Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

D6.3: Environmental profiling of XL-Connect solutions

Primary Author(s)	Camilo Ruiz, José Cruz
Lead Beneficiary	Eurecat
Deliverable Type	R – Document, report
Dissemination Level	SEN - Sensitive
Due Date	31.05.2026 (Month 41)
Pages	51
Version	01
Project Acronym	XL-Connect
Project Title	Large scale system approach for advanced charging solutions
Project Number	101056756
Project Coordinator	Virtual Vehicle Research GmbH (ViV) Alois Steiner (alois.steiner@v2c2.at)

Contributors

Name	Organisation
Camilo Ruiz	Eurecat
José Cruz	Eurecat
Niccolò Pezzati	UNIFI
Eleonora Innocenti	UNIFI

Reviewers

Name	Organisation
Alois Steiner	VIV

Version Log

Version	Date	Author	Description
01	22.05.2026	Camilo Ruiz	First version of the full report
02	27.05.2026	Camilo Ruiz	After partner comments

1. Executive Summary

This deliverable presents the **environmental profiling of selected electric vehicle (EV) charging solutions** developed within the XL-Connect project. Its objective is to assess and compare the environmental performance of advanced charging strategies, including **unidirectional smart charging (V1G)**, **bidirectional charging (V2G)**, and reference charging configurations, using a consistent **life cycle assessment (LCA)** framework.

As EV adoption increases across Europe, charging strategies play an increasingly important role in shaping interactions between mobility and the electricity system. Beyond technical performance, it is essential to understand how different charging approaches influence environmental impacts, considering electricity consumption, infrastructure requirements, battery usage, and system-level effects. This deliverable address that needs by providing a structured and comparative environmental analysis of XL-Connect solutions.

The assessment follows the principles of **ISO 14040 and ISO 14044** and adopts the **Environmental Footprint (EF) 3.1 methodology**. A scenario-based approach is applied, using simulation outputs and project-specific data to model system operation under different charging strategies and geographical electricity mixes. The primary comparison is based on an **energy-based functional unit** (1 kWh of energy delivered to the EV battery), complemented by vehicle-use and cumulative perspectives to capture battery degradation and long-term effects.

The results show that, when expressed per unit of energy delivered, **differences between charging strategies are relatively limited**. Across all scenarios, the operational use phase dominates environmental impacts, confirming the central role of electricity supply. The analysis clearly identifies the **electricity mix as the main driver of environmental performance**, with variations across countries having a much larger influence than differences between charging strategies.

Infrastructure impacts are found to be **secondary but relevant**, and strongly dependent on system utilisation. Scenarios with higher throughput achieve lower infrastructure impacts per unit of service, while underutilised infrastructure leads to higher relative contributions. When extending the analysis to a vehicle-use and cumulative perspective, **battery degradation becomes a key differentiating factor**, particularly for bidirectional charging scenarios, where increased battery cycling can lead to higher long-term environmental impacts.

Despite these trade-offs, the study highlights that controlled charging strategies such as **V1G and V2G provide clear technical and operational advantages**. In countries with higher shares of fossil-based electricity generation, the adoption of smart or bidirectional charging instead of uncontrolled charging represents a **potential improvement over conventional EV charging practices**, even if absolute environmental gains remain constrained by the broader energy system.

The analysis is based on a **robust and well-validated simulation framework**, developed and refined across previous XL-Connect deliverables, and complemented by early-stage demonstrator configurations. While real-world operational data are still limited, simulations allow the consistent exploration of a wide range of scenarios and provide a reliable basis for environmental comparison at this stage of the project.

Overall, this deliverable provides a **transparent and consistent environmental evidence base** for the XL-Connect project. Its results support subsequent assessments within WP6, particularly the **Do No Significant Harm (DNSH) evaluation (D6.4)** and the final synthesis of recommendations (D6.5), contributing to informed decision-making on the deployment of advanced EV charging solutions in Europe.

Keywords: Electric vehicle charging, Life Cycle Assessment, Smart charging, Vehicle-to-Grid, Environmental Footprint