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Towards a Standardized Digital Product Pass for Green Steel: Developing Novel Framework with Real-Time CO_2 Tracking and Secure Data Connectivity for ESPR Compliance

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Transformation towards climate-neutral production in the metal industry requires innovative solutions for tracking and optimizing greenhouse gas emissions. While major steel manufacturers are already exploring digital product passports (DPP) as part of their sustainability strategies, small and medium-sized enterprises (SMEs) in the metal processing industry often lack standardized and real-time compatible methods for quantifying product-specific emissions.

This paper introduces a novel DPP architecture tailored for SMEs in metal processing, integrating edge-computing-based models to dynamically assess the CO_2 footprint of individual products during manufacturing. Unlike conventional static product information systems, the proposed approach enables real-time tracking of energy consumption at critical process stages, merging sensor data with model-based digital twins. This ensures a more precise, verifiable, and scalable solution for sustainability reporting across the supply chain, with necessary interfaces and access control mechanisms to address privacy concerns of SMEs during product-related data exchange. The architecture leverages industry-compatible interfaces for automated data exchange with existing ERP/MES systems and regulatory platforms, ensuring compliance with the Ecodesign for Sustainable Products Regulation (ESPR) and interoperability with EU-wide standarized data models. By developing a green steel DPP framework that meets future standardization, regulatory and certification requirements, it provides an early-stage solution that aligns with upcoming industry and legislative needs.

Pilot projects in a real-world hot rolling mill and foundry validate the system's ability to enhance transparency and energy efficiency with real-time emission monitoring. By integrating dynamic energy monitoring into the green steel DPP framework, this research presents a pathway toward standardized and verifiable CO_2 assessment in metal processing. The findings contribute to ongoing EU standardization efforts and set a foundation for scalable, industry-wide applications.

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