white paper

THE SUSTAINABILITY THREAD

Rethinking the digital thread to drive sustainability performance and green R&D

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EXECUTIVE SUMMARY

The digital twin and digital thread concepts are now mainstream best practices for product lifecycle management (PLM) practitioners and innovation-minded organizations. The interconnectivity of product data models provides superior agility for manufacturers as the digital thread breaks through to once-siloed stakeholders with real-time, accurate information from R&D to commercialization to the customer and back.

Enter sustainability. With regulatory, consumer, and investor pressures on the rise, many manufacturers are running into stakeholders in new silos in the rush to deliver products to market—all the while, leadership wrestles with scattered data, multiple reporting frameworks, and aspirations of a more proactive green R&D posture.

In this white paper, the author posits the creation of a digital thread for sustainability data, simply stated herein as the sustainability thread. The paper explains how integrating sustainability requirements in an organization's digital thread strategy can transform both sustainability performance and product development. It also explores through real-world use cases how the digitalization of sustainability-related processes can greatly improve operational efficiency and reporting accuracy.

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What Is the Digital Thread?

The digital thread concept refers to a seamless, integrated flow of information that connects all product lifecycle phases—from design, development, and manufacturing to service and disposal. It allows for real-time data sharing and tracking, providing a single source of truth across different systems and departments. The digital thread links various digital models, simulations, and data points, ensuring stakeholders have consistent and accurate information to optimize decision-making.

Here's an example focused on the chemical manufacturing sector:

A chemical engineer designs a new formulation in an electronic lab notebook (ELN) integrated into a PLM system, incorporating data on raw materials, reaction pathways, and safety protocols. All initial designs, specifications, and safety data sheets (SDS) are linked to a central repository.

Chemical processes are simulated in modeling software. Results, including yields and potential hazards, are documented in the PLM system, adding to the digital model. This data informs adjustments to the formulation and process parameters.

With the validated recipe, the production team generates comprehensive batch records and instructions in the manufacturing planning system, including equipment specs and process controls. Real-time data from the manufacturing execution system (MES) is integrated, capturing details like temperature, pressure, and flow rates.

Throughout production, samples are taken for quality assurance testing. Results are recorded using the information from the digital thread, linking to the specific batch and formulation. Any deviations trigger automatic alerts, and corrective actions are documented in a quality management system, ensuring compliance with industry regulations.

After the product is manufactured, it is distributed to customers. Feedback on product performance and any issues encountered are collected and analyzed. This information is fed back into the digital model to inform future formulations or adjustments in the production process.

When the chemical product reaches the end of its useful life, data related to disposal methods, safety measures, and environmental impact is documented. This helps improve sustainability practices and informs future product development initiatives.

This example illustrates how the digital thread in the process industry can significantly enhance collaboration, efficiency, and safety throughout the product lifecycle.

What Makes a Thread a Thread (and How It Relates to Sustainability)

Thinking of the previous example and translating it to your business, it is important to understand how a digital thread truly connects people, data, and processes. This boils down to nine fundamental attributes: connectivity, traceability, interoperability, comprehensive data model, effectivity and versioning, collaboration, analytics and insights, lifecycle management, and real-time data.

The design and execution of a digital thread strategy is the successful orchestration of these attributes across a business process or set of business processes. The caveat, however, is that a 30,000-foot view of processes across your enterprise is needed to avoid digital silos, understand relationships, and acknowledge where digitalization is not a reality. So, when you think about PLM and sustainability, evaluate what these attributes mean in your business context and capitalize on where the people, processes, and data converge.

When applying the attributes of a digital thread to sustainability data, the goal is to ensure the continuous flow, traceability, and analysis of environmental, social, and economic data not only throughout a product's lifecycle but also to determine the corporation's sustainability KPIs like energy intensity or the corporate and product carbon footprint and to feed ESG reporting.

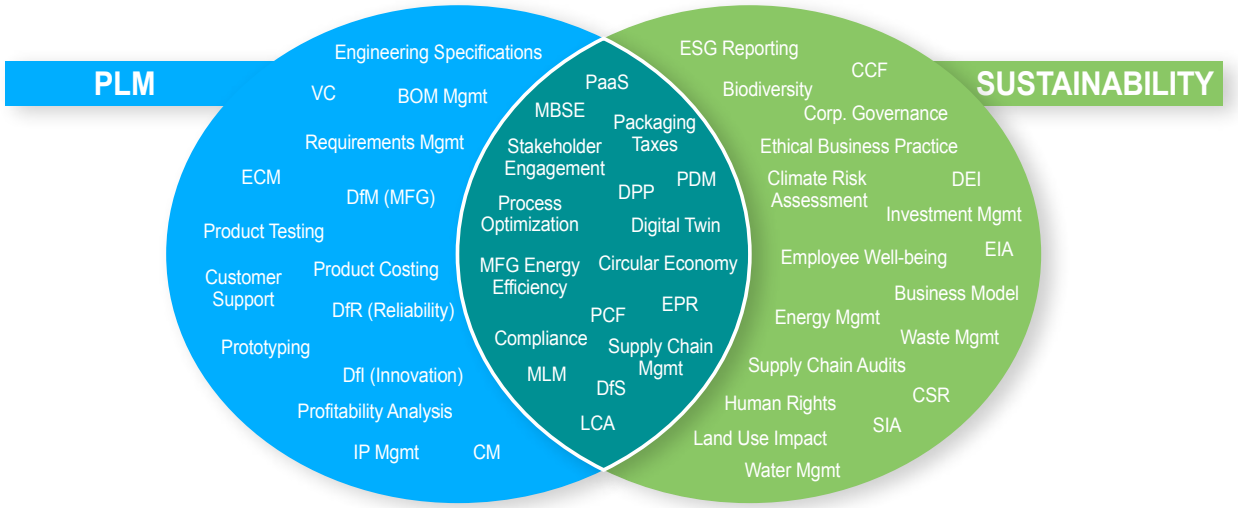
When you think about PLM and sustainability, evaluate what these attributes mean in your business context and capitalize on where the people, processes, and data converge.

Let's take a look at a side-by-side comparison of digital thread attributes for PLM and sustainability:

Attribute	PLM Context	Sustainability Context
Connectivity	Data integration across various stages and systems enables information to flow freely between design, engineering, manufacturing, and maintenance.	Integrating data sources like energy consumption, material use, or business activities into the data stream to determine environmental impacts like carbon footprint, water consumption, ecotoxicity, or others allows sustainability data to be factored into decision-making at every stage of the product lifecycle.
Traceability	Comprehensive tracking of changes and decisions throughout the product lifecycle allows users to trace back to original requirements and specifications and understand the product's evolution.	Comprehensive tracking through the determination process for sustainability metrics enables companies to comply with audits and gain transparency in their supply chain.
Interoperability	The ability to work across different platforms, software, and tools, ensuring that data can be shared and understood regardless of the system used.	Sharing sustainability data across platforms, software, and organizations such as carbon accounting, tracing systems, and ERP tools. Interoperability guarantees that all stakeholders, understand the environmental impact, from product designers to sustainability managers and government entities.

Attribute	PLM Context	Sustainability Context
Comprehensive Data Model	The data model is the backbone of the digital thread, ensuring data integrity, integration, and utility through a product's lifecycle. The digital thread connects systems, processes, and stakeholders. Without a solid data model, this web of information would lack coherence and limit its full potential.	A comprehensive data model is essential when information must be gathered and communicated during business activities. For example, a company producing consumer goods must integrate data on packaging materials into its product data model to track the percentage of recyclable or biodegradable packaging.
Effectivity and Versioning	Managing different document versions and data and their effectiveness ensures that the most current and relevant information is easily accessible while maintaining a history of changes.	Managing data validity and the applicability of factors gives organizations the flexibility to improve data quality and reflect the sustainability improvements they have achieved. It fosters the process from secondary to primary data.
Collaboration	Enhanced ability for teams across disciplines and organizations, from product design to manufacturing and service, to collaborate effectively, sharing insights and data in a unified environment.	Cross-functional collaboration allows engineers, designers, procurement, and sustainability experts to share data on material selection, energy use, and emissions, promoting sustainable decision-making throughout the product lifecycle.
Analytics	Tools for analyzing data collected throughout the product lifecycle allow for continuous improvement and informed decision-making based on historical performance.	Sustainability analytics monitor carbon footprints, resource efficiency, and waste reduction performance. Such insights allow for continuous data-driven process improvement, ensuring sustainability targets are met.
Lifecycle Management	Support for managing the entire product lifecycle, from conception to end-of-life, ensuring that all phases are interconnected and informed by previous stages.	Supporting the entire product lifecycle from selecting eco-friendly materials to recycling or disposing of products. Sustainability KPIs from each phase inform the operation with a continuous feedback loop to ensure long-term environmental objectives are met.
Real-Time Data	Data from IoT sensors during manufacturing or usage is the critical enabler that transforms the digital thread into a digital twin, turning a historical data flow into a dynamic, real-time representation of physical assets and systems.	Real-time emissions data, resource consumption from IoT sensors, or environmental impact assessments allow an organization to monitor sustainability performance and make immediate adjustments. It provides a potential solution to the tension between careful public reporting and the need for accurate internal data for decision-making.

The Synergy Between PLM and Sustainability



To optimize digital thread strategy to include sustainability data requirements, analyze where business processes and supporting systems converge. While sustainability and PLM complement one another, distinct differences remain that must be accounted for in the data model.

When developing a digital thread strategy for both PLM and sustainability, leveraging the synergy between the two requirement sets can provide significant value to both business areas. Examples of overlap between the digital thread of PLM and sustainability include scenarios where data and insights from both domains align to support product and sustainability goals. Here are some specific examples:

Material Selection and Design for Sustainability (DfS)

- During the design phase, PLM tracks materials used, their properties, and manufacturing requirements to optimize product performance, cost, and quality.
- Sustainability teams use material data to evaluate environmental impacts, such as carbon footprint, recyclability, and toxicity, ensuring materials align with eco-friendly criteria.

Business Benefit: By integrating PLM and sustainability data, design teams can choose materials that meet both performance and sustainability criteria. For example, they can select recycled or low-impact materials that reduce their carbon footprint while maintaining product durability. On the other hand, design roles can be defined and set to enforce ambitions and achieve sustainability goals.

Lifecycle Assessment (LCA)

- PLM systems store and track data across the product's lifecycle stages, from design to end-of-life, providing a comprehensive view of product components and processes.
- Sustainability teams conduct lifecycle assessments to evaluate a product's environmental impact throughout its lifecycle, considering metrics like energy use, emissions, and waste.

Business Benefit: The digital thread in PLM supplies detailed data for accurate lifecycle assessments. Integrating LCA tools with PLM allows companies to conduct real-time impact assessments, helping design and sustainability teams make informed decisions that improve product performance and environmental impact.

Supply Chain Transparency and Traceability

- PLM tracks product components, supplier information, and production processes across the supply chain, providing insight into sourcing, quality, and logistics.
- Sustainability initiatives require transparency in sourcing, including responsible material sourcing, ethical labor practices, and reduced carbon emissions from suppliers.

Business Benefit: The digital thread connects data from suppliers through the entire supply chain, allowing companies to verify that materials and processes align with quality and sustainability standards. For example, PLM can help trace the origins of raw materials, ensuring they meet quality and ethical sourcing criteria.

Energy Consumption and Efficiency in Manufacturing

- PLM tracks manufacturing parameters, including machinery usage, process efficiency, and production times, to optimize manufacturing performance and cost.
- Sustainability initiatives focus on reducing energy consumption and emissions in manufacturing to lower the overall environmental impact.

Business Benefit: By combining manufacturing data from PLM with energy and emissions metrics, companies can identify high-impact processes and optimize them for energy efficiency. Adjusting equipment use to off-peak hours or implementing energy-efficient technologies can reduce production costs and environmental impact.

Product End-of-Life and Circular Economy Initiatives

- PLM tracks data on product components, assembly methods, and material properties, which is critical for designing products that are easy to disassemble and recycle at the end of life.
- To minimize waste, sustainability strategies emphasize circular economy practices, such as recycling, reuse, and product take-back programs.

Business Benefit: The PLM digital thread provides essential data for end-of-life management, such as material composition and recyclability, helping sustainability teams design circular processes. This collaboration enables companies to establish take-back programs or refurbishing initiatives, extending product lifespans and reducing waste.

Compliance and Regulatory Reporting

- PLM systems manage compliance data related to product quality, safety, and industry standards, ensuring products meet regulatory requirements.
- Sustainability reporting involves compliance with environmental regulations (such as emissions limits) and ESG standards, such as the EU's Corporate Sustainability Reporting Directive (CSRD).

Business Benefit: Integrating PLM and sustainability digital threads streamlines compliance reporting by connecting product data with environmental metrics. For example, PLM systems can help gather and report data for sustainability regulations like carbon emissions or waste disposal, reducing administrative burdens and ensuring comprehensive compliance.

Real-Time Monitoring and Process Optimization

- PLM allows real-time monitoring of manufacturing processes, providing data on equipment performance, production quality, and workflow efficiency.
- Sustainability efforts benefit from real-time energy consumption, emissions, and waste generation data, which allows them to take immediate action and inform stakeholders frequently beyond carefully crafted reports being published.

Business Benefit: Real-time data integration allows both PLM and sustainability teams to identify areas for improvement. For example, if real-time monitoring shows high emissions during a specific manufacturing step, teams can collaboratively optimize the process to reduce emissions while maintaining quality and efficiency.

Digital Twin for Product and Environmental Performance

- Digital twins in PLM represent virtual models of physical products, allowing companies to simulate performance, predict maintenance needs, and optimize design.
- Sustainability teams utilize digital twins to simulate the improvements sustainability programs can achieve, using the results to decide the best path to meeting corporate sustainability goals.

Business Benefit: A digital twin that integrates PLM and sustainability data provides a powerful tool for modeling product performance and sustainability outcomes. For example, simulating a product's lifecycle can reveal how design choices impact energy efficiency or recyclability, helping teams optimize for operational performance and sustainability goals.

The Sustainability Thread Beyond PLM

While there is significant overlap between PLM and sustainability digital threads in areas like lifecycle tracking and material selection, some areas remain distinct to each domain. For example, customer support, customization, IP management, costing, and manufacturing speed optimization are primarily relevant to PLM. These distinctions allow PLM and sustainability digital threads to complement each other without fully overlapping, each fulfilling unique roles in supporting operational, environmental, and social objectives.

The breadth of scope for sustainability however is wider and not as linear process-wise as PLM. In considering design of the sustainability thread, it is critical to account for the digitalization of requirements such as:

- **ESG Reporting**
  While PLM data certainly contributes to the overall ESG reporting effort, corporate data related to impacts on people and communities and how a company is managed fall solely within the sustainability domain.
- **Corporate Carbon Tracking**
  Beyond the carbon produced by the manufacturing, distribution, and consumption of a company's products, consideration of carbon released in day-to-day operations needs to be factored in as well.
- **Environmental and Social Impact Assessments (EIA and SIA)**
  Required in many industries before significant projects, particularly in construction, infrastructure, and mining. EIAs evaluate potential impacts on air, water, land, and biodiversity, while SIAs assess implications on local communities, labor conditions, and socio-economic factors.
- **Social and Ethical Supply Chain Audits**
  To ensure ethical sourcing, sustainability initiatives often conduct social audits and verify suppliers' compliance with labor standards, human rights, fair wages, and working conditions. This includes verifying certifications like fair trade or Responsible Business Alliance (RBA) compliance.
- **Biodiversity and Land Use Impact Management**
  Tracks the impact of operations on biodiversity, land use, and natural habitats, particularly in industries like mining, agriculture, and forestry. This includes measuring land disturbance, ecosystem disruption, and conservation efforts.
- **Water and Waste Management**
  Requires detailed tracking of water usage, wastewater treatment, and waste generation, including hazardous waste. This data is critical for environmental compliance, particularly in water-intensive industries such as food processing, textile manufacturing, and mining.
- **Community Engagement and Social Responsibility Programs**
  Includes community engagement and corporate social responsibility (CSR) initiatives that focus on community development, local employment, charitable contributions, and education programs.
- **Climate Risk and Resilience Assessment**
  Evaluates the company's exposure to physical and transitional climate risks, such as extreme weather, sea-level rise, and regulatory shifts. These assessments help companies prepare for long-term climate resilience.

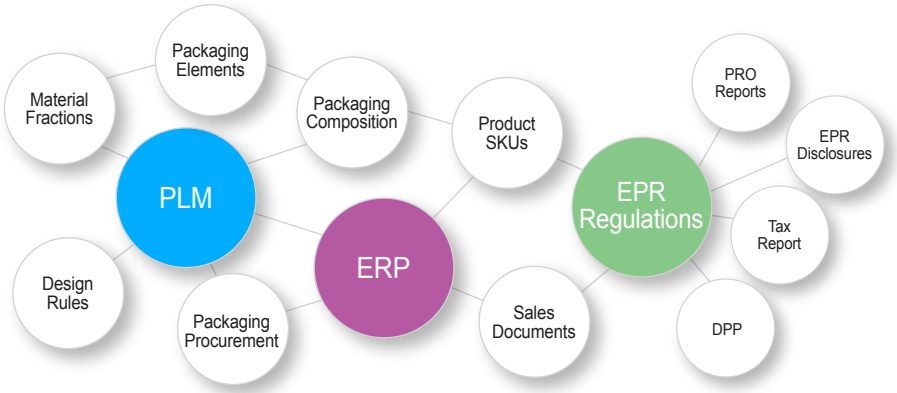
The Sustainability Thread: Reality and Opportunity

Digitalizing Your Carbon Footprint

A digital thread for sustainability data is exemplified by automating utility data integration to determine GHG emissions in scope 1 and 2. Scope 1 covers direct emissions from company-owned sources, such as vehicles and manufacturing equipment, while scope 2 includes indirect emissions from purchased energy. Utility data — electricity, natural gas, water, waste, and fuel usage— can be collected via smart meters, energy management systems, data-gathering platforms, or IoT sensors.

Automating data collection ensures precise measurement, reduces manual errors, and streamlines emission calculations by assigning energy consumption to relevant activities. For instance, electricity usage can be monitored daily alongside eGRID emission factors to determine location-based scope 2 emissions.

This process improves the accuracy and efficiency of carbon footprint reporting, freeing resources for strategic analysis. Real-time data enables organizations to track emissions, adjust operations to reduce environmental impact and provide transparent, auditable data for stakeholders, boosting trust. By adopting such digital threads, companies enhance emission tracking and focus on broader sustainability initiatives.



Compliance with packaging laws and plastic tax regulations provides an ideal model to visualize the sustainability thread and interconnectivity of systems, data, and business requirements.

Packaging Laws and Plastic Tax

Packaging laws and plastic taxes highlight the importance of system and data interoperability. These regulations aim to reduce the environmental impact of plastics by taxing non-recyclable or virgin materials. Organizations must analyze and combine data on packaging composition, material fractions, product sales, and transportation methods to determine tax obligations.

Relevant data may come from various systems: procurement systems for material attributes, PLM systems for packaging compositions, shipping software for transport details, and ERP systems for regional sales data.

A well-designed sustainability thread integrates these systems and establishes a data model to streamline plastic usage reporting. This enables organizations to automate data collection, organization, and reporting, ensuring compliance and efficiency.

ESG Reporting

A global fashion brand sourcing materials like cotton from worldwide suppliers face challenges in manually tracking social aspects of its supply chain, such as labor practices and fair wages. This process is inefficient and error-prone.

By adopting a digital thread, the brand can centralize data from all supply chain stages. Suppliers and manufacturers log compliance details like labor laws, certifications, and audits. This data is tied to products, enabling real-time updates and traceability from raw materials to finished goods.

For ESG reporting, the digital thread ensures accurate sourcing and social responsibility adherence reports. It also allows the brand to quickly identify and address issues like audit failures, improving governance and accountability.

Transparency for Ethically Sourced Products

Deep supply chains complicate transparency for producers answering consumer questions about material sourcing, such as whether mica in cosmetics is tied to human rights abuses or if smartphone rubber contributes to deforestation. Addressing these concerns requires thorough supply chain tracing or reliance on certifications.

Palm oil illustrates the challenge: its supply chain includes numerous intermediaries, with certified and non-certified materials often mixed. Tracing its origin, mainly from smallholder farms, requires mass balancing. Similarly, certifications may fall short, as laws demand more detailed attributes, like whether recycled plastics are chemically or mechanically processed. Regulations like the EU Deforestation Regulations (EUDR) also require exact data about sourcing.

A digital thread bridges disparate systems and organizations, enabling seamless data exchange and centralized access to meet these complex tracking and reporting demands.

Lifecycle Assessments in the Early Design Stage

A digital thread relies on a comprehensive data model to provide accurate, actionable insights into a product's lifecycle, from material sourcing and manufacturing to transportation, usage, and disposal. This unified view enables a complete assessment of environmental impacts as required for LCAs.

For example, a consumer electronics company designing a new smartphone can use a digital thread to track environmental data from existing products, such as energy use, water consumption, packaging, and recycling rates. Integrated into the design team's engineering software, this data helps identify wasteful materials in circuit boards and explore eco-friendly alternatives. It also informs design changes, such as simplifying disassembly for recycling, reducing power consumption, and using biodegradable packaging.

The company can create more sustainable products by incorporating environmental data into the early design stage.

Extended Producer Responsibilities (EPR) and the Digital Product Passport (DPP)

EPR shifts the environmental costs of a product's lifecycle—take-back, recycling, and disposal—from municipalities to producers and consumers, promoting sustainable design, reduced waste, and greater use of recycled materials.

DPP is a digital record of a product's materials, components, and lifecycle, supporting EPR by providing traceability and transparency. It tracks environmental impacts from raw material extraction to end-of-life, offering sourcing, manufacturing, and production process details.

DPPs, currently driven by EU regulatory initiatives like the Circular Economy Action Plan and Sustainable Products Initiative (SPI), aim to make products longer-lasting, more repairable, and environmentally friendly. Initially voluntary, DPPs are expected to become mandatory for the electronics, textiles, and furniture sectors, with global adoption likely. Manual DPP creation is unsustainable due to the sheer volume of data and the need for real-time updates.

For instance, a furniture company producing a sustainable wooden chair would track data on certified wood sources, manufacturing emissions, and eco-friendly materials. Real-time data on energy use, transportation emissions, and waste would populate the DPP, creating a detailed sustainability record. Such comprehensive DPPs require a sustainability thread to ensure seamless data integration and accessibility.

Getting Started with a Sustainability Thread Strategy

The business scenarios described in the previous section are use cases where the digital thread can help organizations arrange, streamline, and automate sustainability data. It is excellent if an organization can identify the one or two most important requirements and address them pragmatically. However, sustainability teams must deliver on all these aspects very often in parallel. They are frequently occupied by administrative tasks and requests to report on an additional issue or a different ESG standard. The current hassle most companies are experiencing in preparing CSRD reporting and taking actions to comply with EPR, or EU's Deforestation Regulations (EUDR), demonstrates that a strategic approach to sustainability data is often missing.

Aligning sustainability goals with a corporation's IT strategy is a significant challenge, as both domains have different objectives, timelines, and success metrics. However, the key to achieving alignment lies in identifying shared priorities, such as improving digital transparency in the supply chain, establishing the digital thread for sustainability data, or integrating real-time sustainability data tracking tools. This reassures us that alignment is not only possible but also beneficial for both domains.

An approach to this alignment begins with understanding the materiality assessment, which most companies with sustainability programs have conducted or are conducting right now. This assessment identifies the critical ESG issues most relevant to the organization's stakeholders and business operations. Double materiality, as it is required by the EU and the ESRD/CSRD standard, is a concept that recognizes two perspectives on materiality: financial materiality and environmental and social materiality. It reflects the idea that businesses must consider not only how external sustainability factors (such as climate change or social issues) impact their financial performance (financial materiality) but also how their activities affect society and the environment (environmental and social materiality).

In the next step, it is essential to filter the material issues directly or indirectly linked to IT. Sustainability issues with strong IT ties typically include:

- Energy efficiency (especially data centers and IT infrastructure)
- Data security and privacy are growing concerns within social governance
- Digital tools for managing emissions (IoT, data analytics)
- Supply chain transparency and traceability technologies
- Digital tools to manage ESG reporting

Developing an inventory of sustainability data and identifying what systems create or what databases already store such data is helpful. This inventory can be mapped to KPIs, environmental permits, and ESG reports. A gap analysis will then define specific projects to close these and lay a roadmap to create the sustainability thread.

By linking materiality assessment outcomes with the IT strategy, companies can ensure that their IT investments advance digital transformation and contribute to achieving sustainability goals. This alignment is critical for building resilient, efficient, and responsible businesses that can meet the challenges of a sustainable future. Integrating sustainability into IT strategies creates a synergistic relationship where both areas reinforce each other's goals and drive value across the organization.

Let Us Guide You in Building a Future Where Sustainability and Technology Work Together to Drive Success.

Linx-AS helps organizations align their sustainability and IT strategies by leveraging the sustainability thread. This powerful concept streamlines, automates, and integrates sustainability data across your operations, providing real-time tracking, reporting, and actionable insights. We can assist you with:

- Sustainability data inventory
- System mapping and gap analysis
- Performance tuning to KPIs, ESG reporting, and regulatory requirements
- Building a comprehensive data model for:
  - EPR reporting
  - Digital Product Passport
- Readiness checks for specific sustainability topics like:
  - Product LCAs
  - Product carbon footprints
  - Packaging declarations and taxes
- Sustainability thread road map

By aligning your IT and sustainability strategies through a digital thread, we ensure:

- Enhanced transparency and compliance with global ESG standards
- Efficient data management that automates time-consuming sustainability reporting
- Integrated IT & sustainability goals, driving digital transformation and environmental/social value creation

For more information, contact info@linxas.com or visit https://linxas.com/sustainability/

About the Author

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Klaus Brettschneider is director of sustainability products at Linx-AS. With over thirty years of experience in product lifecycle management and formal training as an environmental engineer, he brings a holistic perspective to the sustainability challenges facing today's manufacturers as well as the vision to turn those challenges into strategic business value.

Learn more at www.linxas.com