

Insights paper

The Green IT Value Case

Reducing carbon, cost and complexity of your IT landscape

TNO innovation for life

Foreword

Technology Evolution and Sustainability: The Green IT Imperative

Technology is evolving at an unprecedented pace. Innovations such as generative AI, edge computing and quantum technologies are rapidly reshaping the digital landscape, continuously redefining both challenges and opportunities for environmental sustainability. As organizations face mounting pressure from regulators, customers and talent markets to reduce their IT footprint, the need for clear guidance and collaborative approaches has never been greater.

This publication, supported by Accenture's wide industry experience, is based on insights from our January 2025 roundtable with 20 influential Dutch organizations, and provides a **snapshot of the dominant themes in the Green IT transformation**. Rather than an exhaustive analysis or a theoretical framework, it serves as an initial **guide to current priorities, challenges, and actionable opportunities**. It combines strategic direction with grounded experiences from the field—what organizations are actually doing and where they're running into real-world constraints.

Why this matters now

Green IT represents a strategic business opportunity, as well as a way to address environmental concerns. With the increasing adoption of, and investments in GenAI by enterprises, the environmental impacts and resource consumption of IT will increase drastically. Traditional green IT best-practices are also relevant in creating green AI as they share the same foundation – optimizing value while minimizing the environmental footprint. Hence, the lessons-learned from this publication can be applied to both traditional IT and newer innovations such as Agentic AI. As digital technologies consume an increasing share of global electricity, organizations that optimize their IT sustainability gain competitive advantages in cost efficiency, regulatory compliance and talent attraction. Beyond carbon, sustainable IT addresses critical raw materials, e-waste and water usage that directly impact business continuity and resilience.

Who should read this?

- **Strategic decision-makers in large organizations** seeking peer insights and implementation guidance
- **Ecosystem enablers** including policy-makers, researchers and technology partners

This paper aims to engage stakeholders across the Dutch Green IT ecosystem. We invite you to join us in addressing the challenges ahead through collaboration—building a more sustainable digital future, both for the Netherlands and beyond.

With this whitepaper, we aim to:

- **Empower organizational sustainability and IT decision-makers** to drive market transformation
- **Showcase proven strategies** from industry leaders including ABN Amro, Air France-KLM, Philips, Maasstad Ziekenhuis and Rijkswaterstaat
- **Facilitate pre-competitive collaboration** on shared challenges
- **Provide immediate action items** alongside longer-term transformation guidance



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Executive summary

As digital transformation speeds up and energy becomes scarcer, the environmental impact of IT is becoming a critical concern for Dutch organizations— especially now that generative and agentic AI are rapidly expanding the scale of IT systems. Drawing on insights from a high-level roundtable with 20 leading Dutch organizations—including ABN Amro, Air France-KLM, Philips, Maasstad Ziekenhuis and Rijkswaterstaat—this whitepaper provides a timely snapshot of the Green IT landscape and actionable guidance for decision-makers.

Our research shows that while awareness of IT sustainability has grown significantly, many organizations still struggle to turn that awareness into effective action. Several key challenges stand in the way:

- Lack of reliable data, due to both limited transparency from technology providers and the absence of tools that can measure energy use and GHG emissions with sufficient detail.
- Fragmented governance structures, which hinder coordinated decision-making and accountability.
- Complex supply chain emissions, which are difficult to trace and manage across vendors and partners.
- Challenges in achieving net positive IT, where digital systems deliver both business value and societal benefits while reducing environmental impact.
- The growing impact of AI, which brings immense potential but also introduces substantial energy and resource demands. Green IT principles are crucial here. They help guide organizations in responsibly managing the computational footprint of AI model training and inference, and in exploring strategies to optimize AI's environmental impact alongside its societal benefits.

Large IT users occupy a unique strategic position in driving market transformation through their procurement power, innovation capabilities and ecosystem influence. By leveraging these strengths—individually and collectively—these organizations can accelerate progress while realizing business benefits including cost reduction, risk mitigation, talent attraction and competitive differentiation.

This whitepaper provides actionable guidance for organizations in three critical areas: (1) integrating digital and sustainability governance, (2) addressing technical challenges such as data and impact measurement and (3) accelerating Green IT adoption through prioritized initiatives and partnerships. These practical actions help organizations move from awareness to impact. Beyond individual efforts, we also identify opportunities for collective progress—through shared standards, evidence generation and strategic policy engagement.

The path forward requires collaboration between IT users, technology providers, knowledge institutions and policymakers.

This whitepaper serves not just as a guide for individual organizational action but as a call to collective effort to create a more sustainable digital future for the Netherlands.



From insights to action: What works in practice

Our roundtable surfaced clear patterns in what's driving meaningful progress. The examples below reflect practical lessons from organizations already implementing Green IT—and what others can replicate.

- **Compelling business case drives adoption:** Leading Dutch organizations recognize that sustainable IT delivers strategic value, including reduced operational costs through data center optimization, lower capital expenditure through extended hardware lifecycles, and enhanced competitive position in markets where B2B buyers increasingly consider sustainability credentials in vendor selection.
- **Start with available data:** Several roundtable participants already collect and analyze IT sustainability metrics, demonstrating that organizations making the most progress use existing data rather than waiting for perfect measurement systems to begin prioritizing initiatives.
- **Target supply chain impact:** Participants highlighted that the vast majority of IT emissions are typically in Scope 3 and that they need specific collaborative approaches such as joint engagement with major cloud providers, shared supplier assessment frameworks and industry-specific benchmarking data-bases.
- **Collaborate beyond procurement:** Additional high-value collaboration opportunities include regular knowledge exchange forums, shared research initiatives with universities, coordinated talent development programs, and even staff exchanges between organizations.
- **Engage early with policy and standards:** Organizations that participate in sustainability standardization or policy consultations gain strategic benefits—from shaping practical requirements to accessing funding and driving market alignment.

This whitepaper provides practical insights for organizations ready to transform awareness into impact through strategic, coordinated action. The Netherlands' collaborative tradition and digital density create unique advantages for pioneering a sustainable IT approach within Europe. The time to act is now—as the push for a sovereign, sustainable IT infrastructure across Europe accelerates, organizations that move early will shape the standards, capture the benefits, and future-proof their operations.

Disclaimer: Insights derived from industry dialogue complemented with initial research findings, representing a snapshot of current perspectives.

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1 The Foundation: Why Green IT Matters Now

The digital economy's growth has created a significant environmental footprint. In the Netherlands, where digitalization drives economic development, organizations are now recognizing that their IT operations must be sustainable - not just enable sustainability elsewhere.



The distinction between the sustainability of ICTs and the positive impact of ICTs on sustainable goals is critical: while digital technologies can help reduce emissions across business functions (often called "handprinting"), organizations must simultaneously address the footprint of their own IT operations. The IT sector's contribution to global greenhouse gas (GHG) emissions, at about 4% of global emissions,[1, 2] is significant and growing rapidly - nearing or exceeding the emissions of sectors whose material and CO_2 footprint is more obvious to some. This growth is largely driven by the increasing demand for data centers and AI-related services, which consume substantial amounts of energy[1]. The concentration of energy consumption in specific locations leads to disproportionate impacts on local electricity grids and emissions[2]. In addition to data centers and AI workloads, roundtable participants emphasized that hardware—especially end-user devices—also constitutes a major and often overlooked source of emissions in the IT landscape. Projections indicate that the ICT sector's share of global GHG emissions is expected to increase substantially in the coming years.[3]

However, the **business case for Green IT extends beyond environmental concerns** for organizations across sectors – from finance, to health care or the public sector and mobility.

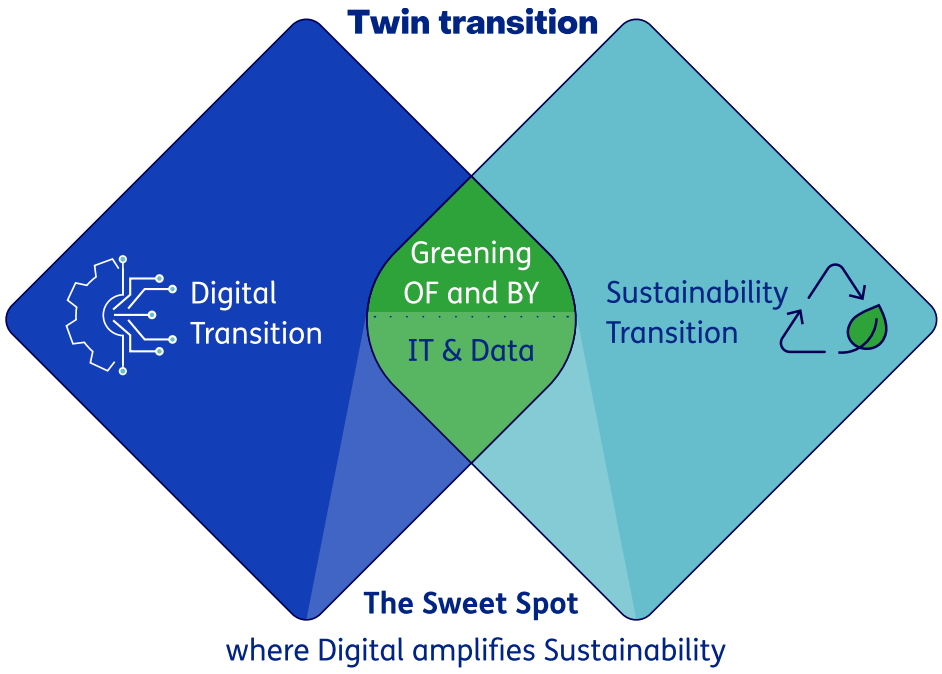
Key benefits in futureproofing organizations include:

- **Financial advantages** through energy efficiency, extended hardware lifecycles and optimized cloud resources.
- **Risk mitigation** against resource scarcity, material constraints, and evolving regulations.
- **Enhanced competitive positioning** through brand recognition, improved talent attraction, procurement opportunities and customer satisfaction.

Organizations are at different stages of maturity in their Green IT journeys. As highlighted in this white paper, frontrunners like ABN Amro, Air France-KLM, Philips, Maasstad Ziekenhuis and Rijkswaterstaat have developed pioneering approaches to issues like impact measurement, green IT governance, supply chain management and net positive technology impact. These frontrunners benefit beyond reputational advantages—they gain validation of their approaches, share development costs for new methodologies, access emerging best practices early and influence industry standards. They now possess a foundation to confront the 'wicked problem' of digital sustainability. Yet, the systemic nature of this challenge necessitates collective action; only through collaboration can they drive the transformative change required.

This paper provides a snapshot of current challenges, shares lessons from these industry leaders and offers practical guidance for decision-makers and change agents in both public and private sectors. Rather than prescribing a one-size-fits-all approach, we recognize the diverse starting points and priorities of different organizations while highlighting shared challenges that benefit from collective action.

We hereby aim to activate and inspire similar large organizations deploying significant IT resources to take concrete steps toward transformation and help shape the research agenda to create a multiplier effect that accelerates progress across the entire ecosystem.



1 International Energy Agency. (2025). Energy and AI. *International Energy Agency.*
2 World Bank en International Telecommunication Union. (2024). Measuring the emissions & energy footprint of the ICT sector: Implications for climate action. *World Bank; International Telecommunication Union.*
3 Assessment of the digital environmental footprint in France in 2020, 2030 and 2050 - ADEME-Arcep study (March 2023)

1.1 The Business Case: Quantifying Green IT Value

While the business case for Green IT cannot be universally defined, our research and stakeholder dialogue show that clear value components are beginning to take shape. This section outlines three areas where benefits are already being explored: cost efficiency, risk reduction, and competitive positioning. These serve as building blocks for organisations to develop a tailored Green IT case, depending on their sector, IT landscape and maturity level.

Quantifying impact across these dimensions remains a challenge, but also a critical enabler. As metrics and methods mature, they can support more robust internal discussions and investment cases. While cost efficiency is often the first driver, financial value can also emerge from reduced risks, improved resilience and in some cases, market differentiation. These developments suggest that environmental and business performance are not in conflict—but increasingly intertwined.

Financial Benefits	
Element	**Impact**
Cost reduction: Implementing green ICT strategies can lead to significant cost savings for organizations. For instance, consolidating data center workloads into more sustainable facilities can yield approximately 25% in total energy savings[4]. Additionally, green computing practices enhance energy efficiency, thereby lowering energy costs and reducing greenhouse gas emissions[5].	Green IT uses energy more efficiently
Extended hardware lifecycles: Extending the hardware lifespan through maintenance, repair and remanufacturing can significantly reduce costs by minimizing the need for new equipment purchases and lowering waste disposal expenses. These practices enhance resource efficiency and operational reliability, leading to further financial savings[6]. Green IT practices such as recycling can reduce the cost of raw materials and manufacturing by 42%[7].	Green IT enhances resource efficiency and lowers the cost of technology.
Competitive edge: Sustainable new products and services can enhance the top line by an estimated €370 to €460 per ton of GHGs reduced, while a sustainable image enables ICT companies to charge premium prices for their offerings[8] [based on US figures].	Green IT can help gain competitive edge

4 *United States Data Center Energy Usage Report | Energy Technologies Area.* (n.d.). https://eta.lbl.gov/publications/united-states-data-center-energy
5 Sunardi, Febriani, R., Supian, S., Abdoellah, O. S., & Supriatna, S. (2019). Economic and environmental benefits of practicing green computing in the corporate sector in Indonesia. Environmental Practice, 21(2), 50-56.
6 Barteková, E., & Börkey, P. (2022). Digitalisation for the transition to a resource efficient and circular economy. OECD Environment Working Papers, No. 192. Organisation for Economic Co-operation and Development. https://dx.doi.org/10.1787/6f6d18e7-en
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8 Friedrich, R., Ullrich, S., & Hill, K. (2025). How Tech and Telecom Can Create a Triple Win in Green. Boston Consulting Group. Retrieved from https://www.bcg.com/publications/2023/role-of-ict-in-sustainable-development-triple-green-win

Risk Mitigation

Element	Impact
Supply chain resilience: Green IT supply chains experience fewer disruptions as a sustainable value chain minimizes chances for supply chain interruptions due to environmental or labor issues[9].	Green IT leads to higher productivity due to fewer disruptions
Energy security: Energy-efficient IT infrastructure is less vulnerable to price fluctuations[10].	Green IT uses energy more efficiently
Regulation: With the increasing due diligence legislation in Europe, adopting green IT practices proactively can help organizations stay ahead of regulatory requirements, thereby preventing potential compliance issues and associated penalties[11].	Green IT reduces regulatory risks
Less dependance on international markets: Green IT initiatives, like energy-efficient data centers and cloud optimization, complement renewable energy deployment, further reducing import dependence. The EU forecasts gas imports will drop 50% by 2030 (56-64% with aggressive sustainability measures), potentially cutting costs by billions[12].	Green IT reduces dependance and cuts national costs

Competitive Advantage

Element	Impact
Talent attraction: 76% of Dutch organizations (and by extension potential employees) pay more attention to sustainability compared to previous years[13].	Green IT helps attract and retain talent
B2B market differentiation: 73% of B2B buyers consider the sustainability credentials of vendors[14].	Green IT creates competitive advantage
Access to sustainable finance: Organizations with strong ESG credentials—including Green IT practices—are more likely to access favorable financing conditions, such as green bonds, sustainability-linked loans, or public funding incentives (e.g. LIFE, Horizon Europe).[12]	Green IT positioning enhances access to capital and reduces financing costs.

9 Essa-Egh, M. (2024, March 14). *Driving data center sustainability*. Schneider Electric Blog. https://blog.se.com/sustainability/2023/07/17/transforming-data-centers-sustainably/

10 *United States Data Center Energy Usage Report | Energy Technologies Area*. (n.d.). https://eta.lbl.gov/publications/united-states-data-center-energy

11 OECD (2022), The role of sustainability initiatives in mandatory due diligence: Background note on Regulatory Developments concerning Due Diligence for Responsible Business Conduct https://mneguidelines.oecd.org/the-role-of-sustainability-initiatives-in-mandatory-due-diligence-note-for-policy-makers.pdf

12 EU Comission. (2022). Non paper on Complementary Economic Modelling undertaken by DG ENER analysing the impacts of overall renewable Energy Target of 45% to 56% in the context of discussions in the European Parliament on the revision of the Renewable Energy Directive. In https://energy.ec.europa.eu/document/download/45f86d2d-bc71-48a3-a2c0-36fa7ae74008_en?filename=2022_06_20%20RED%20non-paper%20additional%20modelling.pdf. Retrieved April 11, 2025, from https://energy.ec.europa.eu/document/download/45f86d2d-bc71-48a3-a2c0-36fa7ae74008_en?filename=2022_06_20%20RED%20non-paper%20additional%20modelling.pdf

13 Dutch organizations are more engaged with SDGs. (2023, January 23). *School for Business and Society*. https://www.tias.edu/en/news-and-articles/item/dutch-organizations-are-more-engaged-with-sdgs

14 Charney, C., Kawles, R., & American Marketing Association-New York. (n.d.). *THE NEW B2B*.

2 The Key Forces Shaping the Green IT Transformation

Dutch organizations pursuing Green IT operate within a rapidly evolving landscape shaped by five external forces — each creating both challenges and opportunities that demand strategic responses from decision-makers.



Regulatory landscape

- **EU green deal convergence:** European frameworks increasingly connect digital transformation with environmental requirements[15].
- **Evolving regulatory frameworks:** The EU's CSRD, EU Taxonomy and other directives are increasingly including IT-related environmental disclosure requirements[16]. While alignment efforts continue (e.g. 'omnibus'), organizations still face multiple overlapping frameworks with significant reporting obligations starting in 2025[17].

Energy transition pressures

- **Grid capacity constraints:** Data center-dense regions face electricity congestion, limiting expansion and requiring strategic location planning[18].
- **High electricity prices:** Dutch organizations face some of Europe's highest electricity costs, driving efficiency needs.

Security imperatives

- **Cybersecurity requirements:** Growing demands for secure IT solutions that also reduce environmental impact[19].
- **Infrastructure resilience:** Security and sustainability both require systems that withstand disruptions while minimizing resources[20].

Technological and geopolitical factors

- **AI & edge computing:** New technologies create both energy challenges and efficiency opportunities[21].
- **Digital sovereignty & materials:** Growing focus on technological independence and critical raw materials.
- **Supply chain regionalization:** Push for secure supply chains accelerates localizing of IT manufacturing.
- **Social impact:** Environmental burdens often shift to developing countries, requiring global rather than local sustainability approaches[22].

Market dynamics

- **Talent attraction:** Many Dutch IT professionals consider employer sustainability commitments important in job decisions[23].
- **Procurement criteria:** Customers increasingly include sustainability in vendor selection[24].
- **Investor pressure:** ESG considerations gain prominence in investment decisions.

"The future of sustainable IT requires us to think beyond just environmental impact. **Organizations must balance what I call the '3S' of Sustainability, Security, and Sovereignty.** As we pursue more sustainable digital operations, we cannot compromise on data security or digital sovereignty. The most successful organizations will be those that address these three dimensions holistically rather than treating them as separate challenges." – *Wiebren van der Zee, ABN Amro*

15 *The European Green Deal.* (2021, July 14). European Commission. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
16 *Directive - 2022/2464 - EN - CSRD Directive - EUR-LEX.* (n.d.). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022L2464
17 ERM. (2025). The EU Omnibus Regulation: Preparing for changes to European sustainability disclosure regulations. Retrieved from https://www.greenomy.io/blog/european-commissions-omnibus?gad_source=1&gad_campaignid=21940542174
18 *Rijksdienst voor Ondernemend Nederland.* (n.d.). RVO.nl. https://www.rvo.nl/
19 United Nations. (2024). 2024 Digital Economy Report. In *https://shop.un.org* (No. 978-92-1-003136-3). United Nations Conference on Trade and Development. https://unctad.org/system/files/official-document/der2024_en.pdf
20 Essa-Egh, M. (2024, March 14). *Driving data center sustainability.* Schneider Electric Blog. https://blog.se.com/sustainability/2023/07/17/transforming-data-centers-sustainably/
21 United Nations. (2024). 2024 Digital Economy Report. In https://shop.un.org (No. 978-92-1-003136-3). United Nations Conference on Trade and Development. https://unctad.org/system/files/official-document/der2024_en.pdf
22 Huang, Y., Surface, D. L., & Zhang, C. (2022). Corporate social responsibility and sustainability practices in B2B markets: A review and research agenda. *Industrial Marketing Management*, 106, 219 239. https://doi.org/10.1016/j.indmarman.2022.08.016
23 Dutch organizations are more engaged with SDGs. (2023, January 23). *School for Business and Society.* https://www.tias.edu/en/news-and-articles/item/dutch-organizations-are-more-engaged-with-sdgs
24 Charney, C., Kawles, R., & American Marketing Association-New York. (n.d.). *THE NEW B2B.*

2.1 Responding and Shaping: Large IT Users in the Changing Landscape

This paper is written for large IT-using organisations—particularly enterprises and public institutions with the scale and influence to drive sustainable change across the digital value chain. Large IT users occupy a unique position at critical leverage points in the digital ecosystem. Their dual role—responding to external forces while actively shaping the broader market—creates strategic opportunities with measurable business returns. Through procurement decisions, innovation investments and supplier requirements, these organizations not only create ripple effects throughout value chains but also secure competitive advantages for themselves: reduced operational costs, mitigated supply chain risks, enhanced market positioning and improved talent attraction.

Balancing internal transformation with external leadership requires strategic deployment of four key capabilities that deliver both environmental and business value. Later sections will explore how these can be leveraged through collaboration with industry partners, research institutes and policymakers to amplify impact while sharing costs and risks.

Market influence through procurement power

Why it matters:
Large IT users have significant purchasing power to shape market offerings and supplier practices.

How to drive change:
- **Implement procurement processes** with explicit sustainability criteria that mandate or strongly favor products with recognized ecolabels, thereby encouraging suppliers to offer more environmentally sound options
- **Leverage scale economics** to make sustainable options more affordable through volume purchasing
- **Create competitive differentiation** for suppliers meeting advanced standards, benefiting both the supply chain and your reputation

Innovation catalysts

Why it matters:
Large IT users have the resources to pioneer new sustainable technologies and establish industry standards.

How to drive change:
- **Establish testbeds for (open) innovation** to demonstrate feasibility of new approaches while reducing implementation risks
- **Develop co-creation partnerships** with suppliers to create tailored sustainable solutions
- **Invest in internal R&D** to develop proprietary practices that can lead market transformation

Data access and benchmarking

Why it matters:
Access to extensive operational data enables large IT users to set benchmarks and demonstrate business value.

How to drive change:
- **Implement performance benchmarking** to identify best practices across technologies
- **Track longitudinal improvements** to showcase business value alongside environmental impact
- **Establish industry baselines** to guide realistic goal-setting across organizations

Stakeholder engagement capability

Why it matters:
Engaging with diverse stakeholders helps shape policies, standards and broader adoption.

How to drive change:
- **Participate in policy development** to create supportive regulatory environments
- **Drive sustainability agendas** within industry associations and sector organizations
- **Partner with knowledge and educational institutions** to foster knowledge sharing and the development of future IT professionals

3 Current Landscape: Challenges and Opportunities

Our panel discussions with Dutch industry leaders not only confirmed, but strengthened the findings from existing literature, which identifies multiple persistent barriers to successful Green IT adoption—such as measurement challenges, governance gaps, supply chain complexity, net positive technology, hardware sustainability, green IT procurement and circular IT practices.

A particularly significant and evolving challenge is the large-scale adoption of AI, which dramatically increases IT energy demands and infrastructure complexity. AI's rapid growth intensifies existing barriers and necessitates new approaches to ensure future-proof, sustainable digital infrastructure.

In this paper, we have chosen to highlight four core challenges—measurement, governance, supply chain complexity and net positive technology—that emerged consistently across sectors and are illustrated with practical case examples developed by pioneering organizations in the Netherlands. While these challenges remain central, the transformative impact of AI underscores the urgency of integrating advanced sustainability strategies into Green IT efforts.

Recognizing that every organization's context and impact are unique, we encourage readers to use these insights as a starting point for assessing their own digital footprint and value chain, enabling them to develop a targeted Green IT agenda tailored to their specific needs and ambitions.



3.1 Data Transparency and Measurement

Organizations face challenges in accurately measuring energy consumption across applications and workloads. This requires going beyond third-party assessments and developing internal capabilities for real-time, granular monitoring[25].

At the same time, progress depends on improved transparency from service providers and the development of standardized KPIs and frameworks across the value chain—an area currently being advanced by the EU Commission[26].

While finalized metrics are still in development, panel participants emphasized that "80% accuracy is enough to take the first step"—organizations shouldn't let perfect be the enemy of good.

Case 1: An Accenture study on the carbon footprint of AWS infrastructure

Case 2: Philips' Energy Monitoring Tool (EMT) Enabling Digital Sustainability Through Granular Energy Measurement

3.2 Governance and Accountability

Effective governance structures are essential for Green IT transformation, yet organizations struggle to integrate sustainability into IT governance[27]. Typically, organizations silo sustainability efforts into separate departments, creating tension with financial and technological objectives[28].

Successfully integrating sustainability into IT governance also requires cultural alignment. Engaging employees early and clearly linking Green IT goals to individual roles helps create ownership and reduces uncertainty during organizational change[29].

Case: ABN Amro Green IT Governance Journey: From Grassroots to Strategic Pillar

3.3 Supply Chain Complexity

Scope 3 emissions account for a substantial part of IT-related emissions for many organizations, creating a complex challenge in supplier management.

For most organizations, a significant part of IT-related emissions occurs in the supply chain including hardware manufacturing, e-waste and the operation of cloud services.

Case: Air France-KLM's Supply Chain Sustainability Strategy

3.4 Net Positive Technology

A key barrier is the conflict between sustainability goals and growth-focused digital business models that encourage wasteful practices like frequent upgrades. True sustainability requires balancing IT's environmental impact against its broader value, measuring net contributions to organizational, social and ecological outcomes, not just operational costs[30].

Case: Maasstad Hospital - Sustainability by digital innovation

25 Charfeddine, L., & Umlai, M. (2023). ICT sector, digitization and environmental sustainability: A systematic review of the literature from 2000 to 2022. *Renewable and Sustainable Energy Reviews*, 184, 113482. https://doi.org/10.1016/j.rser.2023.113482
26 *ICT ENVIRONMENTAL IMPACT*. (n.d.). Interoperable Europe Portal. https://interoperable-europe.ec.europa.eu/collection/rolling-plan-ict-standardisation/ict-environmental-impact-0
27 Molla, A., Cooper, V., & Pittayachawan, S. (2011). The Green IT Readiness (G-Readiness) of Organizations: An exploratory analysis of a construct and instrument. *Communications of the Association for Information Systems*, 29. https://doi.org/10.17705/1cais.02904
28 Demestichas, K., & Daskalakis, E. (2020). Information and communication Technology solutions for the circular economy. Sustainability, 12(18), 7272. https://doi.org/10.3390/su12187272
29 Oyetade, K., Harmse, A., & Zuva, T. (2024). Internal organizational factors influencing ICT adoption for sustainable growth. Discover Global Society, 2(1). https://doi.org/10.1007/s44282-024-00136-7
30 United Nations. (2024). 2024 Digital Economy Report. In https://shop.un.org (No. 978-92-1-003136–3). United Nations Conference on Trade and Development. https://unctad.org/system/files/official-document/der2024_en.pdf

3.1 Data Transparency and Measurement

Case 1: An Accenture study on the carbon footprint of AWS infrastructure

Challenge: Cloud provider opacity

Many organisations struggle to obtain transparent and verifiable emissions data from cloud providers. Reporting boundaries are often unclear, data granularity is limited, and methodologies vary across providers. This makes it difficult to calculate a reliable carbon footprint for cloud-based workloads or to compare providers on sustainability performance. As a result, organisations face barriers in setting targets, steering procurement and meeting compliance expectations.

"Organizations should make software an integral part of their sustainability efforts"
– Sanjay Podder, Global Lead for Sustainable Technology at Accenture.

To drive this vision, Accenture works towards transparency on sustainability impacts. Among these cases, Accenture conducted a study on the environmental impacts of computing and storage workloads on the AWS infrastructure.

The study

AWS commissioned Accenture to conduct a study aimed at quantifying the difference in energy efficiency and carbon footprint between customer-workloads run on-premises versus on the AWS infrastructure. For that, both storage-heavy and compute-heavy workloads were simulated and analyzed. The study first examined the difference between the carbon emissions from moving workloads from on-premise to AWS and further analyzed the difference to workloads optimized for the AWS infrastructure. Across these scenarios, the study compared different locations: the United States and Canada, Europe, Asia Pacific and Brazil.

Approach

To conduct this quantification, Accenture deployed the International Organization Standardization (ISO) Software Carbon Intensity Standard (SCI), introduced by the Green Software Foundation. This standard considers both operational carbon emissions (from running/storing the workload) and embodied carbon emissions (from the IT hardware).

Outcome

The results showed, that moving from on-premise IT hardware to the cloud (in this case AWS) has the potential to drastically reduce carbon emissions. For example, storage-heavy workloads can be 2.5x more efficient when run on the cloud versus on premise. Further optimizing workloads for the cloud infrastructure can come with drastic reductions in carbon emissions.

Takeaway

SCI is an ISO standard developed by the Green Software Foundation to standardize the CO_2 measurement of software. By using the standard, the reported numbers can be compared.

Cloud providers have started with reporting initial carbon insights of the consumer cloud workloads. However, as these reports still lack fundamental data points, open source tools such as Cloud Carbon Footprint, SCI and Impact Framework can be used.

aws

accenture

Amazon (2024, June 25). *How AWS helps reduce carbon footprint of AI workloads* https://www.aboutamazon.com/news/aws/aws-carbon-footprint-ai-workload

3.1 Data Transparency and Measurement

Case 2: Philips' Energy Monitoring Tool (EMT) Enabling Digital Sustainability Through Granular Energy Measurement

Challenge: Lack of Granular Energy Visibility for Software Workloads

While the AWS/Accenture case demonstrates how organisations can address cloud provider transparency through external validation studies, a complementary challenge remains: how to measure energy consumption at the granular level within their own applications and workloads. This requires organisations to look beyond third-party assessments and develop internal capabilities for detailed, real-time energy monitoring of their software systems.

Case challenge

Philips, a global health technology company, increasingly relies on data and AI to streamline workflows and operations, provide clinical insights and intelligence, expand the reach of patient care and support personalized self-care. A key sustainability challenge identified by Philips was the lack of accessible tools that provide fine-grained visibility into the energy use of AI and software-driven workloads. Without such insights, it is difficult for developers to make informed decisions to improve energy efficiency.

The solution: developing EMT

To address this challenge, Philips developed the **Energy Measurement Tool (EMT)**—an open-source, lightweight, Python-based tool that enables developers and engineers to gather energy consumption data, especially for AI and ML workloads. EMT integrates easily into Python code using a context manager, tracking energy use across multiple devices, including GPUs and CPU sockets.

A key feature of EMT is its ability to track energy use in shared resource environments, which is particularly useful in complex scenarios where different workloads run concurrently. EMT thus offers transparency and actionable insights that support more sustainable software development practices. The tool is fully open source, reinforcing Philips' commitment to driving collaboration and transparency in digital sustainability.

How it works

- EMT tracks energy use either by tagging a running application through CLI or by instrumenting a few lines into your Python code.
- Tracked processes are assigned a proportional share of the total system energy, read directly using tools such as RAPL and NVML.
- This enables energy attribution to specific applications, even within shared resource environments with parallel processing contexts.
- It is open source and available for others to use and build upon: https://github.com/FairCompute/energy-monitoring-tool

Recommendations and future direction

To embed sustainability as a software quality metric, Philips recommends integrating energy measurement tools like EMT into CI/CD pipelines and performance evaluation workflows. While EMT is able to deliver granular insights, it needs broader testing across diverse real-world use cases. Philips invites collaboration to enhance usability and integration into broader ecosystems.
In future iterations, Philips aims to extend its platforms support and standardize the derived environmental metrics, for instance using the Impact Framework from Green Software Foundation (GSF). Through continued development and ecosystem engagement, Philips believes EMT can serve as a foundational layer for sustainable software practices in both research and production.

Points of attention

While EMT already delivers reliable and actionable energy insights, several development priorities remain:

- The addition of virtualization support will allow accurate energy attribution in containerized, and cloud-native environments.
- Testing EMT across diverse real-world use cases and integrating it into broader telemetry pipelines are essential steps to embed sustainability metrics in continuous delivery and monitoring workflows.

Conclusion

Philips' EMT initiative highlights the importance of accessible, developer-friendly tools in accelerating digital sustainability. By enabling detailed measurement and promoting open collaboration, EMT lays the groundwork for sustainable software development across industries.

3.2 Governance and Accountability

Case: ABN Amro Green IT Governance Journey: From Grassroots to Strategic Pillar

ABN Amro successfully bridged the gap between sustainability ambitions and IT operations by developing a governance structure that embeds environmental considerations into decision-making at all levels.

Challenge

Organizations struggle to integrate sustainability into IT governance and translate high-level goals into actionable metrics.

- **Varying levels of urgency:** In some organizations, Green IT remains absent from leadership agendas, with decision-makers not yet recognizing its strategic importance or feeling sufficient urgency to act
- **Effective governance structures** are essential for Green IT transformation, but many organizations find it challenging to establish clear accountability mechanisms
- **Disconnected stakeholders:** IT departments, sustainability teams and business units often work in silos with limited coordination
- **Competing priorities:** Sustainability sometimes takes a backseat to cost, performance, and security considerations
- **Translation to personal goals:** Organizations are experimenting with cascading corporate sustainability targets to personal performance indicators

Case challenge

In 2019, ABN Amro faced the common struggle of disconnected sustainability efforts across the organization. While the bank had sustainability initiatives in place, Green IT was not consistently on leadership agendas, with varying levels of urgency felt across different departments. ABN Amro IT teams, sustainability specialists and business units operated mainly from their own departments, missing the benefit of a coordinated approach. Within this setting cost, performance and security would frequently get priority. As a result, defining high-level environmental goals and translating those in actionable metrics and accountability remained challenging. ABN Amro's purpose and call to action resulted in a compelling business case. The materiality of IT operations and upcoming regulations justified the realisation of a sustainable IT team to coordinate and support the IT organization. IT Sustainability goals and priorities are now part of the various roadmaps and deliverables.

The turning point: proving the impact

The journey began with a grassroots initiative in 2019 when a team conducted the bank's first IT-focused Life Cycle Assessment (LCA). The results were eye-opening: the environmental footprint of the bank's IT operations was significantly larger than anticipated. This internal evidence coincided with growing external pressures. The upcoming Corporate Sustainability Reporting Directive (CSRD), shifting market expectations, and the bank's own public sustainability commitments created a compelling case for change.

Formalizing governance

The transformation accelerated when Green IT was formalized in the bank's governance structure through three key mechanisms:

1. **Strategic Integration:** Green IT became one of the bank's seven strategic IT pillars, elevating its importance in planning and decision-making
2. **Organizational Structure:** A dedicated Green (Sustainable) IT team was established with clear positioning in the organizational hierarchy and defined relationships with both IT and sustainability departments
3. **Performance Alignment:** Sustainability metrics were incorporated into Objective Key Results (OKRs) throughout the IT organization, cascading high-level goals into performance indicators

Creating continuous dialog

With the formal structure in place, ABN Amro fostered ongoing dialog across the organization. Regular touchpoints between operational IT units, the group sustainability department, and business/IT strategy teams ensure alignment and learning. The governance framework encompasses multiple impact areas-from CO_2 emissions to electricity consumption-with clear metrics and Target and/or KPI's for each. By managing, guiding, and monitoring on the environmental impact of IT our ISO14001 certification now encompasses IT.

Enabling external collaboration to accelerate

This mature internal governance has enabled ABN Amro to engage more effectively externally. The bank actively participates in industry coalitions and maintains research partnerships, including a longstanding relationship with VU Amsterdam for PhD and master's research on Green IT topics.

From a grassroots initiative to a strategic pillar with dedicated resources and formalized governance, ABN Amro's journey demonstrates how organizations can effectively integrate sustainability into IT governance and translate high-level goals into actionable metrics that drive real change.

3.3 Supply Chain Complexity

Case: Air France-KLM's Supply Chain Sustainability Strategy

Challenge

Scope 3 emissions account for a substantial part to IT-related emissions for many organizations, creating a complex challenge in supplier management.

For most organizations, the majority of IT-related emissions originate from the supply chain, specifically hardware manufacturing and the operation of cloud services.

- **Scale complexity:** Large organizations may have hundreds of suppliers and thousands of sub-suppliers.
- **Data availability:** Limited visibility into suppliers' environmental performance
- **Influence constraints:** Varying ability to influence supplier practices based on purchasing power.
- **Cultural barriers:** Stakeholders, such as suppliers, customers or other parties, may not have fully developed the ecosystem capabilities necessary for effective collaboration across the delivery chain.

By way of collaborative field labs, Air France-KLM engages with suppliers to jointly devise solutions for the complex challenge of IT supply chain emissions and the promotion of sustainable practices across their ecosystem.

Case challenge

Embracing a decentralized, ecosystem approach characterized by transparency, trust, shared goals, and win-win principles, Air France-KLM moves beyond traditional supplier management to proactively address IT emissions within its supply chain, collaboratively working with partners to identify and reduce emissions across their delivery chain, thereby enhancing visibility and fostering substantial sustainability improvements.

Strategic approach

Instead of trying to centrally manage their complex IT supply chain, Air France-KLM established three focused, decentralized "field labs“. To maximize participation and knowledge sharing, these labs were specifically structured to mirror the existing organizational units within Air France-KLM's IT department.

- **Green Coding Field Lab** concentrates on making Air France-KLM's IT operations more energy-efficient by analyzing current software development practices, categorizing them based on their energy consumption and then implementing changes to reduce their environmental impact.
- **Green Data Centers Field Lab:** focuses on reducing the environmental footprint of Air France-KLM's data center environmental footprint. This involves a strategic shift to public cloud infrastructure, allowing for decommissioning older and more energy-inefficient systems, and working with cloud suppliers on energy efficiency, cooling optimization and renewable energy adoption.
- **Green Workplace & Telecom Field Lab:** directly addresses the environmental impact of Air France-KLM's end-user devices through collaboration with manufacturers and suppliers to cut emissions across the complete chain – from production to end-of-life.

How it works

Operating as real-world testing grounds, the field labs enable Air France-KLM and chosen partners to tackle specific sustainability challenges collaboratively. Instead of dictating solutions, Air France-KLM fosters co-development, encouraging partners to document outcomes and share insights. This collaborative approach has energized suppliers, who value being treated as innovation partners rather than mere service providers. As members of the ecosystem, they inspire each other. Beyond technical hurdles, successful ecosystem collaboration necessitated a cultural shift for both Air France-KLM and its suppliers, moving from transactional relationships towards genuine ecosystem collaboration.

Early results

Although in the initial stages, Air France-KLM's field lab approach is already yielding positive results. Partners are starting to implement practices discussed in the labs across their wider operations, generating a multiplier effect that expands the sustainability impact beyond Air France-KLM's direct sphere of influence. A tangible outcome is the significant reduction in IT-related energy costs because of the transition to public cloud infrastructure.

This pioneering strategy signifies a profound change in how Air-France KLM IT Services views supply chain sustainability: moving from control to collaboration, from management to enablement, and from compliance to innovation.

3.4 'Net Positive' Technology

Case: Maasstad Hospital - Sustainability by digital innovation

The Maasstad Hospital aims to leverage IT to reduce the number of hospital visits and thereby improve both healthcare efficiency and the environmental impacts that occur due to in-person hospital visits.

While reducing the environmental footprint of IT operations is critical, organizations must evaluate these impacts against the value IT delivers. A truly sustainable approach considers not just the "cost" of technology but its net contribution to organizational, social, and environmental outcomes.

From Footprint to Handprint: Measuring Positive Impact

IT sustainability should be assessed using a net impact framework that balances:

- **Footprint:** Direct environmental impacts from IT operations
- **Handprint:** Positive outcomes enabled by digital technologies
- **Value alignment:** How IT supports the core mission of the organization and stakeholder needs

This balanced approach prevents sustainability initiatives from inadvertently reducing IT's overall positive contribution.

Case challenge

Annually, the Maasstad Hospital handles approximately 111,500 initial outpatient visits, 26,400 clinical admissions and 20,400 day-treatments. Like many other organizations, the Maasstad Hospital follows sustainability goals. One of the goals is to reduce overall CO_2 emissions, with a focus on lowering direct emissions and cutting CO_2 output across all mobility and transport streams. The number of hospital visits - patients travel to and from the hospital - contributes a considerable amount of CO_2 emissions.

Approach

Instead of regular hospital visits, patients can submit health data (e.g. heart rate, blood pressure) to a dedicated app from the comfort of their homes. A monitoring center continuously analyzes the data using advanced analytics tools to detect any abnormalities or potential health risks. This enables the Maasstad Hospital to respond proactively, offering interventions where needed, while removing unnecessary hospital visits.

This contrasts with the traditional process of patients visiting the hospital on a regular basis for check-ups where no medical interventions are required.

Handprint

The solution developed in collaboration with ZorgbijJou lowers the number of patient visits, meaning that travel to the hospital by car or public transport can be avoided. Overall, Maasstad Hospital reports a reduction in travel related carbon emissions, pursuing their sustainability targets while lowering air pollution and contributing to a healthier environment.

Footprint

While it has various advantages, the IT solution comes with its own impacts that are further affected by data retention rules on the handling of patient data. Currently the Maasstad Hospital is gathering metrics to evaluate whether the reduction in travel outweighs the IT-related environmental impact.

Value alignment

The IT systems and resources required to operate this hybrid healthcare ease the workload on the hospital and its workers created through the volume of patent visits. The result is optimized hospital resource usage and improved healthcare efficiency.

For the patients involved, the approach allows for personalized and efficient care directly from home while maintaining control over their health and reassurance that help is nearby when needed. In this way, Maasstad is able to achieve positive impacts on the customer experience, productivity, costs and the environment all at the same time.

4 Accelerate Action: What Can be Done Today? Part 1 – Organizational Action Path

Green IT transformation doesn't happen in isolation. To move from awareness to action, organizations must work on two fronts: what they can do internally today, and where they can collaborate to shape the system around them.

This section outlines two complementary pathways:

- **Organizational actions** that can be taken within your own context
- **System-level enablers** that require joint effort across the ecosystem

Together, they form next steps toward meaningful, scalable impact.



4.1 Identify High-Impact Opportunities and Quick Wins

Not all Green IT initiatives deliver equal value. This section helps prioritize efforts by highlighting areas with the greatest potential for environmental and business impact. By focusing on these key opportunity areas organizations can maximize returns on their sustainability investments while building momentum for broader transformation.

4.2 Prioritize Actions Throughout Organization

Effective implementation requires coordinated action across the organization. This section introduces a comprehensive set of prioritized actions that are categorized by organizational layer. The actions are evaluated by impact, complexity and timeframe which provides a concrete starting point for the Green IT transformation.

4.3 Leverage Existing Resources and Tools

Organizations need not start from scratch. This section highlights several established methodologies, frameworks, and tools that can accelerate the Green IT journey. From the Green Software Foundation's Software Carbon Intensity method to standardized procurement criteria, these resources provide proven starting points that can be adapted to your specific context, saving valuable time and reducing implementation risk.

4.4 Strategic Policy Leverage: Turning Regulations into Competitive Advantages

Beyond implementing internal best practices, forward-thinking organizations recognize that the regulatory landscape presents strategic opportunities. While many view policy requirements as constraints, organizations that proactively engage with regulations can transform compliance obligations into competitive advantages. This section outlines how to leverage policy frameworks to create business value while advancing sustainability goals.



4.1 Identify High-Impact Opportunities and Quick Wins

To fully realize the potential of Green IT, it is essential to examine its key impact areas. Focusing efforts on hotspots allows for targeted reduction strategies. We have identified the following high impact areas of Green IT[31]. By addressing these areas, organizations can develop targeted strategies to maximize sustainability while maintaining operational efficiency.



Green Software Development Lifecycle

Establish a culture where developers are encouraged to apply energy-efficient software engineering practices throughout the software development lifecycle. This can be achieved through training, hackathons and challenges.

Tip: To efficiently equip developers with green coding skills, organize training sessions that cover the principles - be aware that excellent materials already exist and reuse them if possible. Practical hackatons are a great way to reinforce learning.



GreenOps & Data Centers Optimization

Optimize efficiency and resource use through established GreenOps and infrastructure optimization tools. Many software applications running and much data stored in data centers or the cloud is not used or required.

Tip: Use efficient algorithms and data structures to reduce processing time and energy use.



Circular IT Infrastructure & E-waste Management

Minimize the environmental impact of hardware through responsible procurement, extended lifecycles, efficient operations,and proper end-of-life management.

Tip: Prioritize the full environmental impact of hardware in procurement by requesting or conducting LCAs to compare product footprints.



Energy-Efficient AI

Balance model accuracy with environmental impact. This optimization can be achieved through:

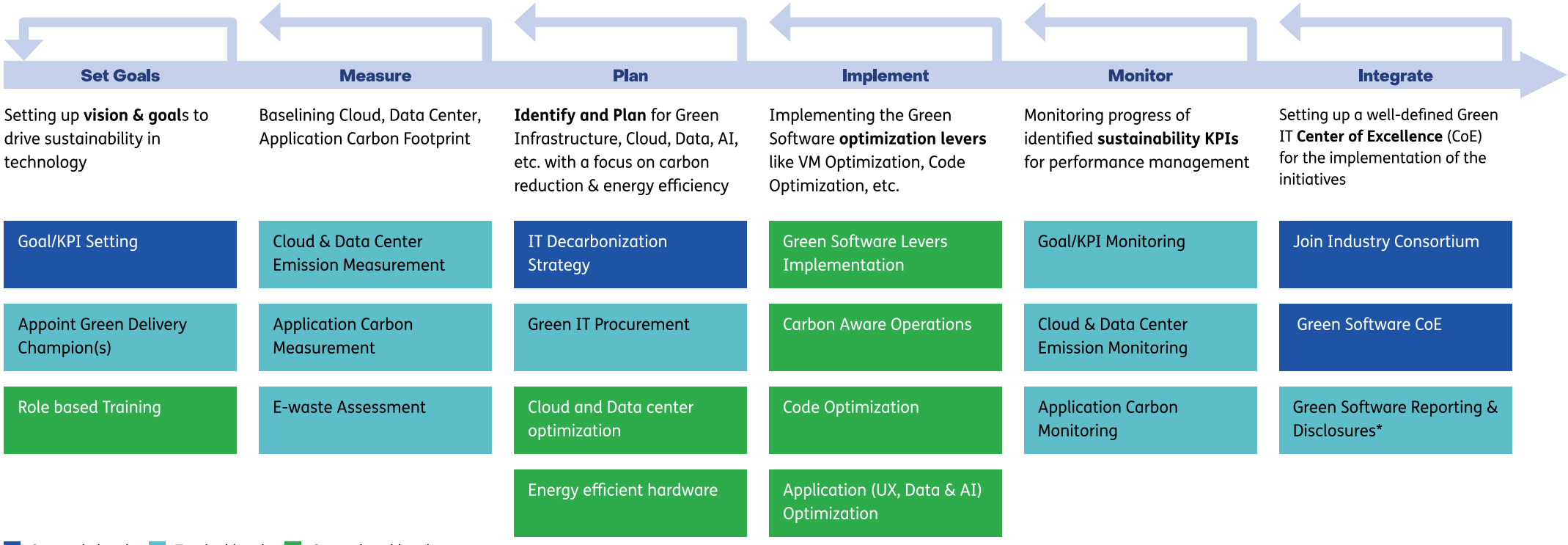
1) Model rightsizing: Evaluate whether smaller models can meet your performance needs. In many cases, small language models (SLMs) are just as effective.
2) Use transfer learning: Start with pre-trained models and fine-tune them for your use case instead of training from scratch.
3) Optimize inference: Deploy models using efficient inference strategies such as batching.

Tip: It is important to track energy use when deploying AI to make well-informed decisions. Tools like CodeCarbon.io can help.

31 Accenture. (2022). *Uniting technology and sustainability.* https://www.accenture.com/content/dam/accenture/final/a-com-migration/pdf/pdf-177/accenture-tech-sustainability-uniting-sustainability-and-technology.pdf

4.2 Prioritize Actions Throughout Organization

Effective Green IT transformation requires coordinated efforts across different organizational layers - from the boardroom to daily operations. This section provides a set of prioritized actions based on Accenture's practical experience, that create alignment while recognizing the distinct roles and responsibilities at each layer within the organization. Both bottom-up and top-down initiatives are required for a successful transformation. The bottom-up initiatives will create a foundation for change whereas the top-down initiatives will ensure urgency.



This section provides a roadmap for organizations seeking to implement Green IT practices, highlighting the importance of coordinated action and clear responsibilities across all levels. **Beyond these concrete steps, fostering a culture of enthusiasm and inspiring individuals to champion sustainability is essential for long-term success.** By motivating employees and stakeholders, organizations can accelerate their Green IT journey and create a lasting impact.

4.3 Leverage Existing Resources and Tools

Organizations seeking to reduce their IT environmental footprint can leverage a robust network of established initiatives, providing frameworks, methodologies, and collaborative platforms for sustainable digital transformation.

Measurement and Assessment Frameworks

Green Software Foundation
Standardize carbon measurement for software with the Software Carbon Intensity (SCI) Specification. This can be operationalized with the Green Software Foundation Impact Framework (IM).

- Quantify the environmental impact of software

Green software foundation

Software Carbon Intensity Specification

Collaborative Platforms and Standards

The National Coalition for Sustainable Digitalization (NCDD)
Brings together public and private partners to accelerate sustainable digitalization in the Netherlands. Through workgroups on topics like Sustainable IT Procurement and Responsible AI, NCDD fosters collaboration, shares best practices, and develops practical guidance. These efforts strengthen the national ecosystem and help organizations take coordinated action.

National Coalition Sustainable Digitalization

Circularity and Hardware Management

Platform for Accelerating the Circular Economy (PACE)
Circular hardware lifecycle frameworks and Circular IT Asset Management Guidelines.

- Reduced electronic waste
- Cost-effective hardware lifecycle management
- Sustainable procurement strategies

PACE circular

Standardization and Interoperability

SustainableIT.org
Interoperable and cross-sector ESG standards for IT.

- Unified reporting frameworks
- ESG compliance support
- Industry-wide sustainability alignment

Sustainable IT.org

Resource deepdive | Green Software Foundation SCI

Green Software Foundation

The ISO 21031: Software Carbon Intensity (SCI) standard is an approach to measure the CO_2eq emissions of software applications, developed by the Green Software Foundation.

SCI is **first Industry-led, consensus-based ISO approved specification** that can be applied to any software to measure and reduce its carbon emissions by creating a standardized and practical methodology.

A consequentialist approach which **focuses on energy efficiency, hardware efficiency and carbon awareness**. Practitioner-based, easy to implement.

GSF member organizations, including Accenture and others, made the SCI Specification actionable through various use cases.

Methodology

Define	Scale	Measure	Quantify	Report	Improve
Define Software Boundary	Define functional unit for scaling (users, transactions, API call/request)	Measurements based on real-world, lab-based approaches	Calculate the SCI value for each software component	Disclosure of the software boundary and the calculation methodology	Use the SCI value as a benchmark to identify ways to improve performance of software

SCI = ((E * I) + M) per R

E – Energy consumed by a software system
I – Location-based marginal carbon emissions
M – Embodied emissions of a software system
R – Functional unit (e.g., carbon per additional user, API-call, ML job, etc.)

Impact Framework

The Impact Framework is a tool to compute and report environmental impacts of software, based on the SCI. Built onto a selection of customizable building blocks, transforming observations into impact.

Find out more here: Green software foundation

Case illustration Software Carbon Intensity Standard

More information about the SCI

Consequential and Attributional Life Cycle Assessment in Streaming Media Sustainability

4.4 Strategic Policy Leverage: Turning Regulations into Competitive Advantages

Strategic policy engagement transforms regulatory requirements into competitive advantages and innovation catalysts. While competitors view regulations as constraints, forward-thinking organizations are turning early policy participation into measurable business value: reduced implementation costs, access to innovation funding streams, and strengthened stakeholder relationships that drive sustainable growth.

A message to governmental agencies: Your dual role as policymaker and major IT buyer creates unique opportunities. While shaping regulations, simultaneously position your organization as a 'launching customer' for sustainable IT solutions. Update procurement guidelines to explicitly favor bids with verifiable sustainability credentials. This signals market direction, creates early-stage demand for innovative solutions, and demonstrates policy alignment through your own purchasing decisions. When government leads by example, both policy impact and market transformation accelerate.

From compliance to advantage

- **Map upcoming CSRD, EED and EU Taxonomy requirements** against your existing IT governance
- **Identify where early compliance** creates competitive differentiation.
- **Utilize data from CSRD and EED reporting of suppliers** to enhance internal sustainability dashboards and decision making.
- **Build supplier relationships** that simplify future reporting requirements

Concrete action example:
Assign the responsibility to regularly update regulation horizon scans to someone or a team and schedule regular meetings to discuss.

Engage proactively with policymakers to shape the ecosystem

- **Actively participate in IT sustainability standardization processes.** Engage with national representatives to influence the European Multi-Stakeholder Platform's Rolling Plan for IT Standardisation, which covers IT sustainability and circularity.
- **Provide feedback on draft regulations** around cloud energy transparency, hardware recyclability, or software eco-efficiency.

Concrete action example:
Identify per quarter at least one relevant draft regulation to provide feedback on, and assign the responsibility to collect input in the organization to a specific person or team.

Leverage funding and incentives

- **Work with sector stakeholders, regulators, knowledge institutions, and other key partners** to expand the scope and scale of current sustainable financing initiatives to include opportunities for sustainable IT financing
- **Leverage available tax incentives** that reward the adoption of circular practices for hardware

Concrete action example:
Current EU funding calls (LIFE, Horizon) rarely concern just topics related to sustainable IT. However, specific work packages within calls might. Make sure you are connected to the right consortia.

Collaborate on policy engagement

Organizations can gain practical benefits by working together on policy engagement. Here are a few examples of activities to accelerate sustainable ICT developments:

- **Facilitating workshops and conversations** between policymakers and businesses
- **Creating momentum for additional sustainable IT measures** by collective agenda setting
- **Developing shared strategic intelligence** on policy trends and regulatory developments
- **Creating shared monitoring resources** and tools to establish a Dutch state of sustainable IT monitor

4 Accelerate action: what can be done today? Part 2 - Collective Action for System-Wide Change

While individual actions are essential, the challenges identified in Section 3 require collaborative solutions. These issues involve shared infrastructure, supply chains and standards that no single organisation can address alone. By working together, organisations can unlock benefits that are difficult to achieve individually: shared learning, influence on suppliers and policymakers, lower costs, and faster, more scalable progress.

This section presents:

A first, practice-informed research agenda (4.5), shaped by the needs of Dutch organisations. While not exhaustive, it identifies critical areas for joint exploration—particularly around data transparency, governance, supply chain engagement and net positive technology.

Practical collaboration opportunities (4.6), with clear suggestions for how organisations can get involved and generate collective impact. TNO contributes to this agenda through applied research and co-innovation. The initiatives shown in the following pages address practical barriers identified in this paper. Where possible, results are shared publicly to accelerate sector-wide progress and reduce duplication.

Collaboration doesn't just distribute risk—it multiplies value.
These shared approaches accelerate progress and help turn complex sustainability goals into achievable steps.



4.5 Research Agenda: Responding to Market-Identified Challenges

What research areas deserve priority to overcome the most pressing Green IT challenges?

This section outlines priority areas for applied research and innovation, aligned with the four systemic challenges identified earlier. These priorities are based on needs expressed by Dutch organisations and highlight where further evidence, methods, and tools are needed to accelerate sustainable digital practices.

4.6 Collaborative Pathways: Your Role in System-Wide Change

How can your organization participate effectively?

Strategic collaboration opportunities across five key areas, with clear roles based on your organization's capabilities and priorities. Includes guidance on determining your optimal contribution to address shared challenges collectively.



4.5 Research Agenda: Responding to Market-Identified Challenges

This section outlines several core components of a research agenda on greening IT, based on needs expressed by Dutch organisations during the January 2025 roundtable and follow-up discussions. While we did not conduct a comprehensive study to define this agenda, the topics below reflect recurring barriers and knowledge gaps raised in practice.

This is not a fixed or exhaustive agenda. It is intended as a starting point to inspire further collaboration between industry, research and government. **We advise that the research agenda be further shaped collectively, so we can align on the right priorities and accelerate the transition toward greener, more resilient IT systems.**

This **effort should be closely aligned with ongoing national policy initiatives**, such as the National Coalition Sustainable Digitalisation, the Ministry of Economic Affairs Sustainable Digitalisation Action Plan, the National Circular Economy Programme, and the Electronics Chain Agreement. These frameworks collectively support the transition toward a circular and sustainable IT sector, ensuring that research directions contribute to broader systemic goals and practical industry impact.

By highlighting these priorities, we aim to:
- Signal where research efforts are currently focused
- Invite organisations to co-shape future research directions
- Connect stakeholders working on similar challenges

The following pages summarise four priority areas aligned with the core challenges in Section 3. Several ongoing TNO initiatives already address these themes in practice, and are presented on page 30 to illustrate how these priorities can be explored collaboratively.



Challenge 3.1: Data transparency and measurement

Challenge & value:
Organisations struggle to access consistent, actionable data on the environmental impact of their digital systems. Lack of standardised metrics and limited transparency from cloud providers make it difficult to assess performance, allocate resources effectively, and meet regulatory expectations. Without robust application-level insights, organisations face increased compliance risks and miss opportunities for optimisation. Emerging standards, such as the Software Carbon Intensity (SCI) Specification by the Green Software Foundation, provide a useful starting point[32].

Research priorities:
- **Complete value chain LCA:** Model environmental impact across interventions[33]
- **Unified energy measurement frameworks:** Standardized methods for application-level consumption aligned with CSRD requirements[34]
- **Digital value assessment:** Frameworks demonstrating sustainability benefits against environmental costs

Challenge 3.2: Governance and accountability

Challenge & value:
Organisations face barriers in embedding sustainability into IT governance. Fragmented responsibilities, unclear decision pathways and limited alignment with business strategy slow progress. Meanwhile, the energy intensity of the Dutch IT landscape — and its reliance on critical materials — calls for more integrated approaches that strengthen resilience while reducing costs and footprint[35].

Research priorities:
- **Change management for IT transformation:** Models to overcome organizational barriers to Green IT adoption[36]
- **Digital sufficiency frameworks:** Methodologies to eliminate unnecessary IT services while preserving business performance[37]
- **User behavior patterns:** Improves design of digital services for sustainable usage patterns

Challenge 3.3: Supply chain complexity

Challenge & value:
IT supply chains are major contributors to digital emissions, yet emissions visibility remains low. Without shared assessment frameworks, organisations cannot align with suppliers, enforce standards, or implement circular design effectively. Even where solutions exist, lack of coordination across value chains undermines implementation success.[38].

Research priorities:
- **Energy-efficient IT infrastructure:** Develop low-power computing and network solutions (including 5G/6G) that address Dutch energy constraints while improving performance, bandwidth, and IoT connectivity[39, 40]
- **Circular hardware design:** Implement approaches that minimize dependencies on critical materials through circularity along the supply chain[41]
- **Supplier assessment models:** Standardized methods for evaluating environmental impact of IT providers

32 Choi, S. (2023). ESG metrics: safeguard against greenwashing or safe harbor for greenwashing?. *Geo. Wash. J. Energy & Env't L.*, 14, 27.
33 Ruggeri, M., Vinci, G., Ruggieri, R., & Savastano, M. (2025). Facing the Risk of Greenwashing in the ESG Report of Global Companies: The Importance of Life Cycle Thinking. *Corporate Social Responsibility and Environmental Management.*
34 Kreuger, F. H. A. (2023). *A Multi-level perspective on a transition towards Green IT in the Netherlands* (Doctoral dissertation, TU Delft).
35 The World Bank and ITU. (2024). Measuring the emissions & energy footprint of the ICT sector: Implications for climate action. Washington, D.C. and Geneva. ISBN 978-92-61-38541-5.
36 World Business Council for Sustainable Development. (2024, December 2). Navigating the net zero transition: Unlocking change management. Retrieved from https://www.wbcsd.org/Overview/News-Insights/General/Navigating-the-net-zero-transition-Unlocking-Change-Management.
37 Santarius, T., Bieser, J. C., Frick, V., Höjer, M., Gossen, M., Hilty, L. M., ... & Lange, S. (2023). Digital sufficiency: conceptual considerations for ICTs on a finite planet. *Annals of Telecommunications*, 78(5), 277-295.
38 World Business Council for Sustainable Development. (2024, December 2). Navigating the net zero transition: Unlocking change management. Retrieved from https://www.wbcsd.org/Overview/News-Insights/General/Navigating-the-net-zero-transition-Unlocking-Change-Management.
39 Li, L. (2025). Research on future 6G green wireless networks. *Green Technologies and Sustainability*, 3(2), 100156.
40 He, Y. (2013). Low power architectures for streaming applications. [Phd Thesis 1 (Research TU/e / Graduation TU/e), Electrical Engineering]. Technische Universiteit Eindhoven. https://doi.org/10.6100/IR759534
41 Ernst, T., & Raskin, J. P. (2021). Towards circular ICT: from materials to components". DURANTON M. et al., HiPEAC Vision, 122-129.

Challenge 3.4: Net positive technology

Challenge & value:
Organisations need to assess not only the environmental cost, but also the broader societal and business value of digital solutions. Generic Green IT approaches often fall short in capturing sector-specific impact. Tailored frameworks are needed to evaluate how digital systems can deliver environmental gains while also supporting innovation, resilience and economic opportunity[42].

Research priorities:
- **Sector-specific implementation playbooks:** Evidence-based guides for Dutch financial, healthcare, and manufacturing sectors
- **Cost-benefit methodologies:** Standardized approaches demonstrating financial and non-financial returns on Green IT
- **Collaborative Business Model innovation:** Identifies new revenue opportunities from (shared) Green IT services



How organisations can engage

The research agenda is a practical tool for organisations to shape and benefit from Green IT innovation. Here's how to turn research into results:

1. **Align research with your strategy**
   Map research priorities directly to your organisation's most critical strategic challenges. This ensures focused and meaningful investigation.

2. **Participate in pilots**
   Actively engage in pilot implementations to gain first-hand insights and validate potential solutions in a real-world context.

3. **Apply research outcomes**
   Systematically integrate emerging research findings into your Green IT strategy, transforming theoretical knowledge into practical organisational advantage.

4. **Help steer future research**
   Join and shape research by contributing to the strategic agenda and sharing operational data to enhance its relevance and impact.

42 de Man, A. P. (2021). Valuing value in innovation ecosystems: How cross-sector actors overcome tensions in collaborative sustainable business model development. *Business & society*, 60(5), 1059-1091.
The World Bank and ITU. (2024). Measuring the emissions & energy footprint of the ICT sector: Implications for climate action. Washington, D.C. and Geneva. ISBN 978-92-61-38541-5.

Current TNO Projects Supporting Green IT

This page highlights a selection of TNO projects that respond to the research priorities outlined in Section 4.5. These initiatives reflect our role as an independent applied research organisation: developing practical tools, data and insights together with partners.

By making these efforts visible, we aim to support organisations facing similar challenges — and invite others to engage, share input, or help shape future directions to increase their relevance and impact.

Sustainable IT Research Program

A four-year interdisciplinary program examining IT's role in sustainability transitions:

- **Business process integration: (LCA)** methods to embed sustainability metrics into existing decision frameworks
- **User behavior analysis:** Understanding how interface design affects energy consumption patterns
- **Policy-business alignment:** Tools to navigate regulatory requirements efficiently

This program helps organizations implement sustainable IT by integrating lifecycle assessment methods, understanding user behavior, and aligning digital systems with evolving policy requirements.

Read more

Modular Integrated Sustainable Datacenters

Modular Integrated Sustainable Datacenters (MISD) is a project under the *Important Project of Common European Interest (IPCEI)* initiative on Cloud and Edge Infrastructure. It tackles key challenges in energy and material efficiency, developing scalable solutions for sustainable data infrastructure.

- **Dynamic workload management:** Algorithms that reduce energy use while maintaining performance
- **Operational integration:** Methods for implementing sustainability principles without disrupting critical services
- **EU infrastructure alignment:** Solutions compatible with emerging European requirements

This project supports data center operators in developing scalable solutions that reduce energy and material use while maintaining service continuity in a constrained regulatory and infrastructure environment.

Read more

Circular IT Hardware – Securing Materials for Digital Sustainability

The sustainability of IT systems depends not only on energy use, but also on the materials used in hardware. TNO contributes to this challenge through applied research on circular electronics, focusing on critical raw materials (CRMs) essential to digital infrastructure. Key efforts include:

- **Developing modular, scalable recycling technologies** for high-value materials
- **Exploring the recovery potential of the Dutch "urban mine"** — end-of-life IT and electronics
- **Collaborating with industry to assess material flows, recycling scenarios and supply risks**

This work supports both national goals from the Dutch Raw Materials Strategy and broader EU strategic autonomy objectives.

For organisations, it provides actionable insights into material risks, circular design strategies and collaboration opportunities across the IT hardware lifecycle.

Read more

EXIGENCE

A collaborative initiative focusing on measurement and standardization:

- **Energy assessment methodology:** Practical tools that work across diverse IT environments
- **Policy-relevant metrics:** Data that satisfies both operational needs and reporting requirements
- **Optimise resource use:** mechanisms that minimize operational costs and infrastructure for given ICT service use.
- **Incentivise fair use:** supply economic incentives for sufficient use.

This project supports data center operators in developing scalable solutions that reduce energy and material use while maintaining service continuity in a constrained regulatory and infrastructure environment.

Read more

Greenify my Code

Applying dynamic model switching to create code optimization software with energy-awareness by design.

Designing a static analysis selection framework with the **aim of selecting the least energy-intensive tool for the job:**

- Integration with existing CI/CD code development pipelines for mass adoption
- **Assessment through optimzing metrics that can indicate net energy gains** through pro-longed utilization of the software

This project aims to show how energy-awareness-by-design is possible, even in a domain that is dominated by extensive use of computationally inefficient tooling.

Read more

Greening of Streaming

Greening of Streaming is a global industry initiative focused on reducing the environmental impact of streaming media.

The Remote Energy Measurement (REM) project delivers real-time, scalable insights into energy use across streaming infrastructure — moving from theoretical estimates to real-world data.

TNO contributes to REM by supporting methodology development and connecting results to broader digital sustainability efforts.

This project helps organizations reduce the energy footprint of digital media systems by enabling evidence-based decisions on infrastructure design and optimization.

Read more

Related Initiatives: connecting Green IT to adjacent domains

While this paper focuses on key Green IT priorities, several related TNO initiatives contribute to the broader sustainability transition. These projects connect digital infrastructure, AI and sovereignty to environmental and societal outcomes—addressing energy use, material impact and policy alignment. They illustrate the importance of system-level thinking: digital sustainability isn't a single domain, but a cross-cutting challenge that demands coherence across technologies, sectors and governance.

Cooling & heat re-use:
TNO's patented microfluidic cooling achieves up to 80% heat re-use, drastically improving datacenter energy efficiency.

Read more

Digital sovereignty:
Consulting government on how to deal with this economic and political vulnerability, linking to initiatives like Eurostack that allow our own choices, also about sustainability.

Read more

Responsible AI:
Developing GPT-NL, a fit-for-purpose LLM with only high-quality, Dutch and lawfully obtained data, minding not only our environmental but also our social responsibility. By using only suitable data to accomplish specific tasks in critical Dutch sectors, we can supply an alternative model that is still useful with a smaller ecological footprint, which we monitor as part of our transparency commitments.

Read more

4.6 Collaborative Pathways: Addressing Key Challenges Together

Beyond research, tackling the four key challenges identified in Section 3 requires strategic collaborations across the Green IT ecosystem. Each collaboration area below directly addresses specific challenges while creating collective benefits no organization could achieve alone.

	Green IT infrastructure optimization	Circular economy and supply chain sustainability	Digital inclusion and workforce transformation	Sustainable procurement and vendor ecosystem	Green Software development
Shared challenge	Data transparency (3.1): Balancing performance with resource consumption; standardizing metrics	Supply chain complexity (3.3): Tracing material origins; reducing e-waste	Governance gaps (3.2): Building digital skills; developing Green IT capabilities	Transparency (3.1) and supply chain complexity (3.3): Developing comprehensive criteria; creating transparent assessment	Net positive impact (3.4) Reducing computational energy; developing efficient practices
Collaborative Strategy	Joint investment in renewable energy infrastructure for data centers	Unified material traceability and recycling programs for e-waste and hardware	Cross-sector upskilling & training and certification initiatives on sustainability for IT professionals	Development of shared supplier sustainability databases	Open-source energy efficiency metrics and optimization tools
Value proposition	Reduced energy costs; enhanced compliance; collective innovation	Reduced procurement and waste costs; enhanced supply chain resilience; resource efficiency	Access to broader talent pool, social responsibility leadership; innovation through diverse perspectives	Reduced procurement risks; improved vendor relationships; competitive differentiation	Reduced infrastructure costs; enhanced performance; lower impact
Primary stakeholders	Cloud service providers, data center operators, utility companies	Hardware manufacturers, recycling specialists, certification bodies	Educational institutions, industry associations, technology companies	Procurement departments, suppliers, certification organizations	Software developers, cloud providers, research institutions

The following case study demonstrates how these collaborative principles are already being applied by Rijkswaterstaat to address specific challenges related to data transparency (3.1) and measuring technology value (3.4).

Collaboration in action | Life Cycle Assessment Research for IoT Networks

Rijkswaterstaat
Ministry of Infrastructure and Water Management

Rijkswaterstaat | Sustainable IoT Networks for Water Management

While the collaboration opportunities described on the previous page represent potential pathways, the following case study demonstrates how one organization is already putting these principles into practice through strategic partnerships that address multiple Green IT challenges simultaneously.

This case example illustrates:
How a public sector organization identified specific environmental challenges (linking to 3.1 Data Transparency)

- The formation of strategic research partnerships to address complex assessment needs
- Multiple collaborative roles played by different stakeholders
- Tangible outcomes that benefit both individual organizations and the broader ecosystem

Rijkswaterstaat, the Dutch water management agency, faces challenges in futureproofing operations while meeting sustainability targets. This focused collaboration between TNO and Radboud University transforms environmental challenges into public value opportunities. This strategic partnership integrates environmental assessment with digital transformation to create measurable public value. By applying complementary research methodologies to IoT networks, the project delivers both sustainability improvements and operational efficiencies for critical national infrastructure.

Public service challenge

Rijkswaterstaat operates extensive IoT sensor networks for water management nationwide but lacked comprehensive understanding of their environmental impact throughout the lifecycle. This knowledge gap hindered sustainability-driven decisions and alignment with government-mandated carbon reduction targets.

Research approach

The Life Cycle Assessment (LCA) project quantifies energy consumption and material usage across the entire IoT sensor network lifecycle. This collaborative research maps the complete IT supply chain ecosystem, identifies significant environmental impact points and prioritizes effective mitigation strategies with clear recommendations to reduce ecological footprint. In this way we create an innovative LCA modelling approach for complex multi-stakeholder IT systems.

Implementation & public value

This research aims to deliver tangible outcomes for Rijkswaterstaat:

- Data-driven IoT deployment decisions based on comprehensive environmental assessment
- Transparent partner ecosystem with shared sustainability targets and metrics
- Reduced operational costs through energy-efficient technologies
- Decreased supply chain vulnerabilities by addressing critical material dependencies
- Transferable methodologies that transform theoretical knowledge into practical advantage

This case demonstrates how targeted research has the potential to transform intricate challenges into public value opportunities and sustainable operational enhancements, delivering both environmental and societal benefits.

Looking forward

We are enhancing this sustainability assessment methodology through application in diverse organizational contexts. Is your organization facing similar sustainability transformation challenges? Contact us to discuss how this approach could address your specific needs.

5 Key Takeaways and Path Forward



5.1 Key Takeaways – The Business Case for Green IT

Key findings from this report:

1 - Green IT creates measurable business value

- Cost reduction through energy efficiency and extended hardware lifecycles
- Risk mitigation by reducing resource dependencies and regulatory exposure
- Competitive advantage in markets increasingly valuing sustainability credentials

2 - Four challenges require strategic attention

- Data Transparency (3.1): Developing standardized measurement approaches
- Governance (3.2): Integrating sustainability into IT decision-making
- Supply Chain (3.3): Managing complexity of hardware and cloud services
- Net Positive Technology (3.4): Balancing environmental impact with operational value

"Sustainability is no longer optional—it's a business imperative. Organizations that fail to address the environmental impact of their IT operations will face increasing regulatory pressure, customer dissatisfaction, and talent challenges." – *Panel participant, January 2025*



5.2 Path Forward - From Challenge to Opportunity

The journey forward: from challenge to opportunity

1 - Integrate the twin transition
Connect digital advancement with sustainability to create aligned decision-making processes that treat these areas as complementary rather than competing priorities.

2 - Move beyond carbon to systems thinking
Expand focus to material circularity, digital sufficiency and sovereignty—creating a more resilient approach that addresses emerging challenges beyond emissions.

3 - Leverage your ecosystem influence
Recognize your organization's power to drive change through:

- Strategic procurement decisions
- Research partnerships and pilot implementations
- Standards development and knowledge sharing
- Policy engagement that shapes enabling conditions

The Netherlands' collaborative tradition and digital density create unique advantages for pioneering sustainable IT approaches. Organizations can transform Green IT from challenge to competitive advantage—advancing both business success and climate goals.



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