AI-informed Holistic Electric Vehicles Integration Approaches for Distribution Grids

D2.3

High-Efficient V2X EV Charger Development

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	05/05/2026	V0.1	EASELINK	Initial version
	15/05/2026	V0.2	EASELINK	Added chapter on CBA
	22/05/2026	V0.3	EASELINK	Improvements after internal Task review
	26/05/2026	V0.4	EASELINK	Formatting issues fixed

	28/05/2026	V0.5	INESC-ID	Use Cases added for INESC-ID testing
	17/07/2026	V0.6	EASELINK	Updated CBA
	27/07/2026	V0.7	EASELINK	Review of content
	04/08/2026	V0.8	EASELINK	Adding test cases evaluation
	26/08/2026	V0.9	INESC-ID	Completing the discharge tests
	27/08/2026	V0.10	EASELINK	Review of comments and minor adjustments
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EXECUTIVE SUMMARY

This deliverable presents the development and validation of the MX.0 automated conductive charging system within Task 2.3 of the AHEAD project. The system provides smart and bidirectional charging functionality and is designed to support vehicle-to-everything (V2X) applications. Its main development objectives included increasing the charging current to 32 A per phase, enabling charging powers of up to 7 kW in single-phase markets and 22 kW in three-phase markets, reducing the size and weight of the vehicle- and infrastructure-side components, and improving the reusability of the software and control architecture.

A comprehensive redesign resulted in a volume reduction of approximately 48% for the Matrix Charging Connector and 53% for the Matrix Charging Pad compared with the previous system generation. The system was subjected to extensive component- and system-level testing covering mechanical durability, environmental resistance, thermal behaviour, electrical safety, docking functionality, communication, efficiency and operational reliability. Efficiency measurements demonstrated an efficiency above 99% across the Matrix Charging interface within the tested power range of approximately 4 to 22 kW. For a complete grid-to-battery comparison, the efficiency of the onboard charger and all other conversion stages must additionally be considered.

The complete automated bidirectional charging system was validated at the INESC ID laboratory in Lisbon using a Chroma 61850 three-phase regenerative grid simulator. The test campaign covered system start-up and shutdown, emergency functions, docking validation, safety and connection checks, user-interface operation, and charging and discharging at different power levels and durations. The completed charging test cases achieved a 100% pass rate, with charging successfully demonstrated at power levels of up to 11 kW. The results confirm the safe and reliable operation of the system under controlled laboratory conditions and demonstrate its suitability for smart-charging and bidirectional energy applications.

In addition to the technical development and validation, a cost-benefit analysis compared automated conductive charging, conventional cable charging, wireless charging and electric road systems across light-duty vehicles, passenger buses and freight vehicles. Conventional cable charging showed the strongest overall economic performance due to its maturity and comparatively low investment cost. Automated conductive charging emerged as the most promising automated solution, achieving positive economic results for light-vehicle applications while offering additional benefits through convenience, reliable automatic connection and increased vehicle availability for V2X services. Wireless charging and electric

road systems remain strongly dependent on infrastructure costs, utilization rates and future reductions in technology cost.

Overall, the results demonstrate that automated conductive charging provides a balanced combination of technical maturity, high efficiency, automation capability and V2X readiness. By eliminating manual cable handling and increasing the time during which electric vehicles remain connected to the grid, the technology can improve their availability for smart charging and bidirectional services and support their future use as flexibility assets within the energy system.

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