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MASTER's Degree Thesis

Model Based Simulation to Support the Decarbonization of Chip Manufacturing

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Abstract:

This thesis develops a model based approach to support the decarbonization of a semiconductor assembly line by integrating discrete-event simulation with stage-level energy and emissions accounting. The case study focuses on a surface-mount technology (SMT) line at Hapro Electronics (Line 5, Jaren, Norway). The AnyLogic model represents the full PCB assembly flow preparation, solder paste printing and SPI, pick and place (PnP), reflow heating/cooling, AOI, and storage and is parameterized using sensor readings and equipment datasheets to estimate per-stage energy use, queueing behavior, throughput, and CO_2 emissions.

Baseline results reveal two dominant levers: the reflow oven is the primary energy hotspot and main contributor to the line's carbon footprint, while the PnP station governs throughput, cycle time, and work in process. Consequently, thermal stability at reflow and congestion management at PnP must be addressed jointly to reduce kWh/PCB and kg CO_2/PCB without compromising delivery performance.

Three strategies were evaluated. First, batching at the reflow oven (batch size = 7) halves weekly reflow energy (-51.6%) and lowers total weekly CO_2

emissions by ~40%, reducing unit intensity from 0.0049 to 0.003 kg/PCB with minimal impact on weekly throughput, although daily cycle time increases due to warm-up and standby behavior. Second, increasing effective PnP capacity (10 → 13) eliminates the structural bottleneck and further reduces unit carbon intensity (≈0.0030 → 0.0028 kg/PCB) by distributing unavoidable thermal overheads across higher output. Third, an on site grid connected photovoltaic system (69 kWp DC, 100 kVA AC), sized with PVsyst, could supply ~74 MWh in Year 1, achieving near-complete coverage of the line's annual electricity demand.

Overall, the results outline a practical roadmap: stabilize the reflow oven's thermal regime, relieve the PnP bottleneck to maintain smooth flow, and align residual electrical demand with low carbon local generation.

Keywords: discrete event simulation, PCBA, Reflow Oven

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