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Sustainable AI for Enterprise Transformation, Innovation and Growth

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The development of AI as a driver of enterprise transformation and innovation opens unique opportunities for aligning systems modernization with green and sustainability goals. This paper shows that the implementation of Sustainable AI as a platform that integrates sustainable supply chains and orchestrates diverse Industry 4.0/5.0 technologies can have a revolutionary impact. It demonstrates Sustainable AI capabilities for sector technologies ranging from farming to urban digital twins.

1. Introduction – Leveraging the Power of AI for a Sustainable Future

This Whitepaper explores the development of Sustainable AI as a driving force for enterprise transformation and fostering sustainable growth. It highlights how AI, particularly generative AI, can integrate existing management systems for improved prediction, optimization, and planning across various business functions. This integration is crucial for effective ESG strategies, enabling data-driven decision-making and streamlining complex sustainability initiatives across departments and value chains.

The paper details how Sustainable AI can help to transform enterprises across all sectors that have been responsible for the majority of environmental emissions. In energy, AI optimizes energy grids, integrates renewable sources, and manages demand, crucial for achieving net-zero emissions. In agriculture, precision farming techniques powered by AI maximize yields while minimizing resource use, impacting both traditional and greenhouse farming. In manufacturing, Sustainable AI can orchestrate productivity gains beyond operational efficiency, driving sustainability improvements in supply chains and reducing the environmental impact of products. In supply chains and logistics, Sustainable AI enables end-to-end integration, optimizing operations and reducing environmental impact across the entire product lifecycles.

Finally, the report examines the role of Sustainable AI in urban planning and development. AI-powered solutions are shown to be vital for optimizing energy consumption, enhancing public transportation, improving waste management, and building climate resilience in rapidly growing urban centers. The overarching message is that while challenges exist, the potential of Sustainable AI to address enterprise sustainability issues and drive economic growth is substantial, and enables a strategic and responsible approach to enterprise transformation.

2. Sustainable AI – A Platform for Enterprise Transformation and Innovation

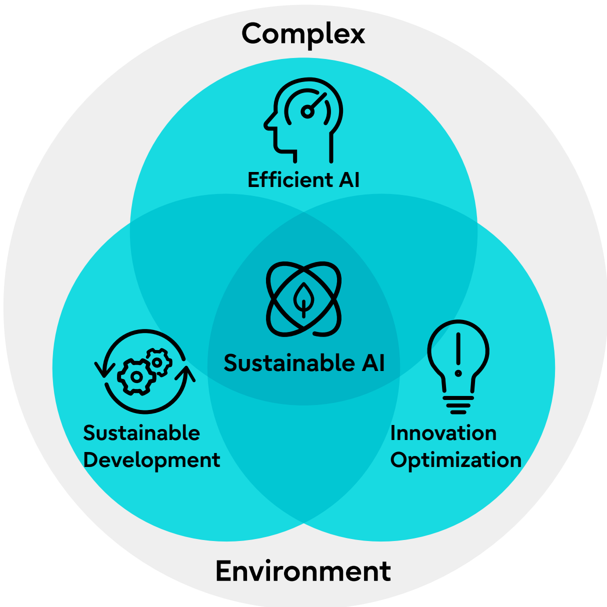
Sustainable AI integrates traditional and emerging AI technologies to discover, plan, monitor, and manage sustainable solutions. For enterprises, it is becoming an indispensable technology for managing complex business environments with ever-increasing regulatory and societal demands. It enables innovation across business functions, and future-proofs operations for emerging sustainable ecosystems and business models.

Sustainable AI is defined as the innovative use of efficient AI technologies for sustainable development in complex environments.

What AI technologies or applications qualify as sustainable AI? As we explain below, Sustainable AI must be efficient at its core to minimize its own environmental footprint (Sustainability of AI). Sustainable AI must be used to improve, optimize, or innovate on business, environmental, or social challenges, such as energy use, waste reduction, and work process efficiency (AI for Sustainability).

Sustainable AI should contribute to sustainable development by enabling sustainable growth. It should also support the ethical governance of information, the responsible management of societal risks, and the development of sustainable policies. However, for the purpose of this paper, which focuses on the management of environmental challenges in the context of business transformation, a narrower focus on sustainable growth seems to be sufficient.

Figure 1 Sustainable AI



Developing and implementing Sustainable AI seems to be on the minds of more than 70% of business leaders, who believe that AI will help solve environmental and social challenges, improve products, security and ecosystems (Fujitsu 2024 SX Survey "Accelerating Sustainability Transformation with AI"). A full 63% of executives believe AI can contribute to the success of a sustainability transformation, while 65% believe it will contribute to their digital transformation.

Gartner's 2024 CEO and Senior Business Executive Survey found similar results, with 69% of executives seeing environmental sustainability as an opportunity for their business growth strategy, while most executives believe that AI and Generative AI are key to their growth strategy.

How can such a platform be developed? In practice, Sustainable AI builds on the integration of enterprise Digital Transformation (DX) initiatives with the accelerating wave of AI investments and the increasingly urgent demand for Sustainable Transformation (SX) outcomes.

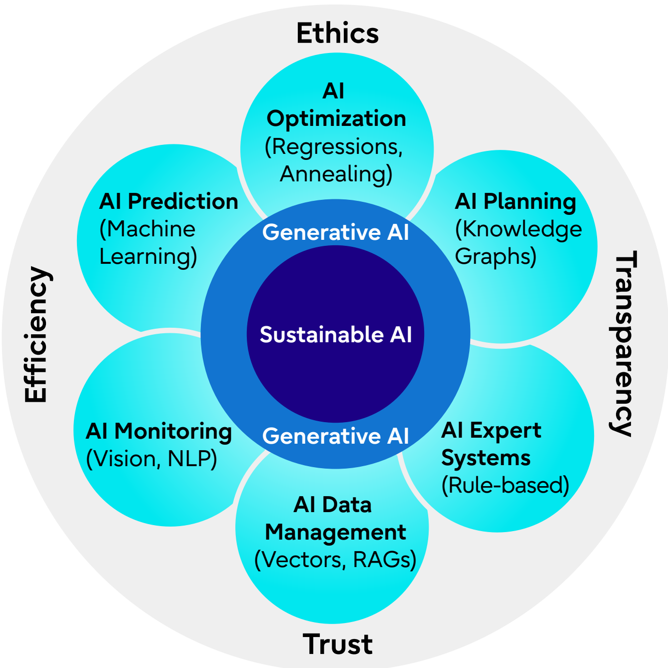
Already today, DX technologies such as cloud computing, the Internet of Things, blockchains, and AI are increasingly being used as tools to manage data, optimize production processes, orchestrate logistics, and increase efficiency. However, in most cases, AI-driven initiatives are not integrated into broader business transformation strategies because they remain too specialized and siloed.

For example, the [2024 Fujitsu SX Survey]() shows that 49% of organizations have not established an enterprise-wide AI strategy. In 36% of cases, each business unit is implementing its own independent AI initiative. Unsurprisingly, organizations struggle even more to leverage AI initiatives for sustainable transformation. More than half (53%) say they are struggling with the "complexity and scale" of the challenge, and 44% feel they do not have the right technology infrastructure in place.

As we will discuss below, this situation is now changing rapidly. The development of Generative AI enables unprecedented integration of information, automation, and management across the enterprise. It also makes it possible to integrate and orchestrate previously disparate DX technologies and AI initiatives with a common, forward-looking purpose that can be shared across and beyond the enterprise.

However, a sustainable AI platform is not an abstract concept. As shown in Figure 2, it builds on existing solutions for managing data, monitoring and optimizing processes, predicting outcomes, and planning solutions. Such AI-based "tools" and "algorithms" are orchestrated and integrated into a Generative AI platform that drives integration with a clear purpose: to support sustainability in the organization and its environment.

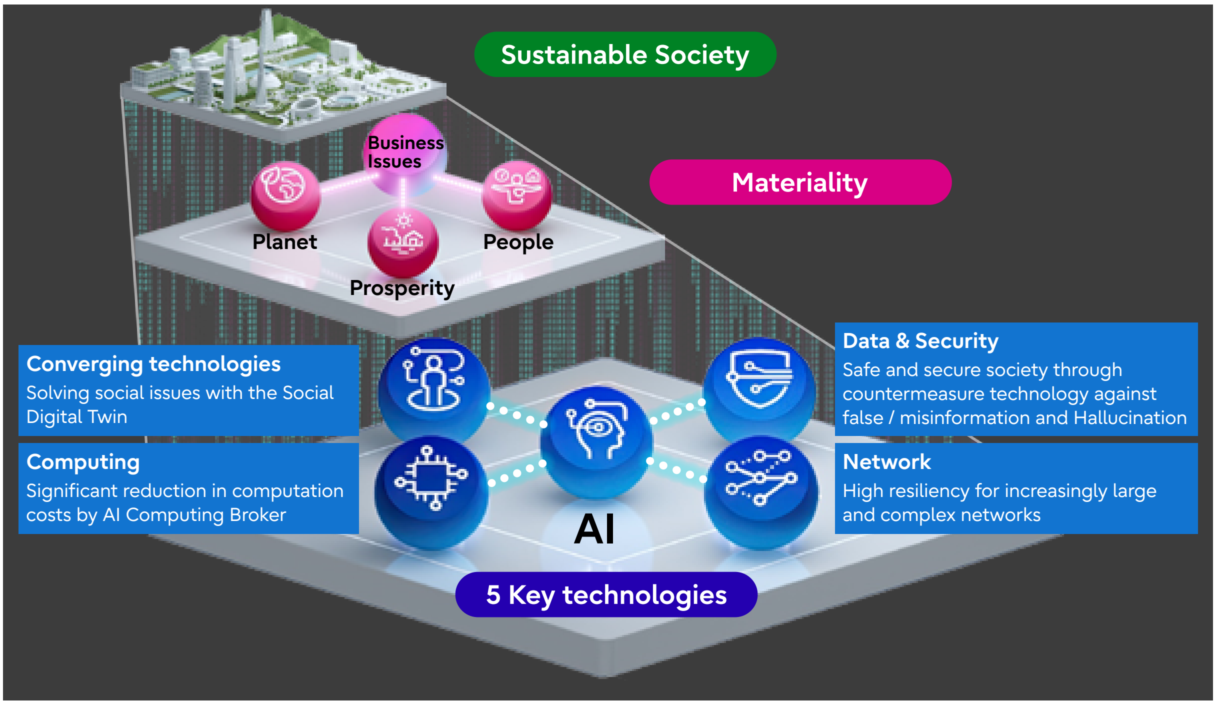
Figure 2 Sustainable AI Platform



Aligning AI technologies with sustainability goals can be empowering and beneficial on many levels. Implementation based on a Generative AI platform core enables seamless access and integration of existing information silos, unstructured corporate documents, and human communications. As more data and information flows become available, Generative AI platforms can help integrate existing management systems for forecasting, optimization, and planning for sustainable solutions.

Generative AI can also help deliver this information to management in the language and level of detail they need to quickly develop actionable solutions. Without such platform integration, management would remain blind to the potential of most sustainability opportunities. Fujitsu's research, for example, shows how its five key-technologies work together to solve complex "materiality" challenges for a more sustainable future (see Figure 3).

Figure 3 Fujitsu Uvance AI for a Sustainable Society



Source: https://activate.fujitsu/en/key-technologies-article/ta-sb-2024jun-20240625

However, Sustainable AI is more than an integrated approach to "AI for Sustainability" initiatives. It is essential that sustainability is at the heart of the platform, providing a common purpose for the entire organization. It explains and justifies the unprecedented information integration, operational monitoring, production optimization, and efficiency planning that will be required to achieve sustainable goals. With sustainability as its purpose, Sustainable AI can provide a framework that enables the trusted implementation of enterprise-wide AI initiatives that might otherwise stall due to ethical concerns, organizational resistance, or lack of collaboration with value chain partners.

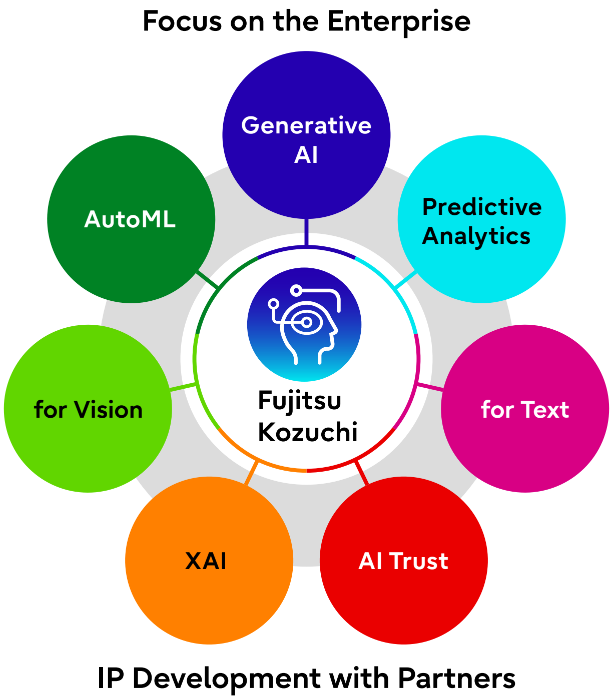
The purpose of Sustainable AI is to enable business transformation through trusted optimization, integration, and innovation of operations in sustainable value chains and ecosystems.

3. Generative AI
– Its Role in a Sustainable Transformation

Specialized AI technologies have existed for a long time. Fujitsu, for example, has delivered over 7,000 AI cases during the last 30 years. Most have been quite specialized solutions (for production control, for example), with limited impact on company-wide operations or business models. This is now changing with the ability of Generative AI to access a far broader range of data and technologies.

As we explain in our Whitepaper "Generative AI Innovation – Where is the Business Value", it provides an unprecedented opportunity because it can work with human language and interactions as well as with other code, algorithms, and diverse computing systems. The Fujitsu Kozuchi set of cloud-based AI services, for example, can now integrate operations functions from vision monitoring to predictive analytics and even building its own AI models if specialized applications are necessary. It also provides increasingly advanced solutions for the trustworthy management of biases and hallucinations. It integrates, at the same time, into a wide range of management applications and communication – far beyond the specialized dashboards of existing operations control.

Figure 4 Fujitsu Kozuchi AI Integration



Generative AI platforms can help integrate existing management systems for prediction, optimization, and planning. Most of these systems were built by using different AI models for different business functions. Regressions and annealing, for example, were used for optimization in logistics and warehouses, machine learning for predictions in production processes, or knowledge graphs for advanced planning in management.

Almost none were used for sustainability planning, which requires complex information across business functions. Generative AI models can now provide this information, which allows the development of advanced management platforms that integrate sustainability planning, or the integration of entire ESG platforms.

Furthermore, since Generative AI can deliver information to management in the language and level of detail they need, management decisions can reverberate far more directly throughout all affected parts of the organization, rather than being stuck in specialized dashboards or trickling down narrow paths of command and control. Without such integration, complex sustainability initiatives that require close coordination across departments and with value chain partners will be far less effective.

As a result, the implementation of Generative AI platforms provides the opportunity to align existing initiatives for data monitoring, aggregation, and reporting in an effective ESG strategy that cannot only report but advance management decisions. This requires, however, that Generative AI capabilities become part of a Sustainable AI platform that gains access to all business functions of product and service lifecycles across the organization and value chains.

4. Enterprise Transformation – "Double Materiality" and ESG Platforms

A key driver of business transformation is regulatory and customer demand for improved sustainability. In our Whitepaper "Green Deals Go Digital – How can Companies Gain from Sustainable Digitalization," for example, we have discussed how green regulation is changing the business environment.

These changes are now being implemented in all major economies. In the EU, the Corporate Sustainability Reporting Directive (CSRD) has introduced stringent Product Carbon Footprint (PCF) reporting across the life cycle of products and services. A Carbon Border Adjustment Mechanism (BAM) adds global taxation, and a Supply Chain Act requires verification of human rights standards. In the United States, the Securities and Exchange Commission (SEC) has introduced mandatory disclosure of climate-related risks and GHG emissions. In Japan, the Financial Services Agency (FSA) has begun requiring audited emissions data and climate-related risk assessments in financial reports.

The result is a "Double Materiality," which requires companies to fundamentally change their reporting and strategic thinking beyond financial performance and economic risks. They must now also identify and prioritize solutions for the second materiality of social and environmental risks that an organization faces and causes by its own actions. This fundamentally changes what operational data an enterprise needs to collect, how it is analyzed, and how operational decisions become aligned with sustainability goals.

The challenges are much greater than most companies thought when they supported the new regulations and committed to progressive emissions targets. In particular, reporting and reducing emissions from the supply chain (Scope 3), which can account for more than 70% of emissions for most organizations, is already proving difficult to implement without significant system modernization.

Initially, it may be possible to meet emissions reporting requirements with rough estimates of Product Carbon Footprints (PCF). However, as emissions targets are set and the process of reducing emissions begins, increasingly precise data for each activity, product, and supplier will be required. Such data integration is far from a reality. For example, PwC reports that more than 50% of companies cannot accurately measure emissions, in part due to a lack of standardized ESG reporting. With the support of major IT companies such as Fujitsu, Microsoft and AWS, global companies are already working on a global "Open Footprint" standard for emissions data management that covers entire organizations and supports the coordination of their supply chains.

Based on such system modernization, optimization for environmental impact becomes possible. However, when aligned with business objectives, the practice of double materiality exponentially increases the complexity of analysis, forecasting, and implementation strategies. Scenario planning, for example, must consider supply chain costs and potential disruptions, as well as their sustainability challenges. As a result, enterprise ESG platforms, often implemented as mere information and reporting tools, must become core elements of corporate accounting and governance, connecting all parts of the production and supply processes to manage the new targets.

For effective business transformation, these new platforms require broad access to many business systems and processes and full commitment of senior management to use their results beyond environmental reporting for decision making. ESG initiatives need to be at the heart of corporate strategies and become a critical part of the business model. As a start, they need to become part of a comprehensive systems modernization, with an increasing number of AI services to manage growing complexity, and a clear purpose to drive the transformation.

5. Systems Modernization – Moving with AI to the Cloud

One of the main challenges during the introduction of any modern AI systems is dated infrastructure. While organizations gain from moving their systems to the cloud in general, effective AI systems require cloud-based data access for almost all their operations. Cost-effective AI solutions and services are increasingly provided on major platforms, such as AWS or Microsoft Azure, and benefit from seamless access to a variety of powerful LLMs. Sustainable AI solutions require but also support such future-oriented cloud integration.

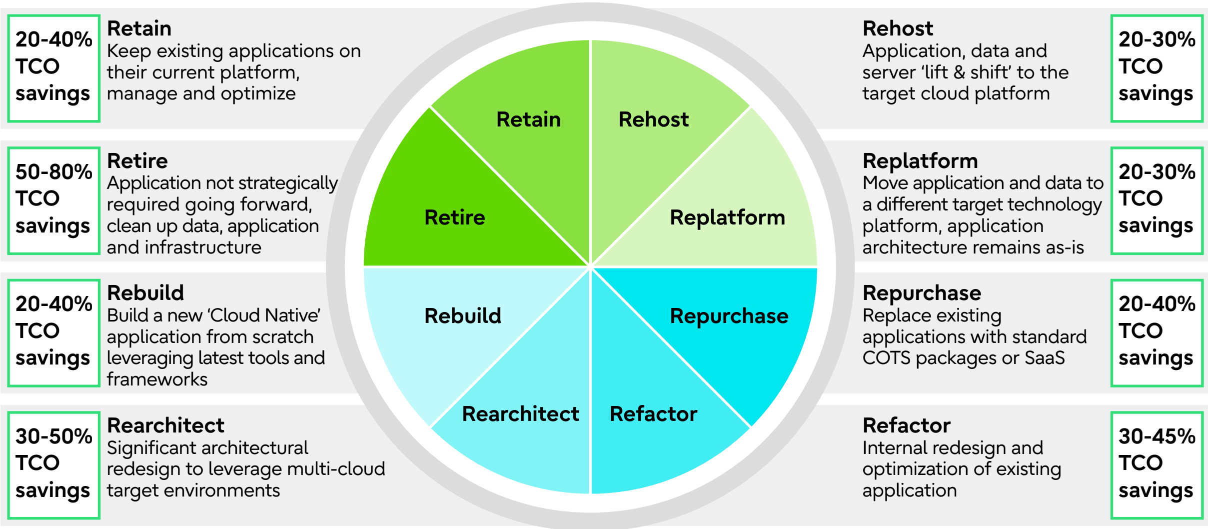
It is therefore not surprising that in the 2024 Fujitsu SX Survey more than half of executives are not only concerned by the "complexity" of a sustainable transformation, but that doubts about the adequacy of their technology infrastructure has jumped from 9th place to second place in 2024. Lacking adequate, reliable, and comparable data follows in third place.

As will be further explained below, the "Sustainability of AI" starts in the cloud: cloud data centres are more energy-efficient than on-premises facilities, leveraging economies of scale, and improving resources utilisation. Providers like AWS, Microsoft Azure, and Google Cloud are also increasingly powered by renewable energy sources; for example, AWS achieved 100% renewable energy for its data centres in 2023. Almost the same is true for the use of "AI for Sustainability." A growing range of AI services on the major platforms support the effective development of comprehensive Sustainable AI solutions.

Cloud Operation Optimization

Increasingly, the migration of data to the cloud is becoming AI-automated by analyzing existing infrastructure, providing comprehensive maps, migration simulations, and optimal deployment strategies. Post-migration, AI tools analyze usage patterns, optimizing efficiency and cost savings. Microsoft and AWS, for example, have provided solutions for this approach that reduces the Total Cost of Ownership, TCO, to 50%.

Figure 5 Efficient Cloud Migration



Source: https://www.fujitsu.com/global/imagesgig5/Progression-Paper-AWS.pdf

Following migration, automated functions, such as Fujitsu Cloud Managed Service can start to optimize cloud operations. Such end-to-end solutions can ensure that all components are integrated, orchestrated, visible, and managed effectively. Intelligent automation proactively identifies and resolves issues. Most importantly, AI-powered cybersecurity ensures compliance. An AI-driven "Automate by Default" strategy utilizes self-healing systems and standardized blueprints to prevent disruptions and minimize manual intervention.

Furthermore, cloud computing continuously improves remote access and work-from-home. Many employees can already work seamlessly on their smartphones from any location, allowing for significant improvements in commuting times and efficiency. At the same time, cloud-based tools, such as those offered by Google Cloud and Salesforce Net Zero Cloud, provide enhanced capabilities for measuring and analysing carbon emissions. These can become the basis for transparency when energy and cost-intensive AI solutions are being used.

When relevant data have moved to a cloud platform, existing AI services can add to sustainable solutions. Microsoft Fabric, for example, analyses ESG data and helps to prepare data for analysis and regulatory reporting. It centralizes ESG data from disparate sources, enabling the computation, analysis, and disclosure of ESG metrics for various regulatory reports, including carbon, water, and waste by connecting to its Sustainability Manager.

While such potentials exist, most enterprise cloud solutions still lack a focus on sustainability. Sustainable functionality needs to be added by an organization's IT department or by solution partners with deep knowledge of available functions in custom cloud setups. On this account, the expertise of service provider with a focus on SX solutions as a strategic modernization partners become indispensable. Specifically, the assessment, migration, and modernization of mission-critical legacy applications running on on-premises mainframes and UNIX servers to the AWS Cloud can help to achieve sustainable goals, too.

Modernization Benefits

On the technology side, the modernization can be leveraged by tools such as AWS Mainframe Modernization, an elastic mainframe service and suite of development tools designed for migrating and modernizing mainframe and legacy workloads. For example, AWS Blu Age, a component of AWS Mainframe Modernization, provides automated refactoring of mainframe applications written in legacy languages like COBOL and PL/I, converting them to Java, and potentially open them for AI functionality.

This modern approach improves operational resilience and boosts staff productivity. The cloud and AI offer significant advantages, including precise cost measurement and prediction, enabling more profitable operational models. Furthermore, AI and generative AI, leveraging CI/CD and Infrastructure as Code, enhance mainframe applications with advanced frameworks like containers and serverless technologies.

The benefits of mainframe modernization are substantial. For example, the Virginia Department of Human Resource Management reduced its operating costs by $15 million annually, while the Washington State Department of Licensing achieved a $1 million annual reduction in total cost of ownership (TCO), plus avoided up to $500,000 in mainframe upgrade costs.

Such public sector migrations often gain massive scale. Three decades of operation, 1,000 business logic programs, 1.5 million lines of code, 40 million data records, and 1.7 GB of database information nearing end-of-life are no exception. Generative AI tools, such as Amazon Bedrock and SageMaker, can significantly help to accelerate code analysis and review. They can also be used, however, for a transition with an added purpose as part of a Sustainable AI strategy. Long-term plans for government digitalization could turn into significant steps towards a sustainable transformation.

6. Sustainability of AI – Effective and Trusted Platform Transformation

As Generative AI is developed, implemented, and used to build sustainable businesses, the sustainability of the use of AI technologies has become a major concern. Its massive models are much more power-hungry than previous solutions and often require new hardware. Its services often replace existing, more efficient AI solutions. For example, a simple information search running on a Generative AI platform currently consumes 10 times more power than previous search engines.

The impact on energy consumption alone can be huge: while current ICT hardware consumes less than 1% of global electricity demand, it is projected to grow exponentially, doubling every 3 years to reach over 6% of global electricity consumption by 2030. In the US, demand is expected to grow to 9% in 2030. In regions with many data centers, consumption is already overwhelming grid capacity. In Ireland, datacenters are consuming more than 20% of grid capacity, even before additional AI capacity is built and deployed.

Frustratingly, building on renewable energy to power sustainable AI development and deployment can only be part of the solution. While most Hyperscaler use green data centers for regular computing needs, such data centers are being overwhelmed by the demands of Generative AI computing. Sufficient stable renewable energy supply for AI-computing will not be available in most locations for years to come.

To improve efficiency, cloud providers will need to implement complex strategies. Different data centers will be needed for specialized AI tasks. "Cross-clouds" can separate data storage and applications, with specialized AI hardware built in remote locations with high renewable energy potential and operations that can "follow the sun." Fujitsu, for example, has developed an AI Computing Broker technology that can increase the efficiency of the use of GPUs, which make up the bulk of AI's computing resources, from 30% utilization rates to up to 100% full GPU utilization. It estimates that the electricity saved by this technology is equivalent to the annual electricity consumption of approximately 24 million households in Japan.

The huge power consumption that is required for initial training of LMS can be reduced by experimenting with more efficient (smaller) models, running on increasingly specialized hardware. Furthermore, the current brute-force approach to improving models by growing and feeding them based on ever more data is already facing diminishing marginal returns. Smaller, much more efficient models that are fine-tuned to local data are starting to perform better for many applications.

On the user side, most organizations do not need to build basic LLMs from scratch. Using other techniques, such as fine-tuning, can help to achieve higher accuracy based on existing LLMs. Composite AI provides opportunities to leverage and optimize different modules such as RAG, knowledge graphs, and vector databases to improve model performance, which can also reduce their energy consumption.

The Sustainability of AI requires minimizing the environmental footprint of AI systems, ethical governance of information, and responsible management of societal risks. While this seems like a tall order, improving the environmental footprint can initially be achieved by moving to the most energy-efficient provider with a proven commitment to sustainability - even if they cannot promise carbon-free computing for AI operations now. For larger projects, energy-conscious planning that considers model usage can significantly improve results at lower resource utilization rates.

Sustainability of AI also requires building trust in ethical governance and responsible management, as we explain in our Whitepaper "Generative AI: Building Trust through Human Empowerment." For building trust, transparency becomes a cornerstone of Sustainable AI platforms. This requires clear information about how the AI system works, the data it was trained on, and the logic behind its outputs. Such transparency can be enhanced through explainable AI (XAI). By making AI's decisions process understandable to humans, XAI can help users make informed decisions, thereby empowering them and fostering trust.

The use of Sustainable AI as a technology to augment human capabilities, can further leverage trust when users and systems learn and train together while producing increasingly sustainable results. To guide the process, organizations and their users will need ethical guidelines for working and training with the new systems. These guidelines should address issues such as privacy, fairness, and misuse of AI-generated content. By adhering to ethical regulation, such as the EU's AI Act, and taking advantage of a growing base of initiatives for the ethical development of general-purpose AI models, organizations can demonstrate their commitment to the responsible use of AI while building sustainable AI platforms.

Such a commitment to trustworthy standards is far less difficult than it may seem. The OECD's AI Principles, which also focus on the use of AI for sustainable development, provide an excellent starting point, while reassuring users that sustainable development should be the common goal, not the proactive development of risk-limiting regulations:

"Stakeholders should proactively engage in responsible stewardship of trustworthy AI in pursuit of beneficial outcomes for people and the planet, ...thus invigorating inclusive growth, sustainable development and well-being." (OECD AI Principle 1.1)

7. AI for Sustainability – Sustainable Value Creation

Sustainable value creation requires that the costs and challenges of "Sustainability of AI" be less than the potential benefits of using "AI for Sustainability." The challenges of Sustainability of AI can be partially mitigated through efficiency gains by cloud providers, transparency of challenges by users, and proactive compliance with regulations. However, the contribution of AI for Sustainability, i.e. the use of AI solutions to solve complex environmental and social problems, is much more difficult to assess. Its impact will ultimately define Sustainable AI's contribution to growth, value creation, and overall development.

Technology, Economic and Business Gains vs Challenges

From a technology perspective, it is easy to be optimistic about the overall role of AI in advancing sustainability. AI should be seen as a General-Purpose Technology (GPT) that has the potential to drive change and productivity gains across most sectors and industries, just as electricity and the Internet did before it. Because it can be used not only for technical advances, such as improving data access or information management, but also to enhance human management and skills, it can potentially have an even greater impact on societal challenges than other GPTs before it. For example, the EU Commission and a growing body of research for its "Green Deal" expect that advancing digitalization will be essential for the effective implementation of its environmental policies. The additional potential of AI for environmental management is now being evaluated at all levels.

From an economic perspective, it also seems certain that AI technologies will have a positive impact on development, including the environment. Estimates of the economic value added of Generative AI applications in the coming years range from $477 billion for the US economy (Oxford Economics) to $4.4 trillion globally (McKinsey). Increasing environmental costs, including the additional use of energy, water, and materials, on the other hand, remain far below these potential benefits. Harnessing even a small fraction of these technology gains, through enterprise initiatives or government taxes, could significantly improve the environment. As our latest Fujitsu Technology and Service Vision explains, even "net-positive" or regenerative enterprises are becoming a possibility.

From a business perspective, however, the sustainable implementation of AI requires further scrutiny. Technology investments can easily be wasted during hype cycles. Alternative investments could have a more positive impact, undermining the value of Sustainable AI for business strategies. Simple targets or internal carbon pricing without a complex AI strategy may be more efficient for achieving sustainability goals. Ultimately, cost-performance, value for money is key to business application.

Weighing Gains and Challenges

Several studies have therefore attempted to estimate the quantitative economic and environmental costs of using AI compared to its potential environmental benefits when used to improve existing operations.

For example, Kaak et al. (2021) "Aligning Artificial Intelligence with Climate Change Mitigation," distinguish between the direct computational impact of AI and its system-level impact on the broader environment. They find that cases with positive direct impacts, driven by better information availability, forecasting, and optimization in energy, manufacturing, and logistics, far outweigh negative use cases, such as supporting emissions-intensive oil and gas activities.

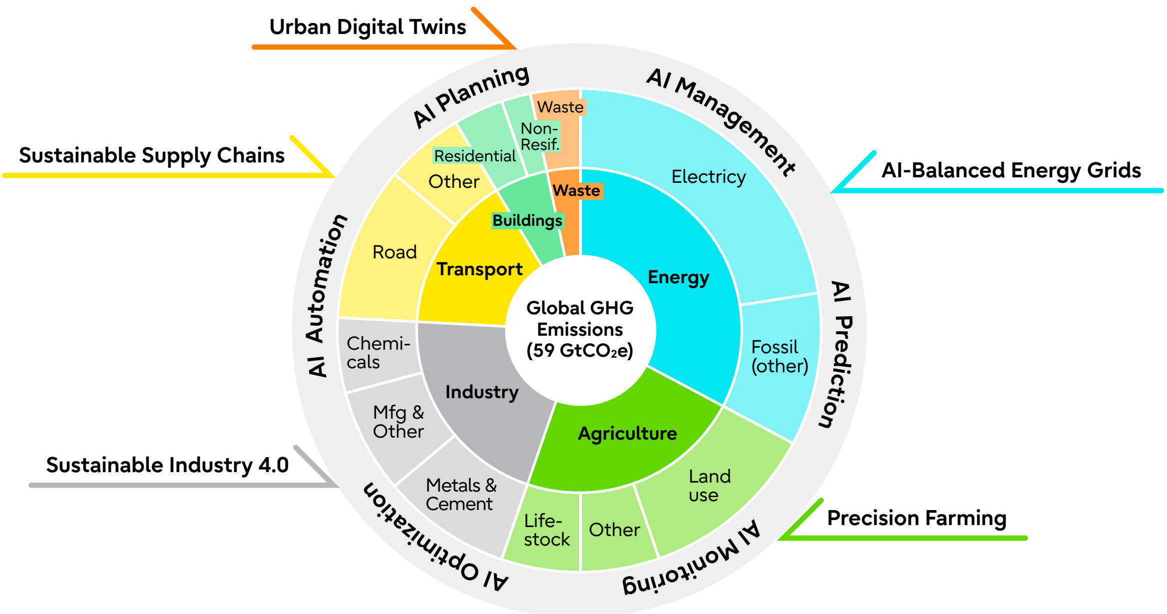
Positive broader system-level impacts result from R&D in low-carbon technologies, the planning and design of low-carbon systems, and the design, monitoring, and enforcement of sustainable policies. While they could not directly quantify these positive impacts, they conclude that the simultaneous optimization and advancement of AI-based climate change mitigation and sustainability innovation should yield overall positive results.

A study by MIT (2024) "The Climate and Sustainability Implications of Generative AI" provides further insight into the beneficial potential of generative AI. They recommend a robust application of Life Cycle Assessments (LCA) to estimate the direct impact of each AI project, as is already common practice for Product Carbon Footprint (PCF) assessments. Evaluating a positive impact of larger AI projects or national strategies, on the other hand, depends on the collaboration between corporate leadership teams and policymakers, practitioners, and supply chain partners. They point to traditional sector analysis to assess potentials and project evaluations. Ultimately, however, their study also concludes that the results of AI-based optimization remain dependent on learning by doing.

"As technology evolves, its exact benefits and impact remain the subject of keen observation and ongoing assessment."

In the following, our assessment of the potential for Sustainable AI follows a similar methodology. It follows the most relevant applications in the highest-emitting sectors of the global economy (see Figure 6). Negative (side) effects are weighed against positive outcomes and potentials. For potentials, positive use cases from technology or industry leaders are used. For positive outcomes, initiatives must significantly contribute to the purpose of Sustainable AI: to enable business transformation through trusted optimization, integration, and innovation of operations in sustainable value chains and ecosystems.

Figure 6 Major Sustainable AI Sector Use Cases



Data Source: WRI (2022) – State of Climate Action 2022.

8. Energy
– Balancing Sustainable Supply and Demand

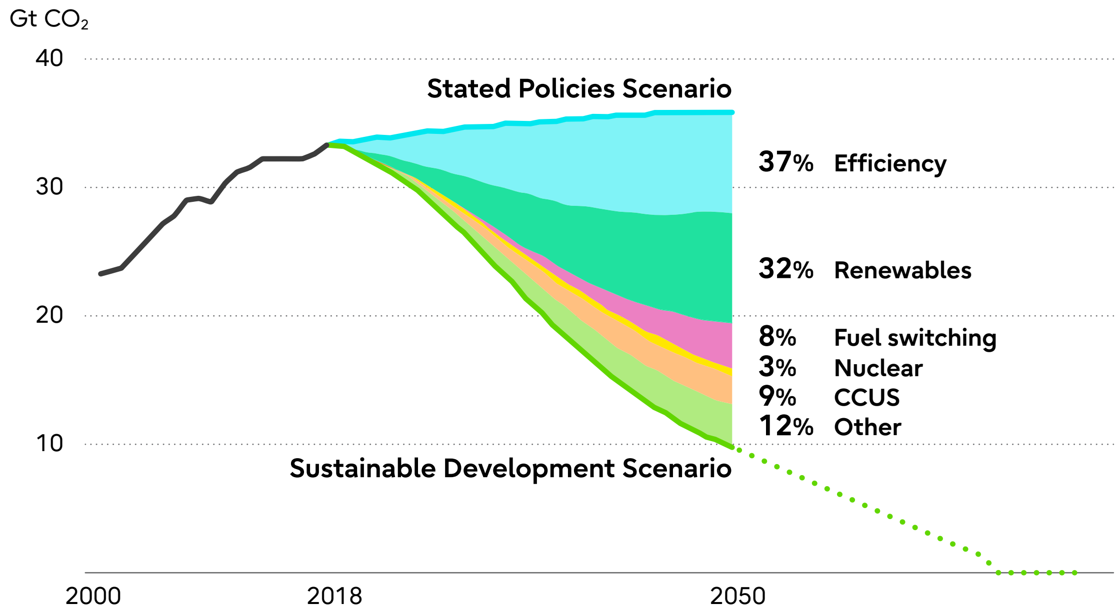
The way to net-zero emissions requires a fundamental transformation of energy supply and demand across industries, networks, and technologies. In our chart of GHG emissions in Figure 6, the energy sector accounts for almost a fifth of all emissions, by far the largest share.

So far, most attention has been drawn to the transition of energy supply to renewable sources because of the enormous investments that are necessary. Less recognized is the challenge of balancing a growing and increasingly complex mix of diverse sources, stores, and networks that will reach from solar and wind, to pumped water and car batteries, and hydrogen in tanks and pipelines. Still often ignored is the vital need for energy saving and fuel switching that will be necessary to achieve overall sustainability goals by improvements on the demand side.

Sustainable AI for Efficiency and Energy Supply Management

The IEA estimates that 37% of CO_2 emissions reductions will need to come from increasing energy efficiency and 8% from complex fuel switching (such as hydrogen) or carbon capture (9% CCUS), while renewables will only be able to provide about 32% to overall savings. During the transition, the World Energy Outlook (2022) expects technology related electricity constraints as early as 2030. Electricity constraints will affect all companies, but technology companies, who position themselves as part of the solution, will need to present their efficiency contributions in far more significant ways in such an environment. However, managing the necessary energy savings will need to be achieved by chasing marginal gains at any corner of operations, from micro power sources, production optimization, to transport efficiency. Without Sustainable AI platforms, managing such growing complexity will be impossible.

Figure 7 CO_2 Emissions and the Energy Mix



Source: IEA (2019) – World Energy Outlook.

Energy generators worldwide are under mounting pressure to transition rapidly from fossil fuels to greener, renewable energy sources such as wind, solar, hydroelectric, geothermal, and wave power. However, these energy generators face the complex challenge of integrating a diverse array of often weather-dependent renewable energy sources while minimizing reliance on non-renewable, fossil fuel-powered generation. This complexity is further compounded by the need to manage smart grids that support small-scale local and micro power generation, which is also frequently weather-dependent. Concurrently, the shift away from fossil fuels for domestic heating and cooking, and the adoption of more sustainable transportation options like electric vehicles (EVs), is transforming power demand and the transmission capacity required to maintain supply.

Virtual Power Plants and Grid Management

The potential of AI-based utility management has spurred the emergence of virtual power plants (VPPs), an integrated network of decentralized distributed energy resources (DERs). These include solar panels, wind turbines, battery storage, and flexible demand-side resources such as smart appliances and electric vehicles. These diverse resources are seamlessly aggregated and managed through advanced software and communications technologies, enabling them to function cohesively as a single power plant. The core goal of a VPP is to optimize the generation, storage, and consumption of electricity, significantly improving grid stability, operational efficiency, and overall reliability.

The UK's National Grid Electricity System Operator (ESO) exemplifies the integration of advanced AI-powered grid management technologies to balance supply and demand, incorporating renewable energy sources and supporting the growing number of EVs. Google's DeepMind has partnered with the UK's National Grid to use AI for predicting energy demand and optimizing the balance between supply and demand, thereby enhancing grid stability. Similarly, IBM's Watson is employed by various utility companies to analyze vast amounts of data from smart grids, predict energy consumption patterns, and optimize the integration of renewable energy sources.

Sustainable AI at the Core of Energy Management

AI has become an increasingly indispensable tool in managing this growing complexity. By forecasting demand, balancing generation, and optimizing smart grids, AI ensures a reliable energy supply regardless of weather conditions. In this context, VPPs, empowered by AI, are not just a technological innovation but a strategic imperative for the future of energy management.

On the demand side, companies are implementing increasingly advanced ESG management systems that not only report emissions, as is increasingly required by law, but also reduce emissions through energy source management, production optimization, and supply chain orchestration. As AI operations become a core part of these systems, the potential to connect and better balance supply and demand with Sustainable AI platforms is growing in both directions.

9. Agriculture – Precision and Greenhouse Farming

Feeding a growing global population is a significant challenge, especially considering that agriculture is a major contributor to CO_2 emissions, both directly and indirectly through fertilizers and pesticides. Rising living standards further exacerbate this issue, as changes in diet lead to an increase per capita CO_2 emission. Many countries have surpassed their domestic food production capacities and rely heavily on food imports, making the global food supply chain a substantial contributor to emissions. Today, the challenge of producing more food with less environmental impact has become increasingly critical.

Sustainable AI's Growing Role in Agricultural Research

In agricultural research, AI is playing an increasingly significant role in accelerating to develop higher-yielding, more disease-resistant, and drought-tolerant crops with a lower environmental impact. The Bayer's Climate FieldView platform already uses AI to analyze data from various sources, helping researchers develop crops that are more resilient to climate change. Corteva Agriscience's Granular software uses AI to provide insights into crop performance and soil health, aiding in the development of more sustainable farming practices.

Genomics research will play a key role in the future agriculture, and its results increasingly depend on the AI-based data analysis and predictive modeling. Getting it right depends on implementing Sustainable AI in agricultural and food research in a transparent and ethical way from the start.

Precision Agriculture – Optimizing Resource Utilization

In practice, the use of AI to power Precision Agriculture is revolutionizing the agricultural sector by enabling growers to maximize yields while minimizing the use of pesticides, fertilizers, and water. Precision Agriculture involves mapping fields and monitoring crops, allowing for the precise application of fertilizers, pesticides, and irrigation only where needed. This significantly reduces resource utilization and helps maximize crop yields, contributing to more sustainable food production. John Deere's See & Spray Technology uses computer vision and machine learning to identify weeds and apply herbicides only where necessary, reducing chemical use by up to 90%. IBM's Watson Decision Platform for Agriculture platform provides farmers with AI-driven insights on weather patterns, soil conditions, and crop health, enabling more informed decision-making and resource optimization.

AI driven Robotic Agriculture

Robotic weeding systems are becoming increasingly popular in agriculture due to their ability to reduce labor costs and minimize the need for chemical herbicides. Bosch's Bonirob agricultural robot uses machine learning and computer vision to identify and mechanically remove weeds. It is designed to work in various crop types and can adapt to different field conditions, and it has done this with technology from a decade ago. Systems development with the support of Sustainable AI will help to jump start the use of robotics in agriculture.

Agricultural Supply Chains – Maximizing Yield to Plate

AI is also crucial in optimizing agricultural supply chains, minimizing wastage, and reducing the carbon footprint of agricultural products. AI-powered image recognition technology is now widely used to identify, sort, and grade agricultural produce, and its application is expanding from processing plants to harvesting machines. TOMRA Sorting Solutions uses AI and machine learning to sort and grade fruits and vegetables, ensuring only high-quality produce reaches consumers and reducing food waste. AgShift, one of the emerging agricultural startups, uses AI to automate the quality assessment of agricultural produce, helping to minimize human error and improve supply chain efficiency. These systems help reduce the carbon footprint by ensuring that substandard produce is not transported from the fields but is instead ploughed back into the soil.

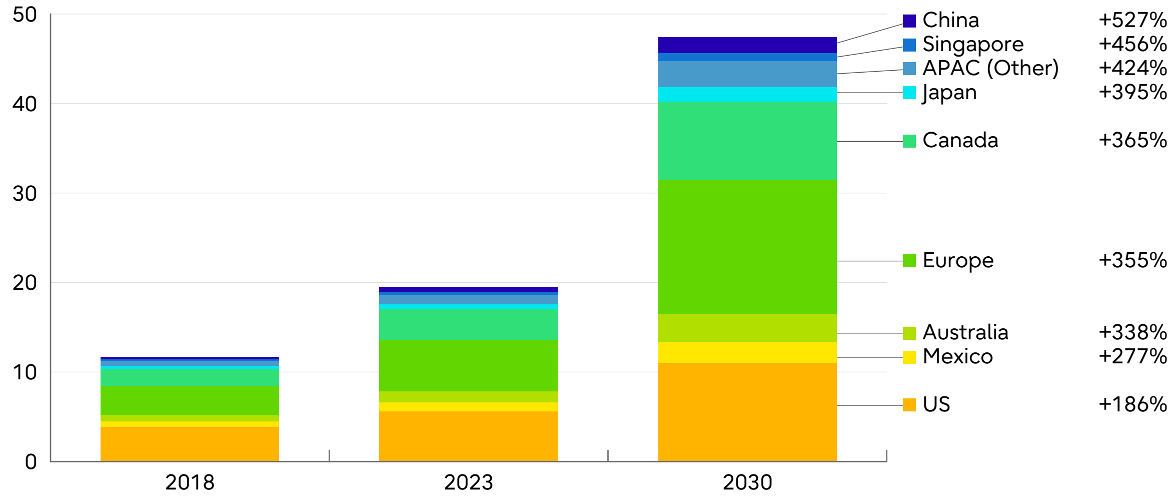
As has happened in Smart Manufacturing before, such AI-based analytics is gaining a significant role in the integration of agricultural Supply Chain Quality Management (SCQM). Our report "From Farm to Fork: AI shows the way towards safe and sustainable food production" shows that SCQM is already having a positive impact on waste prevention and resilience in food safety, leading to reduced risks and greater opportunities to ensure quality.

Smart Agriculture – Future Farming Technology and Greenhouses

While Sustainable AI can have a significant impact on transforming traditional agriculture by supporting precision farming development, it is playing a fundamental role in the fastest growing sectors of "smart" agriculture: greenhouse farming and its more futuristic trends in vertical farming.

Both are driven by growing urban demand and the need to become more independent from (changing) seasons and climate. A few countries, such as Holland or Canada, have been at the forefront of growing vegetables in challenging environments, but the technology is spreading now fast. In Spain's Almeria province, for example, greenhouses already cover an area of 400 square kilometers.

Figure 8 Smart Agriculture Market Size (Bn USD, 2018-30 Growth)



Source: Grand View Research (2024) - Smart Agriculture Market.

The dark side of this trend in Smart Agriculture is that the positive effects of precision farming on the environment might soon be overwhelmed by the power hunger of Greenhouse Farming. Additional heating during the cooler seasons and cooling during ever hotter summers is having an impact already. In Canada, for example, greenhouse produce has doubled over the last decade, while its energy consumption has increased by 55%.

Sustainable AI can help to mitigate or even reverse these negative trends by leveraging the positive potentials of greenhouse and indoor farming. Greenhouses do not only require water, but they also produce humidity, allowing growth in dryer climates. Plants produce CO_2 during the night, which can be absorbed during the day. With proper management, such emissions can be used. Humidity, for example, can be used as a water source, as the Fujitsu partner Botanical Water Technologies already demonstrates today. Research at EU-sponsored fossil-energy-free farming at TheGreefa shows that salt solutions can be used to turn moisture into heat, reducing thermal energy demand by 50%. At the same time, solar startups and major solar panel developers are working on partially transparent and UV-absorbing solar glass that can help to maintain the best light and heat conditions while cogenerating energy.

Urban and Vertical Farming

To have an impact, however, emissions and energy need to be managed in a synchronized way based on complex research. This is why technology companies have been experimenting with farming in highly controlled environments for more than a decade already. Fujitsu, for example, has been using its former semiconductor clean rooms to experiment with lettuce production. It has been found that the produce does not require any pesticides while growing, or cooling during delivery because the lack of bacteria prevents it from rotting. In greenhouse farming, its Akisai Food and Agricultural Cloud showed how advanced AI algorithms can provide optimal conditions for growth. Its partner Vertical Future, a builder of automated vertical farms, now uses up to 98% less water compared to traditional farming.

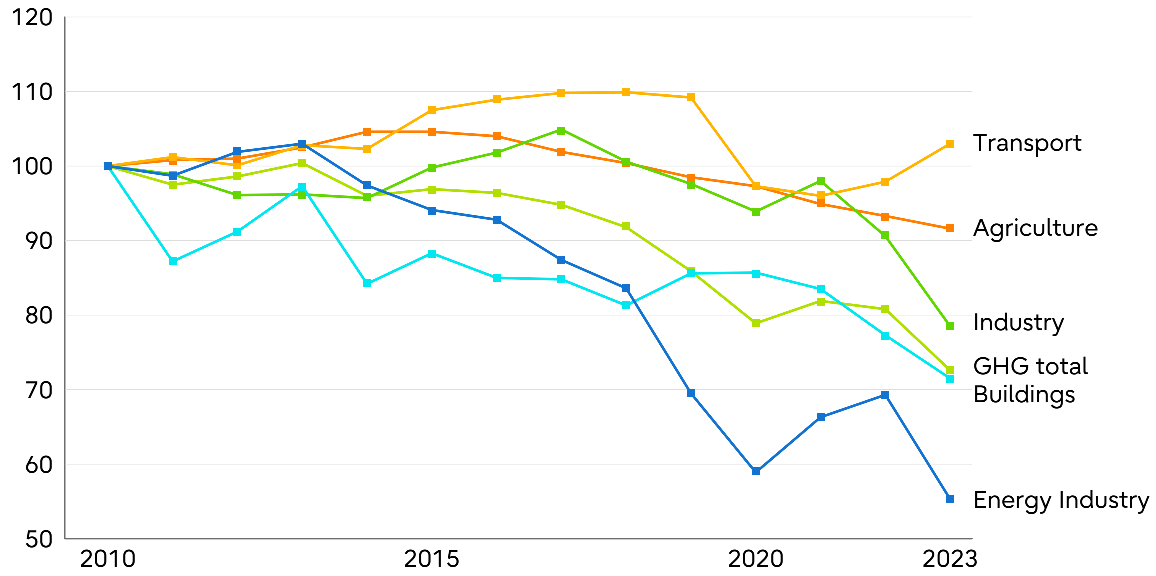
As a result, Controlled Environment Agriculture (CEA) is fast evolving as a technology with greenhouses at the one end and indoor Vertical Farming in the urban sprawl at the other. Without Sustainable AI that helps to manage the complex systems and integrate them into effective urban supply chains, success in smart agriculture seems to be far less likely.

10. Industry – From Industry 4.0 to Sustainable Manufacturing

The use of AI and advanced platform integration in industry and manufacturing is nothing new. More than a decade ago, the Industry 4.0 initiative connected a growing number of sensors and devices (Internet of Things; IoT) with cloud computing, big data analytics, AI control, and advanced robotics. Society 5.0 followed with a broader, service-oriented, and socially inclusive model. More recently, Industry 5.0 has added sustainability, resilience, and a more human-centric perspective to this industry Digital Transformation (DX) model.

So far, however, the resulting increase in productivity has not led to a significant reduction in emissions. As Figure 9 shows, even in environmentally conscious Germany, with its large and highly productive manufacturing sector, emissions from the industrial sector have not decreased since the start of the Industry 4.0 initiative in 2011. The only significant decrease in 2023 was triggered by the negative shock of rising energy costs since the war in Ukraine.

Figure 9 GHG Emissions in Germany (2010=100)



Source: Bundesumweltamt (2024).

Global Lighthouses as Role Models

Despite disappointing progress to date, a greater focus on sustainability could have a significant impact as Generative AI becomes accustomed to orchestrating productivity gains beyond operational efficiency considerations. The World Economic Forum (WEF) and McKinsey argue that the implementation of Industry 4.0 has not led to the expected gains across industries because it requires the transformation of entire organizations, which is time-consuming and requires strong role models. They have therefore initiated a Global Lighthouse Network of advanced manufacturing companies that can support in-depth research on their transformation and serve as role models.

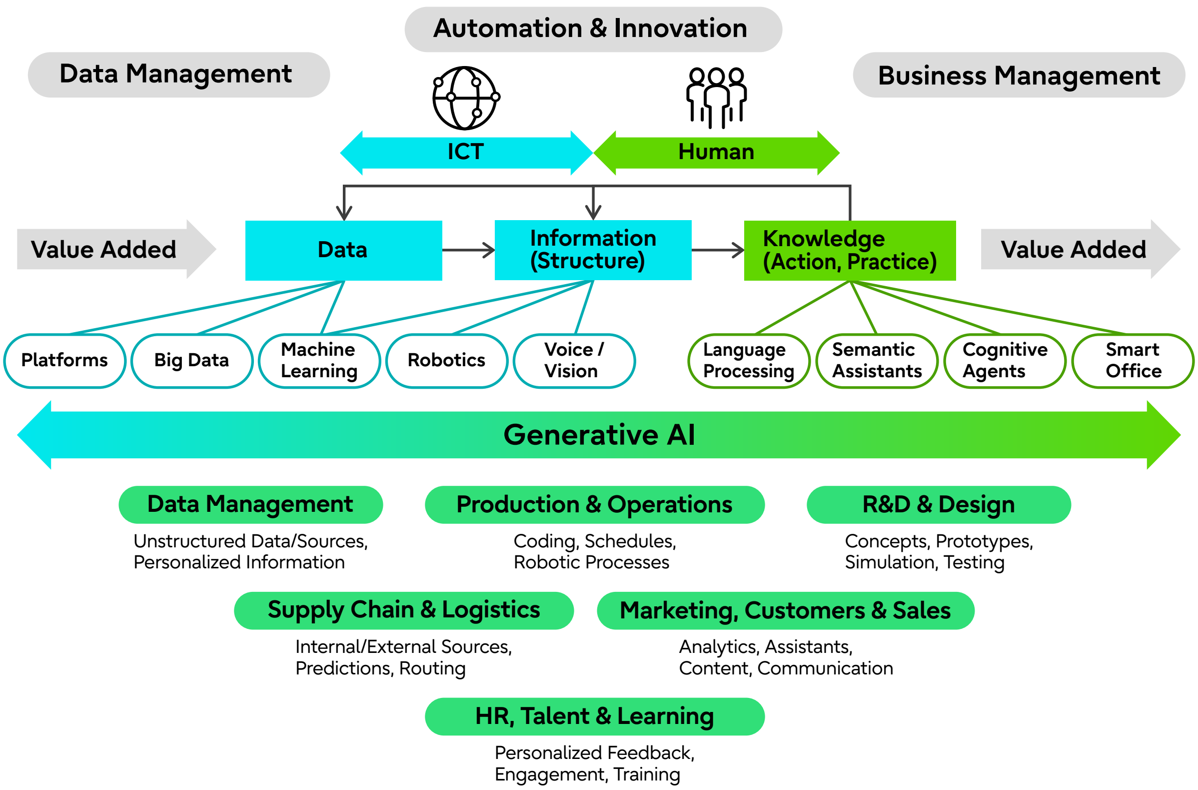
This group of advanced companies has been able to increase its productivity by 15-30% since its emergence in 2019. Each cohort of companies that has been added to the network has increasingly focused on AI as the conductor of their technology development. The most recent group of lighthouse companies (December 2023) achieved AI-related productivity improvements of 10-20% in their supply chain operations, over 40% in process optimization, and over 30% in assembly, quality, and testing.

Generative AI as an Enabler of enterprise Transformation

In our Whitepaper "Generative AI Innovation – Where is the Business Value," we showed that Generative AI can indeed deliver significant improvements across all business functions, not just for large enterprises. As enterprises realize the power of Generative AI platforms for flexible information integration, human-machine communication, and work integration, they can even partner with startup companies to improve and connect all parts of their operations.

Figure 10 provides an overview of the link between AI technologies and the business functions being transformed by AI startups. All major functions, from data management to R&D and learning, show great potential for AI-based productivity gains. Sustainable AI is significantly advancing the modernization of Industry 4.0 systems toward sustainable manufacturing by simultaneously embedding environmental requirements into business functions.

Figure 10 Generative AI Integration of Technology and Business Functions

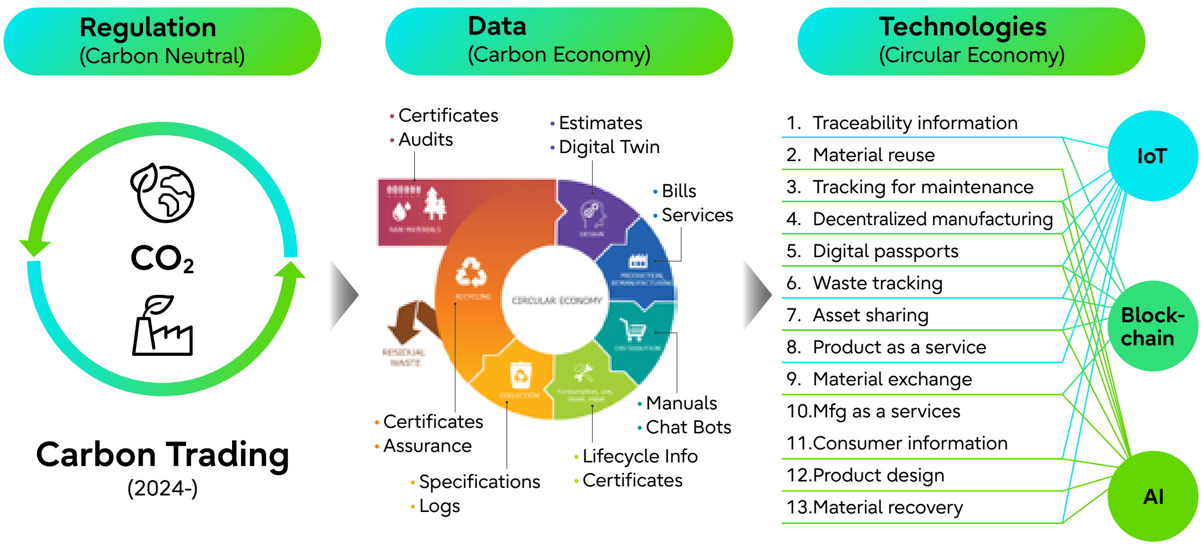


So far, however, the industry's progress in improving sustainability has been underwhelming. This was also evident when the WEF Lighthouse Project added a new category of "Sustainability Lighthouse" leaders in 2021. Of the 103 Lighthouse companies, about 60% were working on sustainability-related projects, but only 6 were recognized as sustainability leaders in 2022.

Steps towards a Circular Economy

Given slow progress in Industry 4.0 concepts towards sustainable manufacturing, it is likely that regulatory requirements, rather than technological opportunities, will drive major change in industry. This has already been the case in the transportation and automotive sectors. Starting this year, carbon reduction requirements and carbon pricing will demand significant reductions in carbon footprints. Sitting at the center of long supply chains for the manufacture of products with often high carbon footprints, organizations now need to assess the entire carbon economy to improve the sustainability of their operations and products. The result is an innovative approach to managing data across the entire value chain, from material certification to digital twin-based design for lifecycle improvement and disposal orchestration. This requires Industry 4.0 technologies, such as IoT and blockchains, to monitor increasingly circular processes, and sustainable AI to manage them (see Figure 11).

Figure 11 Industry 4.0 and Circular Economy Data and Technologies



The process of AI-based innovation and integration accelerates as technology and competition begin to transform business models. In the automotive industry, Tesla and Chinese EV companies could gain such a huge advantage by reimagining EVs and their production processes as “software defined” from the ground up. In such cases, Sustainable AI strategies offer huge opportunities - not only for innovators, but also for incumbents.

As they transform their businesses, incumbent internal combustion engine competitors can benefit from effective Sustainable AI initiatives just as much as their digitally focused competitors, as their operations become more complex and require even smarter management. They will need to decarbonize their entire supply chains in the best way possible to regain competitiveness. Sustainable AI could help them reimagine their manufacturing operations to identify and manage carbon-intensive components, processes, and suppliers.

By incorporating Sustainable AI into the design and development of their products, manufacturers can take a big step toward an effective Circular Economy with products that use less material, are more durable, and require less maintenance. This not only reduces their environmental impact, but also potentially makes them less expensive to produce, making them more competitive in the marketplace.

11. Supply Chains and Logistics – Sustainable End-to-End Integration

Supply chains and logistics have a significant impact on environmental emissions. For most companies, supply chain emissions (Scope 3 emissions) account for more than 70% of their total carbon footprint. For suppliers, the CDP reports that supply chain emissions are 26 times higher than their own operational emissions (Scope 1+2). For retailers, the ratio is as high as 92. This shows how long and complex supply chains have become.

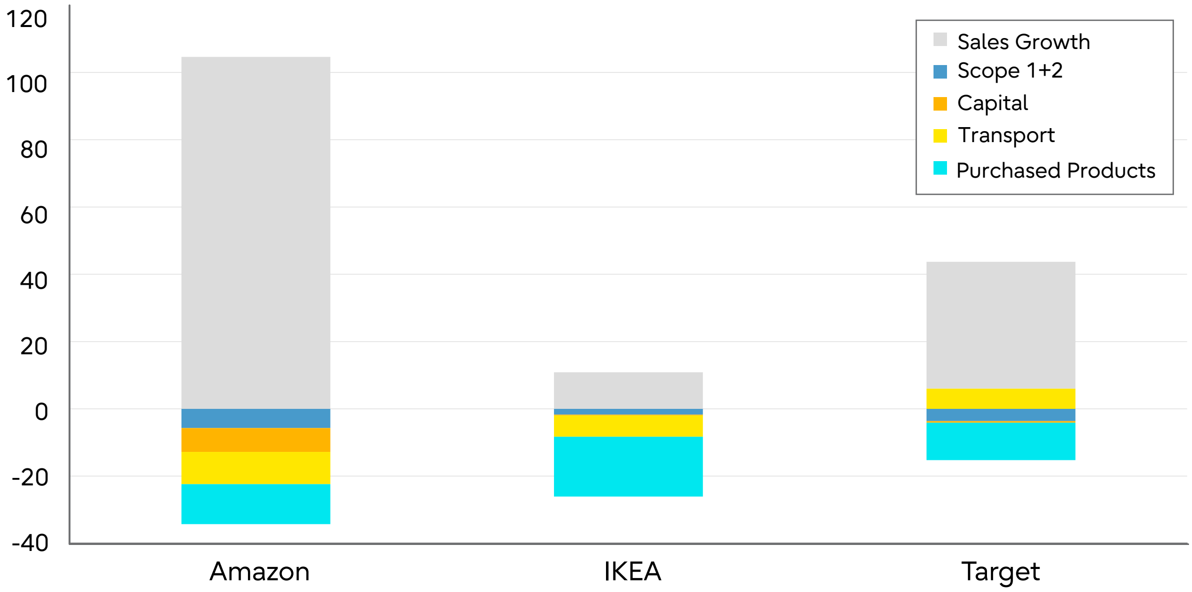
Improving the management of this complexity with sustainable AI platforms can be a game-changer, because it can increase efficiency, reduce costs and improving customer satisfaction. A prerequisite for such gains, however, is that data becomes available at all levels of the supply chain, and that organizations begin to coordinate and optimize product lifecycles “from the cradle to the grave.”

To date, progress in this integration has been limited. According to Gartner’s 2022 Supply Chain Digitalization Survey, 28% of integrated technology companies, which include advanced e-commerce retailers, were using AI and data science platforms. For manufacturers, the percentage dropped to 15%, and among all companies in the survey, only 10% were using advanced analytics.

In such an environment, digital freight brokerages, who have tried to integrate transportation data from end-to-end, have struggled to make an impact. Convoy, one of the technology leaders, even went out of business last year when automation gains failed to keep up with technology costs. Others, such as Uber Freight, are trying to set an example in their own operations by integrating existing databases, SQL queries, correlation analysis, and regression models, under the umbrella of new generative AI solutions.

It is therefore the large companies with long supply chains, and not the smaller player that are driving productivity and sustainability by integrating AI technologies into their Supply Chain Management (SCM) systems. Gartner reports that AI engineering leaders among suppliers can generate at least three times more value from their AI investments than the rest. Figure 12 shows the revenue growth and relative emissions (reductions) between 2019 and 2023 for three of the leaders: Amazon, IKEA, and Target.

Figure 12 Supply Chain AI-Leader Emissions Intensity and Sales Growth (2019-23; %)



Note: For comparability, emissions are calculated as Emissions Intensity by dividing tons of CO_2e by sales per 1000 USD.
Source: Corporate Sustainability Reports.

All three companies are using advanced AI platforms for demand forecasting, inventory management, warehouse optimization, route optimization, and service customization to improve productivity growth. They have also added AI-enabled capabilities to improve sustainable operations, particularly energy and waste management. Amazon has added sustainable packaging, as well as warehouse and data center energy management capabilities. IKEA has integrated flexible and efficient micro-fulfillment centers into its supply chain. Target has installed sophisticated energy management solutions in its stores.

Amazon, as an e-commerce company, has been most successful in reducing emissions because it has been able to build new capabilities into its growing operations and leveraged its own AWS platform, which offers a wide range of AI services. Its CO_2 emissions intensity (CO_2 divided by revenue in USD) fell by 34%, while revenue grew by more than 100%. While Amazon's relative success has been driven by the use of renewable energy in its data centers and the integration of demand management with increasingly sophisticated logistics, it still falls short in the increasingly important effort to reduce supply chain emissions from purchased goods of its supply chain partners.

Amazon only reports its own branded products as emissions for its Scope 3 or "Purchased Products" reporting. These products account for only about 1% of the traded product sales on its platform and are much easier to optimize. IKEA, on the other hand, has achieved a huge reduction in emissions for all of its purchased products. By tightly integrating its entire supply chain across all countries, it was able to make such gains. At the same time, Target was challenged by increasing transportation emissions as it had to report more comprehensive emissions data from its traditional supplier transportation services, which increased reported emissions even as some initiatives may have achieved improvements.

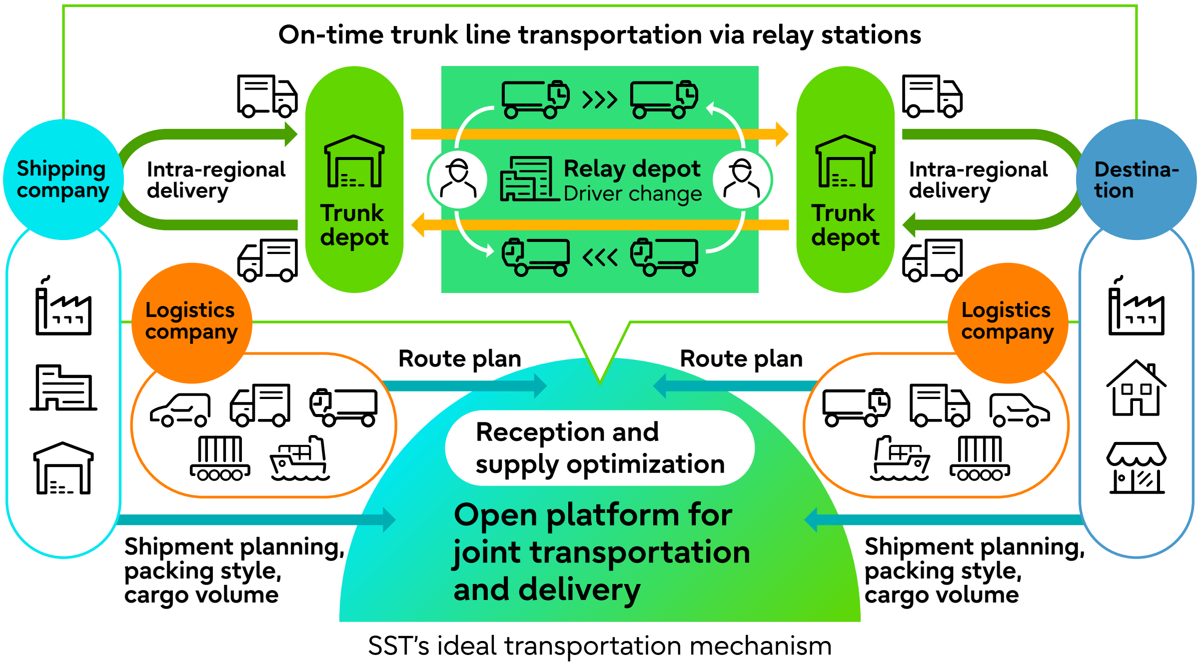
While even supply chain leaders are challenged to improve sustainability, more traditional and smaller suppliers are struggling. Because most suppliers cover only a small part of the value chain, they have rarely invested in improving their data governance capabilities. Relying on busy humans to unload trucks, make phone calls for confirmations, and send emails for orders, automation remains a challenge. Support from large customers in manufacturing or e-commerce to improve digital systems often stops at the gates of their Tier 1 partners and does not trickle down the supply chain. As a result, for most smaller comapnies, supply chain sustainability reporting requirements add cost and bureaucracy, but do not provide significant opportunities unless integrated into larger approaches.

To find the right strategy, companies therefore need to stay abreast of evolving new ecosystems and industry initiatives for data integration and information sharing. For example, Fujitsu in Japan offers a logistics data conversation and sustainable supply chain integration service that integrates the government's "Logistics Information Standard Guidelines" with AWS cloud services. It can automatically transform and standardize logistics data formats from multiple disparate systems in a supply chain. This can become the basis for AI analytics services or data integration with customers' core systems and multiple logistics systems, such as WMS or TMS (Warehouse/Transport Management Systems).

Another example is the Virtual Watch Tower (VWT) initiative, a digital orchestrator for the maritime industry's supply chain and logistics based on advanced AI integration. It is being developed by a collaboration between research institutes in Sweden, Finland and Singapore as well as technology companies such as Fujitsu. The logistics control towers will support end-to-end logistics and supply chain monitoring by sharing private data enriched with public data.

In Japan, the initiative has already delivered results. With support from Fujitsu, Japan's largest and most efficient logistics and home delivery company, Yamato Holdings, has established a new company, Sustainable Shared Transport Inc. It provides an open platform for shared sustainable supply chains and transportation for its 1.6 million corporate customers and more than 4,000 logistics partner companies. By placing relay points with data access for all partners on an initial 80 routes, optimized volumes and packaging for each part of the end-to-end transport can be planned and optimized for each partner (see Figure 13). By the end of fiscal 2025, the company expects to reduce GHG emissions by 42% and labor costs by 65%.

Figure 13 AI-Orchestrated Transport Mechanism with Relay Points



Source: [Yamato Holdings (2024): News Release.]

More Generative AI-based initiatives are now opening the door to such change. With a common purpose driving coordination, supply chain operations can be aligned with sustainability goals as their driver. Alliances for the development of Sustainable AI can help develop algorithms that optimize delivery routes, reduce the environmental impact of warehouses, and orchestrate automation. Ensuring sustainable on-time deliveries can help set new standards for efficiency - and for the organizations that are connected to them.

12. Urbanization – Sustainable AI and Planning

Today, 56% of the global population resides in urban areas, and these urban centers account for over 70% of global carbon emissions. The United Nations predicts that by 2050, 70% of all humanity will live in cities, making urban sustainability a key priority.

As urbanization continues to rise, cities face a growing array of infrastructure, operational, logistical, and sustainability challenges. Power, water supply, waste management, transportation, housing, and education challenges need to be solved. Addressing these challenges will require increasingly innovative and sustainable solutions.

Cities are therefore leveraging the power of AI to build smarter, more sustainable infrastructure. AI is playing an increasingly crucial role in transforming urban life, making cities not only more livable but also more sustainable.

Energy Efficiency - Optimizing Consumption and Integrating Renewables

One of the biggest sustainability challenges cities face is energy consumption. Urban centers have high energy demands to support residential, commercial, and industrial activities, and much of this energy is still derived from fossil fuels. AI can help optimize energy systems by enhancing demand forecasting, facilitating real time energy distribution, and supporting the integration of renewable energy sources into the grid.

In Los Angeles, for instance, AI driven demand response systems monitor real time energy usage and adjust power distribution dynamically. During high demand periods, AI algorithms predict consumption spikes and redistribute energy to avoid overloading the grid. This real time responsiveness also reduces the need to use nonrenewable energy resources to meet peak energy demands. Additionally, by leveraging machine learning, Los Angeles's AI systems can incorporate renewable energy sources like solar and wind more effectively, balancing supply fluctuations and reducing reliance on nonrenewable power sources.

Another noteworthy example is Google's AI-powered energy management in its data centers. By using DeepMind's AI to analyze and predict energy requirements, Google has reduced the cooling costs of its data centers by up to 40%, achieving overall energy savings of around 15%. Such solutions, when scaled across an urban area, can contribute to substantial energy savings and reductions in greenhouse gas emissions.

Sustainable Mobility - AI Driven Transport

Transportation is another sector where AI can significantly enhance urban sustainability. Congested roads, long commutes, and elevated levels of vehicle emissions are common issues in large cities. AI can optimize transportation systems by improving traffic management, enhancing public transit efficiency, and facilitating the deployment of electric and autonomous vehicles (EVs and AVs).

For instance, in London, the city's transportation authority uses AI algorithms to analyze data from traffic cameras, buses, and other sensors to manage traffic flows in real time. This system optimizes traffic light timings and suggests alternative routes to avoid congestion. By reducing stop-and-go traffic, London has managed to lower fuel consumption and cut vehicle emissions. Similar initiatives are underway in Singapore, where AI-driven predictive analytics streamline public transit schedules, reducing wait times and improving overall efficiency.

In addition to traffic management, AI is also central to the development of autonomous vehicles. Sustainable AI comes into play where cities use it to upgrade their transportation systems. Cities like Las Vegas and Helsinki have already begun piloting self-driving shuttle services. These AI powered shuttles offer an efficient and low-emission addition to traditional public transit and could reduce the need for private car ownership in the future. Furthermore, since virtually all AVs are built on electric vehicle technology, AVs can contribute to a cleaner, quieter, and more efficient urban environment.

Waste Management and the Circular Economy

Rapid urbanization has also led to a surge in waste production, presenting a significant sustainability challenge for cities. Traditional waste management approaches often struggle to keep pace with growing urban populations, resulting in inefficient collection processes, overflowing landfills, and missed recycling opportunities. AI can address these issues by improving waste collection, streamlining recycling processes, and promoting a circular economy model where resources are continuously reused or repurposed rather than discarded.

AI driven waste collection systems are becoming increasingly popular in cities like Copenhagen, where smart bins equipped with sensors detect when they are full and communicate this data to waste collection teams. This real time information enables more efficient routing for waste collection trucks, reducing fuel consumption and emissions associated with unnecessary trips. Additionally, by using AI powered route optimization software, waste management companies can lower operational costs and minimize environmental impact.

In the recycling sector, AI is also making a significant difference. Companies like AMP Robotics are deploying AI enhanced robots to automate waste sorting, identifying, and separating recyclable materials with higher accuracy than human labor. These robots use machine vision and deep learning to distinguish between several types of plastics, metals, and paper products. By increasing recycling rates and reducing contamination in recycling streams, AI-enabled systems help ensure that more materials are repurposed rather than sent to landfills.

Water Management and Conservation

Water scarcity is an issue that is increasingly relevant to urban areas, especially as climate change and population growth strain existing water resources. AI can enhance water management systems by improving the efficiency of water distribution, detecting leaks, and predicting usage patterns. In cities like Cape Town and Las Vegas, AI driven water management systems monitor water levels in real time, helping municipalities distribute water more efficiently and reduce wastage.

For example, Cape Town's AI powered system uses machine learning algorithms to analyze data from sensors installed in the water distribution network, identifying leaks and irregularities that indicate potential issues. By addressing leaks promptly, the city conserves water and reduces the strain on local reservoirs. This type of predictive maintenance is essential for urban centers in water-stressed regions, where every drop counts.

In another example, the city of Las Vegas uses AI to predict water demand based on seasonal weather patterns and historical consumption data. This insight enables the city to plan its water distribution more effectively, ensuring that supply meets demand without unnecessary waste. AI-powered water management systems are expected to play an increasingly key role in helping cities conserve water and adapt to the impacts of climate change.

Urban Planning and Resilience to Climate Change

Urban planning has traditionally relied on long term projections and historical data, but the speed and scale of urbanization demand more responsive and adaptable strategies. AI enables cities to model the impacts of new policies, infrastructure projects, and environmental changes with unprecedented detail. By integrating diverse data sources from traffic patterns to climate models planners can create dynamic simulations that help design cities that are not only more efficient but also resilient to climate change.

Singapore, often considered a model of smart urban planning, uses AI to optimize land use and manage its transportation and housing infrastructure. The city has developed a virtual "digital twin" that mirrors the entire urban environment, allowing planners to evaluate various scenarios and assess their effects on congestion, energy use, and environmental impact. This AI-powered model has enabled Singapore to prioritize green spaces, improve public transit routes, and minimize urban sprawl, all while accommodating population growth.

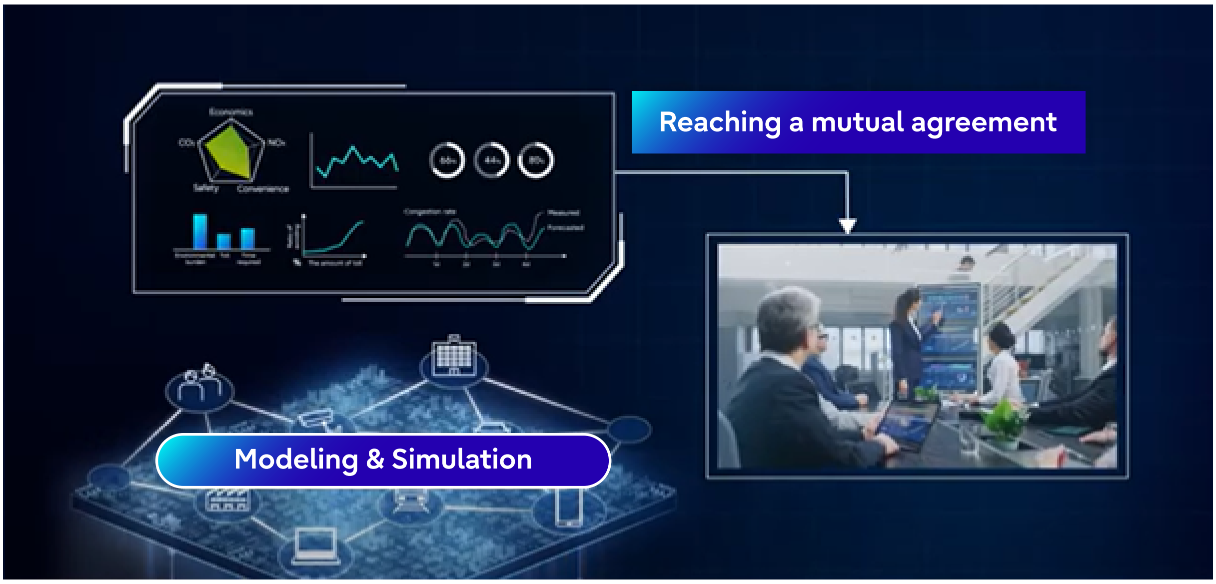
AI also plays a critical role in climate resilience, especially in cities facing increasing risks from natural disasters and extreme weather events. In New York City, for example, city planners are using AI-based simulations to anticipate flooding and storm surges in vulnerable areas. By modeling these scenarios, city officials can implement preventive measures, such as flood barriers and green infrastructure, to protect neighborhoods and critical infrastructure from climate related hazards.

The Potential of Sustainable AI and Digital Twins for Urbanization

The role of AI in promoting sustainable urbanization is clear. By optimizing energy consumption, enhancing public transportation, improving waste management, and enabling climate-resilient planning, AI can help make cities greener, more efficient, and more livable. But realizing this potential will require thoughtful, strategic implementation that balances technological advancement with ethical considerations. Sustainable AI could become an important catalyst for driving not only smarter, but also more sustainable solutions by developing AI technologies and platforms with a clear purpose.

An important development is that cities, universities, and technology companies are increasingly working together to solve social issues. An example is the cooperation between Fujitsu and Carnegie Mellon University for the development of a Social Digital Twin. It digitally reproduces the relationships between people, goods, the economy and society to offer a simulation, prediction and decision-making environment. It also extends capabilities in 3D modeling to monitor activity on streets and determine where issues or accidents may be taking place. Fujitsu's Social Digital Twin can now be used for a growing range of applications, from traffic planning to CO_2 reductions and disaster resilience preparation.

Figure 14 Fujitsu Social Digital Twin Technology



Source: https://www.youtube.com/watch?v=UZnWku3kECY

As urbanization continues to reshape the global landscape, cities must adapt to ensure a sustainable future. Those that harness the power of AI responsibly will be better positioned to meet the environmental and logistical challenges of rapid urban growth, creating urban environments that not only support a high quality of life, but also minimize their environmental footprint. On the path to sustainable urbanization, Sustainable AI is not just a tool, but a catalyst for reimagining the cities of tomorrow.

13. Conclusion

Implementing AI as part of a business transformation not only offers technological and operational opportunities; by integrating it into enterprise platforms with sustainability in mind, Sustainable AI becomes a powerful tool for building a more sustainable future. However, developing and implementing Sustainable AI is not a one-time effort. It is a journey toward managing a much more complex world, where "dual materiality" business and environmental challenges must be addressed simultaneously.

The journey begins with the implementation of cloud-based infrastructure as the foundation for Sustainable AI solutions, emphasizing the importance of data accessibility. From this foundation, Sustainable AI platforms can foster collaboration across departments and with ecosystem partners. By harnessing the power of AI in areas such as energy, agriculture, supply chains, and urban planning, companies can turn their own transformation into a powerful contribution to a more prosperous and environmentally responsible world.

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- Corporate Metaverse – Can it help to prepare for an AI-based digital future? 2023
- Green Deals Go Digital – How Can Companies Gain from Sustainable Digitalization? 2023
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