Wireless Charging for Electric Road Vehicles: Challenges and Opportunities in Standards, Technology, and Energy Management

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Wireless power transfer (WPT) for electric road vehicles is progressing from prototypes toward deployment. This paper reviews standards, technology, energy management, and deployment challenges for static, stationary, and dynamic WPT, with focus on heavy-duty freight and the Netherlands as a case study. Six ERS technology families were compared alongside CCS2, MCS, and battery swapping. A significant standards acceleration occurred in 2024–2025: IEC published PAS 61980-5/6 for dynamic WPT, and ISO published 5474-4/6 for heavy-duty MF-WPT up to 500 kW. Inductive DWPT emerges as the only technology offering invisible infrastructure, all-vehicle-type compatibility, and zero charging downtime.

A techno-economic analysis shows DWPT becomes cost-competitive at >60% fleet penetration on corridors with >2,000 trucks/day. On a cost-per-tonne-km basis, DWPT achieves approximately 18% lower cost than MCS for heavy-duty corridors through battery downsizing (700 to 200 kWh), payload recovery (+17%), reduced thermal stress on batteries, and zero charging downtime. The appropriate unified KPI is *cost per tonne-km of uninterrupted freight movement*.

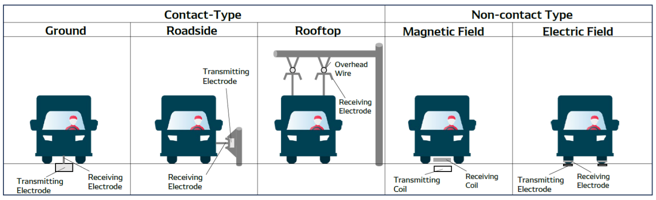

Figure 1: Classification of Electric Road Systems. Source: Yatsuzuka and Honma (2025).(1)

The Netherlands faces severe grid congestion (38 GW backlog, 10-year connection waits) constraining depot charging. DWPT distributes demand along corridors rather than concentrating it at depots. Dutch pilot cases (repeat-route logistics shuttles, port AGVs) and corridor-scale deployments (A15, cross-border TEN-T) demonstrate conditions under which DWPT becomes viable. European demonstration programmes validated DWPT at test sites in Italy (>80% efficiency at 50 km/h) and France (60.1%). A Delft (NL) traffic simulation showed CO_2 reductions of up to 18% and NO_x reductions of up to 24%. Cost-benefit analysis found a 25 km motorway e-Corridor saves EUR 11–144M in fuel (2030–2050), with DWPT-buses achieving ∼35% TCO reduction.

Structural parallels between the Netherlands and Japan – compact geography, dense motorway networks, grid constraints, and strong DWPT research – create opportunities for bilateral collaboration on standardisation and deployment. The key finding is that wireless road charging must be judged by infrastructure integration, traffic impacts, lifecycle considerations, and institutional feasibility – not transfer efficiency alone.

(1) S. Yatsuzuka and Y. Honma, “Advancing Dynamic Wireless Power Transfer: System Development and Infrastructure Optimization,” 46th International Vienna Motor Symposium, 2025.