TOGAF® Series Guide

Environmentally Sustainable Information Systems

Prepared by Céline Lescop, Jean-Baptiste Piccirillo, and Clément Chupeau

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Comments relating to the material contained in this document may be submitted to:

The Open Group, Apex Plaza, Forbury Road, Reading, Berkshire, RG1 1AX, United Kingdom

or by electronic mail to:

ogspecs@opengroup.org

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Preface

The Open Group

The Open Group is a global consortium that enables the achievement of business objectives through technology standards. With more than 900 member organizations, we have a diverse membership that spans all sectors of the technology community – customers, systems and solutions suppliers, tool vendors, integrators and consultants, as well as academics and researchers.

The mission of The Open Group is to drive the creation of Boundaryless Information Flow™ achieved by:

- Working with customers to capture, understand, and address current and emerging requirements, establish policies, and share best practices
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The Open Group publishes a wide range of technical documentation, most of which is focused on development of Standards and Guides, but which also includes white papers, technical studies, certification and testing documentation, and business titles. Full details and a catalog are available at www.opengroup.org/library.

The TOGAF® Standard, a Standard of The Open Group

The TOGAF Standard is a proven enterprise methodology and framework used by the world's leading organizations to improve business efficiency.

This Document

This document is a TOGAF® Series Guide to using a systemic Enterprise Architecture method to Build Environmentally Sustainable Information Systems. It has been developed and approved by The Open Group.

This document proposes an Enterprise Architecture approach to reduce the organization's information system environmental impact and contribute to reaching the 2015 Paris Agreement (COP21) objective.

More information is available, along with a number of tools, guides, and other resources, at www.opengroup.org/architecture.

About the TOGAF® Series Guides

The TOGAF® Series Guides contain guidance on how to use the TOGAF Standard and how to adapt it to fulfill specific needs.

The TOGAF® Series Guides are expected to be the most rapidly developing part of the TOGAF Standard and are positioned as the guidance part of the standard. While the TOGAF Fundamental Content is expected to be long-lived and stable, guidance on the use of the TOGAF Standard can be industry, architectural style, purpose, and problem-specific. For example, the stakeholders, concerns, views, and supporting models required to support the transformation of an extended enterprise may be significantly different than those used to support the transition of an in-house IT environment to the cloud; both will use the Architecture Development Method (ADM), start with an Architecture Vision, and develop a Target Architecture on the way to an Implementation and Migration Plan. The TOGAF Fundamental Content remains the essential scaffolding across industry, domain, and style.

Terminology

This document uses the following terminology:

- Information and Communication Technology (ICT) to speak about the full sector that includes data centers, networks, and terminals

  It is aligned with the wording used by the Shift Project Lean-ICT Work Group. Its synonym could be IT.

- Information system is used to speak about the ICT required by a given enterprise to support its operations
- Digital is also used as a more common term

Conventions Used in this Document

The following conventions are used throughout this document in order to help identify important information and avoid confusion over the intended meaning:

- Ellipsis (…)

Indicates a continuation; such as an incomplete list of example items, or a continuation from preceding text.

- Bold

Used to highlight specific terms.

- Italics

Used for emphasis. May also refer to other external documents.

In addition to typographical conventions, the following conventions are used to highlight segments of text:

	Example An Example box is used to provide an example relating to the text.

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About the Authors

The Shift Project™ Lean-ICT Work Group

This document is a contribution to the international standards of The Open Group on the specific topic of Digital sustainability. The authors consider it a natural evolution of the Shift Project report: Lean-ICT: Towards Digital Sobriety [Shift Project 2019]. This report contains a chapter named "*Guiding Organizations Towards a Sustainable Information System*", which discusses how the systemic Enterprise Architecture approach can be leveraged to deal with long-term energy transition. It demonstrates that this needs short-term actions within an organization's ICT department and proposes a transformation approach to deliver these. The Shift Project is a French think tank, created in 2008, which advocates the shift to a post-carbon economy. As a non-profit organization committed to serving general interest through scientific objectivity, it is dedicated to informing and influencing the debate on energy transition in Europe. Its work can be considered as a continuity of "The Limits to Growth" [Limits to Growth]. In 2018, The Shift Project set up a Work Group of ICT professionals and published a first report "Lean-ICT: Towards Digital Sobriety" that aimed at formalizing the conditions of a digital transition as an enabler to reach the 2015 Paris Agreement [COP21] objectives on climate change.

The main authors of the initial version of the above-mentioned chapter are Arnaud Gueguen, Dayan Brunie, Xavier Verne, Axel Hurgon, Maureen Delaloi, Sylvain Baudoin, François Maitre, Hugues Ferreboeuf, Jean-Baptiste Piccirillo, and Céline Lescop.

AXA® Digital Sustainability Community

As a follow-up of the sponsoring of The Shift Project's October 2020 report by AXA, this document was authored relying on contributions from the AXA Digital Sustainability team. AXA started a Digital Sustainability program at the beginning 2020 and rolled it out across its main entities: France, Germany, Belgium, United Kingdom and Ireland, Japan, US, Hong Kong, Spain, Switzerland, and Italy in 2021. This document was partially inspired by the experience of the AXA Digital Sustainability program. As one of the largest global insurers, the purpose of AXA is to act for human progress by protecting what matters (www.axa.com).

Céline Lescop – Author

Céline holds a Master's Degree (1996) in Computer Science (www.ensiie.fr). She was a Data Project Leader in the pharmaceutical industry from 1999 until 2012 (Galderma and Astrazeneca), an Architect and TOGAF® trainer from 2012 to 2015 at Arismore (The Open Group, France), and has been an Enterprise Architect at AXA® leading the Data Architecture practice since 2016 and AXA Digital Sustainability program since 2020. Céline has participated in The Shift Project Lean-ICT Work Group since 2019.

Jean-Baptiste Piccirillo – Author

Jean-Baptiste holds a Master's degree (2010) in Computer Science (www.ensiie.fr). He was an Architect until 2015 for Arismore (The Open Group, France) until 2015, a Data Scientist for AXA® from 2015 to 2018, and he is currently a Data Architecture, Data Management, and digital sustainability Consultant for Rhapsodies Conseil (www.rhapsodiesconseil.fr) supporting AXA. Jean-Baptiste has taken part in The Shift Project Lean-ICT Work Group since 2020.

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1 Introduction: A Systemic Point of View on the Environmental Impact of ICT

The 2015 Paris Agreement [COP21] commits all parties, from industrialised to low-income (195 countries out of 198, representing over 98% of anthropogenic emissions), to working together to curb Greenhouse Gas (GHG) emissions. The Paris Agreement has for the first time brought all nations together to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. As such, it charts a new course in the global climate effort that concerns all economy sectors, including Information and Communication Technologies (ICT).

Indeed, fossil fuels represent 80% of worldwide energy consumption [Energy Mix]. They are the main sources of anthropogenic, meaning caused by humans, GHG emissions. Any increase in global energy consumption inhibits achievement of this historic and vital challenge: mitigating global warming. The importance of this commitment has recently been reinforced in 2021 by the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report.[1]

Digital technologies have become essential for economic and social development. The digital transition is perceived as critical for countries and companies with digital objects and interfaces which have gradually become part of every aspect of our lives. The digital transition is also often considered as a key tool to help reduce energy consumption in many other sectors and a "no-brainer" solution to dematerialize polluting activities ("IT for Green").

Faster, bigger, smarter: the exponential growth that ICT have generated came with hope for progress. It makes it difficult to reconsider this expansion plan and consider a more practical approach. Nevertheless, a shift in business mindset emerges and may expand as the expected progress is not comparable with the revolution induced by the invention of printing, the arrival of railways and power machinery in the 1840s, the expansion of electricity in the 1920s, or health innovations like antibiotics or vaccines.

The impact of ICT is not a new discovery, and its first levers started to be implemented over 30 years ago. In 1992, the U.S. Environmental Protection Agency launched Energy Star, a voluntary labeling program designed to promote and evaluate the energy efficiency in monitors, climate control equipment, and other technologies. This resulted in the widespread adoption of sleep mode among consumer electronics.[2]

As the understanding of environmental impact progresses, it appears that Digital can, in some cases, support the transition required by the 2015 Paris Agreement, but the advantages it brings are often diffuse and difficult to measure, while its current environmental impact is real, huge, and growing [Lancaster 2021]. Both the green and the digital transitions often contradict each other, as digital technologies have substantial environmental footprints that go against the targets of the green transition. Developing ICT in a direction compatible with the 2015 Paris Agreement requires a strong focus on its environmental impact and a shift to a sustainable ICT market. It will also

[1] Refer to: https://www.ipcc.ch/.
[2] Refer to: https://en.wikipedia.org/wiki/Green_computing.

require a selection by the society of the business use cases that focus on vital activities such as food production, education, health and tracking of climate, biodiversity evolution, etc. ICT professionals will have a role to play in providing the accurate scientific data about environmental impact to guide citizens, and in providing guidance to governments responsible for regulation, Non-Governmental Organizations (NGOs) and citizens willing to reduce environmental impacts.

In some jurisdictions and organizations, ICT departments now have a mandate to shift towards sustainable ICT. Where this is not yet mandated, it is still necessary for ICT departments to consider the environmental impacts of their activities as well as the evolution and trends in their societal acceptance.

To explain why it is important to focus on building "Environmentally Sustainable Information Systems", the following introductory sections provide an overview of ICT environmental impact. Guidance on how to minimize it is provided in Section 1.1.

1.1 ICT Growth and GHG Emissions

In 2007, Simon Mingay, Research Vice-President at Gartner®, published a study [Gartner] observing that: *"The ICT industry worldwide accounts for 2pc of global carbon dioxide (CO_2) emissions – equal to that of the aviation industry – which analyst firm Gartner warns is unsustainable."*

In 2020, ICT was responsible for 3.5% of worldwide GHG emissions, increasing by 6% per year. It has already overtaken the aviation industry [Shift Project 2019].

No other sector is increasing as fast, and this growth is incompatible with the decrease required by the 2015 Paris Agreement. ICT actors should adapt their approach, integrate sustainability as a quality of the systems they build, and be courageous in reinventing the ICT business to make it sustainable.

We have the wrong idea about digital dematerialization

At first glance, digital technology seems to dematerialize the business. By reducing the physical flows of people, the use of paper, and the number of proxies required to access a service, organizations are made lighter, making them more flexible. But on the other hand, the resulting information flows are materialized, stored into servers, transported through network equipment, and displayed on end-user screens. All these activities are energy-intensive, use rare metals, and generate pollution at each step of their lifecycle, from equipment manufacture, power consumption during usage, to end-of-life management.

Our information systems are too big and complex

Driven by decades of internal process digitalization, performance indicators calculation, and business growth support, computing systems are now used in every organizational process. The efficiency of this digitalization and the related growing number of innovations has left little room for rationalization. Today, almost all organizational entities suffer from technological bloat due to a partially controlled stacking of different architectures, applications, data, and technologies.

These strategic ICT systems, envisioned to support business development in an "Agile" way, have grown increasingly oversized over the years, limiting their ability to meet their initial purpose. Until now, rationalization of the ICT landscape has been often deferred, even if started in some sectors, because of the bursting of the dot-com bubble in 2002 and the financial crisis in 2008. However, the transformation of an entire ICT system is expensive, risky, and time-consuming. ICT rationalization programs are often deprioritized to meet the expectations of customers and different business actors that are expected to bring short term business value. ICT departments will soon need to implement a new strategy that addresses these issues while avoiding a transition that is too sudden or abrupt. Explanation, communication, and prioritization with the business actors will be key to success.

... and it shows on the scale!

In its 2019 Lean-ICT Report [Shift Project 2019], the Shift Project describes the environmental impact of digital technology at macro level. Today, with data usage showing tremendous growth, the traffic and consumption of data driven by so-called Big Data raises substantial questions.

According to a study led by Exploding Topics [Exploding Topics]: "*the volume of stored data will reach 181ZB (zettabytes) in 2025; i.e. 5.5 times more than that what was stored in 2018*" (see Figure 1). The Digitization of the World – From Edge to Core [IDC 2018] is an older reference, providing a similar order of magnitude. As each additional byte requires energy to be stored, this generates additional carbon emissions. Given today's goal of CO_2 emissions reduction, ICT professionals must try to stabilize this trend by cleansing current data stocks and dedicating new storage capabilities to only the most useful data use-cases only.

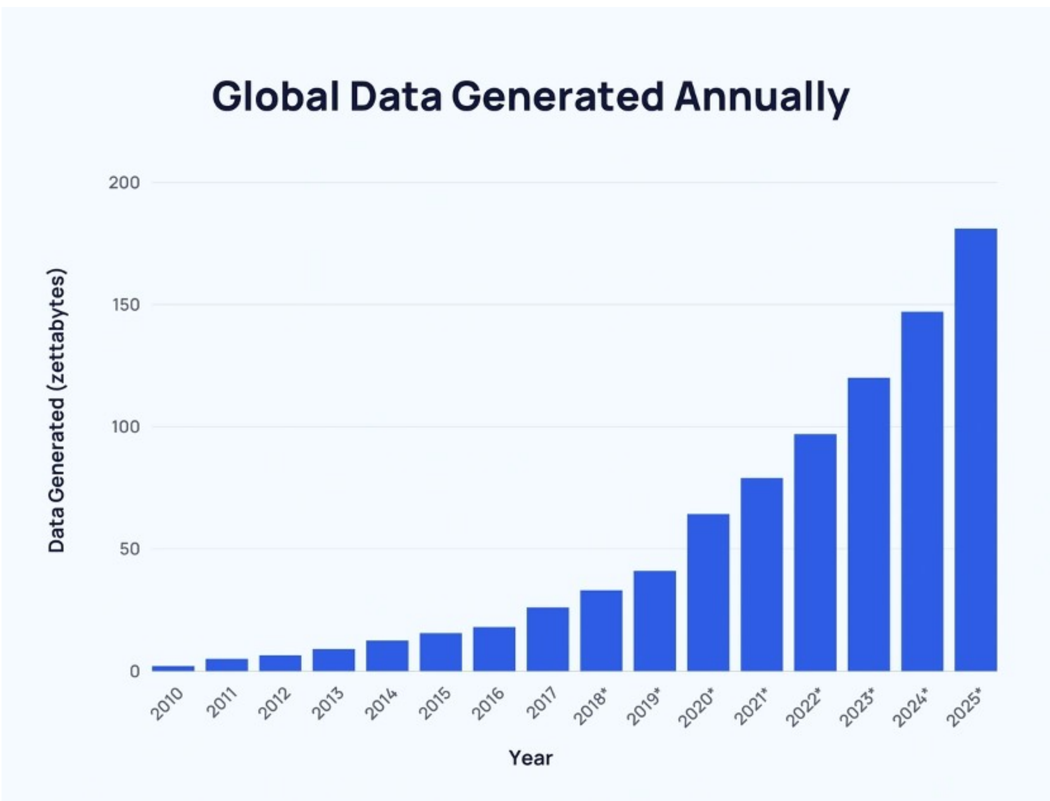


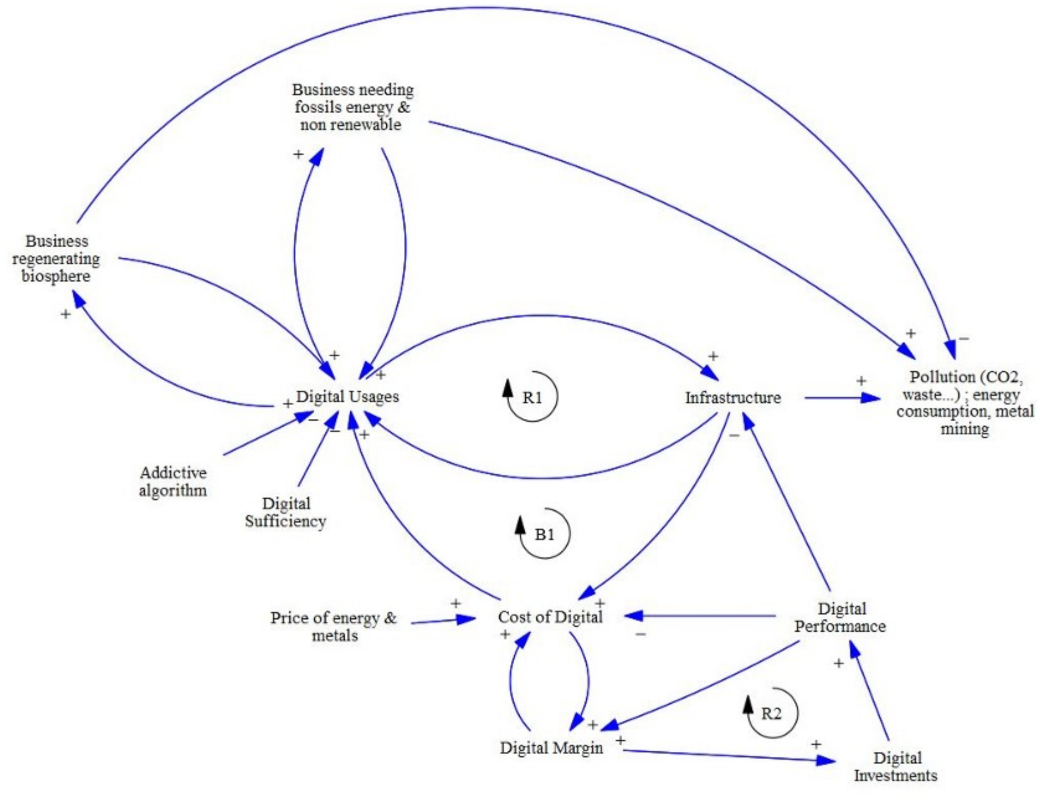
Figure 1: Global Data Generated Annually 2010-2025 [Exploding Topics]

	One zettabyte is equal to 10^{21} bytes, and is sufficient to store 12 million 4K videos. (Refer to: https://en.wikipedia.org/wiki/Byte#Multiple-byte_units)

Systems Thinking and ICT Evolution

The underlying dynamics that generate the ICT growth and GHG emissions are complex and Systems Thinking [Systems Thinking] can help to represent the ICT system structure.

Figure 2 is an illustration of this reinforcing feedback loop at work.



Legend :
Causal linkage A->B : change of element « A » triggers the change of « B »
- + (positive) : increase of « A » triggers the increase of « B »
- - (negative) : increase of « A » triggers the decrease of « B »

« Feedback loop » output variables influence input ones
- R : Reinforcing feedback loop : causes exponential dynamic in the evolution of variables
- B : Balancing feedback loop : causes balancing dynamics

Figure 2: Causal Loop Diagram Representing the Dynamic of the ICT Sector [The Shift Project, from the Work Group Leveraging Vensim® Software][3]

[3] Vensim is industrial-strength simulation software for improving the performance of real systems. Vensim is used for developing, analyzing, and packaging dynamic feedback models; refer to: https://vensim.com/.

This diagram also highlights:

- A reinforcing feedback loop R1 between digital usages and infrastructure

  The more usage is required from the business, the more infrastructure is deployed; and when the infrastructure is deployed, the operator's search for profitability leads to usage promotion and therefore to its increase.

- R1 should be balanced by B1: the more infrastructure, the higher the cost, and the higher the cost, the less the usage

  But in the case of ICT, the performance improvement of both the infrastructure and the business that Digital Services serve decrease the cost and makes it profitable.

- Consequently, R1 is not balanced, generating the exponential dynamics observed in ICT and the yearly 6.2% growth [Shift Project 2021] in final energy consumption required to produce and use digital equipment

- R2 shows that increased performance also generates revenues for the ICT industry allowing investments in performance improvement, which reinforce the current unstable dynamics

The systemic analysis leads to the following conclusions:

- Digital usages that are increasing the performance of activities burning fossil fuels and consuming metals should be reduced and shifted toward biosphere regenerative businesses

- Optimization of ICT services without constraints will not allow reduction of pollution as it creates a rebound effect through which demand grows as the service becomes cheaper and more easily accessible

  Digital usages should be developed with discernment to contain or even reverse their increase considering the environmental urgency.

- Stabilizing the growth of digital usages requires strong actions at different levels, from regulators to operators and organizations using digital services

  It also requires a change in society's aspiration to progress towards biosphere regenerative innovation.

The current dynamic of the ICT sector is a major risk in terms of pollution, but also for the digital capability itself.

Systems that grow in an unstable way meet tipping points when a resource on which they rely on becomes scarce. They then either shift towards another stable state or they collapse. Symptoms that the digital environment is approaching limits appear ever more often in the news (2021, 2022), either as the result of unsustainable growing electricity demands or shortages of computer chips. The challenge for society is to organize the stabilization and decrease of digital systems to be able to guarantee the most important and vital use cases. Systems Thinking tells us that failure to prepare will lead us to face limits by surprise and may create dangerous chaos.

1.2 ICT Consumption of Metals

The technologies required for a green and digital world use most of the elements in the periodic table. Some of these elements – Cobalt, Lithium, Copper, Nickel, Indium, Platinum-group metals, Polysilicon, and rare earths – are scarce or may become so due to rising demand, depletion, or conflict. Metals are the raw materials of any hardware. They are also required for energy transition towards renewable electricity via solar panels and wind farms. The creation of a circular economy may lower the need to extract such metals but none of them are 100% recycled and, for some, recycling is impossible [UNEP 2011].[4] ICT professionals' knowledge of this topic should be increased, relying on the development of approaches to compare existing solutions based on their consumption of resources. It will not be detailed in this document, but several references are available and should be consulted: Green European Foundation [GEF 2021], International Energy Agency [IEA 2021], United Nations Conference on Trade and Development [UNCTAD].

1.3 Electronic Waste

A record 53.6 million Metric Tonnes (MT) of electronic waste (e-waste) – discarded products with a battery or plug – were generated worldwide in 2019, up 21% in just five years, according to the UN's Global E-waste Monitor 2020 [E-waste 2020]. This new report also predicts that global e-waste – discarded products with a battery or plug – will reach 74 MT by 2030, representing almost a doubling of e-waste in just 16 years.

The 2023 Statista study on e-waste confirms this increasing trend forecasting that: "Between 2010 and 2019, e-waste generation increased by roughly 60 percent, and this growth shows no signs of slowing down. By 2030, annual e-waste production is on track to reach a staggering 75 million metric tons.". [E-Waste Statista]

This makes e-waste the world's fastest-growing domestic waste stream, fuelled mainly by higher consumption rates of electric and electronic equipment, short lifecycles, and limited options for repair. In 2019, only 17.4% of e-waste was collected and recycled, and recycling efficiency is very low.

1.4 ICT Water Consumption

Additionally, ICT consumes important amounts of water, as it is an essential component for the manufacturing of semiconductors and chips which are used every day in computers, cell phones, and automobiles. Ultrapure water is used throughout the process, including the removal of impurities from silicon wafers. For example, a single 8-inch wafer, which is the foundation for approximately 100 chips, may require up to 7,500 litres of ultrapure water. As a result, semiconductor producers are focusing on ways to recycle, reuse, and reduce the amount of water needed for their operations [Intel 2019].[5]

[4] "*Recycling rates of metals are far lower than potential for reuse. Less than one-third of 60 studied have a recycling rate above 50 per cent, though many are crucial to clean technologies such as batteries for hybrid cars or magnets in wind turbines.*" [UNEP 2011]
[5] "*Plans from Silicon Valley computer giant Intel to create its biggest water recycling facility are moving forward after the company secured $120 million in tax-free bonds.*" [Intel 2019]

2 Relationship to Existing Standards of The Open Group

2.1 The ArchiMate® Specification

To describe the digital sustainability capability, this document is based on the ArchiMate modeling notation [C226].

To answer to the specific modeling needs in this document, a subset of the ArchiMate modeling notation elements was chosen. This subset is given in Figure 3, with the definition of each concept.

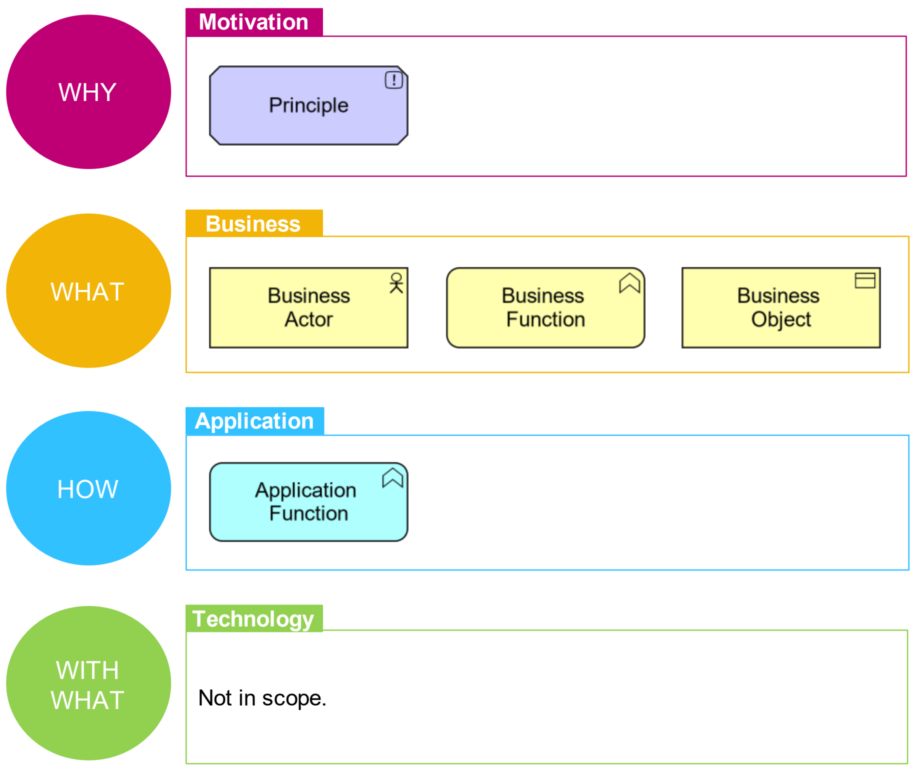


Figure 3: The ArchiMate Modeling Notation Elements Used in this Document

The following elements from Figure 3 are defined in the ArchiMate Specification as follows:

- **Principle**: represents a statement of intent defining a general property that applies to any system in a certain context in the architecture
- **Business Actor**: represents a business entity that is capable of performing behavior
- **Business Function**: represents a collection of business behavior based on a chosen set of criteria such as required business resources and/or competencies, and is managed or performed as a whole
- **Business Object**: represents a concept used within a particular business domain
- **Application Function**: represents automated behavior that can be performed by an application component

2.2 Enterprise Architecture and the TOGAF® Standard

Enterprise Architecture and the TOGAF Standard provide frameworks, tools, and techniques that this guide proposes to use to assist organizations with the development and maintenance of a digital sustainability capability.

A high-level maturity of the Enterprise Architecture capability in a given organization supported by the TOGAF Standard is a foundation for a digital sustainability capability to provide:

- Stakeholders' analysis on the full scope of the organization
- Consistent abstractions of high-level strategies and deliverables to support planning and analysis
- Identification of clear roadmaps to achieve the future state
- Traceability that links ICT assets to other assets and to the business they support
- Support for impact assessment, risk/value analysis, and portfolio management
- Linkage between stakeholders' requirements, ensuring that the needs of each stakeholder community are met, and that each one is aware of the appropriate context

  Those links are essentials to support sufficiency decisions and balance between the sustainability enabled in the business by ICT and the environmental impact of ICT assets.
- The context and analysis capabilities to make the right digital sustainability decision with the best business value and deliver sustainability through the whole information system landscape

In this document, the following aspects from other parts of the TOGAF Standard have been used:

- Capability: The TOGAF Standard definition: "An ability that IT departments, IT professionals, or IT system possesses; digital sustainability" is described in Chapter 3
- Architecture Governance, the practice of monitoring and directing architecture-related work as described in the TOGAF Standard, is used to secure the delivery of the digital sustainability capability and evolution in time; it is described in Section 3.9
- The TOGAF ADM, a transformation approach leveraging the TOGAF Architecture Development Method (ADM) [C220], is proposed in Chapter 4
- The Architecture Principles as general rules and guidelines, intended to be enduring and seldom amended, that inform and support the way in which an organization sets about fulfilling its mission on digital sustainability, are provided in Section 3.9.3

2.3 The Open Group Open Footprint™ (OFP) Forum

There is a need for organizations to use well-founded data models for capturing emissions-related data, performing calculations on this data, and producing emission statements and insights that can be used for decision-making and regulatory reporting.

This is a non-trivial exercise as producing an emissions data model from scratch requires a lot of specialist domain knowledge, and as mapping data into this model, especially for complex, asset-heavy organisations, is challenging.

In addition, making sure that emissions data includes the right provenance that points to data sources and explains methods of calculation is necessary to build trust in emissions statements and to meet challenging new auditing requirements.

The Open Group Open Footprint™ (OFP) Forum's goal is to produce such a model that is rich enough to be used across industries, as well as standard APIs, and a reference open-source implementation. This work also includes supporting the emission factors and calculations that are required to generate emissions estimates from activity data, such as calculating the Carbon Dioxide Equivalent (CO_2e) emissions generated when using a server in a data center that can then be used in regulatory reporting. These standards will help to ease the data sharing challenges related to Scopes 1/2/3 GHG emissions.

These standards, when available, could be used complementary to the ICT footprint measure approach described in Section 3.6.

3 Capabilities

The TOGAF Standard employs the concept of capabilities to indicate the things that an enterprise, person or system can do. The Architecture Development Method describes a systematic approach to identifying, evaluating, and improving capabilities. [C220]

In a world where energy and natural resources used to be abundant, organizations did not have to worry about the sustainability of their information systems. Therefore, digital sustainability is a capability that remains at a very low level of maturity for most organizations. In addition, the current rules of the market are no longer sustainable. ICT is indeed an industry where energy efficiency improvements are important (cf. Moore's Law[6]), but only to enable greater consumption. These improvements are still mostly focused on energy consumption during the usage phase, forgetting the significant environmental footprint required to build increasingly efficient ICT assets.

Changing this situation requires a strong focus on deploying a sustainable information system policy to drive short, medium, and long-term transformation.

3.1 The Purpose of the Digital Sustainability Capability

This chapter describes a framework to implement the capability of an organization to deploy a sustainable information system policy. This policy should contribute to the wider Corporate Social Responsibility (CSR) strategy of the organization and be one of the key pillars of the ICT strategy.

The following, non-exhaustive list of benefits should be adapted to the specific context of each enterprise. The following benefits have been observed among organizations that started the transformation and can be expected from the proposed approach:

- Reduced GHG emissions and use of natural resources (raw materials, water, etc.)
- Improved operational efficiency, reduced information system costs by being more frugal, by implementing approaches limiting volume and principles of sustainable by design, by minimizing low value-added digital resources, and by reducing end-user equipment, etc.

  Indeed, reducing volumes of useless information, applications, and machines can naturally lead to more efficiency and a lower mental workload for collaborators. Until now, having a financial business case was enough to purchase a new technology or to validate an architecture. As we move ahead, the overall environmental business case will have to be checked with science-based metrics.
- Higher adaptability to future regulatory changes
- Lower exposure to raw material scarcity impacting information system equipment supply and cost
- Readiness for serious climatic hazards impacting operations

[6] Moore's law is the observation that the number of transistors in a dense Integrated Circuit (IC) doubles about every two years. Moore's law is an observation and projection of a historical trend. Rather than a law of physics, it is an empirical relationship linked to gains from experience in production. Source: https://en.wikipedia.org/wiki/Moore%27s_law.

- Attractiveness to employees, allowed to support significant societal causes through their professional activities
- Provision to customers, shareholders, and investors of a vision and an approach aligned with their civic concerns
- Accurate reporting of GHG and climate risk data to shareholders and financial analysts comply with existing and foreseeable transparent reporting duties and guidelines

3.2 How to Deploy a Sustainable Information System Policy

Maximizing the digital sector's contribution to carbon neutrality requires minimizing the use of energy and natural resources. Consequently, ICT departments should reduce consumption everywhere and an efficient strategy to achieve this is to focus on the areas of greatest value.

These areas of greatest value must be defined carefully through the sustainability prism. Indeed, when a business itself is unsustainable but ICT makes it more efficient, the impact of ICT will systemically be unsustainable because it contributes to the growth of unsustainable activities.

There is a need for Architecture Policies to reflect the Business Policies for Sustainability; and the need for an appropriate Governance Framework to ensure that they are appropriately applied. The TOGAF Standard [C220] "Fundamental Content, Enterprise Architecture Capability and Governance" provides such a guidance, which needs to be tailored to suit the culture and the operating model of the enterprise.

So far, only a few organizations have adopted an environmental view of their ICT system. Depending on the enterprise, such a view should include, among other things:

- Outsourced services, including their indirect GHG emissions
- The impact of digital equipment's manufacturing process
- The environmental performance of the electrical grid of the sites where the digital equipment is manufactured and operated
- The providers that support and evolve the licensed software

As organizations do not have this complete vision, decisions and trade-offs regarding the numerous uses will suffer from weak points that may hide environmental impacts which could, if visible, be significant enough to affect decisions and outcomes.

The framework presented here aims to support organizations in their transformation towards a sustainable ICT system. It proposes a reference framework to define a common language for multi-disciplinary professionals, allowing ICT professionals and businesses of an enterprise to better collaborate on sustainable digital initiatives.

New activities or changes to existing ones must be implemented to deploy a sustainable information system policy. Those described below are common to all organizations. They allow reduction of the environmental footprint of the ICT system, and influence the IT market towards sustainability, and thus have a systemic impact.

This "fitness program" of the ICT system is intended to serve as a starting point to tackle the infobesity that strikes organizations. It can be used to classify activities already undertaken, to evaluate their maturity, their strengths, their areas of improvement, and how they compare across companies in the market. It should be adapted to the specific context of each organization.

The reference model in Figure 4 describes the seven high-level business functions required to set up and deploy an effective sustainable ICT system policy in any organization. A high-level description of these seven activities is provided in this chapter and then more details are provided in the ones that follow.

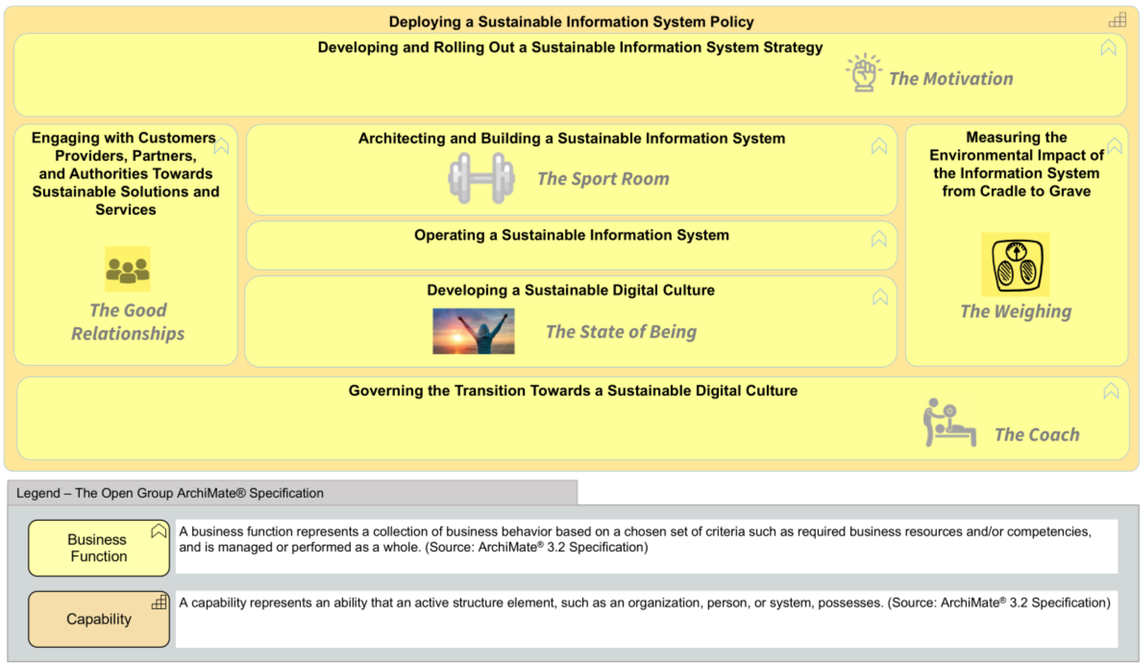


Figure 4: Digital Sustainability Reference Model (High-Level Version): The Information System Fitness Program (Source: The Shift Project Lean-ICT Work Group)

Developing a Sustainable Digital Culture

The lack of knowledge about complex energy-climate issues and the environmental impact of digital technology is one of the root causes of our difficulty in dealing with these subjects. It is a prerequisite for the other activities to succeed. To reach the point where it is decided to launch a transformation towards a sustainable information system, executives and staff need to be aware of the environmental crisis and the urgency to transform. Then, to be executed, this program needs the support of all employees, who must be taught and trained so that they can start to embody a culture of sufficiency and sustainability that will become part of the long-term DNA of the organization.

This business function is described in Section 3.3.

Developing and Rolling Out a Sustainable Information System Strategy

To become more sustainable, the information system needs an ongoing long-term program. This requires the support of the company's leadership and a strong sponsor, such as the director of operations, IT department, or sustainability department. It involves formulating and sharing motivations and objectives for transformation towards a sustainable information system. These objectives must be part of the global sustainability strategy of the organization and reflected in the ICT strategy and Enterprise Architecture.

Once the sustainable ICT strategy has been defined, it is necessary to set up a team that will be responsible for leading the transformation through the activities described below.

This business function is described in Section 3.4.

Architecting and Building a Sustainable Information System

Methods for creating digital tools should be adapted to minimize their environmental impact at all stages of their lifecycle, from design to end-of-life. This new framework will feed the Agile methodologies used for the creation of ICT solutions with new sustainable requirements. Architectures should be chosen depending on their environmental impact. All architecture levels are concerned:

- Business units must question the need for digital solutions

  Among the offers that do provide real business value, they should select the most environmentally efficient, considering the end-to-end value chain, from manufacturing to consumption.

- Implementation of new systems should be coordinated with the removal of older systems they replace in a very timely fashion

  There must be a plan and an end date. Double run period with double impact should be minimized.

- Applications must be resource-efficient on the organization's or provider's servers and on end users' terminals
- Stored data must be managed in a rigorous and economical way, and its presence justified by quantifiable utility

  Data items should have an expiry and deletion date when initiated. Deletion automation can then be configured. Guidance from existing legal policies should be leveraged, and the ICT industry should seek new standards from the governments when missing for some data.

- Technical solutions must be chosen considering their repairability, their durability, their energy efficiency, the origin of their components (for instance, if they rely on a circular economy), the absence of hazardous substance (refer to [European Commission A]) – overall, technical solutions must be fit-for-purpose; see Table 7, Principle 5
- Open source and open standards choices or contribution should be favored as they are solutions to obsolescence and can allow significant longer usage of equipment [Mobbs 2012]

This business function is described in Section 3.5.

Measuring the Environmental Impact of the Information System from Cradle to Grave

Measurement is mandatory to drive organizations' science-based decisions toward a quantitative reduction of the Information System's environmental impact. The process to assess its effective reduction must be developed on the whole lifecycle of hardware components "from cradle to grave". Indeed, the manufacturing production of hardware is responsible for more than half of its emissions. As Paul Mobbs states in *A Practical Guide to Sustainable IT*: "*While many may look primarily at power consumption, the manufacture of digital electronics also has a major impact on the global environment.*" [Mobbs 2012] It uses natural resources, generates waste, and pollutes the soil and water. The search for the optimization of power consumption is leading to intense hardware renewal rates. [Shift Project 2019]. To build a sustainable information system, full end-to-end impacts must be considered, including the "Scope 3" of the carbon accounting method defined by the Greenhouse Gas Protocol. For the implementation of such measurements in an organization, a framework is proposed in Section 3.6. A first order of magnitude of CO_2e emissions can be calculated with reasonable effort and minimum tooling, then more precision or higher granularity will require more investments.

This business function is described in Section 3.6.

Engaging with Customers, Providers, Partners, and Authorities Towards Sustainable Solutions and Services

To date, the information system is characterized by rapid obsolescence. It is at the core of the current economic model of the sector. This is unsustainable and should evolve toward planned sustainability. Furthermore, the energy mix of countries in which ICT employees and service providers operate is rarely considered as a parameter regarding the choice of services, even though it can change the environmental impact by several orders of magnitude.

This transformation requires a collective mobilization of the different actors from the ICT sector, whether they are device manufacturers, service providers, or companies using those services. Indeed, solutions and digital services are most often purchased from third parties.

The ecosystem surrounding an organization is strategic for its transformation. To achieve sustainability objectives, the organization needs to create the relevant ecosystem of partners which can align on its environmental strategy and collaborate on a common set of transformational initiatives.

Finally, even if the organization does not implement the services it uses (e.g., purchased services, cloud, etc.), it remains nonetheless responsible for the amount of data it produces and processes, its network usage, and the choice of service suppliers. External suppliers cannot be treated as a "carbon trash can" that an organization fills up to reduce the scope of its own obligations. Intense collaboration with the entire range of subcontractors is necessary to ensure the completeness of the measurement as well as the implementation of actions to reduce indirect emissions from these third parties.

This business function is described in Section 3.7.

Operating a Sustainable Information System

ICT operations should be adapted to minimize their environmental impact. The following activities will have to be organized or reinforced:

- ICT equipment inventories should be maintained accurately and should cover not only servers but also workplace assets, including peripherals, monitors, printers, televisions, meeting room video tools, etc.
- ICT equipment repair activities will have to be developed

- Digital consumption will have to be monitored
- Data centers must be designed with load-shedding capabilities that can be activated upon request from network operators in case of power shortages

  The purpose is to maintain the integrity of the electric grid and to prevent the entire network from going offline and leading to long-term power outages.

This business function is described in Section 3.8.

Governing the Transition Towards a Sustainable Information System

The transformation requires long-term commitment and associated governance: the environmental criteria must be at the core of the decision-making process driving the evolution of the information system.

This business function is described in Section 3.9.

3.3 Developing a Sustainable Digital Culture

To counterbalance today's unsustainable and ever-growing use of digital products and services, there is a need to develop a new digitalization culture driven by sufficiency. Now that we know that each digital product or service is enabled by non-renewable resources that are becoming scarce, each organization must develop a culture of digital sustainability for better resilience. This is a major cultural shift that must be conducted to ensure the adoption and integration of climatic and environmental issues into both internal and external uses and work methods.

Facing this urgency, a culture transformation within organizations is required. Transformation should start with small victories, gradually rally co-workers and structuring the approach to move towards digital sustainability together.

This transformation can be conducted and evaluated according to four main dimensions depicting the digital sufficiency common goal; see Figure 5.

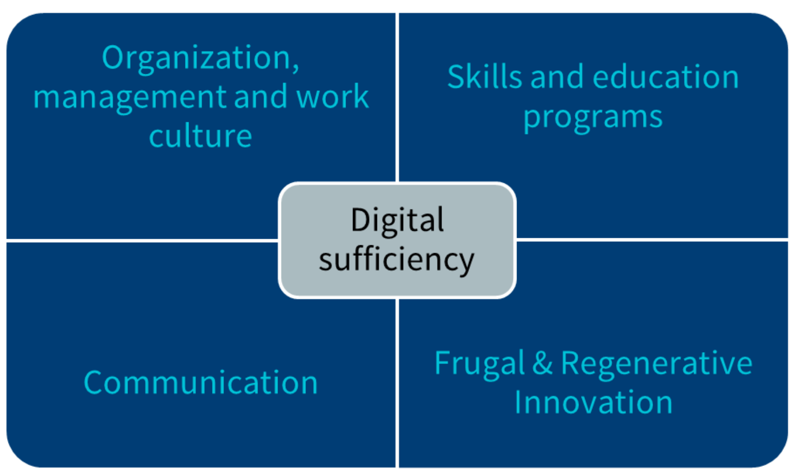


Figure 5:Digital Sustainability Key Culture Axes (Source: The Shift Project Lean-ICT Work Group)

3.3.1 Organization, Management, and Work Culture

To develop a legitimate and long-lasting transformation, the climate crisis and resource availability risks must be mitigated at the highest level of the company and considered in every decision. The principles and orientations taken by the CSR must be reinforced and adapted accordingly. By committing to this transformation, management encourages their employees to actively contribute to a transformation meaningful enough to transcend the organization.

This motivation toward change must be supported by the usual management tools such as the definition of objectives, profit-sharing, etc. Each actor must be aware of the strategic carbon reduction objective and include it in their daily activities. Operationally, objectives must be available at an individual level, but the commitment to the global climate goal must be, more than anything, collective.

More informal methods can also be considered to create emulation. Good practices can be shared through guilds and ICT communities these are powerful recognition and motivation tools.

The possibility for each business unit to measure the environmental footprint of its activity at any time is a key element of such a process. It enables each team, Agile project, co-worker, business activity, or ICT professional to act at their level by defining their own objectives and management indicators (see Section 3.6).

The development of a work culture able to unify co-workers through strategic climate objectives is necessary. The more this culture is supported and carried by an exemplary management team, the more it will inspire all co-workers. It must especially lead to the development and adoption of principles, reflexes based on strong values such as frugality, leadership by example, the right to make mistakes (and learning by doing so), simplicity, the human factor, critical mindset, etc. ICT communities will have to be the driving force within organizations to lead and support the transition towards digital sustainability.

Professionals working in the digital sector have a key role to play in the development of a sustainable digital culture. All the information system actors and especially those with the highest level of expertise must be involved. Thus, depending on their positions, they should:

- Be included into education program plans and receive specific resources for the completion of their mission
- Participate in the construction and follow-up of the various indicators for monitoring the impacts of the information system
- Participate in the various information system steering and governance boards to ensure that projects and decisions are aligned with frugality objectives
- Act as a referent regarding the new digital temperance practices at diverse levels (development, business activity, etc.) and along the whole information system lifecycle

Additionally, because of their key role between ICT and business units, product owners will have to bridge a gap between two vastly different worlds to solve a common issue. Their daily activities will have to evolve to include sustainable digital objectives across their entire action range: it is up to them to question the environmental value and to establish a balance between business value *versus* environmental footprint.

Finally, the processes enabling the transformation of an organization, such as the Enterprise Architecture (particularly suitable thanks to its systemic approach), and the tracking or governing bodies set up within the organization will have to be adapted to integrate digital sustainability an objective, as described in Section 3.4 and Section 3.9.

Overall, strong sponsorship from director level, as part of the company's strategy, is required beyond the ICT department.

3.3.2 Skills and Education Programs

Processes to raise awareness and educate must be implemented within each organization to support the understanding by all co-workers of the strategic low carbon objective and the need for change. The energy-climate and resource scarcity issues as well as the digital technology contribution to these disruptions must be understood. Therefore, workshops such as "Climate Fresk" or "Digital Collages",[7] conferences led by co-workers, pointing out daily actions, etc. are recommended initiatives to benefit of the ecosystem knowledge and challenge. Although it is possible to involve external contributors, it is recommended to prioritize initiatives led by co-workers to maximize adoption and impact.

These education programs should not rely on ICT communities: every single employee must benefit from a training program to understand the environmental impact of ICT resulting from their uses and their decisions or expressions of needs. To do so, it is possible to leverage widely broadcasted Massive Open Online Courses (MOOCs) like the AXA Climate School [AXA] or online communication. The training campaigns performed in some organizations regarding the General Data Protection Regulation (GDPR) or the cybercrime-related risks are good examples to follow and adapt for sustainability.

Let us study the example of "Green Digital". Within a subsidiary of a large French bank, an employee took the initiative in 2019 to create a presentation and education program (workshops on best practices about proper uses) to raise awareness and educate employees and managers about environmental issues and the fight against digital waste. He suggested solutions by showing how to better use digital tools. This initiative has been listed since November 2019 as part of the "company engagement" initiative, which made it possible to raise awareness across more than 1,000 co-workers. It is now a building block of a series of initiatives at the group level that has been set up since the beginning of 2020.

Beyond raising awareness and education program initiatives, digital sustainability requires the development and involvement of new skills such as carbon footprint accounting, eco-design, and software craftsmanship ("develop less but develop better"). These skills complement those already required by ICT positions, especially for architects and senior developers, whose role is, among other things, to guide and implement ICT practices. They will have to be included in HR processes and added to job descriptions for the involved ICT communities and developed by specific education programs depending on the target audience.

The buyers or procurement professionals, whose activity covers a large part of Scope 3 of the organization's carbon footprint, must be subject to special attention in terms of education programs and skills because they play a role of both prescriber ("what we ask our suppliers for") and collectors (gathered measurements of the subcontracting process impact) of the environmental impact of the information system.

[7] Climate Fresk: https://climatefresk.org/; Digital Collage: https://digitalcollage.org/.

At the hiring level, it is essential that businesses ensure that candidates' profiles and skills match their new needs, by hiring recent graduates that have been educated on these topics, but also by integrating into the recruitment process questions related to digital sustainability for everybody, then ensuring that new co-workers will be able to adapt to the new work culture and the ongoing transformation.

3.3.3 Communication Plan

Internal communication respecting digital sustainability principles must reflect the challenges and efforts made at every level. It must kick off and sustain the movement and motivation towards the goal of digital sustainability. It can highlight challenges (Lean-ICT hackathons, etc.), praise noteworthy progress, animate corporations, or support communities during this digital temperance process. Conviction that the organization is progressing at reducing environmental impact can be reinforced with regular communication and transparency about the actions of the organization, such as the evolution of the carbon footprint or electricity consumption or the compliance to the European Union E-waste rule [European Commission B].

External communication will lead to healthy emulation between companies and will lead to higher attractivity for environmentally conscious talents. For instance, it can promote conferences or meet-ups about digital sustainability initiatives. It can be led by employees to generate more motivation. The set-up of public communities based on the open-knowledge principle can also be a good option.

3.3.4 Frugal and Regenerative Innovation

The challenge is "how to do as well, or even better, with less energy and less resources, while regenerating the biosphere, getting inspiration from natural mechanisms". Since ICT lies at the heart of Digital Transformation, it is not about stopping or slowing down innovation but changing part of its paradigm.

Frugal Innovation [Radjoua & Prabhu] is an approach that aims to develop efficient solutions, devoid of sophistication and superfluousness, using as few resources as possible, favouring human interactions over machines. Low-tech approaches are also of interest to deal with physical constraints [Bihouix] and can be considered to innovate with low impact, without any compromises regarding the quality of the provided service and by anticipating the lifecycle of the offer and its use. It must be based on values (simplicity, temperance, etc.) and rely on every skill. The ICT professionals have an appetite to innovate and to cope with recurring challenges in a very dynamic market. The innovation capabilities of the organization must therefore be deployed at every level: every suggestion must be considered if it meets the digital energy/resource frugality objective. Therefore, it will be necessary to implement the tools and methods that will enable innovation to emerge, be deployed, and be accepted by integrating the methods and practices of the lean-ICT approach from the start. ICT projects will then have to be challenged and evaluated by considering digital sustainability criteria.

Frugal Innovation can be a source of major changes and disruptions, especially when it is about changing the way of working and simplifying processes or organizations: every co-worker must accept the need for change and the change itself. To develop a digital sustainability approach, we must recognize that it is not just about optimizing the current information system, it is about changing direction and changing our way of thinking.

Regenerative Innovation is an emerging concept that draws inspiration from nature, which is inherently self-sustaining, collaborative, and resilient. The purpose is to create businesses and economy that regenerate the biosphere that has been destroyed by human development, and thus mitigate climate change with biomass carbon capture, restored water cycle, and preserved biodiversity [Regenerative Innovation].

3.4 Developing and Rolling Out a Sustainable Information System Strategy

3.4.1 IT Strategy: Between Supporting Growth and Managing Associated Risks

An IT strategy is the digital embodiment of an organization's strategy: it is driven by a constant search for growth and improved margins. Depending on the context, it has taken various forms:

- Systematic search for efficiency through the digitization of processes
- Decision support through the multiplication of calculations and management of indicators
- Predominance of the Web for sales and marketing
- Development of new fully digital business models (Digital Transformations, platform economies)

These strategies have been supported by budgets that have increased around 166% between 2005 and 2022 according to Statista [ICT Statista].

The resulting Digital Transformation significantly increased companies' exposure to digital-related risks that began to be addressed in the early 21st century. Rationalization programs driven by cost control, obsolescence control and technology debt, or system complexity and scalability control were initiated. Finally, massive investments in cybersecurity have increased 35-fold between 2004 and 2017 [Cybercrime], and these risks are now overseen directly at the executive management level. The digital sustainability topic is a suitable candidate to follow the same path.

3.4.2 Environmental Risks Linked to Digital Technology

The term "infobesity" is used to express the risk for a company of not being able to adapt quickly to new market conditions because of its ever-growing Information System. When facing environmental constraints, it becomes an aggravating factor regarding the climatic risks that the company is facing.

The taxonomy proposed in Table 1 is a deliverable of the Institute for Climate Economics to support the financial sector in the understanding of major risks associated with climate change [Hubert et al.]. Among transitional and physical climate risks, technologies come with specific transition risk including "Environmental impact of digital technologies".

Table 1: Typology of Transitional and Physical Climate Risks. Adapted from [Hubert et al.]

Transition Risks		**Physical Hazards**
Regulations • Increase in the price of GHG emissions (carbon credits, taxes…) • Increase of reporting obligations • Regulations on existing products and services	**Markets** • Changes in consumer behavior • Uncertainty of market signals • Increase in raw materials costs	**Acute** Increased intensity and frequency of extreme events: • Cyclones • Hurricanes • Floods (Causes of damage on facilities, reduction in production capacity.)
Technologies • Substitution of existing products and services with less emissive options • Unsuccessful investments in new technologies • Initial development costs of new low-carbon technologies • Environmental impact of digital technology	**Reputation** • Changes in consumer preferences • Stigmatization of a particular sector • Increase in negative comments from stakeholders (e.g., greenwashing)	**Chronic** • Changes in weather patterns and increased variability • Increase in average temperatures • Rising sea levels (Causes of damage on facilities, increased operating costs, impact on employee productivity.)

It should be noted that this taxonomy is limited to energy-climate issues, and that the risks induced by the Information System and its physical construction go beyond pressure on finite mineral resources, water and soil pollution, social and political tensions.

As proposed in the TOGAF ADM approach, this taxonomy can be an input to identify the Business Transformation Risks and Migration Activities assessing initial and residual level of risk.

As a conclusion, the understanding of the "**infobesity**" risk by executives of the enterprise is the first step of a sustainable IT strategy.

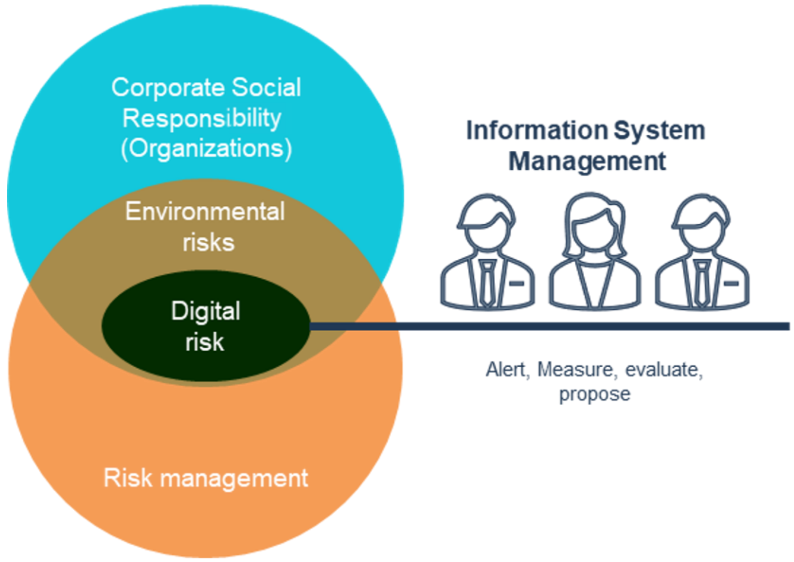


Figure 6: Risks, Responsibilities, and Role of the CIO (Source: The Shift Project, Working Group Production)

3.4.3 Sustainable IT Strategy: Expression of a Responsible Corporate Strategy that Requires CEO Sponsorship

All these risks have the particularity of going far beyond the simple perimeter of the company, and the developing awareness of their share of responsibility as an organization is a societal issue, which is displayed in the company's "**mission statement**". This notion was recently institutionalized by the French PACTE law [PACTE], allowing companies to "specify a mission statement, consisting of the principles with which the company equips itself and for the respect of which it intends to allocate means in the realization of its activity" in their statutes. The growing influence of this mission statement on strategy is increasingly claimed, as explained in BCG's 2019 sustainability report [BCG].

The strategy for sustainable IT is the digital side of this mission statement. It requires **a holistic approach to the problem of digital technology and the cost of its externalities for the company**. This must be considered as a whole: its external constraints, its business model, its organization in the broadest meaning – locations, processes, governance, functions – its partners and suppliers, its culture and, of course, its Information System. In this sense, the scope of the transformation is comparable to the so-called "Digital" Transformation one, which needed strong sponsorship as well and was officially represented at Executive Committees, in the form of a "Chief Digital Sustainability Officer" for example.

The vision of this sustainable IT strategy must be built with the CSR department, Risk Management, and the Business Units: a new articulation must be set up to define it, and to ensure the overall cohesion with the other environmental aspects (travel, buildings, etc.), the development of the company's activity and the applicable regulations.

On this last topic of regulation, it is a good practice to have regular touchpoints with Legal, Sustainability, Audit, and teams in charge of carbon reporting consolidation for regulations and standards that apply.

The publication of sustainability reporting in the non-financial chapter of a company's annual report will reflect this strategy and inform the eco system of the enterprise strategy. It should be delivered through a consensual process involving all concerned stakeholders.

3.4.4 Ambition of a Sustainable Digital Strategy

Determining the ambition of this strategy requires a first and rather complex measurement exercise that aims to identify and quantify the company's current digital environmental footprint in its entirety. The digital environmental impact is due to its direct electricity consumption (known as "Scope 2") but also and above all to the upstream and downstream indirect impacts (known as "Scope 3") – from hardware manufacture and delivery to its use in an external supplier's data center, for example – which at a worldwide level represents 45% of ICT GHG emissions [Shift Project 2019].

Modeling and redistributing this global footprint by value chain within the company will help in the second exercise of defining reduction objectives, quantifying them, and choosing the means to achieve them. Any transformation plan must be questioned regarding the ratio between economic gain and environmental impact. The global objectives can be compared with the Paris Agreement (COP21), **which commits to a reduction in global emissions of 5% to 7%** [Shift Project 2019]. In France, the ambition of the National Low Carbon Strategy is to divide emissions by six by 2050 [SNBC].

As with the implementation of any strategy, investments secured by senior management are required. Initiatives may have positive or negative economic impacts, and while it is difficult to assess the initial impact of actions as diverse as streamlining the Information System, switching suppliers to more responsible ones, and relocating specific operations to countries with a greener energy mix, the potential impact on the company's profitability must be considered. The search for a balance between short-term economic objectives and environmental targets must lead to the formulation of acceptable limits for the possible increase in the operating budget, a limiting factor of the ambition to be clearly formulated. It should be noted that initiatives to ensure the financing of such a strategy (Capital Expenditure (CapEx) and Operational Expenditure (OpEx) impact) start to emerge with internal carbon tax mechanisms, charging the business lines according to their carbon footprint.

3.4.5 Implementation of the Strategy

This document provides a framework to help define the transformation agenda which will roll out this strategy across all company functions. The high level "**RACI**" of this program can be simplified, as shown in Table 2.

Table 2: Simplification of RACI

R	A	C	I
Responsible	**Accountable**	**Consulted**	**Informed**
Chief Information Officer (CIO)	Member of the Executive Committee having authority over: The ICT Department Chief Executive Officer (CEO) Chief Digital Officer (CDO) Chief Operations Officer (COO)	CSR Business Professionals Support Functions Partners Suppliers	Clients

Note the growing importance of the purchasing department within this program, due to the amount of IT outsourcing and the strong trend in the Everything as a Service (XaaS) market. Like any other, the success of this transformation program depends on the support of all employees and partners, and on the change of their daily practices to achieve the cultural change that will make this paradigm shift long-lasting and sustainable.

3.5 Architecting and Building a Sustainable Information System

3.5.1 State the Vision of a Sustainable Information System

The purpose here is to develop a high-level aspirational vision of what a sustainable information system should be, and to catalyse energy towards this goal. This vision is the architect's elevator speech and will play a key role in gaining the buy-in of key stakeholders.

Let us give an example of what a sustainable information system vision should be. As the target information system could be dramatically different to what it is today, it is important to explain its future shape and the rationale behind it. The purpose is to propose a desirable vision of a sustainable information system that can catalyse energy. Each enterprise should design its own vision or adapt the 2030 vision, described below, to its business context.

The 2030 vision requires significant changes in public policies, business models and IT departments organizations but is technically feasible in a significant range and would enable sustainable quality digital services in the long term.

Training on Climate, Energy, Biodiversity, ICT Environmental Impact

Topics such as global warming, biodiversity, water and carbon cycles, waste management, energy supply, along the conclusions of the latest IPCC reports, are included in every student's curriculum, from elementary school to university. ICT's environmental impact and the importance of keeping personal usage under control, for environmental impact reduction as well as for mental health and efficiency is also taught widely. Enterprises have also set up learning journeys to train their employees and keep them updated on the latest findings, made possible by society's increased focus on these topics.

Workplace

Most employees are equipped with a single device, both for personal and professional usage, offered remote working, access to the Internet and a full range of digital services to support their daily activities.

As the services have been eco-designed, they require now very limited computing and connectivity resources, so this device is the size of a smartphone and can be plugged into a workstation providing a comfortable monitor, a keyboard, and a mouse. Standards now make compatibility between all workstations, smartphones, chargers, and headsets a reality, and small solar panels allowing mobile battery loading are available.

This allows total flexibility for both mobility and work from home or at the office. Most public places, enterprise's and homes are also equipped with workstations.

All these equipment have an optimized electricity consumption and can be easily disassembled and repaired with a standard screwdriver. Welding or glue are used only if no other solution is possible. At 10 years old, children are taught how to change a battery. At university level, students are taught how to assemble a new device from scratch reusing components of partially broken devices. The high level of standardization between components allows easy reuse and minimizes the need for recycling. Consequently, digital dump has drastically reduced in the world and the intensity of mining activities has decreased significantly, securing stocks for the long term, and minimizing pollutions.

Equipment have also been designed to reduce the number of metals required and to ease recycling, 50% of their metals are now recycled. The average guarantee is 15 years, and the fashion is now to keep devices as long as possible, the last record was a 25-year usage. There are plans to extend the guarantee to 20 years.

Data Center / Servers

Standardization has happened even faster than in the workspace thanks to the concentration of data centers. The average guarantee period of equipment is 20 years, electricity consumption is optimized, and the number of data centers has now stabilized for five years, which has been instrumental to secure electricity supply. Indeed, the swift exit of fossil fuels for electricity generation has required massive investment in power plants and renewables which has led to a stabilization of the electricity offer that was not compatible with the increase of data center needs still observed in 2023.

Network

When the electricity crisis happened, society had to choose low-energy solutions. Optic fiber is the preferred connection type. There is a unique solution for mobile connection that no longer needs any upgrade to meet increasing bandwidth demand since optic fiber is concentrating most of domestic uses. Telecom operators can now dedicate their effort to deploy network in non-covered area and maintain a high standard quality service under energy supply constraints.

Graduated pricing has also been put in place for all usages. Users struggled at the beginning to stay in the boundaries of their budget but now that many habits and methods are in place to keep volumes under control, there is very little need to plan for additional cost and basic needs are fulfilled at a very low cost.

Electricity Supply

All enterprises have classified their digital usage. In the event of supply tensions on the electricity network, and upon request of the operators, organizations can reduce their electricity needs while maintaining vital activities. This has been also useful to mitigate the rise of electricity costs.

Operating System Management

They are now open source, very stable and maintained by large, motivated communities of developers for 10 years minimum. This stability was a high benefit for all the enterprises that can now dedicate their IT resources to improve their business-specific development and for security. It has also significantly decreased the need for cybersecurity as systems are now secured with mature technics and there is no more security breach coming from non-updated operating systems or new code.

Software

The mandatory maintenance period by editors has increased over time to now reach 20 years, which is aligned with the servers' guarantee period. There has been a lot of difficult discussions with the industry software to reach this state, but it was a critical point to extend time usages of equipment. Moreover, when publishing a software, the delivery on an open-source platform is mandatory so it can be made public either at the end of the guarantee period or if the software company stops its activity.

Data Management

Any new structured or unstructured data is labeled with an owner, business glossary index, and an expiry date allowing automated deletion and stabilization of storage volumes. Some data is labeled for a final storage and is archived on low energy intensive backup solutions in an open standard format that secures future accessibility.

Digital Services

Digital Services design is now optimizing data storage, electricity consumption, network communication and processing, which allows a very high level of accessibility.

Half of digital services are open source, and the other half is now served by operators that have a business model relying on the quality of service and not the volumes of data.

They all embed some features that encourage minimal usage and raise alerts when data volume quotas and time usages are exceeded. They were designed to contribute to the end of digital addiction problems. This change was supported by marketing campaigns at the beginning but now that habits have been created, they are not needed anymore.

Open Data

Free Open Data available have been multiplied by 1000 and they are growing by 5% per year. Their management is performed by international and national government-funded agencies. This enables high levels of interoperability while reducing the storage needs of each organization.

The Science-Based Targets (SBT) initiative [Science-Based Targets] has scaled and Science-based environmental footprint and targets are now certified for most organizations by an independent international organization supported by United Nations, maintain a repository of these targets.

Measure of ICT Environmental Impact

The environmental footprint data (GHG emissions, electricity consumption, water consumption, impact on biomass and biodiversity) is now tracked with the same level of consideration as finance and is available for any product, service or even enterprise. Standards and free reference-shared data are used worldwide, and agencies controlling the data quality are in place in most countries.

Thanks to this shift, ICT environmental impact is now compatible with carbon neutrality targets in most countries, while providing high quality digital services and supporting intensive regeneration of the biosphere worldwide.

Innovation

The Artificial Intelligence (AI) and blockchain hype have been stopped by the historic electricity crisis and voluntary usage restrictions. Innovation is now dedicated to bio-digital solutions with the lowest possible environmental impact and energy consumption. The DNA data storage capability, batteries based on biopolymers that can be then recycled and burned as biomass fuel the hope of young generations for a fully sustainable IT.

3.5.2 A Dual Use-Based and Infrastructure-Based Architecture Approach to Drive Transformation

Shifting towards a sustainable information system is a significant transformation that will impact the full scope of architecture work. After the aspirational vision, a concrete approach leveraging existing Enterprise Architecture capabilities is proposed in this chapter to enable this shift.

Architecture Levers to Reduce ICT Environmental Footprint

The Target Architecture for sustainable information systems must coherently reshape the business processes and uses of the associated systems, applications, and data, as well as the technical infrastructures supporting these components.

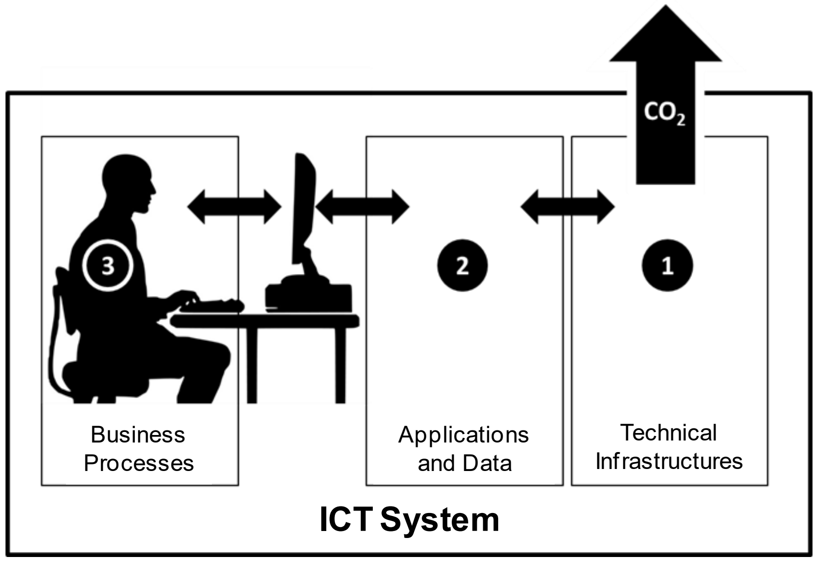


Figure 7: Architecture Layers and Carbon Emissions

1. The carbon footprint of the company's ICT system consists of the ones of its technical infrastructures: equipment components, servers, storage units, network controllers, screens, fixed and mobile devices, and the technical software operating them

   It is not limited to electricity consumption during operation, but also includes energy consumption for construction, installation of components, maintenance, and end-of-life.

   It is not limited to locally produced emissions; it also includes foreign emissions due to the manufacturing of multiple components and operation of multiple servers.

   It is not limited to the components owned by the company, but also includes the emissions of the components of ICT (cloud, for example) and functional subcontractors (advertising agency, for example) who operate on their behalf.

2. Technical infrastructures only exist to store, transfer, and process data, or run application software

3. The ICT system is also characterized by business processes, which use information in oral, written, and digital forms in a controlled way

   Application software automates part of the procedures included in business processes.

Thus, the head of ICT can organize the reduction of the carbon footprint by adapting designs at several levels:

- Informing departments of the environmental footprints of the digital services they request, and offering choices that favor services with high societal value
- Optimizing business processes and automation procedures with application software
- Optimizing the application level and how it calls the technical level
- Optimizing the technical level

Combining Top-Down and Bottom-Up Approaches to Capture Digital Sustainability Requirements

A dual approach to identify sustainability requirements can be implemented combining simultaneously:

- A business uses-based approach, close to business operators, with the goal of reducing the footprint of identified business uses (e.g., sending emails, sharing documents, or the real use of a business application as a whole)

  As explained in Section 3.6.3, initial footprint measurements aggregated at the level of business functions/business applications can designate priorities among business uses.

- An infrastructure-based approach, whose goal is to reduce the footprint of ICT systems identified as consuming resources and data (and potentially carrying several uses)

  Likewise, initial footprint measurements of existing infrastructures should help guide the identification of highly emitting systems.

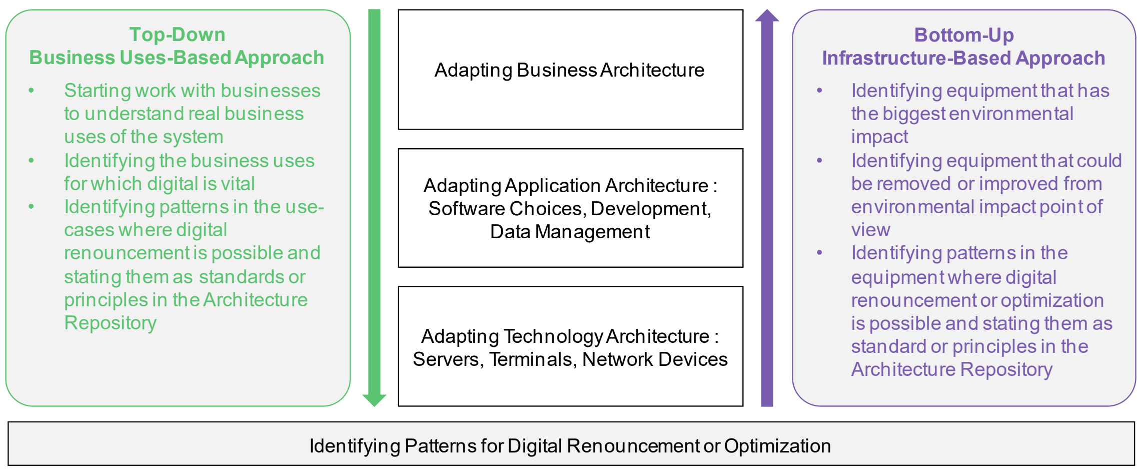


Figure 8: Combining Top-Down and Bottom-Up Approaches to Capture Digital Sustainability Requirements

These two approaches come together to identify a complete set of mitigation actions:

- The business uses-based approach must deliver a prioritized list of business uses that could be renounced or optimized

  It requires:

  — A strategic consideration of how it can be achieved, that may differ from one business to another, indeed, over the last 40 years, organizations have been in a continuous automation process, and it is a significant reversal

  — A mandate from the top management to work on these topics with business units

  — An exchange with business units, end users of the systems

  — Initial metrics, by business unit or business application, to target uses that have the highest environmental impact

- The infrastructure-based approach must deliver a prioritized list of digital equipment that should be disposed of or optimized

  It requires:

  — A mandate from the top management to work on these topics with infrastructure teams

  — An inventory of equipment supporting the information system of the organization

  — Initial metrics about infrastructure (e.g., highest footprint or highest footprint per user) to target systems that have the highest environmental impact

In both cases, decommissioning opportunities and optimizations may be found in the existing infrastructures, developments, software architecture, data, and in the real definition of the business uses of the system. The entry point is the only changing parameter in these two approaches: the optimization of a business use required to "go down" to the technical system, and the optimization of a technical system required to "go up" to its business uses (for example, to ensure the acceptability of the potential impact of a reduction or an optimization of the system by the business unit).

The implementation of decommissioning and optimization opportunities identified from business uses or from infrastructure are the design backbone of an information system with lower emissions.

Revising the Non-Functional Requirements

Overall, the delivery of these mitigation and reduction opportunities must result in revising the non-functional requirements on the systems and in new ICT projects, with the main trends shown in Figure 9.

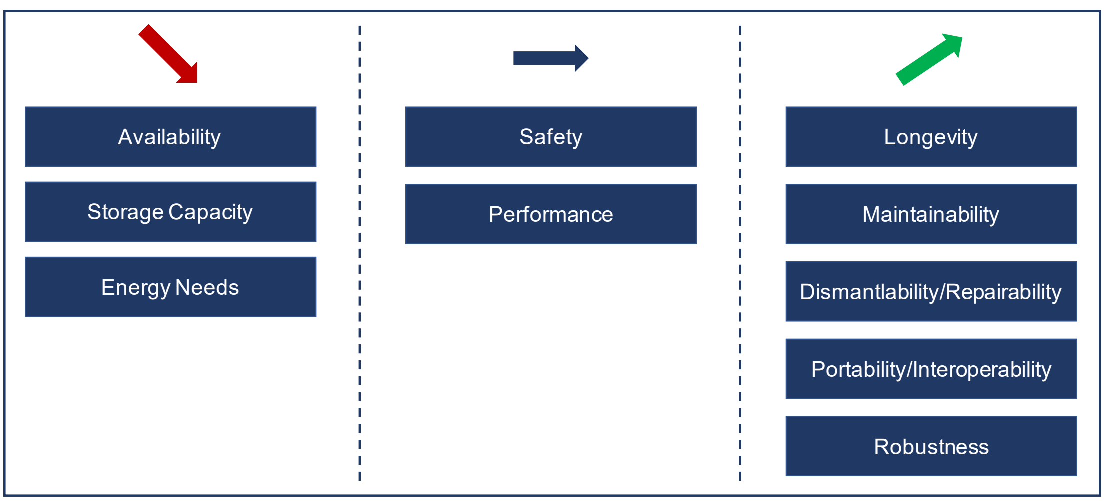


Figure 9: Non-Functional Requirements Move in a Digital Sustainability Initiative (Source: The Shift Project Lean-ICT Group)

Daring to constrain the information system and its uses requires the reduction of availability, storage capacity and energy needs. Requirements in terms of longevity, maintainability, dismantlability, repairability, portability, interoperability, and robustness of the systems will globally be increased.

Beyond the individual use-by-use and system-by-system mitigation options, it is important to set constraints on the system to promote a low-carbon trajectory over time.

Setting Constraints

Setting constraints can be perceived as unpleasant and it must be combined with a culture-change approach and an attractive vision. It is a powerful and essential lever for the architect to drive the change towards sustainability:

- The ecosystem moves towards increasing constraints on resources, regulations, etc.

  To avoid constraining the organization at the wrong time without being prepared, it is better to think in advance of a system under chosen constraints and adapt the organization, processes, uses, and systems accordingly.

- Setting up a system of constraints also makes it possible to limit the rebound effect on the system, by explicitly limiting uses, infrastructures, and data (volumes, location)

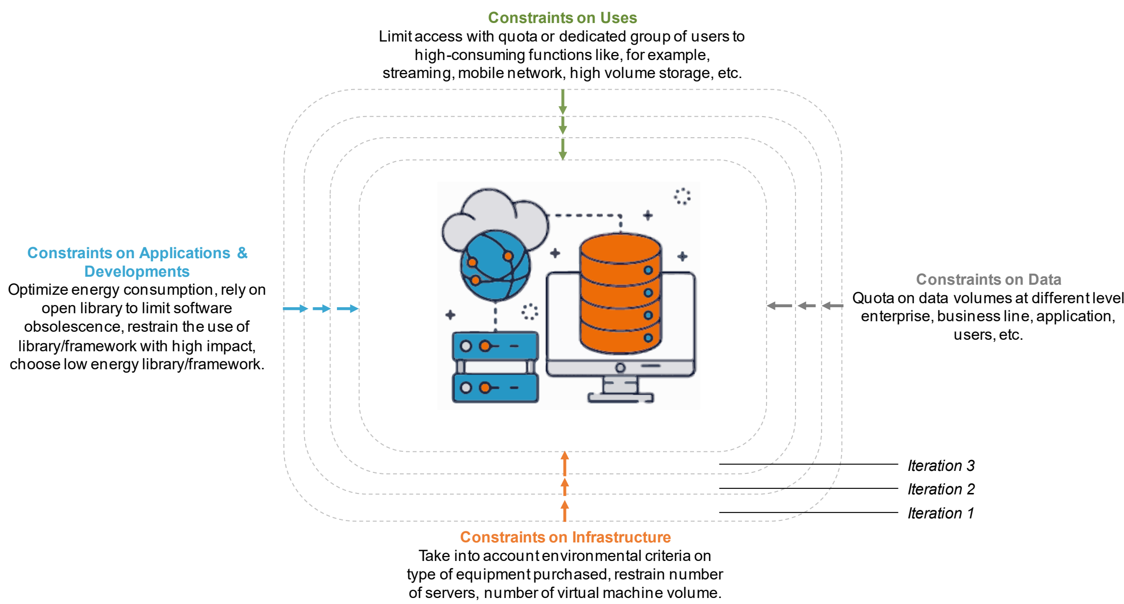


Figure 10: The Four Typologies of Constraints to Apply to be Sustainable

To do so, the system must be constrained gradually. The constraints installed by the architecture must cover several forms:

- Constraints on uses

  For example, limit the volumes associated with some specific uses (volumes of attachments sent per day and per person in an email, volumes of video consumed per day, etc.), limit the frequency of certain uses (number of web pages opened per day and per person), limit certain uses altogether (restrict access to social media, streaming sites, mobile network, high volume storage capabilities, etc.).

- Constraints on data

  For example, set a maximum volume for the company, a maximum volume per user/per application, restrict the geographical perimeter of the physical location of data (favor data storage as close as possible to its end user or in a region where low-carbon electricity is distributed on the grid).

- Constraints on applications and developments

  For example, limit/restrict the use of certain frameworks, certain libraries; restrain the use of high carbon footprint technology. Add constraints on development and test, challenge the need to "DevOps", continuously running a heavy Continuous Integration and Continuous Delivery/Deployment CI/CD pipeline.

- Constraints on Infrastructure/Devices

  For example, restrict the types of equipment purchased, the volume of servers, the Virtual Machines (VMs)/containers, the maximum number of technical objects used (by sizing intervals), and limit the energy consumption of certain infrastructures.

The ICT architect must formalize and validate a path towards a system under selected constraints by involving all stakeholders. The exercise is of course more complicated than it seems. It is not about imposing "unwise" constraints. Being able to design an appropriately constrained system requires having metrics in place. This involves combining constraints at different levels while ensuring through culture and awareness that they are also acceptable and bearable for the organization's business processes.

The constraints must be explicitly expressed, justified, and reviewed periodically, within the framework of the governance activity, in the same way as the Architecture Principles.

Table 3: Setting and Governing Constraints

	Justification	**Complexity in Making or Maintaining the System Compliant**	**Value to Comply with the Constraint**	**Can the Constraint be Automated?** **(Automatic blocking/alert messages, etc.)**	**Compliance Control Modality** **(How do we check that the constraint is respected?)**
The volume of data stored in the cloud must not exceed xTO	…	…	…		
The data must be physically located in the country of use					

3.5.3 Reshape Business Architecture

Business Architects are discovering and documenting business requirements that will be the inputs to design application capacities – data and processing – in a negotiation with business teams to meet business units' needs. The decision to rely on people or on machines will need to balance the

ICT carbon footprint with the one or other people-based, low tech, or biologic solutions. Decisions involving trade-offs on what should be digitalized are levers to contain organic growth and to reduce ICT carbon footprint.

Business Architecture aims at describing processes specific to each business unit of the company, and cross-functional processes like sharing of product line data, internal operating data (messaging, reporting), etc. The challenge here is:

- To decide, for each perimeter and lifecycle, which information should be digitized and which should not, and which processes should be automated and which should not, depending on the carbon footprint of the infrastructures required
- To identify the digital tools and functionalities, which in practice do not serve any use, or are no longer in use because of obsolescence, discrepancy between intended design and user experience of the system
- To measure the real gain of digitization when compared to no digitization: flexibility, staff involvement, operational gain, reduction of the analogue footprint, financial gain, costs reductions, accessibility etc.

Ultimately, the culture change will fuel the desire of business units to focus on essential uses, to eliminate unnecessary ones, and to adapt processes to reduce the footprint of the systems and will enable the shift toward a sustainable information system.

3.5.4 Reshape Application Architecture

Most of the users' functional requirements are implemented at the application level. The software architectures come from either:

- Software/software package companies: In this case, the supplier is required to provide the transparency and tools needed to give a clear vision of the software's carbon footprint and development processes

  Best practices leveraged by the software company in terms of code optimization, performance report/footprints of different configurations should also be documented.

Or:

- An internal development process within the organization

The reduction of the coverage of functional requirements will have to be studied. A review of non-functional requirements, in particular on user interfaces, should also be conducted to avoid for instance the automatic launch of videos on a new page, limit animations, etc.

3.5.5 Reshape Data Architecture to Reduce Data Volumes

Data Architecture is a significant lever. The Chief Data Officer (CDO) with the support of Data Managers should take responsibility on the **control of data volumes** and the reduction of the associated environmental footprint in their "Data Strategy". Organization's data governance processes under their responsibility should evolve to:

- Generalize "Data Minimization"

  The principle is quoted in the GDPR concerning personal data: "personal data must be adequate, relevant, and limited to what is necessary for the purposes for which [it is] processed". This principle must be generalized to all data across the organization. Data "quality" must be favored over data "quantity".

- Adapt "Data Management"

  Data managers need to build sustainability into their practice. Data volume controls should be systematically integrated, as should quality controls and security controls.

- **Manage** data **at end-of-life** by design (maximum retention duration, and not just for personal data)
- Encourage all co-workers to reduce their data/document volumes; organize a data deletion program to automatize some deletion and organize events like a "data deletion day"
- Challenge the relevance of data backup and historizations

3.5.6 Reshape Technical Architecture

The technical level of ICT is made up of subsets of hardware and software components that support a technical service: database, backup, execution of application software, display, data transfer, etc.

Some examples of optimization in technical architecture are listed below:

- Reduction and optimization at the application level will lead to a decline in sizing requirements at the hardware level
- For each technical service (storage, website hosting, etc.), identify technical architecture patterns with a lower carbon footprint, and generalize these implementations
- Choose suppliers wisely (see Section 3.7): server renewal rate for on-premise infrastructure, choice of cloud services suppliers able to provide carbon footprint measurements and electricity consumption transparently
- Strengthen work with the businesses on non-functional requirements that directly impact the technical architecture, to further challenge the need: "Do you really need 99.99% availability? Do you really need to keep a two-year history, for what value?"
- If the organization manufactures or maintains digital material, strive for "planned sustainability" (as opposed to rapid obsolescence) and choose a lifecycle management at a more granular level to enable replacement or repairing at the component level of given equipment, in particular by increasing the requirements for interoperability and durability, improving Mean Time Between Failure (MTBF)

- Work with public bodies to reduce legal compliance constraints: storage for data is in some cases defined by law and not by company choice

3.5.7 Agile Methodologies for Sustainability

The Agile method, an empirical approach based on continuous improvement, was developed to adapt to changing context. Project teams must react to contingencies and changing realities. Agility ensures that the digital product is produced as close as possible to its actual use thanks to the strong integration of the business into short development cycles. It prevents the delivery of applications with a large part of the initially desired functions unused. This approach has been formalized under four values and 12 principles.

Six of these principles seem particularly relevant to develop practical solutions:

- Useful value is at the center of the approach

  The role of the Business Owner has changed. They are no longer simply making requests outside of the development process. They become co-responsible for deliverables, among other things by explaining the reason for their needs, quantifying their value, prioritizing the functionalities, and measuring the business impact.

- Repetitive aspect: short cycles with frequent releases to production

  The delivery check must be concrete: specifications, documentation, theoretical indicators have no value until tangible proof of operation is demonstrated. In case of error, it becomes easier to correct.

- Simplicity: the system must meet needs in the simplest way as this system is also called to be "refactored" in future iterations

  This simplicity is often associated with the principle of anti-waste, a core principle of "Lean" practices also deployed within IT organizations in recent years.

- Autonomous and responsible team: actors are free to choose solutions and implementations for which they have full collective responsibility

  It is a freedom exercised within a framework defined by Enterprise Architecture standards and requirements. The sustainable digital culture as described in Section 3.3 is a pre-requisite to make it work.

- Continuous improvements: complementary to the repetition concept, production is improved incrementally using user feedback, as well as the practices implemented to achieve these improvements

- Measurement: measures "value points", complexity, velocity, quality, etc.

  To steer product development, many of the used indicators are intended to be factual and public.

To deliver a sustainable information system, limitation of the environmental impact must be supported by the business unit in the same way as the use value and be integrated into the decision-making processes (acceptance, prioritization, etc.). The repetitive deliveries enable rapid measurements of these impacts, by automating them during the testing phase, and by taking them into consideration during the continuous improvement process to reduce the carbon footprint in later iterations. Making these indicators public and integrating them into product management strengthens the responsibility of the team and its autonomy in the development of products with limited environmental impacts.

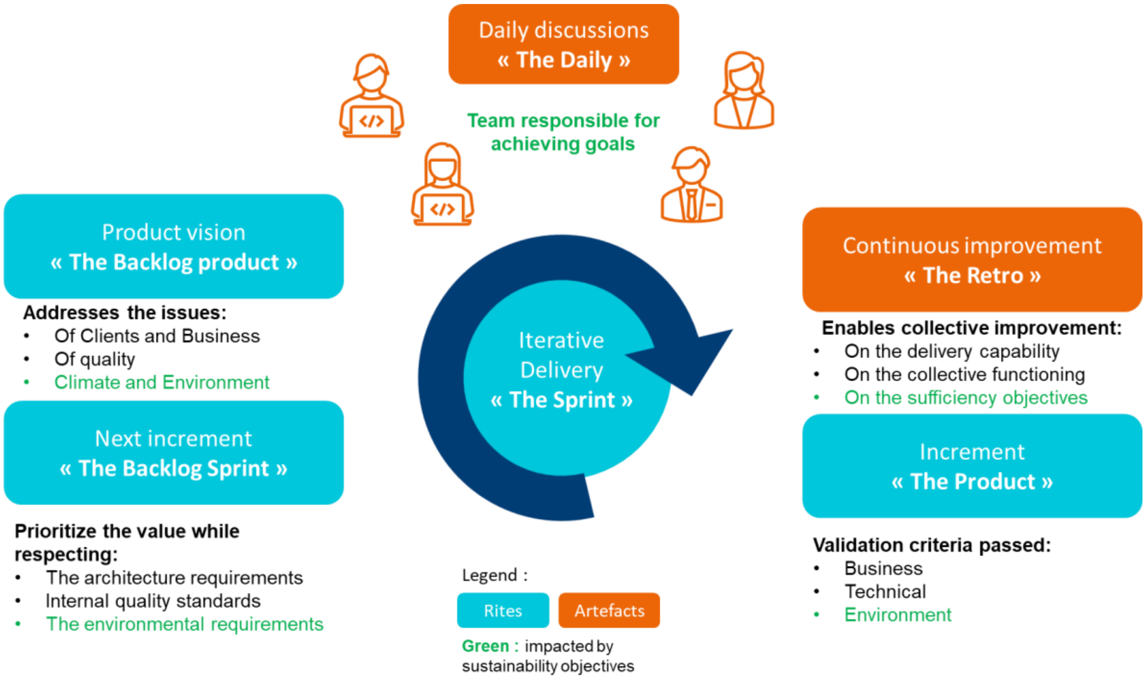


Figure 11: Sustainable Information System Delivery (Source: The Shift Project, Production of the Working Group)

Conditions to Implement a "Sufficient" Agile Approach

To implement this new approach, several tools and catalysts are necessary, stemming from the strategic desire of the company to implement sustainability; for example:

- Means to measure
- Comparative benchmarks
- Requirements and guidelines characterized by the architecture
- But also, and above all, raising the awareness of teams on the subject with the support of IT executives

The key to success, however, lies in finding compromises to align business and environmental requirements. It is a necessary and sufficient condition to immediately initiate eco-design approaches, whose feedback will help rollout and adjust the deployment on a larger scale.

Regarding the need for continuous measurement, let us mention that according to precise and reproducible measurements for the same internet browsing, meaning the same functional service provided, some internet browsers consume almost twice as much energy on the user side as others [Greenspector].

DevOps at the Crossroads of IS Implementation and Operation

DevOps consists of integrating the constraints and non-functional needs resulting from Operations (production and support) in the process of choosing, prioritizing, developing IT, and ensuring the operability of the system before deployment.

CI/CD being components of a DevOps strategy, they raise a fundamental question. They enable continuous integration of the source code into the Information System, end-to-end environments, and multiple processing chains operating 24/7. They are increasing energy consumption for a more frequent and more qualitative delivery.

This raises questions: how to control this rebound effect due to the low-cost availability of ever more powerful computer racks and deployment automation software? How to adapt the level of service according to the criticality? What is the condition for DevOps to support the sustainability of the Information System?

The following example shows how some approaches manage to balance the agility of IT on the one hand, and its carbon resilience on the other hand.

Example	The following result was delivered on the website of a large banking institution with 14 million monthly connections. During a major version upgrade of the website, a campaign to measure the environmental impact allowed the injection into the backlog of optimizations that produced the following results: • 22% energy consumed on the user side • 68% display time in 2G connection (from 46 seconds to 15 seconds) • 74% requests to servers and therefore a possibility of greatly reducing the server infrastructure for the same level of service

3.5.8 Develop in a Sustainable Way

As Paul Mobbs says, "What makes computer hardware more than an expensive collection of electronic circuits is the software we use to give the machine a purpose." [Mobbs 2012] At the heart of the information system, we find digital equipment for material parts, and the code enabling interface with human processes.

The acceleration of Digital Transformation came with requirements to speed up code production, simplify development to make it accessible to more players, and find alternatives to the shortage of competent profiles. This acceleration has often been done to the detriment of quality, and languages have therefore become more accessible but also more resource intensive. **However, the key to optimize equipment use lies within the code, whether for data storage, processing, or network flows.**

The first topic to address is the choice of the development language that has an impact as explained in "Energy Efficiency Across Programming Languages: How do Energy, Time, and Memory Relate?" [ResearchGate 2017].

Some good sustainable development practices are available on the market but are far from being complete and used systematically. Tim Frick's Designing for Sustainability [Frick 2016] or Frédéric Bordage's "*Web Eco-Design: The 115 Best Practices*" [Bordage 2019] offer for example best practices for website development. Section 3.3 proposes an approach designed to reach developers.

Achieving sustainable IT will require the generalization of sustainable development practices among software companies, digital service providers, organizations using digital technologies, teams of developers, and those in higher education and engaged in lifelong learning.

Sustainable development practices will call for:

- The establishment of a measurement of the environmental impact of the code production and its use

  It must be accessible to developers and project teams for continuous management and optimization.

- The systematic consideration of frugality before embarking on a new development: ensure that the functionality has not already been coded and that it will effectively be used
- The implementation and automation of environmental impact tests of the code during its use; as such, Greenspector offers solutions for mobile applications [Greenspector]
- The use of and the contribution to open source projects to avoid unnecessarily increases of the environmental costs of software manufacturing
- The capitalization and the active share of good practices, not only for the development of mobile apps or web front ends, but also for data processing and AI

A consensus emerges on the fact that quality code is generally sustainable code, lighter to operate both in cost and in supervision. It offers a better quality of service to users and is also easier to maintain.

To favor quality and sustainable coding, which often tend to be more time-consuming projects, it is necessary to focus on demonstrating gains in energy, service quality and maintenance during operations (i.e., beyond the cost of the project, often over several years). Finally, the approach described in Section 3.5.7 should reduce the number of functions to be developed and free up resources for others. To sum up, we will have to develop less, but better.

3.6 Measuring the Environmental Impact of the Information System from Cradle to Grave

Establishing a measure of the environmental impact of an enterprise's information system that is exhaustive and with the right orders of magnitude is crucial to properly implement the strategy and to maintain the effort over time. The full scope of the ICT environmental impact should be taken into consideration. But in a first step, the experience shows that a complete and science-based carbon footprint calculation including electricity consumption and manufacturing is enough to drive most architecture decisions. As enterprises move ahead on the digital sustainability transformation and depending on their business model, they should check regularly if other indicators should be added. Nevertheless, in a world where time and financial resources are also finite, it is important to keep the measure as simple as possible to provide science-based guidance for decision and to keep said resources to activate levers to reduce the footprint. Indeed, environmental footprint calculation at a very detailed level and covering the full scope can be quite complex.

Calculating a carbon footprint is by itself complex, and thus requires a pragmatic iterative approach which focuses on trends and orders of magnitude. It should enable the enterprise to initiate effective reduction actions quickly, rather than working on the precision of the reported information.

The deadlines and magnitude of the effort required to mitigate climate change leave little room for error: measurement ensures that new initiatives contribute to sustainability goals quantitatively. Measurement is a prerequisite to implementing governance.

> CO_2e or CO_2 equivalent (CO_2-eq), is a metric measure used to compare the emissions from various GHGs based on their Global Warming Potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same GWP.
>
> Refer to: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Carbon_dioxide_equivalent.

> In France, for instance, providing a carbon footprint is mandatory for legal persons governed by private law employing more than 500 people for mainland France or more than 250 people for overseas France. The mandatory nature covers the activities of the legal entity subject to French law on French territories, i.e., the "Scope 1" perimeters (the direct emissions produced by fixed and mobile sources needed for the activities of the legal entity) and "Scope 2" perimeters (indirect emissions related to electricity consumption, heat, or steam, needed for the activities of the legal entity). The declaration of "Scope 3", other emissions indirectly produced by the activities of the legal entity, is mandatory since 2023 but limited to the subcategories of significative importance amongst the organization's total GHG emissions.
>
> Refer to: http://apc-climat.fr/bilan-ges/reglementation/.
>
> See also Figure 12 for scope definitions.

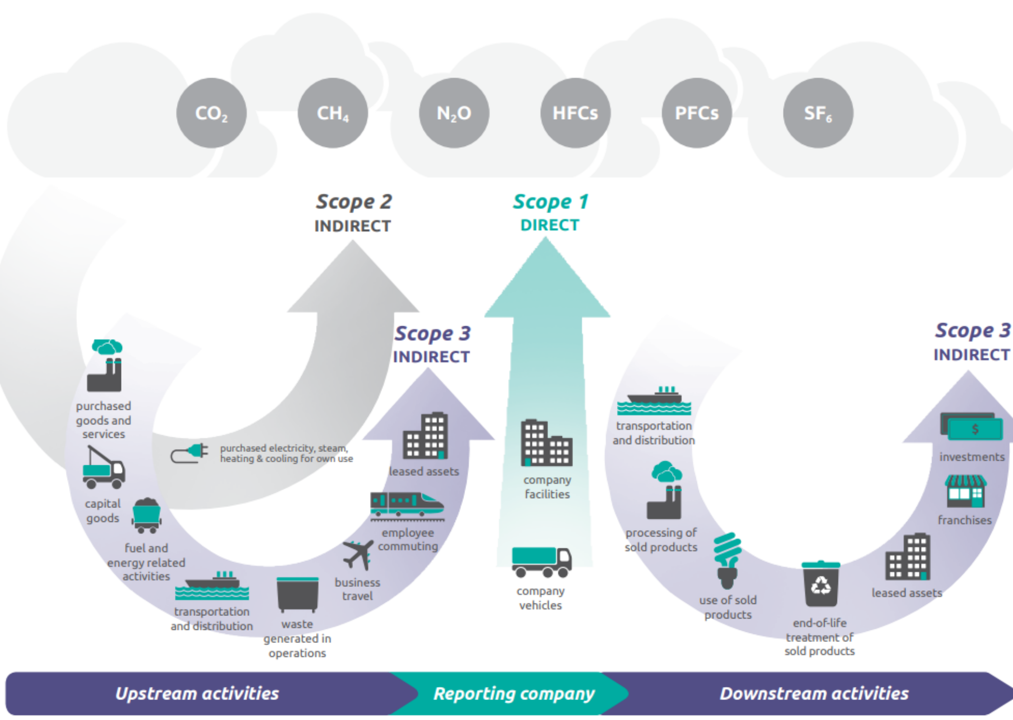


Figure 12: Overview of GHG Protocol Scopes and Emissions Across the Value Chain [Value Chain]

The environmental assessment of ICT equipment supporting the information system of an organization has the following specific features:

- It has a minor impact on Scope 1 direct emissions (e.g., leaks of refrigerants from air conditioning, fuel burned by emergency power generators in data centers)
- An important part of its GHG emissions is related to Scope 2 electricity-related emissions, due to the consumption of its data centers and workplace hardware
- As demonstrated in "*Lean-ICT: Towards Digital Sobriety*" [Shift Project 2019], more than half of its carbon footprint is in Scope 3, which means that it is related to the purchase of goods and services from suppliers

  This category is less affected by regulatory obligations, less targeted and is more opaque because it is operated by other stakeholders.
- The environmental assessment of the information system is made of GHG emissions, metals used (which are finite natural resources) volumes of soil moved to extract them, water resources, and waste and pollution generated

  For most organizations, the intensity of all their other impacts is often highly correlated to GHG emissions of Scope 3. Therefore, a thorough measurement of GHG emissions is a prerequisite to trigger the setting of targets and levers. Each organization, as they move ahead, will have to evaluate the need for additional indicators.

3.6.1 Build and Share Information System Carbon Footprint Measure from Cradle to Grave

The information system reshaping program should start with establishing a yearly environmental assessment considering the GHG emissions related to:

- The electricity consumption of the data centers operated by the organization: taking into consideration emissions intensity of the electricity mix of the electricity production area in kg CO_2/kWh
- The manufacture of servers and network equipment operated by the organization
- The use of services available on the cloud, related both to electricity consumption and manufacture of hardware
- The outsourcing of digital services such as marketing campaigns, counseling, data processing, etc.
- The use of the public Internet network
- The use of specific network suppliers and mobile operators
- The use and manufacture of devices (computers, telephones, screens, etc.) used by employees and service providers working for the organization

The management of this GHG accounting over two to three years will enable dynamic management and to check whether the environmental impact of the organization's information system is increasing, as observed on the market, or decreasing.

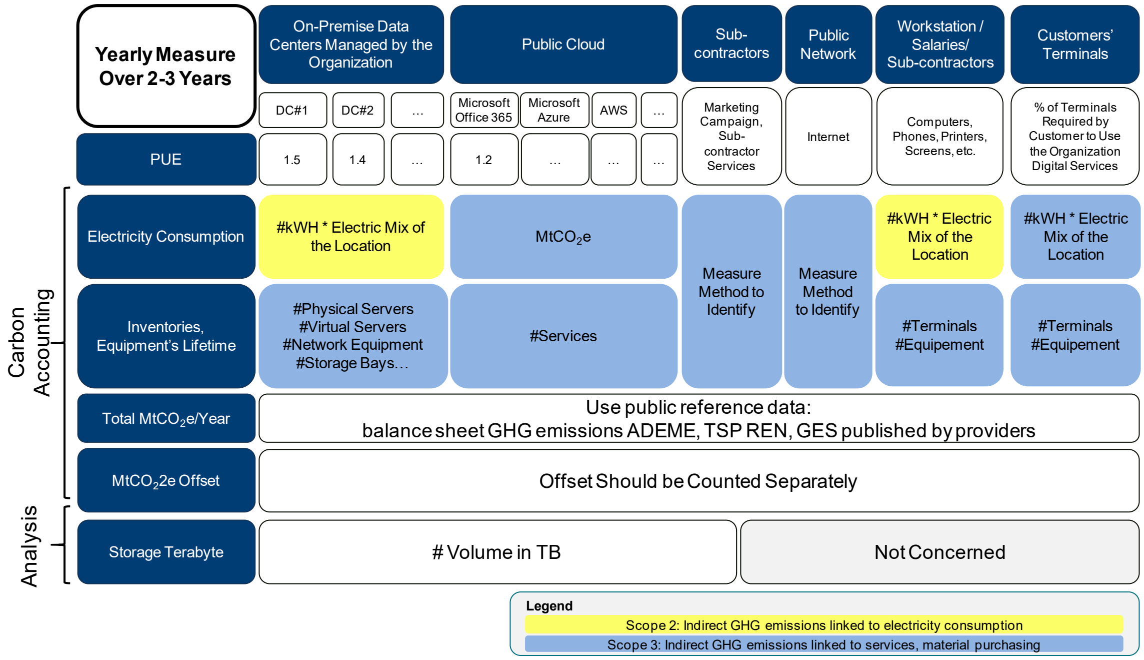


Figure 13: Yearly Environmental Assessment of the Information System (Source: The Shift Project Lean-ICT Work Group)

The model above is inspired by the work conducted by the AXA Group in 2020 as part of the digital sustainability program to measure and manage the impact of ICT.) In this schema, "public network" can also refer to mobile operators' assets.

To be pragmatic, the team leading the transformation needs to make approximations and to prioritize effort in the measurement. Indeed, some data, more often on Scope 3, can be difficult to obtain. In this case, a workaround is to calculate the orders of magnitude while waiting for the suppliers to provide the data. The absence of precise data should never result in no evaluation. For example, for providers publishing their CO_2 emissions in the Carbon Disclosure Project [CDP], one can simply evaluate the Scope 3 emissions based on their global revenue, their global emissions, and the revenue derived from one's organization:

*Scope 3 emissions = (Provider revenue from the organization / Provider Global revenue) * Provider Global emissions*

Once organizations reach this maturity stage, it is better to focus on CO_2 emissions as a steering indicator. They represent a central indicator which, when shared, enables comparison with others and with national objectives. It represents a first significant effort to be established by the organization over its full scope. Once the inventory is complete, if supplier data becomes available, it will be easy to refine this first report with new indicators regarding the use of metals, water resources, or pollution.

It is also relevant to manage offsets, but this should be done separately. The right approach is "reduce what you can, offset what you cannot". The only way to monitor reduction is to track carbon emissions separately.

This end-to-end measurement exercise will reveal "the tragedy of the scopes" which partly explains the failure of organizations to control the environmental impact of their information system despite the publication of carbon footprints.

- The optimization of electricity consumption often comes at the cost of very intense equipment renewal cycles: Scope 2 decreases but Scope 3 increases
- Moving services from data centers operated by organizations to the public cloud also reduces Scope 2 and increases Scope 3

Finally, the outsourcing of digital industry workers to countries where the cost of labour is lower presents financial advantages. However, some of these countries may be at the beginning of their energy transition and their electricity mix in kg CO_2/kWh affects the balance by several orders of magnitude. For more information on this topic, see Section 3.7.

Examples

Examples of Data Repositories and Measure Methodologies

Here are some sources of public data related to the environmental impact of computer equipment and electricity. They are vital for establishing the first measurements by crossing them with the inventories of organizations.

The ADEME (French Agency for Ecological Transition) provides freely accessible data on its website about:

- Electricity – Scope 2: mix of electricity network, means of production
- Purchased goods – Scope 3: emissions from the "cradle to grave" of products such as electrical, electronic, and computer equipment

The Digital Referential Environmental Standard [REN] is made available with Lean-ICT: Towards Digital Sobriety [Shift Project 2019]. The REN provides everyone with data on GHG emissions and metal use for the production and execution phases.

Ecoinfo is a Services Cluster Generic Data Service (GDS) bringing together engineers, researchers, research, and higher education students in France around a common goal: "Acting to reduce the (negative) environmental and societal impacts of ICTs." Among other things, with Ecodia, they provide a freely available service, which can be used to calculate the carbon footprint of an information system and the data on which the service is based.

On the supplier's side, even if the methods are not yet standardized, audited, and auditable, the following information is mentioned:

- Data in kg of CO_2-eq provided by Apple® on devices, including production, use, transport, and recycling
- Data in kg of CO_2-eq provided by Dell™ on servers, including also production, use, transport, and recycling
- Data in kg of CO_2 provided by HP™ on equipment such as workstations, printers, screens, projectors, etc.
- The durability calculator provided by Microsoft®, although presented mainly to highlight the Azure® offer, provides the MtCO_2-eq of Azure services, distinguishing between compensation and the impact of Internet network flows generated by cloud architectures
- In its site dedicated to sustainability, Google® provides information on GHG emissions, materials, etc.

NegaOctet is a carbon database for ICT assets assessing and improving the environmental performance of digital services. The repository was co-constructed by responsible digital experts on an order of ADEME, the French environmental agency. NegaOctet proposes a database containing 1,500 components and equipment classified according to four levels of granularity. Each piece of equipment is associated with up to 30 impact factors: from depletion of abiotic resources to global warming and eutrophication.

Boavizta is a French open carbon database and working group for ICT assets. It is a Non-Governmental Organization (NGO) proposing an open database and the sharing of best practices on an environmental ICT assets' footprint.

The ICT Sector Guidance [GHG ICT] provides guidance and accounting methods for the calculation of GHG emissions for ICT products and ICT services. It is built on, and in conformance with, the GHG Standard.

The OFP is currently working on a draft set of standards for representing emissions data which, when published, would be a firm foundation on which organizations can base their ICT and non-ICT emissions data in a consistent, transparent, and shareable way as explained in Section 2.3.

On the supplier's side, even if the methods are not yet standardized and auditable, the following information is available:

- Manufacturers such as Apple, Dell, or HP provide data in kgCO_2e about their devices, including production, use, transport, and recycling
- Cloud Services Providers such as Microsoft Azure or Google provide dashboards presenting the carbon emissions linked to the services that the client organization is purchasing

3.6.2 Develop Activities to Measure the Information System Environmental Impact

To perform this calculation with internal skills, the organization can rely on its employees, and/or be assisted by professional ICT consulting companies or companies specializing in carbon footprint reports.

To achieve this, the team in charge of these calculations must have or must acquire precise knowledge of the information system, in addition to the data repositories on GHG. The following data must be obtained:

- Data of hardware inventories by using, for example, the CMDB set up by ICT operations as part of Information Technology Infrastructure Library (ITIL®) procedures
- Electricity consumption of the data center and GHG emissions related to purchased digital services
- History of digital material purchase, ideally over two to three years to be able to reveal a trend
- Public cloud provider's data and reporting

3.6.3 Provide to Stakeholders a Measure of their Environmental Impact

Once the measurement of GHG emissions has been conducted for the technical components, it must be applied to the main functions of the organization, on the value chain for production of goods and services, on finance, human resources support functions, and on customer relations functions. This breakdown aims to identify the lines of business with the highest impact, making it possible to determine emission reduction goals for each function.

To achieve this, intermediate measures and indicators familiar to ICT professionals can be implemented: the increase of GHG emissions can indeed be linked to the increase in volumes stored, network traffic, and treatments carried out. In the case of services delivered by third parties such as cloud computing, when the details are not known to the user company, these intermediate measures can enable management to act while waiting for publication standards and obligations of this data to be implemented.

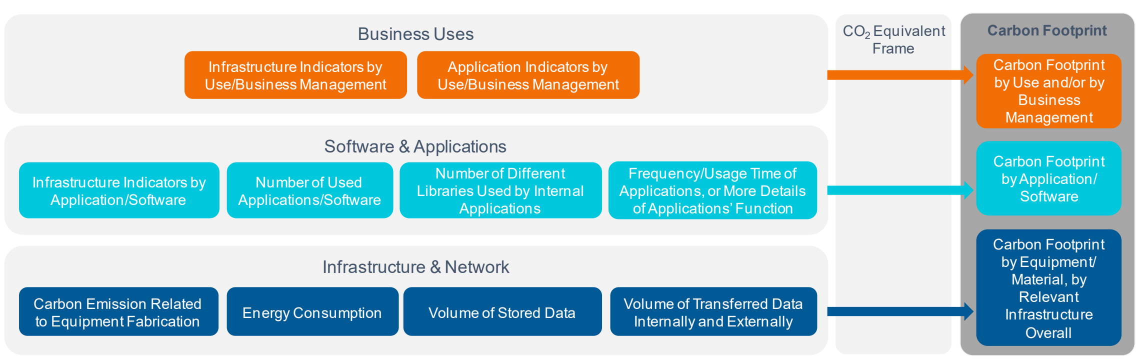


Figure 14: Measuring the Environmental Impact of the Information System at Different Levels (Source: The Shift Project Lean-ICT Work Group)

In order to give stakeholders the ability to propose levers on their decision perimeter and to assess the associated potential emissions reductions, it is useful to provide a common repository of the data used by the company to calculate its GHG digital emissions. Such a database will not only help local leaders gain time by not having to collect these inputs, but will also ensure a common calculation basis across the organization and therefore facilitate peer review and inspire others. It will also help to fight against greenwashing communications from the market and help avoid obsolete data remaining available online.

This file should include the initial, uninterpreted unitary data with its source for each perimeter considered: emissions factors from device manufacturers (run and build phases) and related electricity consumption, calculated emissions and consumption from on-premise data centers, and emissions from public cloud services. To be fully transparent on the calculation methodologies, other physical values must be communicated, such as the reference carbon intensity of energy mixes considered by the company. This repository should be presented as part of a larger onboarding of suborganizations, to help them become autonomous on the subject and to support their own bottom-up initiatives.

Table 4: Non-Exhaustive List of Fields to be Included in a Shared Carbon Database

Field Name	Unit	Type of Source	Comments
Device electricity consumption	kWh/year	Device manufacturer	To specify for the company's average models.
Device Scope 3 emissions	$kgCO_2e$/device	Device manufacturer	*Idem*.
On-premise data center consumption	kWh/vCPU, kWh/GB, or any other storage KPI	Company's data center management	To be calculated from data center energy consumption, PUE and VMs allocation per service.
Public cloud run and build emissions	$kgCO_2e$/ monetary unit	Cloud provider inputs (or CDP estimations; see previously)	A monetary indicator is easier to manipulate for entity allocation.
Carbon intensity of electricity production	$kgCO_2e$/kWh	National or international agency	For example, IEA or ADEME.

3.7 Engaging with Customers, Providers, Partners, and Authorities Towards Sustainable Solutions and Services

Many stakeholders participate in the development of a digital solution. To successfully deploy its policy, the organization will need to work in partnership with the different players involved in the sustainable ICT ecosystem. These stakeholders can be customers, service or equipment suppliers, regulatory and informational institutions, such as environmental protection agencies, higher education, or non-profit organizations acting as precursors and enabling the mobilization of citizens when corporate funding is scarce.

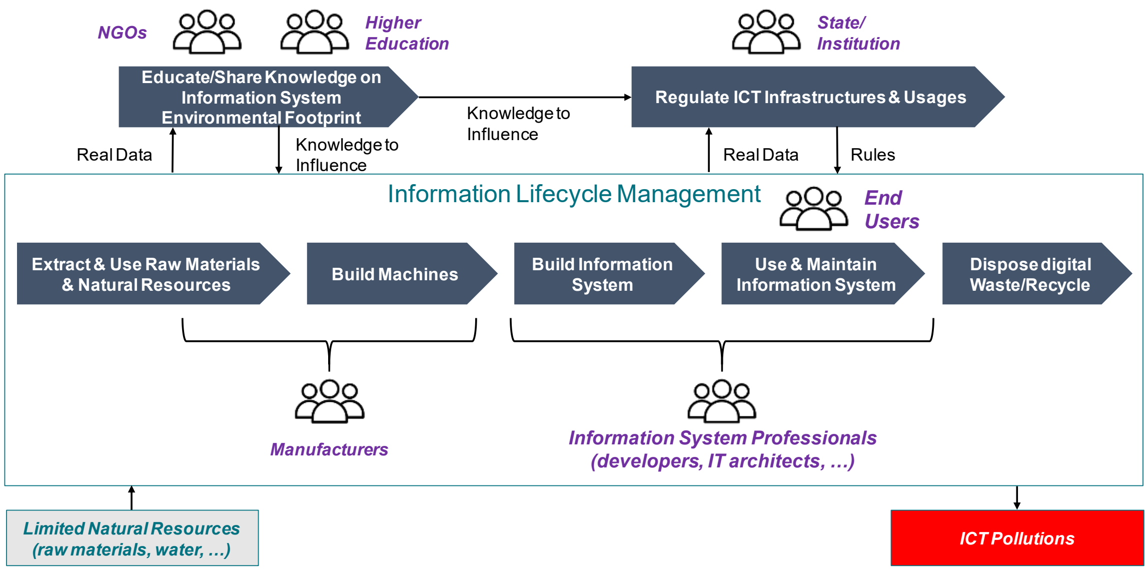


Figure 15: Information System Ecosystem Stakeholders Along the ICT Assets Lifecycle

In Section 3.7, different activities are discussed to interact with this ecosystem.

3.7.1 Ask Service Providers for End-to-End Environmental Footprint Transparency

To be able to fulfil selection criteria, the supplier must give access to comprehensive and transparent environmental footprint measurements of the equipment and services provided.

In the non-financial results chapter of their annual report, most large companies publicly share the carbon footprint of their operations, at least on Scope 1 and 2, but also increasingly on Scope 3. The Carbon Disclosure Project [CDP], an international Non-Governmental Organization (NGO), collects and publicly shares said carbon footprints in a standardized format. It enables the organization to read these reports easily, as a first step to collaborating with suppliers.

Another step towards transparency, reinforcing confidence in a provider's commitment, is external validation of action plans like the SBTi or B Corp™ certifications.[8]

The organization will also need to know the impact of its own consumption of equipment or services. Some of the hardware manufacturers provide measurements over the entire lifecycle, from "cradle to grave". However, although service providers communicate on the optimization of electricity consumption, only a few cover the full lifecycle and publish compensations and purchases of renewable energy separately. Indeed, including offsets in consolidated emissions figures is one of the bad practices across organizations, generating ambiguity and lack of transparency.

[8] Refer to: https://www.bcorporation.net/en-us/certification.

Transparency on all these indicators must be reached quickly, by emphasizing that environmental impact management can yield a significant competitive advantage. Optimization being the supplier's duty, decisions regarding uses are made within each organization and require precise data. The following actions may be considered:

- Publicly announce via the sponsor that transparency and environmental impact reduction plans give competitive advantages
- Identify the main suppliers of ICT services and equipment, set up a dialogue on the issue of sustainable ICT, work in partnership on ICT solutions with high added value and low need for resources
- Describe the expected reporting and communicate it to the supplier: electricity consumption, GHG emissions, consumption of rare metals, displaced earth, etc., and in the case of services: data volume, processing, network traffic
- Mobilize all stakeholders in contact with the suppliers to require this transparency during their exchanges, including management, technicians, and business units
- Decide to make a purchase based on environmental factors, even if costs are higher; this will send a strong signal to suppliers

3.7.2 Adapt the Selection Criteria for Calls for Tenders and Contracts with Suppliers and Partners

In calls for tenders, selection criteria related to environmental impact should be made explicit. To enable this, it will be necessary to train buyers on the criteria of sustainable ICT selection: maintenance contracts enabling extended product lifetime, purchases of robust and repairable equipment, low consumption, description, and qualification of the recycling and reuse process, etc.

New contracts signed with suppliers must reflect these commitments which are often cumbersome and difficult to implement. Finding a way to introduce environmental criteria compliance will have to be worked out with legal experts, either by revisiting the clauses relating to corporate responsibility, or by adding them where they do not exist.

Example	An example of environmental criteria in contracts is the French "matinfo" market, which is the purchasing group for computer equipment for higher education and research, in which environmental and social requirements have been considered. Refer to: https://www.matinfo-esr.fr/ecoinfo and https://ecoinfo.cnrs.fr/2018/12/04/enseignement-superieur-et-recherche-achats-informatiques-et-developpement-durable/. See also the EU GPP Criteria for Cleaning Services: https://ec.europa.eu/environment/gpp/pdf/210309_EU%20GPP%20criteria%20computers.pdf.

It is, for instance, feasible to add the following to requests for tenders or contracts:

- Obligations of means: raising awareness or training staff, adapting work methods, committing to respect specific good practices, setting up measures and indicators, etc.

  This implies the need for suppliers to be able to prove that their staff are well trained, via third-party certificates or the availability of training program results.

- Obligations of results: maximum amount of data, energy consumed during the user process, ability to operate on low-power equipment, etc.

To promote the use of long-lasting equipment, the following approaches can gradually be adopted:

- Considering Total Cost of Ownership (TCO) over the full lifetime – until waste treatment – for the purchases of equipment (PC, smartphones, servers, etc.) will favor considering the environmental criteria, over only considering initial acquisition costs
- Choosing suppliers enabling both the maximum reuse of the material making up their equipment, and a change in the way their products are consumed, by favoring access to digital services over acquisition

  Such offers are still rare but are starting to appear on the market, with players offering rental of smartphones, computers, and headsets, for businesses and individuals, by committing to transparent and eco-responsible management. In this type of operation, the supplier no longer has an interest in renewing the equipment but, on the contrary, benefits from making it as sustainable as possible.
- Defining what is going to happen for equipment after your company has used it: refurbishment, end-of-life, dismantling, etc.

3.7.3 Define the Procurement Strategy

The procurement of equipment or services faces two strategic choices:

- Insource or outsource the capacity
- Choose the location of the assets: onshore (e.g., national territory of the organization), nearshore (depends on the organization location), or offshore

These choices can influence CO_2 emissions by several orders of magnitude due to variations in the energy mix of different countries.

Beyond the carbon footprint, changes in the choice of suppliers will be necessary to reduce to a minimum the number of intermediaries between producer and consumer. The objective will be to limit logistics flows, to pinpoint negative externalities and avoid forgetting them, and to have maximum proximity and access to the supplier's activities. From a corporate accountability perspective, the more distant the supplier (either physically or through intermediaries), the more difficult it is to ensure its ethics.

Finally, the ability to participate in the decision-making process regarding the evolution of the service or of the supplier's product will also be a factor to ensure the sustainability of the provided service. Thus, already existing user groups will have to be strengthened, and better involved in the supplier's strategy.

3.7.4 Comply and Go Beyond the Regulatory Environmental Reporting Requested by Authorities

The organization will have to conduct the regulatory environmental reporting defined by the local authorities. The measure of the environmental impact is today normalized by the ISO standards that organizations should follow. These are:

- Lifecycle assessment:
  - — ISO 14040:2006: Environmental Management – Lifecycle Assessment – Principles and Framework [ISO 14040:2006]
  - — ISO 14044:2006: Environmental Management – Lifecycle Assessment – Requirements and Guideline [ISO 14044:2006]
  - — ISO 14009:2020: Environmental Management Systems – Guidelines for Incorporating Material Circulation in Design and Development [ISO 14009:2020]
- Carbon accounting:
  - — ISO 14064-1:2018: Greenhouse Gases – Part 1: Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals [ISO 14064-1]

In France, companies must record their carbon footprint [Carbon Neutrality] on a regulatory GHG report (see Section 3.6.2 for details about the different scopes).

In the US, the Securities and Exchange Commission (SEC) [SEC] proposes to include Scope 3 more systematically.

These regulations should continue to be reinforced in France, in Europe, and eventually worldwide, as already observed in the regulations related to personal data management (GDPR in Europe). In France, the REEN Law [REEN Law] was adopted in November 2021 as a baseline for stronger regulations, aiming to reduce digital environmental impact.

While awaiting these regulatory changes, and given the urgency to act, it is beneficial for organizations to anticipate and go beyond regulatory obligations. They should decide to move ahead on transparency, publish and share with their customers the GHG emissions of ICT equipment related to the service they provide and tools to reduce it.

Half of ICT's environmental impact is driven by manufacturing [Shift Project 2019], which does not necessarily take place in the country where the resource is used. As a result, being compliant with regulatory reporting does not necessarily make it possible to move towards sustainable ICT. This trend is reinforced by using digital hosting services to replace data centers directly operated by organizations.

3.7.5 Involve Customers in the Goal of Digital Sustainability

Societal awareness of climate risk has led many companies to take committed positions on environmental impact to improve public perception.

If such announcements can increase environmental climate risk awareness on the market, it should nevertheless be noted that it is counterproductive to communicate on CO_2 emissions reduction by only talking about consumption of renewable electricity or by including carbon offset. It gives the illusion that it is possible to extend uses without environmental drawbacks, which is incorrect, dangerous, and ineffective from the point of view of the collective evolution towards a sustainable digital world. It also poses a reputational risk from greenwashing of the organization. In fact, optimizations in electricity consumption come at the cost of very frequent hardware renewals. It is only useful for an organization to communicate its objectives and results if the full scope is taken into account. Furthermore, once "net electricity GHG emissions are zero", the company cannot develop sustainability anymore, because there is apparently no more environmental saving. This is a dead end.

> Behind the green electricity ("market-based" accounting) lies a complex mechanism of certificates proving that a certain volume of renewable energy is injected into the national grid; however, actual consumption is not linked to what is bought, but physically linked to the local energy mix ("location-based").
>
> These certificates are dependent on market conditions, and still play a secondary role in financing the development of renewable energies, which strongly depends on national policies.
>
> Refer to the Greenhouse Gas Protocol [GHG Protocol] and "Green" Electricity: A Useful Tool for Businesses? [Carbone4 2019].

It will therefore be necessary to enhance this activity following the steps recommended by the Net Zero Initiative [Carbone4 2020] to:

- Publish objectives and results of the full scope excluding carbon offset
- Be transparent about the computation method and the benchmarks used
- Share data related to actions towards sustainable ICT with transparent sources and methodology

In addition to communicating at the company level, it is important:

- To provide customers with a measurement over time of the environmental impact of the digital services they use (e.g., website, online sales application, hosting or computation services, etc.); this will enable customers to play their part, to moderate their uses based on this criterion, and to choose the most responsible suppliers, or at least the most transparent
- To support customer efforts towards digital sustainability (for example, by enabling customers to self-impose limits to their use of the provided services)

3.7.6 Influence the Market, Capitalize on Knowledge by Contributing to Public Papers

To win the race against time to contain CO_2 emissions, the organization can contribute by sharing good sustainable ICT practices. The objective is to make them freely available to higher education teachers, all organizations using digital solutions, and all suppliers of ICT equipment and services. It is about creating emulation in the sector, enabling a collective acceleration towards sustainable ICT that meets the urgency of the situation.

This activity can be broken down into different actions:

- Contribute to inter-organization working groups capitalizing on good sustainable ICT practices
- Share data related to the environmental impact of the information system to increase publicly available data on this topic
- Provide financial support to non-profit organizations managing open resources
- Ask suppliers to refer to these publications

Examples of non-profit organizations involved in the transformation towards sustainable ICT include:

Worldwide:

- The Open Group is an international organization dedicated to the development and deployment of standards in the digital world
- The Green Software Foundation aims to build a trusted ecosystem of people, standards, tooling, and best practices for creating and building green software

In Europe:

- European Institutes for Sustainable IT (ISIT) is a European network of institutes for sustainable IT grouping French, Swiss, and Belgian analysts [ISIT GR491]

In France:

- The Shift Project through the Lean-ICT Work Group, sponsored by organizations and associated publication work
- The Cigref is an association representing the largest French companies and public administrations which exclusively use digital solutions and services, supporting its members in their collective reflections on digital issues; a "Digital Sobriety" working group is working on the publication of recommendations on this subject
- The Institute of Responsible Digital Technology (INR) is a French think tank bringing together experimentation and promotion of good practices for more regenerative, inclusive, and ethical digital technology

To conclude, the digital ecosystem has already started to optimize resources and share infrastructure with digital hosting services, which will come to replace a sizeable portion of the data centers operated directly by organizations.

All stakeholders in place must now weigh in to make digital technology sustainable, and make it evolve towards a virtuous economic model from the viewpoint of planned sustainability and of the tools of frugality. It must enable all stakeholders, customers, businesses, and developers to reduce their usages and "do their part". The approach is intended to develop current economic models so that they can continue to function in an environment in which resources and equipment renewal are no longer infinitely available and where environmental pollution is minimized.

3.8 Operating a Sustainable Information System

3.8.1 Manage Digital Equipment Inventories

An accurate inventory of digital equipment required by the organization is one of the foundations of the environmental impact measure. It should cover servers and network equipment, but also monitors, laptops, desktops, tablets, smartphones, meeting room video equipment, peripherals (keyboards, mice, headphones, etc.), printers, TV screens, etc. Inventories can be maintained automatically (for connected devices), through purchasing and invoices, or manually. ICT asset inventory management is one of the functions of a Configuration Management Database (CMDB).

3.8.2 Support the Increase in Usage Period of Digital Equipment

Increasing the usage period of digital equipment also requires changes to the habit of always buying brand new equipment, which is more fashionable and better performing, and then dispose of old devices. For enterprises, this means dedicating more resources to equipment protection and repair. Repairing means creating the ability and culture for the help desk and technical employees to have the ability and willingness to tackle basic recurrent problems, like changing batteries or repairing screens.

3.8.3 Monitor Digital Consumption

With the optimization of all ICT functions like storage, network, processing, and the development of Software as a Service (SaaS) solutions, ICT departments have lost some of the monitoring habits they formerly adopted for indicators like server activity, data volumes, and number of connections. There is a strong link between consumption of digital services and pollution. Indeed, while improvement of technical efficiency has allowed absorption of part of the digital pollution impact, efficiency boundaries will soon be reached. If the volumes continue to increase, the worst-case scenario is that impacts will increase as well.

The development of cloud architecture that offers "on-demand" ICT resource has led to the creation of a new activity in ICT departments called FinOps9. It is a management practice that promotes shared responsibility for an organization's cloud computing infrastructure and costs. A good practice is to add the environmental Key Performance Indicators (KPIs) – such as electricity consumption, GHG emissions – to FinOps monitoring.

3.8.4 Load-Shedding for Data Center on Demand of Electricity Operator

In a context of tensions on the electricity network, expected to occur more frequently due to physical constraints and geopolitical conflicts, a contract can be established between an organization and the local electrical network operating company so that its facilities can be disconnected from the grid, and therefore prevent a general power outage.

On the enterprise's side it means being able to:

- Switch off "nice to have" electricity consumption (e.g., information TV screen, double monitors in the workplace, etc.)

[9] FinOps is an evolving cloud financial management discipline and cultural practice that enables organizations to get maximum business value by helping engineering, finance, technology, and business teams to collaborate on data-driven spending decisions. Refer to: https://www.finops.org/introduction/what-is-finops/.

- Switch off electricity consumption that is not mandatory for the core business of the organization
- Postpone intensive digital consumption with no critical real-time requests
- Switch on its own electricity generator (but that often requires fossil energy stocks to run and produces carbon-intensive electricity)
- Monitor its electricity consumption

3.9 Governing the Transition Towards a Sustainable Information System

Implementing a strategy for information system durability requires an enterprise to broaden its point of view by including environmental factors in its decision-making process. Businesses then face deep changes in the way they evolve, especially in how they define their economic model, their strategic vision, their architecture, their partnerships, or their solutions. The success of this strategy requires real synergy between all these aspects, which eventually leads to setting up strong governance to make the transformation happen.

> Governance is the system through which an organization makes decisions and applies them to reach its goals. The decision-making process can be formal, relying on well-defined processes, or informal, relying on the individual actions of people in the organization.

Including environmental aspects in the decision-making process requires the use of new indicators, related to GHG emissions potential, rare metals mining, or water usage, which will inform decisions and enable the monitoring of the transformation process.

The point is to consider the entire business ecosystem instead of keeping a narrow point of view (which may threaten the balance and sustainability of the organization). In other words, it is about "systems thinking".

> Systems thinking is a way of making sense of the complexity of the world by looking at it in terms of wholes and relationships rather than by splitting it down into its parts. It has been used as a way of exploring and developing effective action in complex contexts, enabling systems change. In organizations, systems consist of people, structures, and processes that work together to make an organization "healthy" or "unhealthy". (See "*Thinking in Systems*", by Donella Meadows [Systems Thinking].)

3.9.1 Making Decisions with the Environment in Mind

At every level of the company, formally or not, decisions impacting the environment are made, directly or indirectly. Making these decisions compatible with digital sustainability requires stalwart decision management that favors balance.

> Decision-making is the key element of governance and must be managed accordingly. Decision-making is critical to design choices having a measurable impact on business; those choices are usually seen as difficult to make and/or expensive to change.

This new decision-making process is based on two essential notions of the architectural governance framework: the decision log and the decision repository.

The Decision Log

The decision log makes it possible to list the various criteria that the organization wishes to put forward in its decision-making – these should include the environmental criterion. The decision log enables the company to track decisions, share information among staff, and update this information.

Table 5 shows a decision-making example where a company wishes to set up a new mobile application for its customers. (Note this is only an example as the development of a mobile application requires in-depth case-by-case analysis.)

Table 5: Example of Implementation Scenarios Definition Considering Environmental Criteria

Scenarios	**Scenario 1**	**Scenario 2**	**Scenario 3**
Description	Implementation of a native mobile solution.	Implementation of a hybrid mobile solution.	Implementation of a progressive web app solution.[10]
Meaning	Development of a solution for each mobile operating system (iOS®, Android™, etc.).	Development of a web-based common core integrating with operating system-dependent solutions.	Development of a common solution for all operating systems.
	Hosting of mobile applications on the organization's hosting platform.		
Substantiation	Not selected	Not selected	Experience close to that of a native mobile application; reduction of development volume, of costs, and of environmental impact; compatibility with continuous deployment.
Owner	Business		
Stakeholders	Business, ICT professionals, Finance, Environmental Management Person		
Validation	Executive Committee		
Scope of Application	Customer Channels		
Field	Business and Information System		
Environmental Criteria			
GHG (Manufacturing)	1,200 tCO2e	890 kgCO2e	400 kgCO2e
GHG (Use)	580 kgCO2e/year	360 kgCO2e/year	170 kgCO2e/year

[10] Type of application software delivered through the web, able to provide the user with the same interface as a native or mobile app.

Scenarios	Scenario 1	Scenario 2	Scenario 3
Rare Metals	2,050 kg	1,400 kg	960 kg
Potable Water	21,000 liters	15,000 liters	6000 liters
Financial Criteria			
Business Value			
Functional Criteria			
Non-Functional Criteria			
User Experience Criteria			

To add the environmental criterion to decision-making, it is important to have reference tables enabling fast and efficient measurement of CO_2e emissions, rare metals extraction, and drinkable water use, according to the company's assumptions. This reference data can come from multiple sources.

Here, the company weighed the environmental criterion across several fundamental criteria, such as finance, functional coverage, and customer experience.

The Decision Repository

The decision log can be recorded in a decision repository that is shared within the company, ensuring traceability, sharing, updatability, and availability of decisions.

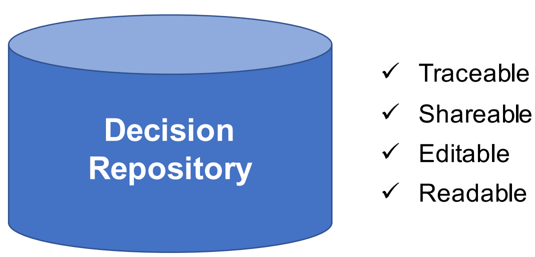
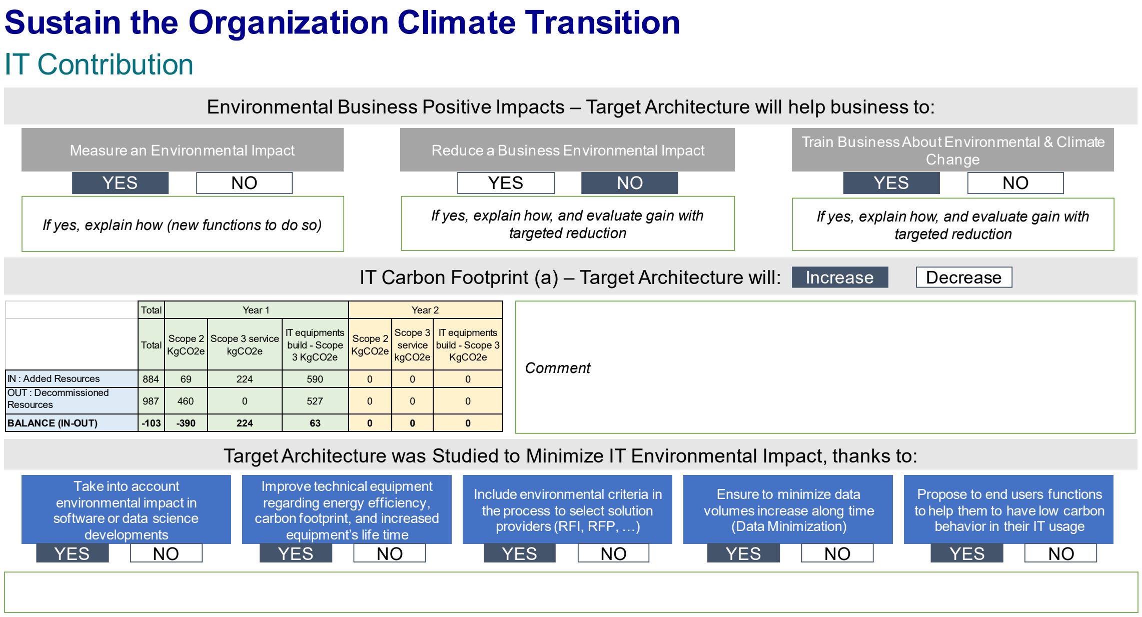


Figure 16: The Decision Repository

Figure 17 shows an example of a template for a digital sustainability review in an Enterprise Architecture governance board.



	Total	Year 1			Year 2		
	Total	Scope 2 KgCO2e	Scope 3 service kgCO2e	IT equipments build - Scope 3 KgCO2e	Scope 2 KgCO2e	Scope 3 service kgCO2e	IT equipments build - Scope 3 KgCO2e
IN : Added Resources	884	69	224	590	0	0	0
OUT : Decommissioned Resources	987	460	0	527	0	0	0
BALANCE (IN-OUT)	**-103**	**-390**	**224**	**63**	**0**	**0**	**0**

Figure 17: Template for Digital Sustainability Review in AXA Enterprise Architecture Governance Board

3.9.2 Setting up Decision Validation Bodies Aligned with the Environmental Issue

Governing the information system in a context of energy transition requires adjusting the decision-making bodies, by including decisions with a significant environmental impact. To achieve this, there must be criteria determining whether a decision should be submitted to a governance body. Table 6 shows examples of such criteria.

	A decision-making body assembles all stakeholders to facilitate decision-making by considering all viewpoints.

Table 6: Example Criteria for Submitting a Decision to a Decision Committee

Criterion	Substantiation
New application hosting service	Changing the hosting service is a critical choice regarding the information system's energy consumption, and therefore its environmental impact.
New application service	Any new application component consumes additional resources.
Emission greater than Y tCO2e	The company deems that beyond this threshold, the environmental impact is significant.

Several levels of governance are possible depending on the size of the organization. Depending on its environmental impact, a decision may just be recorded, then communicated for endorsement, or be escalated to the relevant body according to the chosen criteria. This process is like the one used in budget impact-based decision-making.

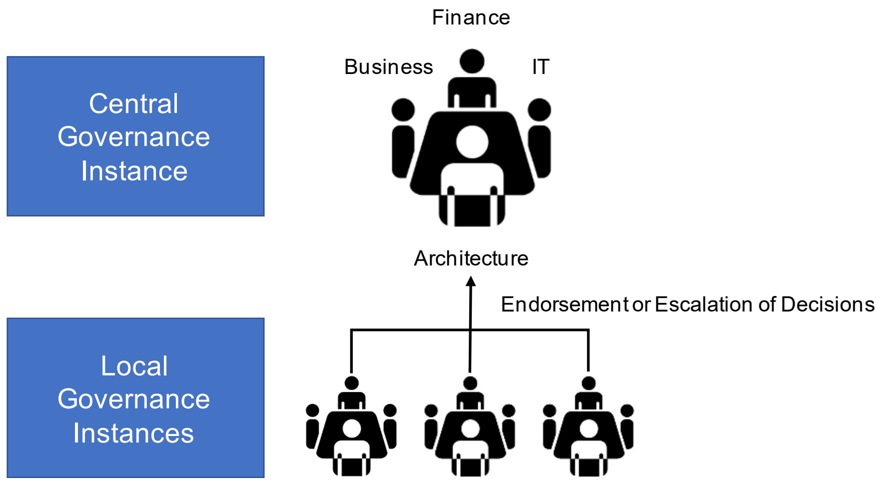


Figure 18: Diagram of a Distributed Governance Model (Source: The Shift Project Lean-ICT Work Group)

3.9.3 Setting up Architecture Principles for Eco-Responsible Decision-Making at All Levels

Most decisions are made informally, during day-to-day work among operational teams. Guidelines help all employee decisions converge towards the information system's sustainability strategy.

These guidelines can be communicated, for instance, through manifestos, standards, or flowcharts.

> Architecture Principles define general properties that should apply to every system in the company.

Figure 19 shows examples of company Architecture Principles.

Figure 19: Governance Principles for a Sustainable Information System (Source: The Shift Project Lean-ICT Work Group)

Table 7: Description of Key Company Architecture Principles for Sustainability

Company Architecture Principle	Description	Substantiation
1: Training, internal, and external communication	Provide employees, managers, and shareholders with training on the energy/climate issue and the environmental impact of digital technology. Rigorously communicate, internally and externally, on the sustainable ICT approach by following the external communication processes.	Make all stakeholders understand the need for significant change. Weigh on the market so it evolves. Brand: Attractiveness for customers and employees.
2: Transparent measurement of the environmental footprint of digital services	Measure the end-to-end environmental footprint of the organization's digital services, and communicate the results to employees, suppliers, customers, partners, etc. Start with CO_2e over the entire product lifecycle and move towards other indicators when necessary to raise awareness and make reduction decisions.	Making Scope 3 impact visible to customers gives them the means to reduce their environmental impact. External transparency enforces more results. Brand: Attractiveness for customers and employees. Regulations: Comply with transparency requirements of national regulations
3: Responsible use of digital services and equipment	Avoid anything that is not necessary; avoid rushing into adopting new technology (which often turns out to be nothing more than hype). Help users be more frugal with their use of services. Set constraints and limits via quotas (data cap, network usage cap, etc.).	Limiting use reduces demand for technical systems whose production and use have an impact on the environment. Regulations: A note from the French Senate suggests regulating the offer of phone plans and limiting the impact of video usage [French Senate].
4: Use of shared, sustainable digital services	When a new digital service is put in place, it should be designed and built to maximize reuse and sharing. For instance, encourage renting ICT equipment and services (computers, phones, infrastructure, etc.) from responsible suppliers, depending on the offer.	Mutualization reduces the total amount of resources required. The organization needs the service provided by digital equipment; it does not need to manage digital waste. Choosing suppliers committed to their products' entire lifecycle will naturally make suppliers evolve towards sustainability.

Company Architecture Principle	**Description**	**Substantiation**
5: Knowledge sharing	Use open source, open data, open architecture, fabrication laboratory. Encourage and contribute to "open" initiatives. Learn to share; instill a culture of sharing: document, build architectures by separating generic structure from specifics (the Architecture Continuum principle of the TOGAF Standard). Get involved in standardization processes.	Choosing open source can be a solution to avoid technical obsolescence and allow longer usage of hardware [Mobbs 2012]. Share everything that can be shared without harming the organization, to avoid the environmental costs of reinventing the wheel; focus efforts on sustainable transformation. More openness and sharing will promote interoperability; for example, on low-level components, and therefore repairability. Finally, optimization (Principle 7) will only have to be done once. Brand: Attractiveness for customers and employees.
6: Reusing, repairing, and recycling equipment	Be efficient: use equipment while functional, and make sure to shut it down after replacement. Favor a circular economy. Repair rather than replace. Encourage reuse, in particular recyclable/recycled components.	Reuse and repair: limit both the use of materials and energy consumption. Operational efficiency: not buying new equipment saves costs.
7: Optimization of resources, decrease of pollution	Optimize not only infrastructure use, but also manufacture and repair: energy efficiency, use of low carbon energy, limit use of materials, choice of renewable materials, etc.	Reduce the environmental impact of operations.
8: Design of repairable, reusable hardware and services	Favor modular designs assembling interoperable and reusable components as described in the TOGAF Standard with concepts such as interoperability and building blocks.	Ease reuse, maintenance, and sharing of architecture patterns, design, and ideas as well as hardware or software. Operational efficiency: not buying new hardware or new services reduces costs.

Company Architecture Principle	Description	Substantiation
9: Selection of suppliers that apply these principles	Know the environmental impact of purchased products and services to measure the organization's Scope 3 and take action to reduce it. Promote local production and repairs (i.e., reduce need for transportation). Choose suppliers involving their customers in product development choices.	Organizations use many suppliers and partners. Value chains are regularly reconfigured, leading to changes in the scope of responsibilities and transfers of environmental impacts between countries, between organizations. To be fully effective, these principles must be applied to the whole value chain (upstream and downstream). Physical proximity reduces distances travelled, and therefore energy consumption. Involvement in developmental choices of services and products makes it possible to guarantee their relevance over time for the organization.

This list is intended to inspire organizations; they will have to make it their own and adapt it. It was developed to move the information system towards a sustainable state. It is based on the principles explained in:

- The TOGAF Standard [C220]
- Leverage points: places to intervene in a system [Systems Thinking]
- The Symbiotic Economy [Delannoy 2017]

There are also reference principles, developed by actors addressing digital sustainability:

- Software eco-design principles, offered by the Green IT association[11]
- Principles of green engineering offered by the United States Environmental Protection Agency[12]

Governing based on principles and patterns is one of several good practices fostering self-governance and autonomy of agile teams. It is up to every architectural organization and to every architect to adapt them to context, to associate them with the most relevant patterns, and to put forward the most efficient technological standards.

Just like decisions, new manifestos, standards, and flowcharts must be evaluated against environmental criteria, and validated by a dedicated body.

[11] Refer to: https://www.greenit.fr.
[12] Refer to: https://www.epa.gov.

3.9.4 Monitoring and Assessing the Architecture's Compliance with Environmental Goals

Monitoring and verifying the compliance of the architecture enables the early detection of deviations from sustainability goals, which then enables either a realignment towards the goal, or identification of an "environmental debt" (see Section 3.9.5).

"Acceptance criteria" are means to confirm the adequacy of the implementation with the architectural decision, by providing proof.

Acceptance criterion: The "delivery" service of application X that is no longer used is decommissioned and this is properly tracked in the CMDB.

Justification: Conforming to the **"Maximize reuse of functions and application data flow"** principle, after having processed a functionality, the company must not forget to decommission unused features.

> Some checks can also be automated by leveraging the software production chain. For instance, with website design: implementation patterns can follow the "Avoid data transfer when possible" principle, such as caching data or using a Content Delivery Network (CDN). Use of these patterns can be automated via software production lines (CI/CD).

3.9.5 Managing Environmental Debt in the Information System

An information system built without considering the environmental aspect will inevitably lead to debt.

> Environmental debt is the consequence of a decision misaligned with the trajectory of the company aiming to establish a sustainable information system.

Debt must be managed so that it can be properly absorbed in accordance with the established sustainability strategy. It can be classified along several criteria, such as the principles, standards, or thresholds beyond which the architecture is considered unacceptable. The information system's debt can be recorded in the "debt journal".

Acceptance criterion: Duplicated functionality in the information system.

Justification: See the "Maximize the reuse of functions and application data flows" principle.

It is important to be aware of the creation of intentional debt when taking a decision – this may be due to time constraints, legal constraints, etc. It must be identified, tracked, and measured. It is also important to be aware of the creation of unintentional debt during architecture audits.

Finally, debt must systematically lead to the creation of an elimination plan describing how it will be reduced over time. Debt should be reviewed on a recurring basis to ensure the proper execution of the elimination plans.

Examples of Debt

Decision Reference	#1
Debt	Delivery initiation is duplicated across channel types.
Description	Historically, every channel has defined its own delivery functionality, multiplying the number of required resources by the number of channels.
Elimination Plan	Coalesce delivery functionality into a service that is atomic enough to meet all specifics.
Environmental Cost	1,000 kgCO2e/year
Risk	Failure to meet the annual target of a 30% reduction in CO2 emissions carbon tax.

Technical debt measurement is a concern in most organizations. To this, we now add environmental debt measurement. New native cloud architectures and increasingly automated software production chains now enable the user to imagine functional redundancy-based or data flow-based debt identification.

4 Process and Methodology: Using the TOGAF ADM to Build a Digital Sustainability Capability

In this chapter, the proposition is to leverage the full TOGAF ADM to support governance and decision-making for the incremental transition towards a sustainable information system.

This chapter describes how to leverage the TOGAF ADM to deliver a digital sustainability capability from a baseline to a target architecture in an incremental approach supported by transition architecture. It maps ADM phases with activities described in the digital sustainability capability and it proposes a sequence to deliver them. The mapping was done to propose a coherent sequence that could be followed to set up a digital sustainability capability while leveraging the tooling provided by TOGAF ADM. This is not intended as a self-standing description, and it should be read in conjunction with the TOGAF Standard.

For each phase, the high-level objectives are reminded and customized to the specific topic of digital sustainability while inputs, steps, and output are mentioned only when relevant.

4.1 Preliminary Phase

Launching a transformation process to build a digital sustainability capability in each organization requires a **prerequisite sustainability culture** that can come from the ecosystem and/or from internal cultural change that can be instigated by the top management and CSR teams.

This culture at some point will allow to decide the launch of a transformation to create a digital sustainability capability that will be the starting point for a TOGAF ADM preliminary phase.

Objectives:

- Determine the digital sustainability capability desired by the organization
- Establish the digital sustainability capability for the organization

Inputs:

- Reference Materials External to the Enterprise:
  - — Perform a review of authorities' sustainability requirements and existing sustainability standards; refer to Section 3.7.4
  - — Check available standards on environmental footprint measure and choose the one relevant to the enterprise business; refer to Section 3.6.1
- Non-Architectural Inputs:
  - — Enterprise Sustainability Strategy

Steps:

- Confirm and elaborate upon Architecture Principles for Sustainability, including business principles: guidance is provided in Section 3.9.3

Outputs:

- Request for Architecture Work for a digital sustainability capability is worth to formalize and can be a topic for internal and eventually external communication towards vendors and the ecosystem.
- Architecture Principles for Sustainability

4.2 Phase A: Architecture Vision

Objectives:

- Develop a high-level aspirational vision of the digital sustainability capabilities and business value to be delivered resulting of the proposed Enterprise Architecture

  The level of maturity expected at the end of the transformation on each activity of the digital sustainability capability described in Chapter 3
- Obtain approval for a Statement of Architecture Work that defines a program of works to develop and deploy the architecture outlined in the Architecture Vision

Steps:

- Establish the architecture project
- Identify stakeholders, concerns, and business requirement: the importance of executive sponsorship is detailed in Section 3.4.3
- Confirm and elaborate business goals, business drivers, and constraints: understand the "Climate Strategy" of the organization and define digital sustainability goals consistently
- Evaluate capabilities
- Assess readiness for business transformation
- Define scope
- Confirm and elaborate Architecture Principles for Sustainability, including business principles
- Develop a Sustainable Architecture Strategy; Section 3.4.3 provides guidance
- Develop an Architecture Vision of what the sustainable information system should be in a 10-year delay to allow concrete action, give a sense of the change required and create a sense of urgency
- Define the Target Architecture value propositions and KPIs: a baseline of the information system's carbon footprint needs to be calculated with the definition of a high-level improvement target aligned with enterprise commitments; guidance on the measure is provided in Section 3.6
- Identify the business transformation risks and mitigation activities. Guidance on risk assessment is provided in Section 3.4.2
- Develop Statement of Architecture Work, secure approval

Outputs:

- Approved Statement of Architecture Work
- Strategy for Sustainable Information Systems: guidance is provided in Section 3.4
- Sustainable ICT Architecture Vision
- Communication Plan; see Section 3.3.3

4.3 Phase B: Business Architecture

Objectives:

- Develop the Target Business Architecture that describes how the enterprise needs to operate to achieve the business goals and respond to the strategic drivers set out in the Architecture Vision, in a way that addresses the Statement of Architecture Work and stakeholder concerns
- Identify candidate Architecture Roadmap components based upon gaps between the Baseline and Target Business Architectures

Step:

- Develop Target Business Architecture Description: refine the high-level environmental target set in A-Vision

Outputs:

- Digital sustainability Education Program with list of available trainings, list of skills; see Section 3.3.2 for guidance
- Procurement Strategy; see Section 3.7.3

4.4 Phase C: Information System Architecture – Data and Application Architecture

Objectives:

- Develop the Target Information Systems Architectures, describing how the enterprise's Information Systems Architecture will enable the Business Architecture and the Architecture Vision, in a way that addresses the Statement of Architecture Work and stakeholder concerns
- Identify candidate Architecture Roadmap components based upon gaps between the Baseline and Target Information Systems (Data and Application) Architectures

4.5 Phase D: Technology Architecture

Objectives:

- Develop the Target Technology Architecture that enables the Architecture Vision, target business, data, and application building blocks to be delivered through technology components and technology services, in a way that addresses the Statement of Architecture Work and stakeholder concerns
- Identify candidate Architecture Roadmap components based upon gaps between the Baseline and Target Technology Architectures

4.6 Phase E: Opportunities and Solutions

For digital sustainability, the analysis of the Opportunities and Solutions phase could be particularly complex because it depends on the ecosystem maturity (suppliers, users, customers, etc.) and available external solutions. It requires engagement with customers, providers, partners, and authorities to deliver sustainable solutions and services. It is also important to multiply available opportunities and encourage a market shift towards more sustainable solutions.

Refer to Section 3.7 for more details.

Objectives:

- Generate the initial complete version of the Architecture Roadmap, based upon the gap analysis and candidate Architecture Roadmap components from Phases B, C, and D
- Determine whether an incremental approach is required, and if so, identify Transition Architectures that will deliver continuous business value
- Define the overall Solution Building Blocks (SBBs) to finalize the Target Architecture based on the ABBs: check the compliance of the chosen solutions with the environmental footprint measure transparency requirement and an effective contraction of the environmental impact

  This is where we make the important choices about which technologies will be used to maximize the benefits to the sustainability objectives.

4.7 Phase F: Migration Planning

Objectives:

- Finalize the Architecture Roadmap and the supporting Implementation and Migration Plan
- Ensure that the Implementation and Migration Plan is coordinated with the enterprise's approach to managing and implementing change in the enterprise's overall change portfolio
- Ensure that key stakeholders understand the business value and cost of work packages and Transition Architectures

Step:

- Prioritize the migration projects through the conduct of a cost/benefit assessment and risk validation: the measure of environmental footprint guide priorities and allow balancing the size of the impact and the difficulty of the transformation; guidance on the measure is provided in Section 3.6

4.8 Phase G: Implementation Governance

Objectives:

- Ensure conformance with the Target Architecture by implementation projects
- Perform appropriate Architecture Governance functions for the solution and any implementation-driven architecture Change Requests

Steps:

- Perform Enterprise Architecture Compliance reviews to check that environmental targets are delivered: guidance is provided in Section 3.9.4
- Implement Business and IT Operations: refer to Section 3.7.2 for guidance

Output:

- Governance Decision log; refer to Section 3.9.1

4.9 Phase H: Architecture Change Management

Objectives:

- Ensure that the Architecture Development Cycle is maintained
- Ensure that the Architecture Governance Framework is executed
- Ensure that the Enterprise Architecture Capability meets current requirements

4.10 ADM Architecture Requirements Management

The Requirements Management phase should be based on concrete validation criteria, where the carbon footprint measure will be a key input. Indeed, measuring is central to alignment and to check reduction requirements. Guidance on the measure is provided in Section 3.6.

Objectives:

- Ensure that the Requirements Management process is sustained and operates for all relevant ADM phases
- Manage architecture requirements identified during any execution of the ADM cycle or a phase

- Ensure that relevant architecture requirements are available for use by each phase as the phase is executed

Output:

- Sustainability Measurement Framework; see Section 3.6

A list of requirements will have to be determined for each enterprise, but some will appear in many of them to reach the goal a sustainable information system, such as:

- The system should allow the measurement of its electricity consumption
- The system should measure its GHG footprint from electricity and manufacturing
- The system should stabilize the increase of data volume, processing, network traffic, amount of equipment required
- The system should provide accurate measurements to those who build it on the environmental impact of allowing technical choices with less impact and put out of scope technologies with high impact
- The system should provide its users with accurate measurements on the environmental impact of allowing usages choices with less impact and minimize usage
- The system should be free of addictive features
- The system should encourage its users to minimize their usage

5 Reference Models: Detailed Business Function Reference Model for Deploying a Sustainable Information System Policy

A detailed version of the high-level reference model presented above is proposed in this chapter, including:

- A graphic representation
- The description of each business function

5.1 Detailed Graphic Representation

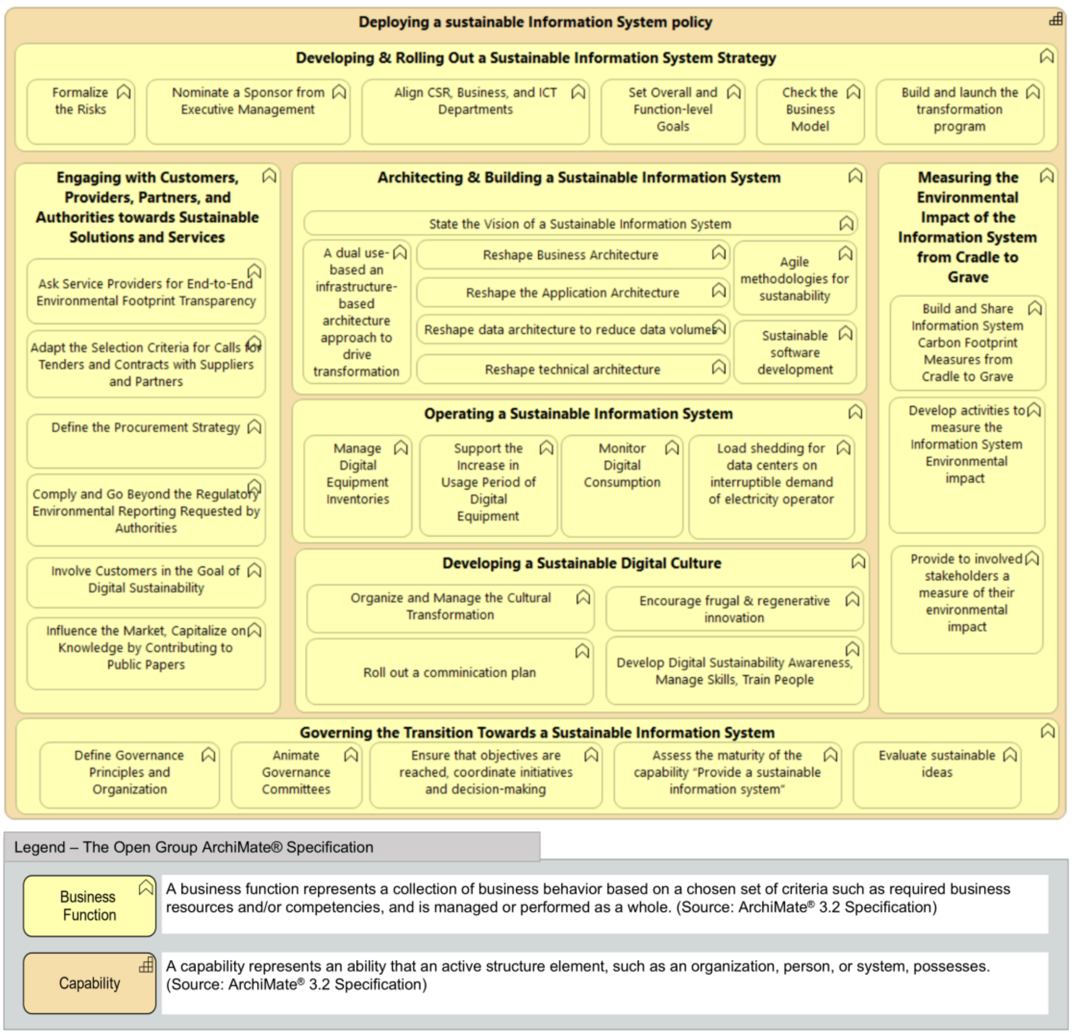


Figure 20: Digital Sustainability Reference Model (Detailed Version) (Source: The Shift Project Lean-ICT Work Group)

5.2 Business Function Descriptions

In addition to Sections 3.3 through 3.9, this chapter proposes a description of each detailed function of the framework.

Table 8: Description of Detailed Reference Model Functions

Business Function	**Description** **(Description of High-Level Functions is provided in Section 3.2)**
Developing a Sustainable Digital Culture	
Organize and Manage the Cultural Transformation	Organize and manage the cultural transformation of the organization. For example, establish internal active communities to think and exchange ideas about the topic or make people talk about the various aspects of the digital sustainability transformation. Identify digital sustainability ambassadors in teams to talk about the topic from different points of view: development and engineering teams, architecture and infrastructure teams, ICT procurement teams, CSR team, etc.
Encourage Frugal Innovation	Digital sustainability needs a frugal innovation mindset. Encourage collaborators to propose and share their ideas to improve the digital sustainability.
Roll out a Communication Plan	Communicate internally on the topic of digital sustainability: About the internal transformation program About market news on the topic: external feedback, regulator news, provider news, market vision, etc. Organize events with people from different departments to create contacts and discussions among the teams.
Develop Digital Sustainability Awareness, Manage Skills, Train People	An understanding of the climate/energy/resources stakes is mandatory to be able to accept the transformation and execute it. The required change is significant and of an unprecedented nature. Overall training on climate and energy stakes and digital environmental impact must be organized. Skills need to be managed and trained according to different roles: Digital sustainability “citizen”: common skills all collaborators should have in the organization Expert profiles on digital sustainability: digital carbon measure champions, ICT low-carbon design experts (architects), ICT asset management/technical asset lifecycle management experts, low-tech experts, etc.
Developing and Rolling Out a Sustainable Information System Strategy	
Formalize the Risks	Formalize the risks that your digital sustainability program should mitigate climate risks, information systems resilience, future regulations, etc. These are the risks that will define whether you should launch the transformation and, if realized, cause it to fail.

Business Function	**Description** **(Description of High-Level Functions is provided in Section 3.2)**
Nominate a Sponsor from Executive Management	Identify sponsors, ideally a director of the organization and CIO. Raise awareness among executives about ICT's environmental impact. Perform a stakeholder analysis and an interest analysis to clearly identify stakeholders concerned by this transformation in the organization.
Align CSR, Business, and ICT Departments	The digital sustainability topic is at the meeting point of the CSR (Corporate Social Responsibility), Business, and ICT departments. The three parties should share the same knowledge of the context and agree on the vision.
Set Overall and Function-level Goals	Define the goals of the digital sustainability transformation, and of the outcomes. They will include environmental indicators like CO_2e emissions, electricity consumption in kWh, but also, for example, on financial gain, security risk attenuation. Depending on the organization, the high-level objectives can be split into sub-objectives for each business unit or function.
Check the Business Model	Check if the current business model of the organization accepts a digital sustainability transformation and define conditions for this change to happen. This function is focused on continuous work on the compatibility between the organization's business model and the digital sustainability transformation. One example: In the business model of the organization, if profitability is directly proportional to the digital data volumes consumed or produced by the customers, this business model could be incompatible with a digital sustainability initiative, and it would need to be adapted.
Build and Launch the Transformation Program	Build the transformation journey with well-defined transition architectures and clear intermediate results to reach in each step. This plan should be agreed and shared with all stakeholders.
Architecting and Building a Sustainable Information System	
State the Vision of a Sustainable Information System	Build the overall vision of what should be a low environmental impact information system with the Business Architecture and Usage, Application and Data Architecture, and Technology Architecture. Show the main concrete levers to reduce this impact.
A Dual Use-Based and Infrastructure-Based Architecture Approach to Drive Transformation	A dual approach to identify sustainability requirements can be implemented combining simultaneously: a business uses-based approach and an infrastructure-based approach

Business Function	**Description** **(Description of High-Level Functions is provided in Section 3.2)**
Reshape Business Architecture	Act to regulate ICT business usage. Work proactively with the business. Adopt a process and a mindset of minimization of ICT assets such as equipment, data, applications, network, etc. Challenge the actual business needs to keep essential components, consider low-tech solutions, and remove "nice to have".
Reshape the Application Architecture	Adapt solution choices criteria to integrate digital sustainability requirements. Define data minimization as a principle for solution architecture design. All data should be documented with proper complete metadata and owners to define end-of-life dates by design. The use of open-source development frameworks or applications is also a way to mitigate technology obsolescence and increase the lifecycle of equipment.
Reshape Technical Architecture	Work with equipment providers to extend infrastructure lifecycle and manage properly the end-of-life (cradle to grave). Optimize the infrastructure design to minimize the amount of equipment used. When purchasing hardware, express requirements for extended use, reparability, and recyclability.
Agile Methodologies for Sustainability	Feed Agile approach with sustainability requirements
Sustainable Software Development	The software development capability should be adapted to continuously monitor and minimize processing, network traffic, volumes of data, electricity consumption, and, finally, environmental impact (e.g., share development guidelines on sustainable development, around framework to use, open source, image formats use, etc.).
Measuring the Environmental Impact of the Information System from Cradle to Grave	

Business Function	Description (Description of High-Level Functions is provided in Section 3.2)
Build and Share Information System Carbon Footprint Measures from Cradle to Grave	Measures should cover all ICT equipment required for the operations of the organization, whether managed directly by the organization or by its sub-contractors: • Workplace (laptops, smartphones, PC, monitors, etc.) • Data centers, physical machines, and network equipment used to store, compute, and exchange data of the organization • Cloud services (PaaS, SaaS, IaaS, etc.) • Measures must cover the full lifecycle of equipment from cradle to grave: • Building phase (environmental impact of the industrial build process of the physical assets used) • Running phase (environmental impact due to the energy consumption caused by ICT assets use) • Recycling phase (environmental impact of the recycling process/technologies used to recycle machines)
Develop Activities to Measure the Information System Environmental Impact	New projects/initiatives should be clearly assessed with appropriate measures. This activity would support both digital sustainability governance and ICT environmental debt management.
Provide to Stakeholders a Measure of their Environmental Impact	Collaborators should be made aware, in their daily activities, of the environmental impact of their digital actions, such as the effect of the data they create. End users (including collaborators and customers) should be supported on this, as well as developers and architects (for example, to assess their technical implementations regarding environmental footprint criteria, etc.). This measure activity is also a lever of the cultural transformation of the organization towards sustainability.
Engaging with Customers, Providers, Partners, and Authorities towards Sustainable Solutions and Services	
Ask Service Providers for End-to-End Environmental Footprint Transparency	Solution providers, service providers, and partners may use ICT equipment to provide services purchased by the organization. Transparency about their environmental impact is required as they are spread and linked across many different organizations and systems. A global picture cannot exist without transparency on all actors. The organization must require transparency from this ecosystem to be able to present the full environmental footprint of its value chain to its customers and investors.
Adapt the Selection Criteria for Calls for Tenders and Contracts with Suppliers and Partners	Adapt the way providers and partners are selected, including their ability to respect new contract clauses related to the measurement and reduction of environmental impact.

Business Function	Description (Description of High-Level Functions is provided in Section 3.2)
Define the Procurement Strategy	Decisions to internalize or externalize a service should consider the environmental impact of the services.
Comply and Go Beyond the Regulatory Environmental Reporting Requested by Authorities	Respect and, if possible, overtake all current regulatory requirements in terms of the ICT environmental footprint depending on your country. Leverage international standards for environmental impact calculation. Be attentive to new regulations on digital sustainability being prepared locally and internationally.
Involve Customers in the Goal of Digital Sustainability	Develop the awareness of customers on digital environmental impacts when they use the organization's services or products. Give them tools to adapt their behaviour/use to lower environmental impacts.
Influence the Market, Capitalize on Knowledge by Contributing to Public Papers	Communicate externally on the organization's digital sustainability transformation program by, for example, contributing to events and publications on the topic. External communications are an opportunity to challenge your approach, support other organizations, and benefit from the good practices of others. They also provide a good opportunity to onboard executives. They can significantly accelerate concrete results on the topic of digital sustainability.
Operating a Sustainable Information System	
Manage Digital Equipment Inventories	An accurate inventory of digital equipment required by the organization is one of the foundations of the environmental impact measure. It should cover servers and network equipment, but also monitors, laptops, desktops, tablets, smartphones, meeting room video equipment, peripherals, printers, TV screens, etc... Inventories can be maintained automatically (for connected devices), through purchasing and invoices, or manually. ICT asset inventory management is one of the functions of a CMDB.
Support the Increase in Usage Period of Digital Equipment	Increasing the usage period of digital equipment also requires changes to the habit of always buying brand new equipment, which is more fashionable and performant, and then throwing away old devices. For enterprises, this means dedicating more resources to equipment protection and repair. Repairing means creating the ability and culture for the help desk and technical employees to have the ability and willingness to tackle basic recurrent problems, like changing batteries or repairing screens.

Business Function	Description (Description of High-Level Functions is provided in Section 3.2)
Monitor Digital Consumption	With the optimization of all ICT functions like storage, network, processing, and the development of SaaS solutions, ICT department have lost some of the monitoring habits they formerly adopted for indicators like server activity, data volumes, and number of connections. There is a strong link between consumption of digital services and pollution. Indeed, while in the past improvement of technical efficiency has allowed absorption of part of the digital pollution impact, in the future efficiency boundaries will be reached. In this scenario, if volumes continue to increase, the worst-case scenario is that impacts will also do so. The development of cloud architecture that offers "on-demand" ICT resource has led to the creation of a new activity in ICT departments called FinOps, which means financial operations. It is a management practice that promotes shared responsibility for an organization's cloud computing infrastructure and costs. A good practice could be to add the environmental KPIs (electricity consumption, GHG emissions) to FinOps monitoring.
Load-shedding for Data Centers on Interruptible Demand of Electricity Operator	In a context of tensions on the electricity network, expected to occur more frequently due to physical constraints and geopolitical conflicts, some contracts can be established between an organization and the local electrical network operating company so that its facilities can be disconnected from the grid, and therefore prevent a general power outage. On the enterprise's side it means being able to: • Switch off "nice to have" electricity consumption (e.g., information TV screen, double monitors on workplace, etc.) • Switch off "non-mandatory" electricity consumption • Postpone intensive but not real-time digital consumption • Switch on its own electric generator (but that often requires fossil energy stocks to run and produce carbon-intensive electricity) • Monitor its electricity consumption
Governing the Transition Towards a Sustainable Information System	
Define Governance Principles and Organization	First, Enterprise Architecture sustainability principles must be defined. Then, as decisions to drive change towards sustainability must be taken at different levels, the concerned existing governance committee must formally update their term of reference to respect sustainability principles. New governance bodies should be created to monitor the operations carbon footprint of the enterprise if not existing, but the best practice is to rely on existing governance as much as possible.

Business Function	Description (Description of High-Level Functions is provided in Section 3.2)
Animate Governance Committees	Review the ICT governance committees, to ensure that: • Digital sustainability principles are fully included in the ICT governance process • Environmental debt of the information system is tracked over time like technical debt • Extended stakeholders concerned by the digital sustainability topic are included in ICT governance; such stakeholders include the digital sustainability lead, CSR lead for ICT topics, etc.
Ensure that Objectives are Reached, Coordinate Initiatives and Decision-Making	Manage the digital sustainability transformation program through its different streams. Define digital sustainability objectives and get the engagement of stakeholders. Check that the necessary transformation decisions are taken to either read objectives or to redefine/update them.
Assess the Maturity of the Capability "Provide a Sustainable Information System"	Build a digital sustainability maturity assessment model (or use an existing one) to evaluate the overall maturity of the organization. The following six dimensions of the reference model should be considered: • Strategy • Governance • Business, Data, Application, and Technology Architecture • Culture • Digital environmental footprint measures • Ecosystem (providers, partners, customers, etc.)
Evaluate Sustainable Ideas	To deliver the innovation capability on digital sustainability, introduced in the "Developing a sustainable digital culture" function, check that governance is in place to consider and evaluate new innovative ideas.

6 Integration Methodologies: Standardizing Environmental Data Sharing about Cloud Computing Services

With the move of infrastructure to hyperscale data centers, the need for accurate reporting on the environmental impact of the services executed "on the cloud" is critical. Indeed, access to the hardware inventory and to the electricity consumption is no longer possible. There is currently no standard to support the sharing of this information between service providers and consumers. A data standard for that purpose is proposed in this chapter.

The following proposed model is a minimal set of data to be provided by service providers that rely on ICT equipment. It would allow the organization that uses such services to monitor its footprint and reduce it. Services providers concerned are Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS) cloud providers, and more extensively any service sold that relies on ICT equipment.

Table 9: Data to be Provided by Service Providers

Data	Description
Provider name	Name of the service provider.
Provider evaluated service	Name of the specific service evaluated.
Concerned organization entities	List of concerned entities in the organization using the service.
Period	Period of the measure: year/month.
Electricity consumption (kWh)	Consumed electricity in kWh evaluated for the complete year.
Renewable electricity purchased (kWh)	Renewable kWh purchased.
Scope 2 Market-based emissions ($kgCO_2e$)	GHG emissions (Scope 2) in $kgCO_2e$ evaluated for the complete year, based on the market-based methodology as defined by the Greenhouse Gas Protocol [GHG Protocol].
Scope 2 Location-based emissions ($kgCO_2e$)	GHG emissions (Scope 2) in $kgCO_2e$ evaluated for the complete year, based on the location-based methodology as defined by the Greenhouse Gas Protocol [GHG Protocol].
PUE	Power Usage Effectiveness of the hosting infrastructure.
Comments on Scope 2 data calculation	Optional comments from the provider to document the Scope 2 emissions evaluation.
Total Scope 3 emissions ($kgCO_2e$)	GHG emissions (Scope 3) in $kgCO_2e$ evaluated for the complete year. Include global Scope 3 of the providers that is allocated to the client organization's service.

Data	Description
Scope 3 emissions linked to digital equipment ($kgCO_2e$)	GHG emissions (Scope 3) in $kgCO_2e$ evaluated for the complete year. Include only digital equipment Scope 3 of the providers that is allocated to the client organization's service.
Comments on Scope 3 data calculation	Optional comments from the provider to document the Scope 3 emissions evaluation.
Carbon credits and offsets	Emissions that are "discounted" from the providers due to the purchasing of carbon credits.
Digital waste weight (kg)	Weight in kg of digital equipment that has been disposed of during the complete year.
Recycled digital waste (kg)	Weight in kg of digital equipment that has been collected for recycling during the complete year.
Water consumption (volume)	Water consumed (in litres or cubic meters) during the manufacturing phase, either due to mining or industrial activities or during the use phase for cooling, for instance.
Volumes of data stored (GB)	Total volume of data stored associated to the service. In case of replication, the full volume including replication should be provided.
Network traffic generated (GB)	Total network traffic input and output generated by the service in the period.

Acronyms & Abbreviations

ADEME	*Agence De l’Environnement et de la Maîtrise de l’Energie*, French Agency for Ecological Transition
ADM	Architecture Development Method
AI	Artificial Intelligence
CapEx	Capital Expenditure
CDN	Content Delivery Network
CDO	Chief Data Officer
CDO	Chief Digital Officer
CEO	Chief Executive Officer
CI/CD	Continuous Integration and Continuous Delivery/Continuous Deployment
CIO	Chief Information Officer
CMDB	Configuration Management Database
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COP	Conference of the Parties to the United Nations Framework Convention on Climate Change
CSR	Corporate Social Responsibility
FinOps	Financial Operations
GB	Gigabyte = 109 bytes
GDPR	General Data Protection Regulation
GDS	Generic Data Service
GEF	Green European Foundation
GHG	Greenhouse Gas
GWP	Global-Warming Potential
I4CE	Institute for Climate Economics

IaaS	Infrastructure as a Service
IC	Integrated Circuit
ICT	Information and Communication Technologies
IEA	International Energy Agency
INR	*Institut du Numérique Responsible*, French NGO: Institute Institute of Responsible Digital Technology
IPCC	Intergovernmental Panel on Climate Change
ISIT	(European) Institutes for Sustainable IT
ITIL	Information Technology Infrastructure Library
Kg	Kilogram
KPI	Key Performance Indicator
kWh	Kilowatt-Hour
MOOC	Massive Open Online Course
MT	Metric Ton
MTBF	Mean Time Between Failure
NGO	Non-Governmental Organization
OpEx	Operational Expenditure
PaaS	Platform as a Service
PUE	Power Usage Effectiveness
REN	*Réferentiel Environnemental du Numérique*, The Shift Project's Reference frame of Environmental Negative Impacts
RACI	Responsible, Accountable, Consulted, Informed
REEN	Réduire l'Empreinte Environnementale du Numérique
REN	Digital Referential Environment (The Shift Project)
SaaS	Software as a Service
SaaS	Solution as a Service
SBTi	Science-Based Targets initiative
SEC	(US) Securities & Exchange Commission
TCO	Total Cost of Ownership

TSP	Territorial Sea Plan
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNITAR	United Nations Institute for Training and Research
VM	Virtual Machine
WEEE	Waste from Electrical and Electronic Equipment
XaaS	Everything as a Service

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