When Smart Is Not Sustainable: Digital Parasitism in AI-Driven Industrial Automation[⋆]

Luís Frölén Ribeiro[1*,3†], Larysa Savosh[1,2,*,†] and Bernardo Farrero[3,4,†]

[1] *Instituto Politécnico de Bragança - Bragança - Portugal*
[2] *Lutsk National Technical University – Lutsk - Ukraine*
[3] *GICoS - Instituto Politécnico de Bragança - Bragança - Portugal*
[4] *Universidad Politécnica de Madrid - Madrid - Spain*

Abstract

Smart automation, robotics, and artificial intelligence are increasingly presented as key enablers of a sustainable industrial transition. Through optimisation, monitoring, and digital integration, these technologies are assumed to reduce resource use, waste, and environmental impact. However, the causal link between "smarter" and "more sustainable" industry remains analytically fragile. This paper introduces the concept of digital parasitism to explain a recurrent failure mode in which digital layers extract legitimacy, strategic priority, and investment from sustainability narratives while remaining weakly coupled to demonstrable biophysical outcomes, such as absolute reductions in material and energy throughput or lifecycle environmental burdens. The analysis shows how semantic capture, metric capture, and institutional capture allow informational performance and audit-ready artefacts to substitute for material transformation. Beyond institutional dynamics, the paper argues that digital parasitism becomes self-reinforcing through cognitive capture, reshaping how organisations interpret sustainability, evidence, and success. Sustainability increasingly comes to be associated with what is digitally measurable and verifiable, rather than with binding physical constraints. The paper distinguishes between enabling digitalisation, where digital systems are subordinated to explicit material constraints and redesign choices, and parasitism-prone digitalisation, where efficiency and visibility gains function as proxy achievements. By providing a rigorous conceptual framework rather than a technical metric, the paper aims to support more discriminating evaluation of sustainability claims in smart automation and robotics, particularly in contexts where digital evidence risks displacing biophysical accountability.

Keywords

Digital parasitism; Smart industry; Sustainable manufacturing; Industrial digitalisation; Rebound effects; Sustainability governance; Industry 5.0; Cognitive capture

1. Introduction

Smart automation and robotics are increasingly positioned as the operational backbone of a "sustainable" industrial transition: AI optimises schedules and energy use, IIoT instruments assets and flows, digital twins model performance, and cyber-physical systems promise higher yield with lower waste. The policy and industrial narrative is now explicit that advanced digitalisation should contribute to sustainability objectives, not merely to productivity, i.e. an emphasis evident in the European framing of Industry 5.0, which links industrial innovation to planetary boundaries, resilience, and human-centricity [1].

However, the causal link between "smarter" and "more sustainable" remains analytically fragile. Much of the evidence base underpinning "Sustainable Industry 4.0" consists of enabling arguments, i.e., digital technologies can support resource efficiency, predictive maintenance, quality control, and closed-loop strategies; rather than demonstrated, system-level reductions in absolute industrial burdens. Reviews in the sustainable manufacturing/Industry 4.0 literature highlight substantial potential but also reveal the central difficulty: the digital layer primarily improves information,

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[1*] Corresponding author.

[†] These authors contributed equally.

frolen@ipb.pt (L. Frölén Ribeiro); larysa.savosh@ipb.pt (L. Savosh); bernardo.farrero@ipb.pt (B. Farrero)
0000-0003-4336-6216 (L. Frölén Ribeiro); 0000-0003-0831-2010X(L. Salvosh); 0009-0000-1666-2154 (B. Farrero)

coordination, and control, while the material layer is driven by scale, competition, and throughput logics that can overwhelm local efficiency gains [2].

This paper addresses a recurrent mismatch that is increasingly visible across smart manufacturing programmes: digital projects are routinely justified as sustainability interventions based on proxy improvements (per-unit energy reduction, improved traceability, better reporting granularity, or a more “intelligent enterprise”), while aggregate impacts remain ambiguous or may even rise due to rebound and scale effects. The rebound effect is not a rhetorical concern; it is a well-established mechanism by which efficiency-driven reductions in unit costs can induce additional consumption, offsetting expected savings. Empirical reviews show that rebound magnitudes vary by sector and service, but the structural implication remains stable: efficiency and optimisation do not automatically translate into absolute reductions in resource use [3].

In parallel, the digital layer is not environmentally “free”. Industrial AI, pervasive sensing, and platform-based management depend on compute, networks, and device lifecycles whose own energy and embodied emissions can be material at scale. ICT footprint assessments have repeatedly warned that digital growth trajectories can become a non-trivial contributor to global emissions, particularly if demand grows faster than efficiency improvements [4]. These trends intensify the need for conceptual clarity: when digitalisation is promoted as a sustainability instrument, what exactly is being improved; and how should that improvement be interpreted in biophysical terms?

To systematise this problem, the article develops the concept of digital parasitism as a diagnosis for a specific failure mode in smart industrial transformation. Digital parasitism does not dispute the utility of AI, robotics, or IIoT; instead, it describes the structural tendency for digital layers to extract sustainability legitimacy and strategic priority while remaining insufficiently coupled to absolute material outcomes. The conceptual contribution is intended to provide a rigorous vocabulary and mechanism set that allows researchers, industrial engineers, and decision-makers to distinguish between enabling digitalisation (digital deployment under binding material constraints) and parasitic digitalisation (digital expansion validated by sustainability claims without commensurate transformation of industrial metabolism).

The remainder of the paper proceeds as follows. Section 2 clarifies why efficiency and digital optimisation are frequently misread as sustainability progress, with particular attention to rebound and boundary effects. Section 3 defines digital parasitism and specifies its principal mechanisms: semantic capture, metric capture, and institutional capture. Section 4 explains why smart technologies are structurally prone to this failure mode. Section 5 introduces a decision distinction between enabling digitalisation and parasitism-prone digitalisation, together with a qualitative screening protocol for early project appraisal. Section 6 develops the cognitive capture mechanism through which digital parasitism becomes self-reinforcing [5]. Section 7 summarises implications for research, governance, and evaluation practice, followed by the conclusion.

2. Digital Parasitism

2.1. Definition

Digital parasitism is a structural condition in which digital layers in industrial systems (e.g., AI optimisation, IIoT monitoring, digital twins, and automated reporting) extract legitimacy, strategic priority, or investment from sustainability narratives while remaining uncoupled from demonstrable biophysical outcomes, such as absolute reductions in material and energy throughput, lifecycle environmental burdens, and product-system durability losses. It manifests when improvements in visibility, control, traceability, or per-unit efficiency are treated as sustainability progress despite unchanged or rising aggregate impacts driven by scale effects, rebound dynamics, or burden shifting across system boundaries [3].

This definition focuses on the relationship between informational performance and biophysical performance, and on how digital improvements in visibility, control, and optimisation become interpreted as sustainability progress within industrial decision-making. In smart factories, the digital layer frequently delivers measurable, impressive results: reduced downtime through predictive maintenance, improved yield through machine vision inspection, optimised energy scheduling, and better asset utilisation. The parasitic condition arises when these achievements acquire stand-alone legitimacy as sustainability evidence in governance, investment, or reporting contexts, thereby elevating informational performance to a proxy for system-level sustainability. Efficiency contributes to sustainability when it operates within explicit constraints on throughput, product lifetime, and lifecycle burdens, rather than functioning as a stand-alone performance objective.

2.2. Conceptual positioning relative to adjacent constructs

Digital parasitism intersects with, but is not reducible to, greenwashing. Greenwashing scholarship generally defines greenwashing as the use of environmental claims that mislead audiences by creating unjustified positive beliefs about an organisation's environmental performance. Importantly, this definition is grounded in deceptive effects rather than in demonstrable intent, as intentionality is difficult to observe and not required for analytical or regulatory purposes. Digital parasitism differs in scope and mechanism. It describes a socio-technical configuration in which digital capabilities themselves become the primary vehicle through which sustainability legitimacy is produced, typically via data generation, metrics, dashboards, and auditable narratives, even when the underlying industrial system remains governed by proxy indicators rather than by binding biophysical constraints. This distinction clarifies why digital parasitism can stabilise without deliberate misrepresentation, while still producing deceptive effects that resemble those discussed in the greenwashing literature [5,6].

2.3. Mechanism I — semantic capture

The first mechanism is semantic capture, in which sustainability language is attached to digital properties as if they were intrinsically sustainable. Terms such as "smart", "intelligent", "connected", "autonomous", and "data-driven" are increasingly used as quasi-environmental descriptors, implying that optimisation and instrumentation are equivalent to progress towards sustainability. This is reinforced by the dominant framing in the Industry 4.0/5.0 discourse, which emphasises digital technologies as enablers of sustainable manufacturing and societal goals [2].

Semantic capture is not merely a marketing issue; it influences engineering priorities. When a project is framed as "sustainable" because it implements a digital twin or an AI optimiser, the evaluation focus shifts from what is materially reduced to what is digitally improved. The resulting design tendency is to maximise instrumented scope and analytic sophistication, while leaving throughput drivers, product durability, and boundary choices (plant vs. value chain vs. lifecycle) underspecified. Semantic capture thus functions as the linguistic precondition for the next mechanism: metric capture.

2.4. Mechanism II — metric capture

Metric capture occurs when the metrics that digital systems can readily produce are promoted to the status of sustainability indicators, even when their relationship to absolute environmental outcomes is contingent or weak. Smart manufacturing excels at producing high-frequency performance data: energy per unit, cycle time, scrap rate, overall equipment effectiveness, logistics routing efficiency, or predictive maintenance accuracy. These metrics are operationally valuable, but they can be environmentally misleading when interpreted as proxies for absolute reductions rather than as indicators of local efficiency.

Metric capture has three typical pathways.

1. Per-unit substitution: per-unit improvements (e.g., kWh per part) are treated as sustainability outcomes despite rising total output or higher utilisation. This is precisely the

pathway through which rebound dynamics can dominate: efficiency reduces production costs or improves reliability, enabling scale expansion that offsets per-unit gains [3].

2. Boundary contraction: metrics are computed within a narrow operational boundary (single line, single facility), while burdens shift upstream (materials, device supply chains) or downstream (use-phase, maintenance burden, end-of-life). Digital systems can intensify boundary contraction by rendering the local boundary legible in exquisite detail, making it tempting to treat local data completeness as system completeness.
3. Dashboard authority: sustainability credibility is transferred to whatever is instrumented and visualised. If a decision arena privileges auditable artefacts (dashboards, reports, machine-generated traceability), the existence of digital evidence can crowd out harder-to-measure but more decisive variables (absolute throughput constraints, product longevity, substitution effects, induced demand).

Metric capture is especially plausible under contemporary "data-driven sustainability" narratives, and it becomes more consequential as regulatory and investor environments demand verifiable methods and documentation [7].

2.5. Mechanism III — institutional capture

Institutional capture occurs when funding, strategy, compliance, and organisational rewards systematically favour digital interventions that can be narrated as sustainable, even when their coupling to biophysical outcomes is weak. Digital projects often score highly on criteria that institutions value: innovation visibility, scalability, auditability, and alignment with strategic buzzwords (AI, smart enterprise, Industry 5.0) [9].

Several structural conditions can reinforce institutional capture:

- Investment logic: Digital retrofits and analytics platforms often have clearer ROI pathways than material redesign, product durability programmes, or fundamental process substitution [8]. This creates a selection bias towards projects that optimise the existing industrial regime rather than transform it.
- Compliance logic: When the evidentiary burden of sustainability shifts towards documentation and substantiation, digital systems are attractive because they produce records, logs, and traceability. This can lead to substituting compliance capacity for biophysical performance, particularly if what is substantiated remains a proxy [7].
- Reputational logic: Smart-industry artefacts are communicatively powerful. A digital twin, an AI monitoring system, or an IIoT platform can be showcased as a sustainability initiative even when the material transformation is marginal.

Institutional capture is the mechanism that stabilises digital parasitism over time: once organisations and ecosystems build routines, vendors, and evaluation templates around digital evidence, the system becomes path-dependent. Under such conditions, smart industry risks converging towards "sustainability legibility" rather than sustainability itself.

2.6. The digital layer is not environmentally neutral

A further reinforcing factor is that digital parasitism can be underestimated because the digital layer's own footprint is treated as negligible or external. Yet multiple assessments and energy-system analyses highlight that data centres and wider ICT infrastructure represent non-trivial and potentially growing electricity demand, and that ICT device lifecycles contribute to embodied emissions [4]. The point is not to claim that digital technology is inherently environmentally harmful, but to note that any sustainability claim that relies on expanding digital infrastructure must treat that expansion as part of the system boundary, not as a cost-free enabler.

This matters directly for smart automation and robotics because industrial digitalisation increasingly assumes high-frequency sensing, cloud analytics, continuous model training, and platform integration across supply chains. Digital parasitism becomes more likely when the net effect is a redistribution of attention: intensive optimisation and monitoring in the local domain. At the same time, the systemic and infrastructural burdens of the digital layer remain poorly constrained and underaccounted for. These mechanisms together explain how digital parasitism emerges and stabilises in smart industrial contexts.

3. Sustainability, Efficiency, and the Smart Industry Narrative

3.1. From efficiency engineering to sustainability claims

Industrial engineering has long treated efficiency, yield, and reliability as first-order objectives. Within smart factories, these objectives are now pursued through algorithmic optimisation, sensor-rich monitoring, and cyber-physical integration. The sustainability argument often follows a seemingly direct chain: higher efficiency reduces waste and energy intensity; lower intensity implies lower environmental impact. This chain is plausible at the unit level, but it is insufficient as a sustainability criterion at the system level. The main reason is that sustainability is defined by aggregate, boundary-aware outcomes, whereas smart automation metrics typically reflect local performance improvements inside a narrow operational envelope.

Efficiency metrics remain indispensable for production management, but their environmental significance depends on scale, substitution, and boundary choices. When a line reduces kWh per unit, the environmental outcome depends on total output, on upstream burdens embedded in materials and equipment, and on downstream burdens in the use-phase, maintenance, and end-of-life. Consequently, a smart manufacturing intervention can be simultaneously excellent in operational terms and ambiguous in biophysical terms, particularly when increased utilisation and throughput are treated as the default pathway for capturing economic value.

3.2. Industry 4.0 and 5.0 as a “green enabler” discourse

A substantial body of work frames Industry 4.0 as a technological enabler of sustainable manufacturing through enhanced transparency, predictive maintenance, quality improvement, and circular strategies such as remanufacturing and closed-loop logistics. Typical examples include the use of sensor-based condition monitoring and machine learning to extend equipment lifetime and reduce unplanned downtime, digital twins to optimise process parameters and reduce scrap rates, vision-based inspection systems to improve yield and material efficiency, and digitally supported traceability systems to facilitate remanufacturing, component reuse, and reverse logistics across extended value chains [2]. A substantial body of the Industry 4.0 literature emphasises that digital technologies can support sustainability by reducing defects, enabling condition-based servicing, and improving process control in energy-intensive operations. However, many of these claims remain enabling rather than constraining: they describe what digitalisation can make possible, rather than what it compels or guarantees [2,12].

More recent European policy framing associated with Industry 5.0 explicitly links industrial transformation to sustainability, resilience, and human-centric objectives. This strengthens the normative expectation that smart enterprise technologies should contribute to sustainability outcomes. At the same time, it increases the risk of conceptual inflation: the tighter the rhetorical coupling between digitalisation and sustainability, the easier it becomes for digital projects to inherit sustainability legitimacy by association, even when their material coupling is weak.

3.3. Why relative gains dominate decision-making

The prevalence of relative indicators in smart industry is not accidental. Per-unit energy, scrap rates, OEE, and similar metrics are attractive because they are measurable at high frequency, actionable at the equipment level, and aligned with continuous improvement programmes. They also map cleanly onto the capabilities of AI and IIoT systems, which thrive on instrumented data streams and closed-loop control. In contrast, absolute lifecycle outcomes are slower to emerge, harder to attribute, and often depend on decisions beyond the shop floor, including product design, procurement, distribution, and market strategy.

This asymmetry yields a predictable institutional outcome: what is most measurable becomes what is most governable, and what is most governable becomes what is most rewarded. Smart automation therefore tends to optimise that which is visible within the operational boundary, while sustainability outcomes that require cross-boundary coordination remain secondary. This is a fertile substrate for digital parasitism, because the digital layer can produce increasingly sophisticated evidence of local improvement without resolving the system-level constraints that define sustainability.

3.4. Rebound and scale effects as first-order confounders

The rebound effect is a critical confounder for any narrative that equates efficiency with sustainability. Efficiency improvements reduce the effective cost of producing a unit of output, or they increase capacity utilisation by reducing downtime and variability. Both pathways can induce additional production, offsetting expected energy and resource savings. Rebound is not merely behavioural; in industrial contexts it can be structural, mediated by competition, capital utilisation incentives, and growth-oriented investment logics. Even when the rebound is partial, it undermines the inference that local efficiency implies reduced aggregate impact.

Smart automation can intensify rebound pathways by targeting the variables that unlock higher throughput at lower marginal cost. Predictive maintenance reduces unplanned stoppages; robotics reduces cycle time variance; AI scheduling improves asset utilisation; quality analytics reduces scrap. These are legitimate engineering achievements. The sustainability question is whether such achievements are coupled to binding constraints on absolute material throughput, lifecycle burdens, or product durability. If they are not, efficiency-led narratives become parasitism-prone because they allow digital performance to substitute for biophysical performance in evaluation arenas.

3.5. The ICT burden and the boundary problem

Digitalisation also has a material footprint. Sensors, controllers, networks, compute, and storage involve embodied burdens and operational energy demand. At scale, these burdens can be non-trivial, particularly when systems rely on extensive connectivity, cloud processing, continuous monitoring, and model training. The sustainability significance is not that ICT is inherently harmful, but that any claim that digitalisation enables sustainability must treat the digital infrastructure as part of the system boundary. If the digital footprint is ignored, the evaluation becomes systematically biased in favour of digital expansion.

This boundary issue is also methodological. Digital programmes tend to improve measurement within the factory while leaving upstream supply-chain and downstream use-phase burdens poorly characterised. The result is a pattern of boundary contraction: extensive data within a local perimeter is mistaken for comprehensive sustainability evidence. This reinforces metric capture and creates a pathway for digital parasitism to persist even in organisations that value verification.

4. Why Smart Technologies Are Prone to Digital Parasitism

4.1. AI optimisation and the dominance of informational performance

AI and machine learning systems in industrial settings are usually deployed to improve forecasting, control, classification, and scheduling. Their success is assessed through predictive accuracy, reduced downtime, improved yield, or decreased energy intensity per unit. These are operationally appropriate targets, but they are informational and local by construction. AI does not intrinsically encode biophysical constraints unless those constraints are explicitly imposed in the objective function, the governance rules, or the production strategy.

This creates a systematic gap: the better the AI performs on local objectives, the stronger the case for rollout and scaling. Yet scaling amplifies the very factors that determine sustainability outcomes: total output, demand response, and the distribution of burdens across the value chain. Without binding constraints, AI-driven optimisation can therefore increase the efficiency of an industrial regime while leaving its aggregate burdens unchanged or higher. Digital parasitism arises when sustainability legitimacy is granted primarily on the basis of demonstrable AI performance, rather than demonstrable biophysical coupling.

4.2. IIoT and digital twins: visibility without obligation

IIoT systems and digital twins are powerful instruments for visibility, traceability, and diagnostics. They reduce uncertainty, enable faster decisions, and support predictive maintenance and process control. They also produce audit-ready artefacts: dashboards, logs, reports, and key performance indicators. This evidentiary strength can become an institutional substitute for material change. In other words, visibility can be mistaken for progress.

Digital parasitism is especially likely when governance environments reward the existence of monitoring systems as evidence of sustainability intent or maturity. A plant may instrument energy use and emissions, or implement a digital twin that calculates efficiency and environmental indicators, yet still pursue throughput expansion as the primary business logic. In such cases, digitalisation strengthens the organisation's capacity to demonstrate control and compliance while the material system remains structurally similar.

4.3. Robotics and automation: throughput amplification under sustainability language

Robotics and automation offer consistency, quality, and productivity. In manufacturing, these benefits often reduce scrap, rework, and variability. They can also enable new manufacturing paradigms, including remanufacturing and disassembly automation, which have a more direct connection to circular strategies. The parasitism risk emerges when robotics is positioned as sustainable primarily because it is precise, efficient, or advanced, while the dominant effect is increased throughput, increased product turnover, or accelerated obsolescence through faster production cycles.

Robotics can therefore occupy both sides of the parasitism distinction. It can be enabling when deployed under constraints that privilege durability, remanufacturing, repair logistics, and lifetime extension. It becomes parasitism-prone when it is justified through sustainability language but deployed primarily to increase capacity utilisation in a throughput-oriented model.

4.4. Summary of the vulnerability structure

Across AI optimisation, IIoT, robotics, and cybersecurity, the vulnerability structure is consistent. Digital systems are exceptionally effective at producing measurable performance gains and auditable evidence. Sustainability outcomes, in contrast, are boundary-dependent and often slow to manifest. As a result, organisations can rationally prioritise digital interventions that are easy to validate and communicate, while treating sustainability as an interpretive layer applied ex post to operational achievements. This is the systemic pathway by which digital parasitism becomes normalised in smart industry.

5. Parasitism vs Enablement: A Decision Distinction for Smart Industry Interventions

5.1. Why a distinction is required

If digital parasitism is a recurrent failure mode, the practical question is how to distinguish parasitic digitalisation from enabling digitalisation at the level where projects are scoped, funded, and deployed. Smart automation programmes are typically evaluated through operational performance indicators, demonstrators, and evidence artefacts that the digital layer is well suited to produce. This creates a systematic selection pressure: interventions that yield rapid, local, instrumented improvements tend to be prioritised, even when their system-level sustainability meaning is uncertain.

This selection pressure is reinforced by the broader narrative coupling between advanced digitalisation and sustainability in contemporary industrial policy frameworks. In European terms, the Industry 5.0 framing explicitly links industrial transformation to sustainability and resilience, increasing the expectation that digitalisation supports societal goals [9]. At the same time, the evidentiary burden of sustainability claims is tightening. The European Commission's proposed framework on substantiation and communication of explicit environmental claims exemplifies a regulatory trend towards science-based, verifiable methods [7]. In such an environment, the capacity to produce audit-ready evidence becomes valuable, and digital systems can become the primary means of producing that evidence. This increases the risk that evidence production substitutes for biophysical performance.

Accordingly, a usable distinction must operate without requiring a full formal model at this stage. It should be compatible with engineering decision processes and provide criteria that can be applied during concept design and before scale deployment. It should also be robust to rebound dynamics, since rebound effects can offset efficiency-led claims when capacity utilisation and output expand [3].

5.2. Definition of enabling digitalisation

Enabling digitalisation refers to the deployment of AI, robotics, IIoT, and cyber-physical systems under conditions where the digital layer is instrumentally subordinated to explicit biophysical constraints and redesign choices. The sustainability claim is anchored in system outcomes, not in digital properties. Digital tools support the enforcement, verification, and optimisation of those constraints, but do not constitute the constraint.

An intervention is enabling when at least one of the following holds.

1. Constraint coupling: the digital intervention is explicitly coupled to constraints that bind absolute burdens, such as caps, enforced throughput limits, mandated reductions in specific lifecycle burdens, or design-for-longevity requirements that reduce replacement cycles.
2. Design coupling: the digital intervention is inseparable from a material redesign that alters the industrial metabolism, for example, remanufacturing capability, disassembly automation, process substitution that reduces virgin material demand, or product architecture changes that increase reparability and service life.
3. Boundary integrity: the sustainability claim includes explicit boundaries and addresses burden shifting across relevant stages, including upstream supply chains and downstream maintenance or end-of-life.

This definition recognises that enabling effects can be mediated through governance choices rather than through the digital technology itself. Digital systems are often necessary to implement constraints efficiently, but the constraints are what define sustainability performance.

5.3. Definition of parasitism-prone digitalisation

Parasitism-prone digitalisation refers to the deployment of digital technologies where sustainability legitimacy is largely derived from the existence of digital capability, from proxy metrics that the digital layer readily produces, or from compliance artefacts, while the material system remains structurally governed by throughput, scale, and cost reduction.

An intervention is parasitism-prone when at least one of the following holds.

1. Proxy substitution: per-unit efficiency, monitoring completeness, or analytics sophistication is treated as sufficient evidence of sustainability, without credible demonstration of absolute reductions or lifecycle improvements.
2. Throughput default: the business pathway for capturing value is increased utilisation and output, and the sustainability claim is not evaluated for rebound and scale effects. The rebound literature highlights why this is a first-order risk when efficiency reduces effective cost and expands consumption or production [3].
3. Boundary contraction: the evidence base is rich inside a narrow operational boundary and weak outside it, enabling burden shifting to remain undetected.
4. Digital burden omission: the footprint of the digital layer itself is excluded from evaluation, despite evidence that ICT infrastructure and device lifecycles can represent non-trivial and potentially growing burdens at scale [4].

Parasitism-prone is a diagnostic label that identifies susceptibility. It indicates that sustainability credibility can be produced without requiring material transformation, and that the system is likely to drift towards semantic, metric, and institutional capture.

5.4. Diagnostic propositions

The concept can be operationalised in later sections through testable propositions, without introducing a formal index at this stage.

Three are sufficient to guide the paper’s later scenarios:

- P1 (Coupling requirement): A smart-industry intervention is non-parasitic only if it is explicitly coupled to constraints or redesign choices that plausibly drive absolute reductions in lifecycle burdens under realistic scale conditions.
- P2 (Rebound sensitivity): The stronger the link between digital optimisation and reduced unit cost / increased capacity utilisation, the stronger the requirement for rebound and scale effects to be treated as first-order design variables [3].
- P3 (Boundary integrity): Sustainability claims supported primarily by digitally produced performance metrics are parasitism-prone unless boundary choices are explicit and burden shifting is actively assessed.

These propositions are deliberately framed to be compatible with sustainable manufacturing discussions in Industry 4.0/5.0 literature—where opportunities are recognised but implementation and evaluation challenges persist [2].

5.5. A qualitative screening protocol for project appraisal

To make the distinction actionable, this paper proposes a qualitative screening protocol suitable for early project stages. It consists of five questions that can be answered with existing engineering and management evidence.

5. What is the binding constraint?
6. Identify the explicit constraint that the digital system is meant to enforce or support. If no constraint exists beyond local efficiency targets, the intervention is parasitism-prone by default.
7. What changes in total throughput are expected under scale-up?
8. State whether the intervention is expected to increase utilisation and output, and whether rebound and induced production are treated explicitly. If rebound is not addressed, sustainability claims remain conditional [3].
9. What is the boundary and where can burdens shift?
10. Define whether the claim is plant-level, value-chain-level, or lifecycle-level. Identify plausible burden shifts upstream and downstream.
11. What evidence links digital performance to biophysical outcomes?
12. List the causal pathways from digital functions to absolute outcomes, not just to proxies. Evidence should not be reducible to the existence of dashboards or reporting completeness.
13. What is the digital layer footprint and lifecycle?
14. Describe sensors, compute, networks, update cycles, and replacement risks. ICT footprint studies provide a rationale for including the digital layer in boundary choices when claims depend on expanded digital infrastructure [4].

The protocol is intentionally conservative. It treats sustainability claims as hypotheses that require explicit constraints, credible boundary statements, and rebound sensitivity.

6. Cognitive Capture and Self-Reinforcing Dynamics

Digital parasitism is stabilised not only by institutional capture, but also by a host-level transformation in how sustainability is perceived and processed within organisations. Once digital initiatives are repeatedly validated as “sustainable” on the basis of proxy improvements and audit-ready artefacts, decision-makers adapt their internal criteria for credibility. Sustainability becomes cognitively mapped onto what the digital layer can easily render legible: dashboards, traceability, compliance records, and per-unit efficiencies. This produces a selective attention regime in which what is measurable is experienced as what is real, and what is real is treated as what is strategically actionable. This dynamic resembles accounts of cultural transmission in which ideas propagate by fitting cognitive and institutional selection environments, not necessarily by benefiting their carriers. In memetic framings, cultural items can act as replicators whose persistence depends on transmissibility rather than on host welfare, a point introduced in early discussions of memes and cultural replication Richard Dawkins and later debated and refined in cognitive-anthropological approaches such as the epidemiology of representations [10]. In the present context, sustainability-through-digitalisation persists because it aligns with cognitive and institutional selection environments that reward representations which are easily communicated, instrumented, and stabilised in organisational routines, even when their adequacy with respect to biophysical outcomes is weak [9,10].

Cognitive capture then feeds back into institutional capture. Once the organisation learns that digital evidence functions as a sufficient marker of sustainability, it preferentially funds interventions that produce such evidence, builds governance routines around those artefacts, and selects vendors and consultants who reinforce the same evaluative grammar. Over time, this can create path dependence: the organisation becomes better at producing sustainability legibility than at changing the industrial metabolism that sustainability ultimately concerns. In this sense, digital parasitism is not merely a communications distortion but a self-reinforcing selection process operating on what counts as evidence, success, and feasibility.

7. Discussion and Implications

The argument developed here has three implications for research and practice in smart automation and robotics. First, it introduces a conceptual vocabulary centred on digital parasitism and its associated mechanisms, including semantic capture, metric capture, institutional capture, and cognitive capture, to describe a specific failure mode in which digital capability inherits sustainability legitimacy by association and thereby competes with, or displaces, more materially decisive interventions. Second, it clarifies why verification regimes can inadvertently intensify the problem: when substantiation focuses on methods and documentation, digital systems may dominate by producing audit-ready artefacts, even if the underlying indicators remain proxies and system boundaries remain narrow [6,7]. Third, it motivates an appraisal discipline that treats sustainability-labelled digital projects as hypotheses requiring explicit constraints, boundary integrity, and rebound sensitivity, rather than as inherently beneficial by virtue of improved optimisation or visibility [6,7].

For scholarship, the most immediate research agenda is to test the proposed mechanisms empirically. Candidate pathways include comparative studies of project appraisal documents, sustainability reports, and investment decisions across firms adopting advanced digitalisation, with attention to how proxy indicators become institutionalised and how boundaries are chosen. For practice, the screening protocol offered in Section 5 can function as a minimum evidence threshold for sustainability claims in smart industry programmes, particularly where AI and IIoT systems are scaled beyond pilot deployments.

8. Conclusion

The title *When Smart Is Not Sustainable* reflects the central diagnostic of this paper. The analysis has shown that smart automation and digital intelligence can generate convincing signals of progress while remaining only weakly connected to changes in material throughput, lifecycle burdens, and durability. In such cases, digital sophistication functions less as a driver of sustainability than as a substitute for it, allowing informational performance to stand in for biophysical performance.

Smart automation can support sustainability objectives, but the relationship is not automatic. This paper makes six claims, in order of importance.

1. Digital performance can be mistaken for sustainability outcomes. In smart industry programmes, improvements in visibility, control, and optimisation often function as proxy evidence of sustainability, even when biophysical outcomes remain indirect or conditional.
2. This failure mode is conceptualised here as digital parasitism. Digital parasitism describes a recurrent decoupling between informational performance and biophysical outcomes, in which digital layers acquire sustainability legitimacy by association.
3. Three capture mechanisms explain how digital parasitism operates. Semantic capture attaches sustainability meaning to digital properties. Metric capture elevates what is measurable to what counts. Institutional capture privileges interventions with legible evidence and attractive return-on-investment pathways, thereby reinforcing proxy-based evaluation.
4. Digital parasitism can stabilise through cognitive capture. Over time, organisations internalise a grammar of sustainability in which what is digitally measurable and auditable is treated as what is environmentally decisive.
5. A diagnostic distinction follows. The paper distinguishes enabling digitalisation from parasitism-prone digitalisation and articulates qualitative diagnostic criteria related to

coupling, rebound sensitivity, and boundary integrity. These criteria are not a formal index, but a screening logic to identify when sustainability claims rely primarily on informational performance.

6. A conditional claim follows from the analysis. Smart systems can be credibly described as sustainable only when digital improvements are explicitly coupled to biophysical constraints and boundary-aware outcomes, rather than functioning as stand-alone sources of legitimacy.

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Declaration on Generative AI

The authors declare that artificial intelligence–based tools were used in a supporting and editorial capacity during the preparation of this manuscript. Grammarly was used for language refinement, grammar checking, and stylistic consistency. ChatGPT was used to assist with text restructuring, clarity improvement, and refinement of argumentative flow. All conceptual development, analytical reasoning, interpretations, and final editorial decisions are the sole responsibility of the authors. The use of these tools did not replace scholarly judgement, originality, or critical analysis, and the authors assume full responsibility for the content of the manuscript.

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