

## SYSTEMIC IMPACT ASSESSMENT

# AI-NATIVE INDUSTRIAL MANUFACTURING PLATFORM



**Aris Machina**

As the first European venture capital fund, Planet A relies on its own scientific team to assess the environmental and climate impact of an innovation. Prior to an investment, a systemic impact assessment, like this one, is conducted and integral part of the investment decision. All assessments as well as the methodology are published for maximum transparency.

# About Aris Machina

Aris Machina is a Stockholm-based industrial tech company building an AI-native platform that unifies fragmented manufacturing systems. By integrating real-time data, intelligent co-pilots, and process emulation, Aris enables faster commissioning, higher-quality production, adaptive operations, and improved material and energy efficiency, with reduced waste, across sectors such as batteries, semiconductors, and pharmaceuticals.

Developed by the team behind Northvolt's MES, Aris not only boosts efficiency and traceability but also reduces waste and emissions, positioning Aris as a key enabler of low-carbon industrial growth.

## About this study

This assessment evaluates the systemic sustainability impact of intelligent manufacturing enabled by Aris Machina. While Industry 4.0 technologies have shown promise in improving factory-level efficiency, their broader environmental effects depend on how (and where) they are deployed. This study combines insights from scientific literature, real-world performance data, and a rebound-aware systems lens to quantify the environmental and economic implications of Aris's platform.

Specifically, the analysis explores how AI-native manufacturing can reduce material waste, energy intensity, and time-to-production in sectors critical to the low-carbon transition. It also identifies key rebound risks that may limit these gains and outlines strategies to mitigate such effects through thoughtful deployment, sectoral alignment, and policy support.



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# 1. The challenge: Industrial manufacturing in the age of the climate crisis

## 1.1 Driving Planetary Overshoot: Industrial Manufacturing's Expanding Footprint

Industrial manufacturing is foundational to the modern global economy. It delivers the goods and infrastructure that underpin nearly every aspect of human development, from homes and hospitals to energy systems, vehicles, and digital technologies. However, it also represents one of the most resource- and carbon-intensive sectors globally.

According to the 2024's UN Emissions Gap Report, industrial activity accounted for approximately 11.5 Gt of Greenhouse Gas (GHG) emissions in 2023 (UNEP, 2024). This figure amounts to 20% of total global emissions, underscoring the sector's outsized environmental footprint (UNEP, 2024). These emissions arise not only from direct fossil fuel combustion in manufacturing processes but also from upstream supply chains and downstream logistics.

The urgency of reducing the industry's impact on the environment is further intensified by growing global demand. The United Nations (2022) projects that the global population will rise to 9.7 billion by 2050. This demographic growth is anticipated to drive a substantial rise in demand for manufactured goods and construction materials. According to the United Nations Environment Programme and the International Resource Panel (UNEP and IRP, 2024), global natural resource extraction has already tripled over the past 50 years. Without systemic change, it is projected to rise by another 60% from 2020 to 2060, further intensifying environmental degradation and resource scarcity. Much of this growth will be driven by heavy industries such as steel, cement, chemicals, and mining, which already pose significant decarbonisation challenges.

Beyond its climate impact, industrial manufacturing places considerable strain on other planetary boundaries. It is a major contributor to freshwater withdrawals, accounting for approximately 19% of total global use, with significantly higher shares in high-income regions (UN, 2021). Water-intensive sectors such as textiles, paper, and chemicals not only consume large volumes but also discharge pollutants that degrade aquatic ecosystems.

Moreover, industrial expansion is a key driver of biodiversity loss. Land conversion, pollution, and resource extraction associated with manufacturing contribute to habitat destruction and ecosystem fragmentation (IPBES et al., 2019). The growing production of electronic waste, hazardous chemicals, and construction debris adds to the burden of solid waste, much of which remains mismanaged, especially in lower-income countries, resulting in soil and water contamination (UNEP, 2024b).

Reducing emissions from industrial manufacturing is essential to meet climate goals and reduce pressure on the environment. At the same time, addressing its broader ecological footprint, including impacts on water, biodiversity, and waste, is critical to ensure a just and sustainable industrial transformation. Doing so requires new approaches that enhance productivity while significantly lowering environmental impacts.



## 1.2 Fragmentation Undermines Digital Integration and Sustainability Potential

Despite its strategic importance, the manufacturing industry suffers from a persistent structural weakness: the fragmentation of its digital and operational ecosystems. Knowledge is typically developed and stored in isolation across various stages of product development, from R&D and prototyping to industrialisation and full-scale manufacturing. Each phase relies on its own software systems, often with incompatible formats and data standards.

A recent analysis by Ji and Abdoli (2023) identifies this fragmented architecture as a key barrier to operational integration and digital progress. Factory systems (e.g. Enterprise Resource Planning (ERP), Supervisory Control and Data Acquisition (SCADA), Programmable Logic Controller (PLC), and Product Lifecycle Management (PLM)) are rarely interoperable, which hinders information sharing and complicates efforts to optimise production. As a result, crucial process insights are lost between departments, stalling innovation, slowing problem resolution, and impeding continuous improvement.

This fragmentation also undermines the environmental potential of I4.0 technologies. While the World Economic Forum (WEF 2023) estimates that digital solutions could deliver 4-10% of emissions reductions by 2030 and up to 20% of the total decarbonisation needed by 2050 in high-emitting sectors, these gains are not guaranteed (Figure 1). Efficiency improvements, such as those enabled by AI, digital twins, and smart monitoring, can trigger rebound effects, where cost savings lead to higher overall resource use (see Chapter 3) (Brockway et al. 2021; Barker, Dagoumas, and Rubin 2009; X. Wang, Wen, and Xie 2018). Realising the benefits of Industry 4.0 therefore requires integrated, rebound-aware deployment across the full production lifecycle.

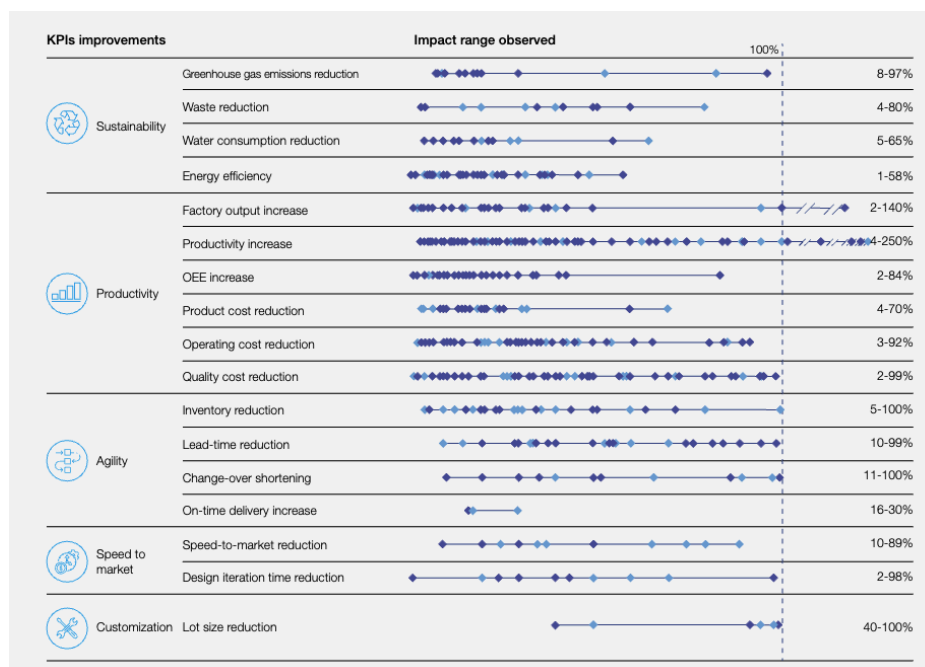


Figure 1: Observed impact ranges of digital technologies across sustainability and productivity KPIs.

Source: [WEF, 2023](#).



## 2. The solution: Aris Machina to transform manufacturing

Aris Machina directly addresses these limitations through a vertically integrated, AI-native platform that operationalizes the Industry 4.0 vision across the entire factory lifecycle. It transforms complexity into actionable intelligence, enabling the rapid and responsible scaling of low-carbon technologies. This is achieved through five key features:

### 2.1 An AI-native operating system for Industry 4.0

Aris Machina is designed to operationalise the full potential of Industry 4.0 through a coherent, modular software stack. Its architecture unifies traditionally disconnected systems, embedding intelligence, standardisation, and traceability into every layer of factory operation.

At the heart of this system is Aris Core OS, an edge-ready platform that harmonises SCADA, PLC, ERP, and PLM environments into a single data backbone. This “Hyper-stack OS” enables real-time orchestration and continuous optimisation by enforcing a unified namespace, standardised data ontologies, and open APIs.

Surrounding this core are purpose-built layers for every phase of the factory lifecycle:

- **Aris DevKit** empowers domain experts to build low-code applications without requiring deep programming skills. Through open protocols and flexible interfaces, engineers can tailor functionality to specific industrial needs.
- **Aris FactoryZero**, a full-featured emulation engine, enables operational “what-if” testing, modular equipment configuration, and pre-deployment optimisation. By simulating production before physical assets are installed, it reduces commissioning time and risk.
- **Aris Apps and AI Co-pilots** provide conversational, intelligent interfaces for quality control, maintenance, traceability, diagnostics, and production management. These co-pilots integrate past performance data to improve future decisions, preserving institutional memory and enabling autonomous problem-solving.

This vertically integrated software stack is already operating in high-performance industrial environments. At Northvolt Ett, Aris supports live production across three factories in Sweden and Poland, processing over 1 million events per hour, managing 10,000+ parameters per cell, and enabling 3,500+ unique users to interact with real-time factory data. This coherence allows Aris to support traceability, responsiveness, and system-level intelligence from greenfield planning to high-volume execution.

### 2.2 Turning complexity into lifecycle intelligence

Modern manufacturing is not only fragmented, it is complex. Each product and process may span dozens of software tools, hundreds of quality checkpoints, and thousands of parameters. Without a unified control layer, this complexity generates friction: dead stock, rework, yield losses, and time-intensive troubleshooting.



Aris Machina resolves this through end-to-end data standardisation across more than 280 manufacturing processes. From R&D trials to prototyping, commissioning, and full-scale production, it transforms disjointed telemetry and quality data into a coherent intelligence layer.

Aris' AI-powered co-pilots assist operators and engineers in root cause analysis, anomaly detection, and continuous improvement, enabling more consistent processes, faster scaling, and greater resource efficiency. By embedding this intelligence into daily operations, Aris supports a shift toward more adaptive, resilient, and sustainability-aligned manufacturing systems.

This integration also supports environmental monitoring beyond carbon by linking process telemetry to quality and throughput data. Thus, Aris enables early detection of material losses, potential water overuse, or hazardous byproducts. Such capabilities allow factories to track and reduce water intensity, waste generation, and pollutant discharge at the process level, enhancing environmental compliance and resource stewardship.

### 2.3 Measurable operational and environmental gains

Aris Machina's platform has demonstrated measurable operational and environmental benefits in active industrial settings. According to company data:

- **Throughput:** A 400% increase in production throughput through automation and knowledge consolidation.
- **Downtime:** 30-50% reductions via closed-loop AI-powered defect detection.
- **Scrap reduction:** 60% reduction in complex assemblies; 2% in high-volume lines using predictive quality assessment.
- **Commissioning:** 2x faster line commissioning using FactoryZero's emulation capabilities.
- **Scalability:** Over 3,500 users and real-time processing of 1 million+ events per hour across multiple factories.

These improvements are especially critical in domains such as battery cell manufacturing, where scrap rates can reach 20-30% when defects are detected only at the end of the line (Rehman et al. 2025). Aris supports the reduction of this with in-line quality inspection and detailed genealogy, which can help lower material waste, rework, and embodied emissions.

These results mirror broader trends observed across the manufacturing sector. The U.S. Department of Energy (2010), reports that predictive maintenance programs can reduce maintenance costs by 25-30%, eliminate up to 75% of unplanned breakdowns, and cut downtime by up to 45%. Real-world deployments corroborate this: ALTEN Group (2025) reported a 2% scrap reduction in high-volume lines using AI-driven quality prediction, while Retrocausal (2024), documented a 60% reduction in scrap in complex assembly through an AI-powered co-pilot system.

These findings are consistent with assessments from the World Economic Forum's Lighthouse Factory network (Figure 2), which has recorded systematic reductions in energy use, material waste, and emissions in factories that implement digital solutions across the production lifecycle (WEF 2023).



These operational gains are not limited to energy and emissions. In resource-intensive industries, reducing defect rates and rework also translates to avoided raw material losses, lower water consumption, and less waste treatment. As scrap and off-spec production are key contributors to environmental degradation, minimising them yields benefits across multiple environmental indicators.

These gains reflect a convergence of operational efficiency and environmental benefit, particularly when digital tools are integrated across the entire production lifecycle.

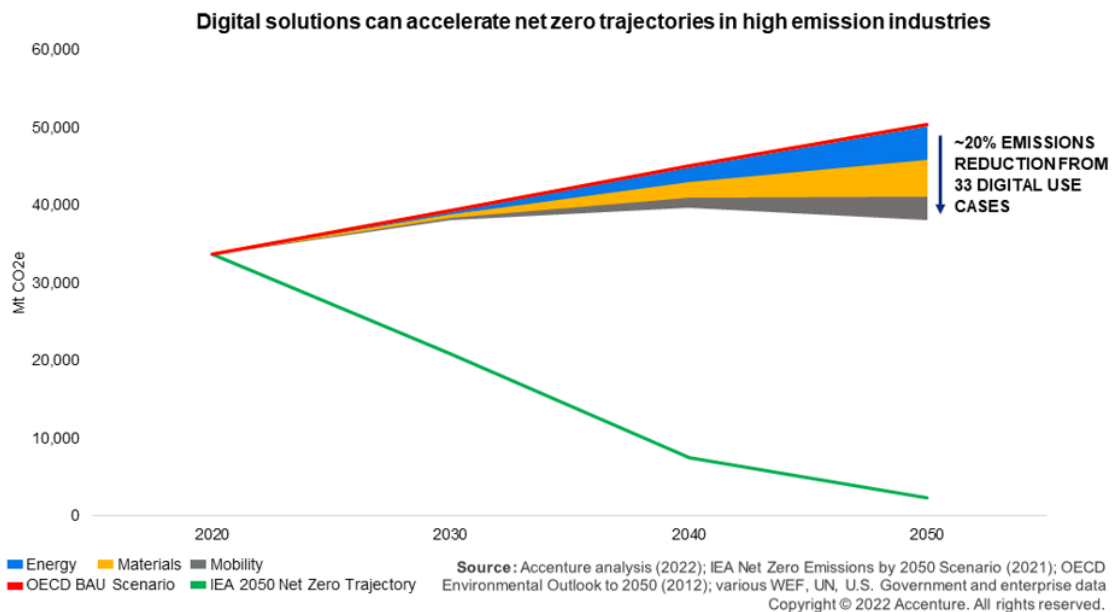


Figure 2: Digital technology applications across high-emission sectors can reduce up to ~20% of global CO<sub>2</sub>e emissions by 2050. Source: [WEF 2022](#).

## 2.4 Strategic deployment in green technology sectors

Aris Machina prioritises sectors where digitalisation can deliver outsized environmental and economic benefits. Namely batteries and energy storage, semiconductors, robotics, pharmaceuticals, and advanced manufacturing.

These industries are not only resource- and emissions-intensive, they are also foundational to the broader sustainability transition. Aris’s modular architecture enables rapid deployment and strict compliance in highly regulated, complex environments. By reducing commissioning time and increasing yield, it accelerates the industrialisation of critical low-carbon technologies.

In addition to their climate significance, these sectors also face growing scrutiny for their use of water, critical minerals, and hazardous chemicals. Aris’s traceability and quality management capabilities are well-suited to reduce these impacts by ensuring first-pass yield, improving material utilisation, and supporting closed-loop production systems.

## 2.5 Enabling grid-aware, renewable-aligned operations



Manufacturing does not exist in isolation; it is increasingly shaped by the dynamics of the electricity grid. As renewables account for a growing share of energy supply, operational flexibility within factories becomes essential to reduce emissions, avoid curtailment, and lower systemic costs.

Aris Machina enables factories to dynamically align production with the availability of clean electricity, turning traditionally rigid industrial systems into flexible assets for the energy transition. Its architecture integrates time-of-use optimisation, real-time load shifting, and direct coordination with grid signals, allowing production schedules, process intensities, and machine runtimes to adapt in real time to external conditions such as renewable generation profiles, price volatility, and grid congestion.

This form of AI-native coordination is rapidly becoming a system-critical capability. Without sufficient demand-side flexibility, the EU could face up to 310 TWh of curtailed renewable energy per year by 2040, a figure equivalent to roughly 10% of projected demand (Joint Research Centre 2024). Intelligent process control can reduce peak electricity demand in factories by 10-15% and total energy consumption by up to 15% when AI-optimised (Johnson, Fraser, and York 2024; Segun-Falade et al. 2024).

More granular interventions in energy-intensive sectors such as cement and aluminium offer even greater potential. Studies show that flexible operation of equipment like crushers and smelting pots can yield energy savings of 16.9-20.7% and cost reductions of up to 34.2%, primarily through load shifting and demand shaping strategies (Golmohamadi 2022). At scale, coordinated industrial flexibility across the EU-15 could lower CO<sub>2</sub> emissions by 1.5-5% and reduce the need for new power generation infrastructure by 2-8% (Papagiannis et al. 2008).

By embedding digital intelligence, lifecycle traceability, and grid responsiveness directly into production workflows, Aris Machina goes beyond improving conditions within factory walls. It enables factories to become **active participants in grid decarbonisation and resilience**, helping to balance supply and demand in a renewables-based energy system.

## 3. Rebound effects and the limits of efficiency

While Industry 4.0 technologies, such as those enabled by Aris Machina, present strong environmental and economic advantages, a growing body of scientific literature points to an important caveat: the rebound effect. If not addressed, this systemic phenomenon can erode or even reverse the sustainability gains of increased efficiency. Understanding and addressing this risk is essential to ensure that digitalisation serves as a genuine enabler of sustainable industrial transformation.

### 3.1 Understanding the rebound effect

The rebound effect describes a paradox: when efficiency improvements reduce production costs, they can lead to increased consumption of goods and services. This is the famous “Jevons



Paradox”. In sectors where demand is elastic, these cost savings stimulate additional output, thereby offsetting some or all of the energy and emissions savings from the original efficiency gains.

Multiple studies have quantified rebound effects at the global scale, consistently indicating that their magnitude is significant. Meta-analyses by Brockway et al. (2021) and Barker, Dagoumas, and Rubin (2009) estimate average economy-wide rebounds of around 50%, meaning that half of the anticipated energy savings from efficiency improvements may be negated by increased activity. In some contexts, rebounds exceed 100%, leading to a “backfire effect” where total energy use and emissions rise despite efficiency gains (Ibid).

Case studies illustrate the magnitude of this challenge:

- Lin and Li (2014) estimated a 74.3% rebound effect in China’s heavy industry sectors, indicating that almost 3/4 of the energy savings achieved through efficiency were counterbalanced by growth in output.
- Kunkel et al. (2023) found limited energy-related benefits of digitalisation in Chinese manufacturing, attributing this to structural factors such as outsourcing and politically driven growth targets.
- J. Wang et al. (2023) noted that the use of industrial robots resulted in both emissions reductions and energy rebound effects, producing mixed outcomes.

In Germany, firm-level machine learning analysis involving more than 25,000 companies found that digitalisation was more often associated with increased energy consumption than reductions, especially in firms without clear systemic constraints or complementary measures in place (Axenbeck, Berner, and Kneib 2022). Similarly, a case study from Sweden shows that long-term rebound effects can significantly reduce energy savings, with a 10% improvement in energy efficiency leading to only a 1% net decrease in energy use due to a 90% rebound effect (Amjadi, Lundgren, and Zhou 2022). This same study shows sector-level averages of the short- and long-term energy rebound effects depicted in Figures 3 and 4.

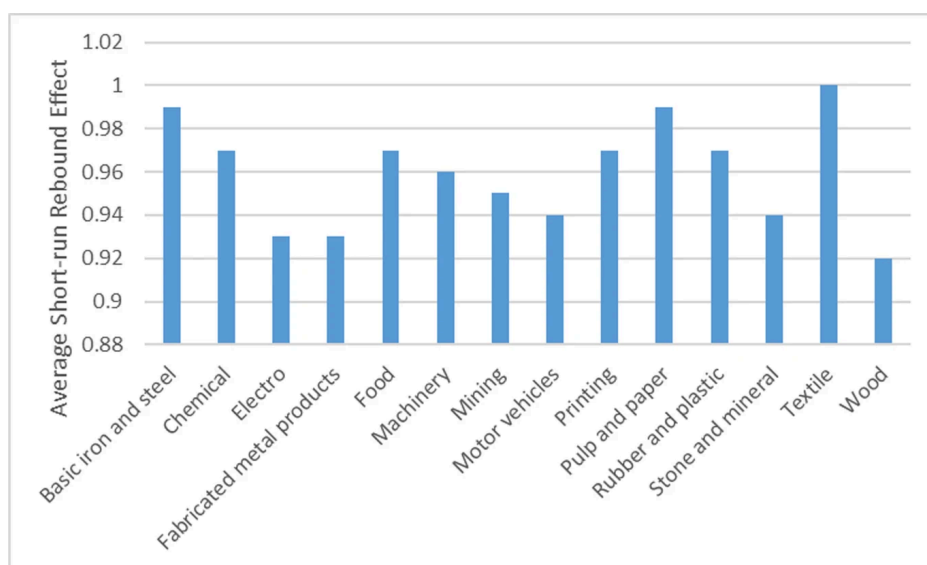


Figure 3: Average short-term rebound effect for Swedish manufacturing (Amjadi, Lundgren, and Zhou 2022).

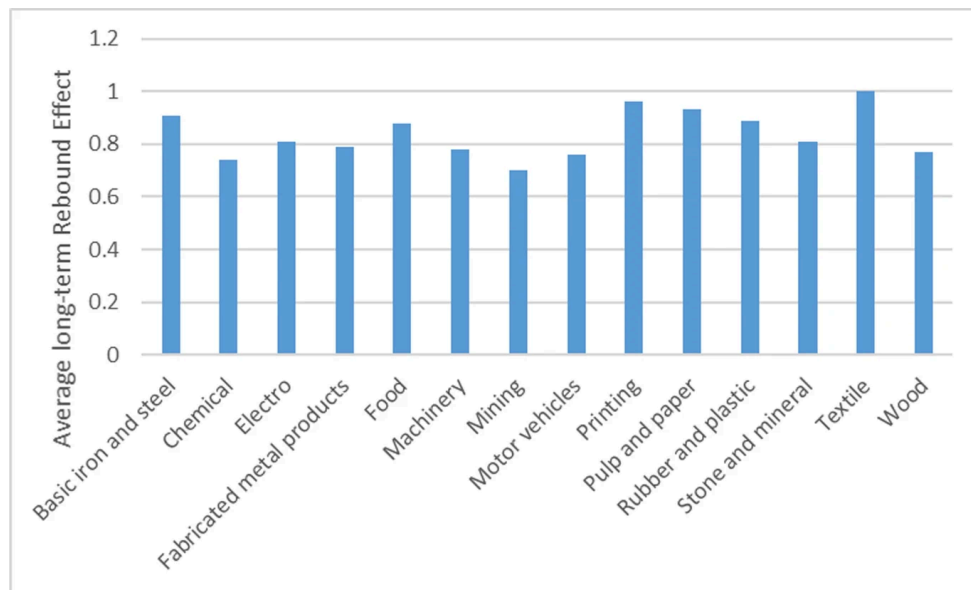


Figure 4: Average long-term rebound effect for Swedish manufacturing (Amjadi, Lundgren, and Zhou 2022).

These findings underscore a critical point: efficiency alone does not guarantee environmental progress. Without complementary changes in behaviour, business models, and policy, digitalisation can become a vector for increased production and emissions, rather than mitigation.

### 3.2 Pathways to minimise rebound effects

The extent and impact of rebound effects vary significantly across sectors. A nuanced, context-aware strategy is therefore essential to safeguarding sustainability outcomes. In broad terms, industries can be categorised by their **price elasticity of demand** and their **potential to influence consumer behaviour**:

#### High elasticity / low influence sectors

Sectors like consumer electronics, fast fashion, and general-purpose manufacturing often exhibit high price elasticity. Here, efficiency-driven cost reductions may lead to increased production volumes, undermining environmental progress. Unless carefully managed, these sectors are at high risk of triggering rebound or even “backfire” effects, where total emissions increase despite improvements in unit efficiency.

For these industries, rebound mitigation demands more than technical efficiency. It requires:

- **Behavioural nudges** that promote repair, reuse, or reduced consumption.
- **Circular business models**, such as leasing or buy-back schemes.
- **Policy interventions**, such as Pigovian taxes on high-emission products or incentives for durable goods.



## Low elasticity / high system leverage sectors

Industries like battery manufacturing, renewable energy infrastructure, grid technology, and sustainable agriculture present lower rebound risks. In these sectors, demand is relatively inelastic, tied to long-term climate targets, and less driven by consumer price sensitivity. Efficiency improvements here tend to amplify climate benefits, supporting faster and more cost-effective deployment of essential green technologies.

These distinctions are not static. As technologies mature and policies evolve, sectors can move between categories. What remains essential is to design digital strategies with explicit awareness of rebound dynamics, tailored to each sector's unique economic logic.

### 3.3 Aris Machina: enabling rebound-aware industrial growth

Aris Machina sits at the intersection of high-impact potential and systemic responsibility. By design, it addresses several structural barriers that make sustainable industrialisation difficult, such as data fragmentation, operational opacity, and slow commissioning cycles.

Crucially, Aris targets low-rebound, high-leverage sectors. Its focus on batteries, robotics, semiconductor, and other capital-intensive, mission-critical industries aligns with the types of production most urgently needed to achieve net-zero goals. In these domains, improving process efficiency does not simply lower costs; it accelerates the deployment of climate solutions that underpin the energy transition.

Moreover, Aris's architecture is built for system-level coordination:

- Real-time data integration enables alignment with renewable energy availability, supporting load balancing and reducing the carbon intensity of electricity use
- Advanced traceability and telemetry make it possible to embed environmental accounting into production processes, ensuring greater transparency, accountability, and responsiveness.
- Factory emulation and co-pilot tools reduce the need for physical iteration, improving time-to-value while avoiding excess energy and material use during scale-up.

However, Aris is not immune to the rebound risk. Like any efficiency-enabling technology, its success must be understood within the context of how it is deployed. To mitigate unintended consequences, it is critical that:

- The Aris platform continues to prioritise climate-aligned sectors with systemic impact.
- Partners and investors adopt policies that discourage overproduction, especially in high-consumption markets.
- Metrics for evaluating impact extend beyond factory KPIs to include lifecycle emissions, demand elasticity, and product-level sustainability outcomes.

In this way, Aris serves as a strategic enabler of sustainable industrial growth, one that can help reconcile economic productivity with planetary boundaries, if integrated thoughtfully into the evolving industrial system.



## 4. Conclusion

Aris Machina plays a pivotal role in enhancing industrial sustainability through integrated digital infrastructure. By embedding intelligence across the factory lifecycle and replacing fragmented systems with a coherent, data-driven infrastructure, Aris enables faster, cleaner, and more adaptive manufacturing.

Field deployments show clear gains in throughput, defect reduction, and commissioning speed, with corresponding reductions in scrap, energy use, and downtime. These operational benefits position Aris as a powerful enabler of clean technologies (from battery cells to precision medical devices), especially in sectors where demand is driven by long-term sustainability goals rather than discretionary consumption.

However, as with all efficiency-enabling innovations, the full impact of Aris depends on the deployment context. To avoid rebound effects and maximize systemic benefit, digital acceleration must align with climate-positive sectors, avoid unsustainable scale-up in high-elasticity markets, and be coupled with policies that support circularity, demand moderation, and clean energy sourcing.

By enabling resource-efficient production in climate-aligned sectors, such as batteries, EVs, and advanced manufacturing, Aris becomes more than a software platform; it presents a strategic lever for reconciling industrial growth with an economy within the planetary boundaries.



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