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# INTELLIGENT WASTE-TO-ENERGY SYSTEMS: A HYBRID IOT-ALNS APPROACH FOR OPTIMIZED COLLECTION AND ANAEROBIC DIGESTION

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*Urban waste management faces challenges from increasing volumes, inefficient collection, and environmental impacts. This paper presents Smart-Waste-Bin, an IoT-enabled system integrating intelligent sensing and waste-to-energy conversion. ESP32-based smart bins equipped with ultrasonic, weight, humidity, and infrared sensors collect real-time data processed through cloud analytics. An ALNS-VND hybrid algorithm optimizes vehicle routes based on real-time fill levels and traffic conditions. Biodegradable waste undergoes automated segregation and IoT-based anaerobic digestion for biogas production. A 30-day simulation with 200 bins and 8 vehicles demonstrates significant improvements over fixed-schedule collection: 39.7% faster collection, 27.1% lower fuel consumption, 87.2% fewer overflows, and 34.8% reduced distance. The system achieves 35-50% GHG emission reduction while transforming waste management from reactive to proactive operations for sustainable smart cities.*