



A Systematic Review of Industry 5.0 Sustainability Pillars in Enhancing Planetary Health Outcomes for the Kulim Hi-Tech Community

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Abstract. By 2026, the industrial paradigm in Malaysia will change from just automation to a focus on overall health and well-being through the Industry 5.0 framework. As a significant center for technology, Kulim Hi-Tech Park (KHTP) is having a hard time striking a balance between industrial expansion and the sustainability of “Planetary Health,” which has an immediate effect on the community. The purpose of this systematic review study is to determine how much the three pillars of Industry 5.0 sustainability—human centrality, sustainability, and resilience—have been incorporated to enhance planetary health outcomes for the KHTP community. This study was conducted using a systematic literature review (SLR) approach based on the PRISMA protocol, analyzing academic publications and industry reports from 2021 to 2026. Focus is given to the relationship between industrial green technology and the well-being of the ecosystem in the Kulim industrial zone area. Initial analysis indicates a significant awareness gap where existing advanced technologies are more focused on economic productivity than on the ecological restoration of communities. However, the element of resilience through smart technology is found to have great potential in mitigating the effects of local climate change, such as the urban heat island (UHI) effect. This study proposes a new integration framework that positions planetary health as a key performance indicator in the future development of the industry. The results of this study are expected to provide critical input to policymakers and TVET institutions to produce a workforce that is not only technologically skilled but also aware of Earth’s sustainability.

Keywords: Industry 5.0, Planetary Health, Kulim Hi-Tech Park, Community Sustainability, Systematic Review.

1 Introduction

The evolution from Industry 4.0 to Industry 5.0 reflects a critical shift from efficiency-driven automation toward a more human-centric and sustainability-oriented industrial paradigm. While Industry 4.0 has significantly advanced digitalization and productivity, it has also contributed to increased resource consumption and environmental stress [1], [2]. Industry 5.0 addresses these limitations by emphasizing sustainability, resilience, and human well-being. These principles are closely aligned with the concept of Planetary Health, which underscores the interdependence between industrial development and ecological integrity [3]. The concept of planetary health has gained importance as a framework that links human health and well-being to the integrity of the Earth [4]. Industrial zones, and particularly high-technology parks, are critical to the achievement of Planetary Health outcomes because they affect land use patterns and energy consumption, greenhouse gas emissions, and the well-being of the entire community [5]. Despite this alignment, a significant gap persists in translating Industry 5.0 principles into measurable Planetary Health outcomes, particularly within rapidly industrializing regions such as Kulim Hi-Tech Park (KHTP). Existing implementations often prioritize economic gains over ecological restoration and community resilience [6], [7]. Accordingly, this study aims to systematically examine how Industry 5.0 sustainability pillars can be operationalized to enhance planetary health outcomes within the KHTP community. This research contributes by bridging conceptual gaps and proposing an integrative framework linking industrial innovation with environmental sustainability and societal well-being.

2 Theoretical Background

The theoretical foundation of this study is anchored in the intersection between emerging industrial paradigms and ecological health mandates. At the core of this discourse is Industry 5.0, which represents a fundamental evolution from the purely efficiency-driven models of Industry 4.0 towards a more balanced, value-centric approach. This paradigm shift aligns synergistically with the concept of Planetary Health, an interdisciplinary field that recognizes the inextricable link between human domains converged within a high-tech industrial ecosystem. To understand how these two domains converge within a high-tech industrial ecosystem like Kulim Hi-Tech Park (KHTP), it is essential to first deconstruct the core pillars of Industry 5.0—human centricity, sustainability and resilience—and their theoretical capacity to mitigate environmental stressors while fostering community well-being.

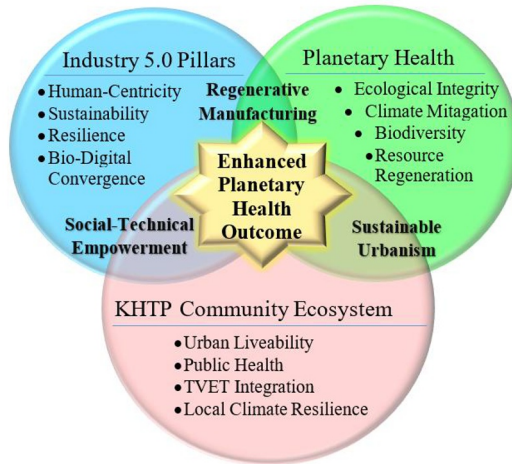


Figure 1: Bio-Digital Synergies Framework for Planetary Health

Fig. 1. Bio-Digital Synergies Framework for Planetary Health. The framework integrates the industry 5.0 pillars (Human-Centricity, Sustainability, Resilience, Bio-Digital Convergence), Planetary Health dimensions (Ecological Integrity, Climate Mitigation, Biodiversity, Resource Regeneration), and the KHTP Community Ecosystem (Urban Liveability, Public Health, TVET Integration, Local Climate Resilience), converging toward Regenerative Manufacturing, Socio-Technical Empowerment, and Sustainable Urbanism for enhanced planetary health outcomes.

Figure 1 illustrates the Bio-Digital Synergies Framework, conceptualizing the intersection between Industry 5.0, Planetary Health, and the KHTP community ecosystem. The core of this framework represents the ideal ‘sweet spot’ where technological innovation (Industry 5.0) directly feeds into the restoration of natural systems (Planetary Health) while simultaneously elevating the quality of life for the local community. This synergy is particularly crucial for KHTP as it transitions from a traditional high-tech hub into a human-centric, ecologically resilient industrial region.

2.1 Industry 5.0 Sustainability Pillars

Industry 5.0 is structured around three interrelated pillars. Human-centrality emphasizes the role of technology in enhancing worker well-being, skills development, and community inclusion rather than replacing human labor [3], [8]. Sustainability focuses on minimizing environmental impacts through energy efficiency, circular economy practices, green manufacturing, and responsible resource use [2], [9]. Resilience refers to the capacity of industrial systems and surrounding

communities to anticipate, absorb, and adapt to disruptions such as climate change, pandemics, and supply-chain shocks [10].

2.2 Planetary Health Framework

Planetary health extends beyond traditional environmental protection by explicitly linking ecological integrity with human health outcomes [4], [11]. It highlights how climate change, biodiversity loss, air pollution, and urbanization directly affect physical and mental health, social equity, and economic stability [12]. Within industrial zones, planetary health outcomes are shaped by factors such as emissions control, green infrastructure, thermal comfort, and access to healthy living environments [5], [13]. Integrating Industry 5.0 with planetary health therefore requires a shift from productivity-driven metrics toward holistic performance indicators that include ecological restoration, community well-being, and long-term system resilience [7], [14].

3 Methodology

This study employed a systematic literature review (SLR) guided by the PRISMA protocol [15]. Academic articles were retrieved from major scientific databases, including Scopus, Web of Science, IEEE Xplore, and ScienceDirect. In addition, relevant policy documents and industry reports related to Industry 5.0, sustainability, and Malaysian industrial development were included.

3.1 Inclusion and Exclusion Criteria

Publications were included if they (i) were published between 2021 and 2026, (ii) addressed Industry 5.0, sustainability, resilience, or planetary health, and (iii) discussed policy, community, or industrial-zone implications. Studies focusing solely on technical automation without sustainability or human-centric considerations were excluded.

3.2 Data Extraction and Analysis

Selected studies were analysed thematically and mapped against the three Industry 5.0 pillars and key planetary health dimensions [2], [7]. Attention was given to findings relevant to industrial parks, urban sustainability, and Southeast Asian or Malaysian contexts [6], [16]

4 Results and Discussion

The systematic literature review conducted through the PRISMA protocol yielded a comprehensive synthesis of current research trends and practical applications of Industry 5.0 within the industrial-urban landscape. The findings reveal a significant paradigm shift from the efficiency-driven models of Industry 4.0 towards the value-driven pillars of Industry 5.0, specifically in the context of fostering Planetary Health. To provide a clear overview of the current research landscape, Table 1 summarizes the critical alignment between Industry 5.0 pillars and identified gaps in Planetary Health outcomes specifically observed in high-tech industrial ecosystems like KHTP. This synthesis forms the basis for the following critical analysis of how human-centricity, sustainability, and resilience can be operationalized to enhance community well-being and ecological restoration.

Table 1. Synthesis of Industry 5.0 Pillars and Planetary Health Gaps in KHTP.

Industry 5.0 Pillar	Focus of Current Literature	Planetary Health Missing Link	Proposed Integration for KHTP
Human-Centricity	Worker safety & digital skills [4], [7].	Impact of industrial environment on community mental health and urban liveability.	Developing AI-driven “Eco-Stress” monitoring for both workers and residents.
Sustainability	Resource efficiency and carbon reduction [5], [19].	Passive compliance vs active ecological restoration (Kulim River health).	Implementing regenerative manufacturing that supports local biodiversity.
Resilience	Supply chain and production stability [20].	Community-level resilience against Urban Heat Island (UHI) effects.	Deploying “Digital Twins” to predict and mitigate local thermal emissions.

4.1 Human-Centricity and Community Well-Being

The review indicates that most Industry 5.0 implementations remain concentrated on workplace ergonomics and digital skills development, with limited extension to surrounding communities [8], [17]. In the context of KHTP, human-centric approaches have the potential to improve community health outcomes through inclusive planning, workforce upskilling, and integration of social infrastructure [6], [18]. However, the systematic review indicated that Industry 5.0 must transcend workplace ergonomics to address the broader sociolect-ecological impact on the surrounding community. In the context of KHTP, a human-centrist approach necessitates the integration of industrial safety protocols with local urban livability,

ensuring that technological advancements do not compromise the mental and physical health of residents living within the industrial-urban fringe.

4.2 Sustainability and Environmental Performance

Sustainability-oriented technologies, such as energy-efficient manufacturing, renewable energy integration, and green building design, are widely discussed in the literature [9], [19]. Nevertheless, many studies highlight a persistent gap between technological capability and ecological restoration [5], [14]. For KHTP, advanced green technologies are primarily deployed to meet regulatory compliance and cost efficiency, rather than to actively restore ecosystems or mitigate local environmental stressors such as UHI and air quality degradation [6], [13]. The findings highlight a critical shift from compliance-based sustainability to regenerative sustainability. For KHTP, this implies that industrial players should move beyond minimizing harm to actively participating in the restoration of local ecosystems, such as the Kulim River basin. This proactive restoration aligns with the Planetary Health mandate, where industrial prosperity is intrinsically linked to the health of the natural environment.

4.3 Resilience and Climate Adaptation

Resilience emerges as the most promising pillar for enhancing planetary health outcomes [10], [20]. Smart monitoring systems, digital twins, and data-driven environmental management tools show strong potential in mitigating climate-related risks [16], [21]. In industrial zones similar to KHTP, resilience-oriented technologies can reduce heat stress, improve disaster preparedness, and support adaptive urban planning [13], [22]. However, the literature emphasizes that resilience must be co-designed with local communities to ensure equitable benefits [18]. Digital transformation, specifically through Digital Twins and IoT monitoring, offers a robust mechanism to bridge the resilience gap. By utilizing real-time data to monitor and mitigate Urban Heat Island (UHI) effects within KHTP, the community can develop a predictive capacity against climate-induced stressors, thereby fostering an industrial ecosystem that is not only productive but also ecologically resilient.

5 Implications for Kulim Hi-Tech Park

The synthesis reveals a significant awareness gap in positioning planetary health as a core performance metric within industrial development [7], [14]. While KHTP demonstrates technological maturity, its sustainability strategies remain largely economy-centric [6], [23]. Aligning Industry 5.0 pillars with planetary health requires integrating environmental and health indicators into industrial governance, urban planning, and workforce development [9], [18].

This review proposes a conceptual integration framework in which planetary health outcomes—such as reduced UHI intensity, improved air quality, and enhanced community well-being—are treated as key performance indicators alongside productivity and innovation metrics [4], [12]. The findings imply that KHTP must

evolve into a Regenerative Industrial Hub where technological advancement is measured by its ecological footprint. For instance, the integration of Industry 5.0 pillars suggests that KHTP should move beyond conventional waste management toward a bio-digital ecosystem that actively monitors and restores local biodiversity. By adopting the proposed framework, KHTP can serve as a national benchmark for Planetary-First industrial zones, balancing high-tech production with the preservation of Kulim's micro-climate and community health.

6 Policy and TVET Implications

For policymakers, the findings underscore the need to embed planetary health objectives into national industrial policies and sustainability roadmaps, such as Malaysia's National Industrial Master Plan 2030 and National Energy Transition Roadmap [23], [24]. For Technical and Vocational Education and Training (TVET) institutions, Industry 5.0 presents an opportunity to cultivate a workforce that is not only technologically competent but also environmentally literate and socially responsible [17], [25]. Furthermore, the transition to Industry 5.0 necessitates a radical shift in TVET curricula, particularly in institutions like PTSB. It is no longer sufficient to produce graduates with technical proficiency; there is an urgent need for Eco-Technical skills where students are trained to design industrial solutions that are inherently sustainable and human-centric. Policymakers should leverage the Industry 5.0 framework to align NIMP 2030 goals with Planetary Health outcomes, ensuring that future technical training programs prioritize environmental stewardship as a core competency for the next generation of engineers and technicians.

7 Conclusion

This systematic review demonstrates that Industry 5.0 offers a valuable framework for re-orienting industrial development toward planetary health. By analyzing the integration of human-centricity, sustainability, and resilience, this study has identified that while Kulim Hi-Tech Park (KHTP) stands at the forefront of industrial innovation, a significant ecological empathy gap persists within its socio-technical fabric. The findings underscore that while sustainability and human-centricity are gaining traction, the strategic deployment of resilience-driven smart technologies such as digital twins and real-time ecological monitoring holds the greatest potential for mitigating localized climate stressors and environmental degradation in industrial hubs. Moving forward, it is imperative that future industrial strategies, particularly within the KHTP ecosystem, explicitly integrate Planetary Health indicators as core performance metrics. Furthermore, this transition necessitates a proactive role from TVET institutions, such as Politeknik Tuanku Sultanah Bahiyah (PTSB), to cultivate a workforce equipped with Eco-Technical competencies. Ultimately, bridging the gap between high-tech production and ecological restoration will ensure that industrial growth in the Industry 5.0 era is not only balanced and inclusive but also inherently regenerative for the planet and the community.

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