Publishable Summary of the Results on Cross-Application & Domain Topic of Sustainability

Project acronym	***PowerizeD***
Project Logo	
Project full title	Digitalisation of Power Electronic Applications within Key Technology Value Chains
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Coordinating Entity	Infineon Technologies AG

Introduction

The Cross-domain and application topic (CDT) focusing on sustainability, led by Aalto University, partnered initially with Infineon Technologies (hereafter IFX), ABB, and Kempower (hereafter KEMP), aims to provide a comprehensive environmental assessment of power electronic components and systems, specifically Si IGBT and SiC MOSFET power modules. The goal is to evaluate different design options informed by thorough analyses of the life cycles. The CDT focuses on two case studies, the first is a use case (referred to as “UC3.1c”) led by ABB, focusing on motor drives. The second use case is “UC1.6c”, involving KEMP, concentrating on EV charging.

Objectives

1. Develop accurate methodologies to estimate the environmental impacts of various material choices throughout product life cycles.
2. Evaluate the environmental impacts of manufacturing processes, energy consumption, and material properties, including durability, repairability, recyclability, and use of secondary sources.
3. Use insights gained to guide research and development activities towards greater resource efficiency and reduced carbon footprints.

These objectives facilitate environmentally responsible design (eco-design [1]) decisions in the power electronics industry.

Methodology

To achieve these objectives, the CDT employs life cycle assessment (LCA) [2], a standardised method crucial for eco-design [3]. LCA enables comprehensive evaluation of a product's environmental footprint across all life cycle stages, guiding decisions and validating design choices.

Key Activities and Developments

The summary of the overall efforts is illustrated in **Error! Reference source not found.**. Note that M = month in the project timeline. The key activities include:

- Aalto University have contributed to LCA model development, focusing initial efforts on the EconoDUAL3 IGBT module and later a comparable SiC MOSFET module. Shareable primary data were obtained from IFX.
- ABB with Aalto University, further explored the energy efficiency of the Si IGBT and SiC MOSFET in a motor drive application. Then, Aalto integrated the losses for the life cycle use phase. Collaborative efforts with ABB enabled cradle-to-grave assessments, along with simplified exploratory work on circularity measures based on data shared from IFX.
- KEMP ventured into carbon accounting for EV charging solutions. Later, with IFX and Aalto, different SiC MOSFET solutions were investigated (SiC discrete vs module in EV charging)
- Aalto University, together with KEMP, compared Si-, SiC-, and GaN-based solutions in a power module utilised in KEMP EV charging stations.

Capacity Development: Recognising tool and expertise gaps, the CDT added a capacity development component to the focus, which includes:

- Developing environmental assessment tools for electronics to aid system-level analysis and for teaching LCA for future electronic engineers.
- Knowledge transfer through dissemination and internal activities, including presentations and a sustainability workshop (organised with IFX).
- **Future Concepts and Innovations:** Exploratory investigations with partners like ETHZ, Ansys, OTH, and Plexim focused on advancing eco-design practices through:
    - Incorporating LCA in multi-objective optimisation (MOO), a concept with existing frameworks yet underutilised.
    - Integrating LCA with design tools and digital twins to facilitate eco-design.
    - Exploring AI applications to enhance or automate LCA processes, including addressing significant challenges such as confidential data sharing.

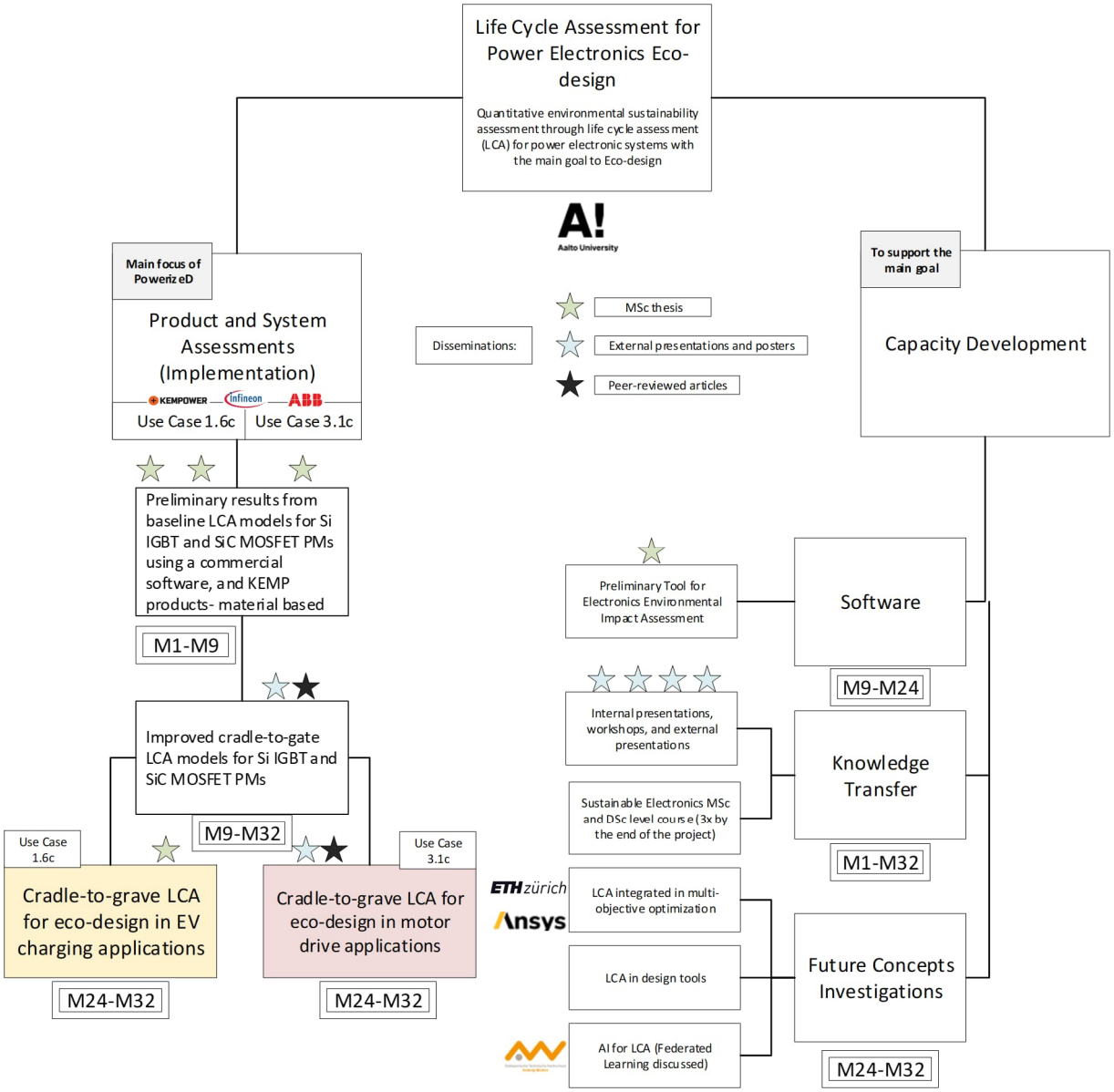

FIGURE 1. SUMMARY OF THE OVERALL EFFORTS

Key Results

The efforts in FIGURE 1 were achieved, some of the highlights include:

- Reliable environmental impact data for Si IGBT and SiC MOSFET modules, including packaging.
- First cradle-to-grave comparisons for the modules in motor drives and EV charging based on consistent LCA modelling.
- Following the recent eco-design for sustainable products regulation (ESPR), the project demonstrates advances beyond the state of the art (beyond the traditional energy efficiency focus), achieving improvements in areas such as resource efficiency and circularity.
- Packaging was identified as a significant contributor to abiotic depletion of elements (ADPe), a measure of how quickly mineral resources are being used up (previously overlooked). Besides higher energy efficiency and the subsequent environmental benefits, wide-bandgap materials have been demonstrated to enable resource savings at the system level.

- Comparative results for Si, SiC, and GaN modules in EV charging applications.
- Established link between LCA results, eco-design strategies, and circularity considerations.
- Strengthened LCA competences.
- Clear environmental drivers identified across life cycle stages to guide design decisions.

The full list of dissemination is summarized in TABLE 1.

TABLE 1. DISSEMINATION

Dissemination	Link
M. Radwan, "Life cycle assessment of power semiconductor module manufacturing," M.Sc. Thesis, Sch. of Elec. Engineering, Aalto Univ., Espoo, 2023. [Online]. Available	
J. Leppänen, "Impact of semiconductor device selection on resource and energy efficiency of power converters," M.Sc. Thesis, Sch. of Elec. Engineering, Aalto Univ., Espoo, 2023. Available upon request.	
V. Vauhkonen, "Product carbon footprint life cycle assessment of Kempower Satellite and Kempower Power Unit," M.Sc. Thesis, Sch. of Energy Systems, Lappeenranta Univ., Lappeenranta, 2024. [Online]. Available	
M. Paulasto-Kröckel and M. Radwan, "Ecodesign of Power Electronic Systems - Current State and Target Setting," presented at the IEC TC91 Jisso Int. Council (JIC) 2024 Spring Meeting, Tokyo, Japan, Jun. 10, 2024.	
Y. Zhabura "Environmental Impact Assessment Tool for Electronics," M.Sc. Thesis, Sch. of Elec. Engineering, Aalto Univ., Espoo, 2024. [Online]. Available	
M. Radwan "CDT 5.1 Sustainability." PowerizeD.EU. powerized.eu/images/poster/Powerized_CDT5.1-Sustainability_for-public-poster.pdf (accessed Jul. 2025)	
M. Radwan, M. Paulasto-Kröckel and V. Vuorinen, "Cradle-to-Gate Life Cycle Assessment of Si IGBT and SiC MOSFET Power Modules," 2025 IEEE Conference on Technologies for Sustainability (SusTech), Los Angeles, CA, USA, 2025, pp. 1-5, doi: 10.1109/SusTech63138.2025.11025776.	
U. Saleem, "Sustainability Assessment of Wide Bandgap (WBG) Semiconductors in Power Electronics," M.Sc. Thesis, Sch. of Elec. Engineering, Aalto Univ., Espoo, 2025.	
M.Radwan et al., "Life Cycle Assessment as an Eco-design Tool in Power Electronics: A Case Study of 1.2 kV Si IGBT vs SiC MOSFET Modules in Motor Drive Inverter," accepted at the 2025 Energy Conversion Congress & Expo Europe (ECCE Europe), Aug. 31-Sept 4, 2025.	Upcoming

References

[1] European Parliament and Council. (2024, June 13). Regulation (EU) 2024/1781 establishing a framework for the setting of ecodesign requirements for sustainable products, amending Directive (EU) 2020/1828 and Regulation (EU) 2023/1542 and repealing Directive 2009/125/EC. [Online]. Available: Regulation - EU - 2024/1781 - EN - EUR-Lex .

[2] Environmental management – life cycle assessment – Requirements and guidelines, ISO14044, 2006.

[3] M.Radwan et al., "Life Cycle Assessment as an Eco-design Tool in Power Electronics: A Case Study of 1.2 kV Si IGBT vs SiC MOSFET Modules in Motor Drive Inverter," accepted at the 2025 Energy Conversion Congress & Expo Europe (ECCE Europe), Aug. 31-Sept 4, 2025.