Chapter 3
Energy Mapping and Resource Efficiency Using Geospatial Tools

Deepak Gupta
http://orcid.org/0000-0003-3929-1362
Institute of Technology and Management, Gwalior, India

Ergashev Nuriddin
http://orcid.org/0000-0002-8274-6193
Karshi State Technical University, Uzbekistan

Rano Muradova
Termez University of Economics and Service, Uzbekistan

Sattarova Mahfuza
Mamun University, Uzbekistan

Rasulov Avazbek
Tashkent University of Information Technologies, Uzbekistan

Muslima Nazarova
Tashkent State University of Economics, Uzbekistan

Khayrulla Urozboev
Alfraganus University, Uzbekistan

ABSTRACT

Manufacturing industries account for a significant share of global energy consumption and greenhouse gas emissions, making resource efficiency an urgent priority. This chapter examines the integration of Geographic Information Systems (GIS) with Industrial Internet of Things (IIoT) technologies, digital twins, and artificial intelligence to enable spatial energy mapping and resource efficiency in manufacturing environments. Energy consumption data collected from smart submeters and edge-computing platforms can be visualized as geospatial layers to identify energy hotspots, quantify waste sources, and prioritize intervention strategies.

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1. INTRODUCTION

The global manufacturing sector faces mounting pressure to reduce energy consumption, lower carbon emissions, and transition toward sustainable operational models. Energy-intensive industries—including steel, cement, chemicals, and automotive manufacturing—collectively account for approximately one-third of global final energy demand. Against this backdrop, the transition toward Industry 4.0 has opened new opportunities to address energy challenges through the convergent application of digital technologies, sensor networks, and spatial analytics (Setyadi et al., 2025; Javaid et al., 2022). The urgency of these challenges is underlined by the growing stringency of international climate commitments, national energy efficiency mandates, and corporate sustainability targets that require manufacturing organizations to demonstrate measurable, verifiable progress in reducing energy use and associated emissions.

Geographic Information Systems (GIS) offer a powerful platform for visualizing, analyzing, and managing energy resources across complex industrial environments. By overlaying energy consumption data onto spatial maps of factory floors, supply chains, and utility infrastructure, GIS enables facility managers and sustainability officers to identify spatial patterns in energy use—commonly referred to as energy hotspots—and develop targeted efficiency measures. When combined with Industrial Internet of Things (IIoT) sensor networks and cloud-based data platforms, GIS can deliver real-time insights into energy flows at the machine, zone, and facility level (Papaioannou et al., 2025; Bin Mofidul et al., 2022). This spatial dimension of energy management is increasingly recognized as a critical enabler of precision efficiency interventions that aggregate monitoring systems are unable to support.

Despite the growing availability of geospatial tools and energy data platforms, many manufacturing organizations still rely on aggregate utility billing data and periodic audits to understand their energy performance. This approach lacks the granularity needed to detect process-level inefficiencies, diagnose root causes of energy waste, or respond dynamically to changing production conditions. The gap between available technology and organizational practice represents both a challenge and an opportunity for researchers and practitioners (Andrei et al., 2022; Geng & Evans, 2022). Bridging this gap requires not only technological capability development but also the organizational knowledge frameworks, data governance structures, and investment justification methodologies that make GIS-based energy management practically accessible to manufacturing enterprises of diverse sizes and sectors.

This chapter presents a comprehensive framework for energy mapping and resource efficiency using geospatial tools in the context of manufacturing industries. The analytical framework developed herein synthesizes evidence from recent literature spanning IIoT-based energy monitoring, GIS spatial analysis, digital twin simula-