Special Session on

Towards Sustainable Electrical Machines: From Materials and Design to Circularity and Life-Cycle Impact

Organized and co-chaired by:

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Abstract

The accelerating electrification of transport, industry, and energy systems is a central pillar of global decarbonisation efforts. Electrical machines play a critical enabling role in this transition; however, their large-scale deployment raises important sustainability challenges related to material criticality, environmental impact, and life-cycle performance. High-performance electrical machines have traditionally relied on critical raw materials, notably rare-earth elements in permanent magnets and significant quantities of copper in windings. The extraction, processing, and supply of these materials are associated with environmental burdens, geopolitical risks, and long-term resource constraints, motivating the development of more sustainable electric machine technologies.

This special session addresses sustainability-oriented research and development of electrical machines, covering materials, design, manufacturing, and life-cycle assessment. The research scenario encompasses both established and emerging machine technologies for demanding applications, where high efficiency, power density, reliability, and cost-effectiveness must be achieved alongside reduced environmental impact and improved circularity. Key motivations include reducing dependence on critical materials, enabling alternative and recyclable material systems, and developing quantitative tools to assess sustainability trade-offs at machine and system level.

Recent advances demonstrate promising pathways towards sustainable electrical machines. These include rare-earth-reduced and rare-earth-free solutions such as ferrite and iron-nitride magnets, synchronous reluctance and electrically excited synchronous machines, as well as alternative conductors such as aluminium windings. In parallel, circularity-driven design strategies—focusing on reparability, modularity, reversible joining techniques, and end-of-life material recovery—are gaining increasing importance. Complementary to technological innovation, life-cycle sustainability assessment methodologies, supported by material databases and digital tools, are emerging as essential enablers for informed design decisions and regulatory compliance.

The expected contributions of this special session are to (i) present and benchmark novel materials, machine concepts, and manufacturing approaches that reduce environmental impact and material criticality; (ii) advance life-cycle-based assessment methods integrating environmental, economic, and social aspects; and (iii) facilitate exchange between academia and industry on the industrial feasibility and scalability of sustainable electric machine technologies. By bringing together experts from electrical machines, materials, manufacturing, and sustainability assessment, the session aims to support the development of next-generation sustainable electric drives.

Topics of interest include but are not limited to:

- Reduction of critical raw materials in electrical machines.
- Rare-earth-free and permanent-magnet-free machine technologies.
- Sustainable conductors, windings, and insulation systems.
- Circularity-oriented machine design and end-of-life strategies.
- Sustainable manufacturing and assembly processes.
- Life-cycle assessment, life-cycle costing, and LCSA.
- Material databases, digital product passports, and decision-support tools.
- Benchmarking, techno-economic analysis, and industrial scalability.

Important dates

- Full Paper Submission: February 1, 2026
- Full Paper Notification: May 1, 2026
- Final Paper Upload: June 1, 2026

Submission of papers

Paper submission follows the rules of regular papers. All the instructions for paper submission are included in the conference website:
https://icem2026.ubi.pt/submission.html