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Editorial

# Advanced Research on Sustainable Performance Optimization in Electrical Systems: Editorial

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The search for intrinsic usage-limited performance can lead to poor life cycle solutions in terms of resource consumption, pollution, greenhouse gas emissions and other environmental impacts. Despite the fact that electrical systems are known to greatly improve energy efficiency, they have disastrous impacts on the environment.

An awareness is growing among research laboratories, increasingly considering environmental issues related to the new and old uses of electrical systems. For instance, although it is necessary, the use of renewable energy for a system to be sustainable. For it to be sustainable, the environmental cost of the system itself over its life cycle must be considered. This complex problem needs first to be characterized specifically for electrical systems. Then, tools must be designed to address the issues, to find the trade-offs between functional and environmental performance. Thus, this defines sustainable performance optimization of electrical systems, the scope of this Special Issue.

Ecodesign can be achieved through various technical levers, including system sizing optimization, control optimization, and design optimization via the selection of materials and processes, circular economy, as well as regulatory measures such as standards and certifications. These initiatives necessitate environmental assessment tools, such as Life Cycle Analysis (LCA) and standardized methods. These topics are highly topical and rapidly developing, extending far beyond the field of electrical engineering. They are also transdisciplinary, with traditional electrical engineering intersecting with economics and environmental sciences.

The present special edition covers the diversity of the previously listed topics, with 4 original papers and 2 literature reviews.

The Contribution 1 from Mohammed Mahmoud Khattab et al. presents a control strategy on a multi-energy grid that integrates electricity, heating, and cooling from various energy sources, including renewables and storage. The originality of the approach is twofold: minimizing CO<sub>2</sub> emissions and financial costs through numerical simulations of the network, and employing predictive control using Kalman filters. Two scenarios are explored: (1) optimizing for reduced CO<sub>2</sub> emissions during operation, and (2) incorporating financial objectives through the sale of renewable production on electricity market. A Pareto front emerges from these scenarios, indicating that the scenario aimed at minimizing emissions results in a greater reduction of CO<sub>2</sub> compared to the cost savings achieved in the second scenario, which also leads to increased emissions.

The Contribution 2 is from Anna Katharina Schnatmann et al. and it presents an extensive characterization of various old photovoltaic panels to investigate their potential for reuse, highlighting the importance of reuse as a short loop in the circular economy to minimize environmental impacts. The investigation revealed that modules from a recycling company exhibited potential for reuse, with 10-year-old modules showing lower or comparable performance degradation to specifications, despite some visible defects like contact corrosion. Older modules displayed more significant defects, such as contact detachment, which could lead to greater performance degradation. The findings suggest a



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time buffer for developing higher quality recycling processes, emphasizing the need for well-differentiated classification systems and age considerations to ensure effective reuse applications with good quality management.

The Contribution 3 is from Laura Vauche et al. and deals with a cradle-to-gate life cycle assessment (LCA) of GaN power semiconductor devices. It explores the environmental impacts of this emerging technology compared to traditional silicon (Si) and silicon carbide (SiC) devices. While the advantages of GaN and SiC in terms of power density, efficiency, and operating frequency are known, there are concerns related to raw material scarcity and toxicity. The findings indicate that for a given power conversion application, GaN devices have lower environmental impacts than SiC and significantly lower than conventional Si modules, although these results vary based on the specific environmental impacts considered.

Fabian Zuñiga-Cortes et al. wrote this Contribution 4 that focuses on microgrid development with renewable energy sources in remote areas of Colombia. It overcomes traditional planning methods that prioritize financial costs, advocating for a multi-dimensional analysis that incorporates technical, economic, environmental, and social benefits. The authors propose a novel two-stage strategy: first, optimizing the microgrid's performance over its lifetime, followed by enhancing operational control. This contribution aims to provide a reference point for the energy industry and policymakers, comparing it with existing strategies in the field.

Members of working group of french researchers focusing on more sustainable power electronic wrote this Contribution 5. This review paper presents the findings of a literature review focused on the intersection of power electronics and sustainability, intentionally excluding reliability studies of power electronics systems. It highlights the growing interest in developing more sustainable power electronics. The review is organized into four complementary topics: tools and methods, databases, methods and software, and circularity. The analysis reveals a wide range of topics that still require attention and underscores the substantial amount of research needed to tackle these issues effectively.

This Contribution 6 is written by Li Fang et al. It addresses the emerging interest in sustainability within power electronics (PE). It highlights the lack of a comprehensive integration of existing regulatory and normative frameworks intended to guide PE designers and industries toward sustainable practices. The literature review focuses on regulatory and normative constraints related to sustainability in PE, specifically in areas such as raw material extraction and manufacturing, usage stage, circularity scenarios, and end-of-life management.

These six contributions encompass a broad range of topics, methodologies, and applications. However, they collectively address an urgent and significant need for the environmental transition of electrical systems. These contributions underscore the following recommendations, limitations, and perspectives for future advancements in the fields:

- Complex energy system planning and control
  - There is a necessity for advanced estimators and predictors to improve the accuracy of control models within multi-energy networks.
  - The incorporation of stochastic models that account for uncertainty factors is essential. It is important to refine and develop comprehensive models of constraints and components.
  - Engaging a group of experts and decision-makers is crucial for selecting the most suitable options based on their preferences and needs, thereby allowing the planning framework to be integrated with a multi-criteria decision analysis model.
  - A systemic approach is vital for evaluating the sustainability of power converters, which should encompass the entire life cycle, the complete system, a sufficient array of indicators, and all stakeholders in the value chain.
- Materials and Components

- Electronic waste has become a significant global challenge due to its complex composition, necessitating careful consideration of treatment and disposal processes. Emphasizing reuse over material recovery is essential to minimize costs, reduce energy and resource consumption, and mitigate environmental pollution, particularly for semiconductor dies, which are energy- and material-intensive in their manufacturing.
- When comparing silicon to wide bandgap (WBG) materials, it is crucial to consider the usage and end-of-life stages to accurately assess environmental impacts. A comprehensive study at the converter product level is necessary, focusing on specific applications, functionalities, and technology deployment projections. While materials can facilitate more sustainable power converters, a systemic approach is essential for a thorough evaluation of their potential, particularly regarding the indirect effects of semiconductor materials on other components and their environmental impacts.
- Addressing the environmental impacts of electrical systems is hindered by a lack of data concerning industrial processes, mining activities, and raw materials. Additionally, there are issues related to the quality of data in LCA databases and software, as well as a lack of identified stakeholders in disassembly channels.
- Optimizing testing methodologies is essential for the practical and cost-effective implementation of second-life applications, whose economic viability depends on the specific application context. There is significant potential for applications with lower power requirements, such as systems designed to enhance self-consumption or provide additional structural functions.
- The databases utilized for LCA must be critically evaluated concerning data quality and uncertainties. Any efforts to enrich these databases with precise and reliable first-source data are highly encouraged.
- Standards, Regulation, and Circular Economy
  - Achieving circularity necessitates further research focused on repairability and the integration of circularity principles into eco-design requirements. An interdisciplinary approach in the design and assembly of power converters is essential to ensure the interoperability of the manufacturing chain concerning materials and circularity, particularly in light of the current lack of transparency obligations regarding compliance with standards and data publication.
  - Comprehensive studies on the existing and future value chains for power electronics converters and their components are imperative. Research examining the impact of power electronics design on the implementation of circular economy strategies at the product level—such as reuse, repair, refurbishment, refabrication, and repurposing—should be prioritized due to a notable scarcity of relevant literature on this topic.
  - Existing standards and regulations impose minimal requirements on the characteristics and "environmental performance" of energy conversion devices, primarily focusing on minimum efficiency levels and standby power consumption. Additionally, there is a lack of definitive positions from public authorities and an absence of arbitration mechanisms.
  - The establishment of standardized methodologies for conducting LCA on power systems is essential for comparing various technological solutions and applications, yet such standards are still lacking.
  - Current standards do not offer a comprehensive methodology for effectively integrating environmental impact assessments and material efficiency evaluations into the various stages of the electrical systems design process, including tasks such as conversion topology design, hardware selection, and three-dimensional layout.
  - Existing literature-based design guidelines are overly general and require further specification and adaptation to be effectively incorporated into the conceptual

design requirements of power electronic products. Furthermore, the indicators derived from LCA are insufficient for guiding the design of more sustainable power converters; thus, complementary indicators related to end-of-life scenarios—such as modularity, reusability, and reparability—should be identified, and new indicators developed as necessary.

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#### List of Contributions

1. Khattab, M.M.; Abdelrahim, A.; Youssef, E.; Hamad, M.S.; Elmanfaloty, R.A. Carbon Footprint Optimization with Data Resolution Conversion via Kalman Filter for Smart Energy Hub. *Sustainability* **2024**, *16*, 8929. <https://doi.org/10.3390/su16208929>.
2. Schnatmann, A.K.; Reimers, T.; Hüdepohl, E.; Umlauf, J.; Kleinebckel, P.; Schoden, F.; Schwenzfeier-Hellkamp, E. Investigating the Technical Reuse Potential of Crystalline Photovoltaic Modules with Regard to a Recycling Alternative. *Sustainability* **2024**, *16*, 958. <https://doi.org/10.3390/su16030958>.
3. Vauche, L.; Guillemaud, G.; Lopes Barbosa, J.C.; Di Cioccio, L. Cradle-to-Gate Life Cycle Assessment (LCA) of GaN Power Semiconductor Device. *Sustainability* **2024**, *16*, 901. <https://doi.org/10.3390/su16020901>.
4. Zuñiga-Cortes, F.; Caicedo-Bravo, E.; Garcia-Racines, J.D. Reference Framework Based on a Two-Stage Strategy for Sizing and Operational Management in Electrical Microgrid Planning. *Sustainability* **2023**, *15*, 14449. <https://doi.org/10.3390/su151914449>.
5. Salomez, F.; Helbling, H.; Almanza, M.; Soupremanien, U.; Vine, G.; Voldoire, A.; Allard, B.; Ben-Ahmed, H.; Chatroux, D.; Cizeron, A.; et al. State of the art of research towards sustainable power electronics. *Sustainability* **2024**, *16*, 2221. <https://doi.org/10.3390/su16052221>.
6. Fang, L.; Turkbay Romano, T.; Rio, M.; Mélot, J.; Crébier, J.C. Enhancing Sustainability in Power Electronics through Regulations and Standards: A Literature Review. *Sustainability* **2024**, *16*, 1042. <https://doi.org/10.3390/su16031042>.

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