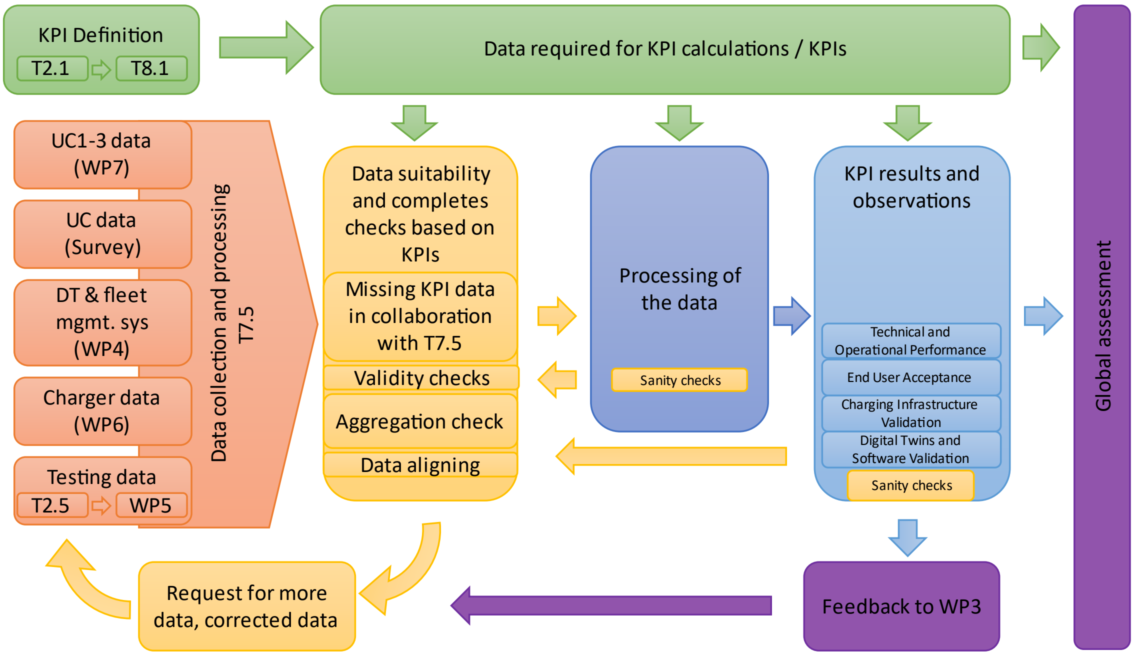


Figure 7: Validation process

Data suitability and completeness checks based on Key Performance Indicators (KPIs) are crucial for the validation process. A comprehensive description of the data within the repository is vital. The data will be examined against the defined KPIs to ensure adherence to data standards and required inputs. Missing data will be identified, and suitable sources will be sought to fill the gaps. Timestamp alignment across different devices will be verified for data synchronization. Sanity checks will be performed on aggregated results to identify outliers or anomalies. These checks enhance data integrity and reliability. By conducting these rigorous checks, the validation process can proceed with confidence, using a robust and reliable dataset aligned with the defined KPIs. This ensures meaningful insights and informed decision-making.

In the step of Data Processing and Statistical Analysis, the collected data undergoes advanced processing techniques and statistical analysis, including thorough sanity checks. This phase involves utilizing custom-made tools developed in Python and MATLAB, which offer robust capabilities for data manipulation, simulation, and statistical computations. The processed data is subjected to sanity checks to verify its accuracy and consistency, ensuring reliable results. The statistical analysis aims to uncover patterns, trends, and correlations within the dataset, providing a deeper understanding of the data and enabling the extraction of actionable insights. Through rigorous data processing techniques and comprehensive sanity checks, the quality and reliability of the analysed data are ensured, enhancing the validity of the conclusions derived from the analysis.

In the step KPI Results and Observations, the collected data will be presented in concise tables, facilitating a comparison between the base vehicle and the NextETRUCK across various use cases. The evaluation will focus on the following aspects:

1. ***Technical and Operational Performance***: A comprehensive assessment of the NextETRUCK's performance, including efficiency, driving range, and energy consumption, in comparison to the base vehicle.
2. ***End User Acceptance***: Ensuring that the technology meets the expectations of end users in terms of functionality, usability (loading capacity), and effectiveness.
3. ***Charging Infrastructure Validation***: Validating the performance, reliability, and compatibility of the Megawatt Charging System (MCS) in facilitating seamless and efficient charging operations.
4. ***Digital Twins and Fleet Management Software Validation***: Verifying the accuracy and usability of the Digital Twins of the trucks and associated Fleet Management Software developed for the project.

Throughout this process, sanity checks will be conducted to ensure the reliability and consistency of the results. The outcomes and observations will be instrumental in providing valuable feedback to WP3 for refining the prototypes, thereby enhancing their readiness for successful commercialization.

In the Global Assessment, a collaborative approach will be adopted to validate the NextETRUCK. This involves close collaboration with partners from WP2, WP4, and WP7, enabling the integration of diverse perspectives and expertise. By leveraging the collective knowledge and experience of the partners, the validation process becomes more comprehensive, ensuring a thorough evaluation of the Use Cases. This collaborative approach fosters informed decision-making, as it allows for a holistic assessment that takes into account various aspects and considerations. It also promotes effective communication and knowledge sharing among the project partners, contributing to the overall success of the validation process.

6 IMPACT ASSESSMENT PLAN

To quantify the potential impact of NextETRUCK, an estimation has been made regarding the number of electric trucks that could potentially adopt the innovations introduced by the project. This estimation encompasses a global scale and considers three different adoption scenarios. The timeframe considered takes into account the project's duration (2022-2025) as well as the expected market penetration and adoption that will occur between 2025 and 2028, as explained in a subsequent section outlining the market exploitation strategy. Consequently, the period of 2029-2033 is projected to have the greatest impact from the project. The three adoption scenarios are described as follows:

Baseline scenario: The baseline scenario represents the adoption rate of the segment without the innovations developed by the project. It is derived from the natural growth of the sector, taking into account recent market predictions regarding the adoption rate of electric vehicles. The numbers included in this scenario are based on data provided by the project partners, assuming that no innovations are achieved.

Moderate scenario: The moderate scenario considers the development and implementation of innovations within the project, and their subsequent impact on adoption. The adoption is considered in two forms:

- Direct adoption: This refers to the adoption of the project's technologies by the project partners, including the original equipment manufacturers (OEMs) and tool providers.
- Indirect adoption: This involves the adoption of solutions or tools by external partners within the sector, who are not part of the project consortium. This adoption will be facilitated through effective dissemination and exploitation of the project's results, tools, and methodologies by the wider European community.

In order to evaluate the project's contribution towards the increased adoption of zero-emission (ZE) trucks, a comprehensive table has been compiled. The table incorporates estimated data provided by project partners and external sources regarding sales volume and uptake. Two scenarios, representing moderate adoption and uptake rates, have been utilised to indicate the potential impact range of the project in the long term, beyond its completion. The direct adoption figures presented in the table have been cross-verified with market forecasts for each of the three original equipment manufacturers (OEMs). To maintain commercial confidentiality, the individual figures have been consolidated into single values.

Use Cases	Fleet Type	*Avg Share of Total Fleet*	Avg Adoption Rate of NextETRUCK	# MDTs sold				
				2029	2030	2031	2032	2033
New sales volume (EU)	Total MDTs sold	*100%*	n.a.	150000	160000	170000	180000	190000
	eMDTs - baseline scenario	*10%*	0	15000	16000	17000	18000	19000
	eMDTs - moderate NextETRUCK adoption scenario (Additional eTrucks introduced on the market)	*12%*	5%	840	896	952	1008	1064
Distribution Vehicles	Total Distribution Vehicles	*60%*	2%	90000	96000	102000	108000	114000
	NextETruck fleet - direct adoption by partner	*60%*	60%	1015	1017	1026	1035	1044
	Indirectdirect adoption fleet by other OEMs	*60%*	*2%*	785	903	1014	1125	1236
RCVs & MDTs in urban applications	Total Recicle Vehicles & Other Urban	*30%*	2%	45000	48000	51000	54000	57000
	NextETruck fleet - direct adoption by partner OEMs	*30%*	60%	508	509	513	518	522
	Iindirectdirect adoption fleet by other OEMs	*30%*	*2%*	392	452	507	563	618
Special Vehicles	Total SV Fleet	*10%*	2%	15000	16000	17000	18000	19000
	NextETruck fleet - direct adoption by partner OEMs	*10%*	60%	169	170	171	173	174
	Iindirectdirect adoption fleet by other OEMs	*10%*	*2%*	131	151	169	188	206
Total	NextETruck fleet - direct adoption by partner OEMs	*100%*	60%	1692	1695	1710	1725	1740
	Indirect adoption fleet by other OEMs	*100%*	*5%*	1308	1505	1690	1875	2060

Figure 8: Potential scenarios for the upscaling of NextETRUCK technologies

6.1 Assessment of fleet upscaling of electric trucks

The main objective is to perform the assessment of upscaling NextETRUCK solutions to fleet operation in urban operation using the verified DT of the demo vehicles in WP4/WP5/WP7 and in task 8.2 to get the KPIs (The KPIs on this fleet upscaling such as energy saving (kWh/year), energy consumption of fleet (kWh), TCO (€/km), charging power (kW), charging time, considering all possible test scenarios (via simulation) on fleet upscaling will be fully investigated.). Several test simulations and virtual test scenarios will be performed via running the DT platform upscaled to fleet operation. The detailed assessment will be reported in another deliverable D8.3 (in M42).

A preliminary plan for the assessment of e-truck fleet upscaling range from planning to vehicle operation, will be going through different stages:

- **Stage 1**, there are a few considerations to be made by authorities and operators to ensure the success of the fleet electrification project. The strategy for e-fleet upscale needs to be integrated in broader sector plans, either at city level, regional, or both. The distribution of tasks and responsibilities between operators and authorities depends on the specific local context as the number and ways to organise the governance of transport are diverse.
- **Stage 2** will aim at understanding the operational and local context to be able to choose a specific technology. In this step the city and the involved stakeholders should define the global strategy towards emissions reduction and assess the best technology to achieve their results. In this sense, develop a suitable TCO model to assess the operational scenario and evaluate possible options. Then assess, also by use of simulation, if this is the right solution for the identified needs, including the intended use of the vehicles procured to renew the city fleet.

- After that, **Stage 3** will need to imply careful and detailed planning, developed based on a system approach with clear governance, and in line with existing policies and supported by decision-makers.
- The last stage (**Stage 4**) will deal with the implementation of the electric vehicle's systems, which requires several changes in different aspects of the operational organization. For example, technology and data management IT intelligence for optimised fleet operation and its integration with charging infrastructure, with the support of telematic diagnosis, scheduling and dispatching, eco-driving, real-time information, etc.

6.2 Market impact and new business models

A comprehensive market analysis will be conducted to evaluate existing solutions for e-trucks, as well as assess relevant trends, market penetration, and benchmarking studies. This analysis aims to identify key marketing strategies, current and emerging system costs, and the major actors and stakeholders in the field. Additionally, a SWOT analysis will be performed as part of this task. Exploitation plans will be developed, taking into consideration the users' willingness to have (WTH) and willingness to pay (WTP). Economic indicators, such as payback period (PBP), internal rate of return (IRR), and net present value (NPV), will be utilised to support informed decision-making.

Based on the findings from the market analysis, cost-benefit analysis (CBA), and SWOT analysis, specific business scenarios will be formulated, targeting different market clusters, including personal ownership and fleets. These scenarios will also take into account potential incentives or supportive legislation.

Furthermore, this task will define innovative use cases that go beyond traditional applications of next-generation e-trucks, with the objective of creating value for multiple stakeholders. The feasibility of these concepts will be assessed in consultation with the project partners, market actors from the Reference Group, and collaboration with relevant ongoing projects, such as URBANIZED. Ultimately, this task will generate new business models tailored to the most promising use cases to facilitate their successful implementation.

In order to achieve widespread commercialization of e-trucks, it is crucial to reassess various aspects of the traditional business model. NextETRUCK aims to take a fresh perspective on the value propositions of e-trucks, particularly from the standpoint of a shared and circular economy. This entails exploring the utilization of vehicles by multiple fleet owners and leveraging second-life batteries for stationary storage. The project will also consider value creation for an expanded network of stakeholders, integrating with the electricity grid and renewable energy sources (RES). The potential and feasibility of new use cases will be evaluated for specific geographical areas, in close consultation with project partners, external industry and public sector stakeholders (Reference Group), as well as through collaboration with relevant workgroups and projects. Through this analysis, the project will develop innovative business models that can drive the advancement of the electric truck market.

To ensure coordination with the logistics sector and the adoption of appropriate criteria, the assessment framework will be presented and discussed with a group of logistics service providers. Topics of discussion will include variations in daily mileage and the impact of fleet size on the feasibility of introducing e-trucks.

6.3 Environmental and cost impact

Part of the impact assessment of the three project demonstrators will be an assessment of the environmental and cost benefits of the NextETRUCK designs relative to both baseline cases of earlier generation e-trucks and diesel vehicles. The findings of this assessment will be reported as a section of Deliverable 8.3.

The environmental impacts will be assessed through tailpipe and well-to-wheel (WTW) greenhouse gas emission savings, which will be calculated for each NextETRUCK vehicle use case using the observed energy usage during the 6-month demonstration period, with supporting data from Digital Twin simulation if required. Relevant emission factors will be applied to the observed energy usage for each vehicle's recharging events. A comparison of emissions for the baseline vehicles completing an equivalent use case will be calculated using the best available data: with priority given to measured performance of a physical baseline vehicle running the equivalent use case mission if available within the project. A best estimation of baseline emissions will otherwise be calculated through simulation, measurement of baseline performance on other missions or use of industry energy average consumption values as available per use case.

The tailpipe air quality emissions savings of the NextETRUCK relative to the ICE vehicle baseline will be calculated using the widely industry recognised tool COPERT.

The results of both environmental assessments will be extrapolated into the wider region-level, using the analysis in the previous subtasks, to model scenarios of emission savings based on different e-truck penetrations in the market. This way the low-medium-high emission savings scenarios will be predicted in the next five to ten years based on different uptake rates of the electric trucks in different cities.

The cost impact of the NextETRUCK vehicles will be assessed by comparing the total cost of ownership (TCO) of the baseline electric vehicles (earlier generation e-trucks) to the TCO of the NextETRUCK innovations as an extension to the work completed in Task 3.6 of this project. The TCO evaluation will account for the impact of both the physical design changes to the vehicle as well as the operational and management tools developed on the project. The assessment will be performed for each use case on a market segment and use profile basis, accounting for changing conditions over time, applying sensitivity analysis on price developments, considering technical improvements (battery etc), and charging strategies. Modelling different scenarios into the future of fleets with increased share of electric trucks will allow the calculation of cumulative cost savings.

7 CONCLUSION

This deliverable serves as an internal plan encompassing the validation and impact assessment of the technical developments within the NextETRUCK. D8.1 establishes a structured approach for evaluating all technical developments within the project. The plan outlines the methodology, procedures, and criteria for validating and assessing the impact of each development. This comprehensive evaluation framework ensures a holistic understanding of the project's technical advancements and their overall contribution to the project's objectives.

The methodology employed in this plan adopts a V-diagram structure, inspired by successful projects such as FESTA and CONVERGE. It aligns the different Work Packages within the project, facilitating a systematic approach to project implementation. By sequentially linking the technical developments and assessing their impact, the methodology ensures a coherent and comprehensive execution of the project. This structured approach enhances efficiency, collaboration, and the achievement of the desired outcomes in NextETRUCK.

To guide the evaluation process, a list of Research Hypotheses has been established in this plan. These Research Hypotheses aim to provide answers and insights necessary for assessing the effectiveness of the project. Each hypothesis is linked to a goal and will be measured using one or more performance indicators. The focus of these Research Hypotheses is to validate individual project developments and evaluate the overall expected impact through an Impact Assessment. This is particularly important as some technical advancements are designed to complement each other rather than being implemented in isolation.

KPIs play a crucial role in defining and assessing the performance of novel electric trucks. By considering range and energy efficiency, charging infrastructure, payload capacity and flexibility, performance, total cost of ownership, and environmental impact, stakeholders can evaluate the effectiveness and economic viability of electric trucks in various operational contexts. Monitoring and optimisation of these KPIs will accelerate the adoption and integration of electric trucks in the transport system. The methodology for KPI definition and assessment follows a systematic approach that encompasses research, stakeholder collaboration, performance goal definition, KPI identification and selection, data collection and analysis. This structured methodology ensures that KPIs are comprehensive, meaningful, and aligned with industry objectives.

In addition to the individual system/vehicle/infrastructure validations, the evaluation process also encompasses an overall impact assessment. This assessment evaluates the collective impact of the project developments. By considering the integrated nature of the technical advancements, the methodology aims to assess how these components complement and enhance one another, contributing to the overall effectiveness and success of the project with regard the e-truck upscale in the commercial fleet, the economic viability of the outcomes and their impact to the environment.

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