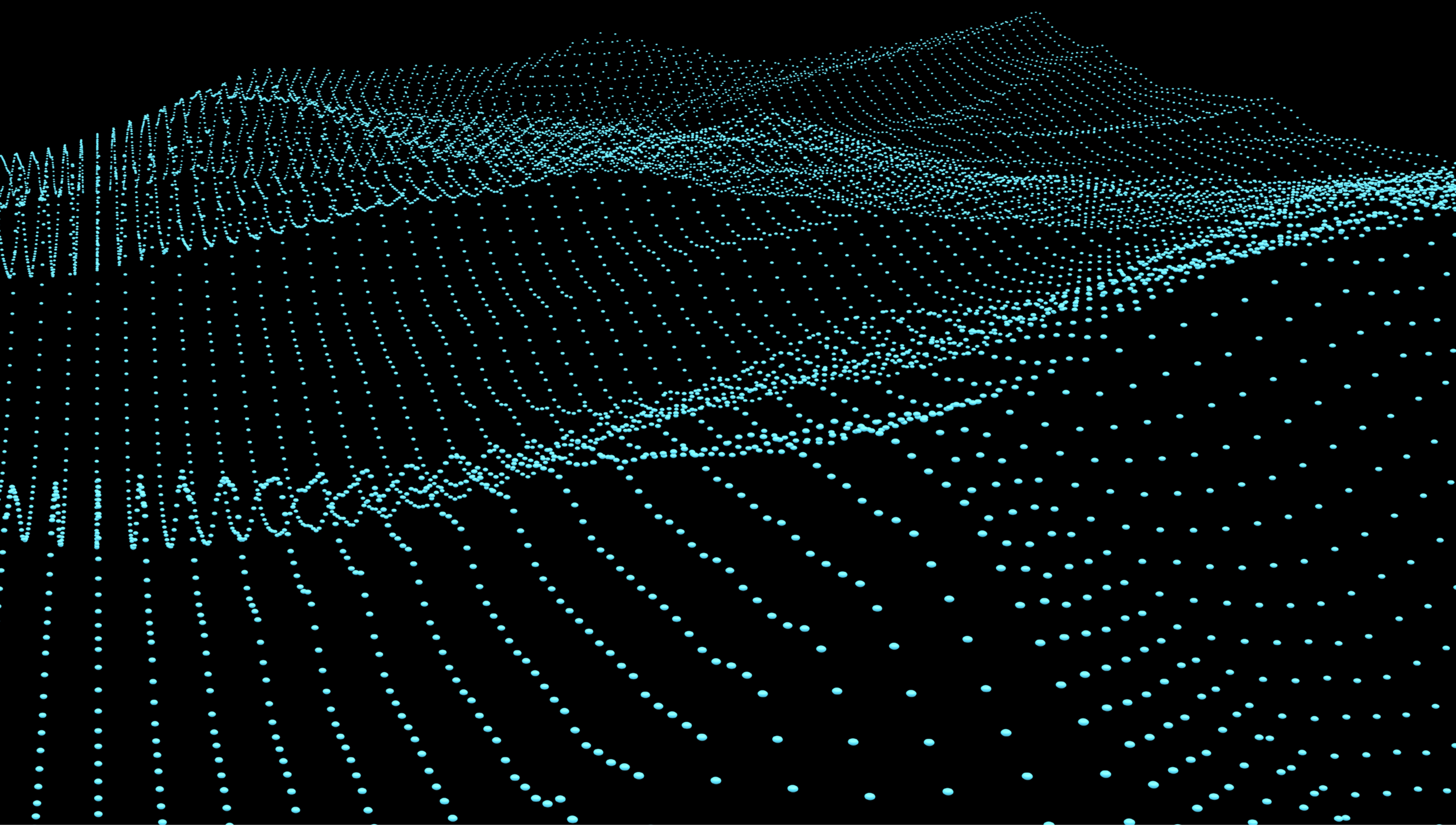
Deploying digital sobriety

OCTOBER 2020



THE SHIFT PROJECT

With the participation of

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Rethinking the digitalisation for low carbon transition

- Meeting the challenges of the 21st century requires a better understanding of the physical constraints limiting our physical and economic systems. Global warming and the gradual depletion of our fossil fuel resources combine into the "twin constraints of energy".

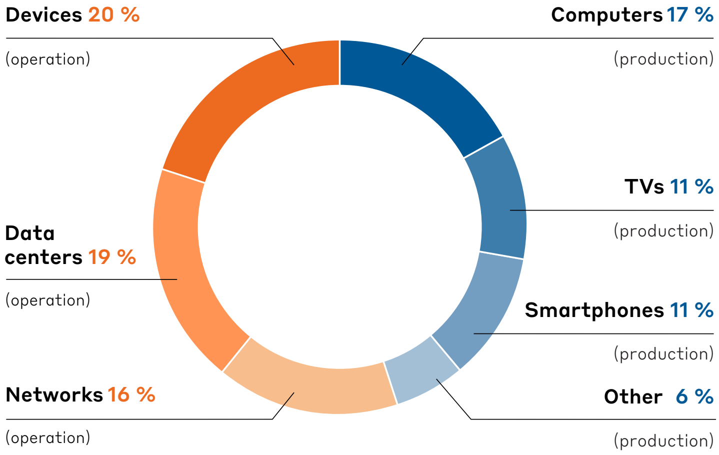
- In order to comply with commitments aiming to protect our global survival (such as the Paris Agreement), we need a drastic reduction of energy consumption as well as the resulting greenhouse gas emissions. Since we have limited resources it is mandatory to understand that each physical process, including information transfer, processing or storage as well as the relevant Information and Communication Technology (ICT) device production, is energy consuming.

- **As a result, digital technologies are both a tool and a challenge to shift towards a low carbon economy: while digital technologies do provide tangible opportunities, they are subject to the same constraints as any global system. Therefore, we ought to design digital practices and infrastructures that are resilient and sustainable.**

- The innovation challenge we are currently facing requires measuring the energy costs and environmental footprint associated with the expansion of digital technologies. The digitalisation of our economy ought to be sustainable from an environmental standpoint.

- As of today, our digital growth is not sustainable: the energy consumption of digital activity increases by 9% per annum. Most business models behind mass digitalization require a constant increase in content and data consumption and in the associated infrastructure to remain profitable on the long run. A phenomenon fueled by the "attention economy."

- **Digital sufficiency** involves switching from an instinctive or compulsive use of digital systems to a more controlled use of digital technologies, built from measuring both the associated risks and opportunities.



Final energy consumption of digital technologies by item for production (45%) and operation (55%) in 2017

Source: Lean ICT, The Shift Project 2018

- Implementing digital sufficiency involves overseeing technolog-ical alternatives, considering both the deployment of ICT infra-structures and their associated uses, that protect the essential benefits of digital technology.

- **In this report, The Shift Project provides the tools to assess the energy suitability of smart and communication technologies, in order to help organisations adopt greater environmental considerations in their information systems and take control over their digital practices.**

- **Without such an approach, the policies and strategies we adopt for digital expansion will destroy as much value as they create since, while pervasive, digital transition will not contribute to resolution of the world's current physical and societal challenges.**

Main conclusions

The assessment of new technologies' environmental relevance should be systematic

- Some IoT innovations have a potential for environmental gain, while others are structurally unfit to this end: **therefore, we should neither dismiss these innovations as a whole, nor endorse them without wholesale.**

- Designing a resilient system involves identifying those conditions under which it is appropriate to develop a given digital solution. These conditions are case-specific: so-called "smart" projects should not be **simply** taken at face value, but should be assessed based on **environmental considerations balancing risks and benefits.**

- Total energy consumption (embodied energy & energy released through operations) of a digital layer may outweigh the energy savings from the energy efficiency gains.

- The net energy savings will often only be positive if users follow the energy saving guidelines defined by decision makers.

Organisations can and should manage their Information Systems

- For organisational Information Systems (IS) – **of corporations, public agencies, local authorities** – to become resilient, digital projects must be conducted in rational way from an environ-mental standpoint.

- Considering the widespread use of digital technologies, we have chartered a **systemic approach** that allows organisations to **integrate environmental factors into the strategic and operational management** of their digital projects.

- This integration requires a **company-wide approach** conducted under the guidance of General Management and with the support of IT Department executives.

- Organisations, **regardless of their size**, need to adopt a drastically new approach to digital technologies instead of solely limiting themselves to buying new (potentially useful) optimisation tools and operating them within otherwise unchanged strategies and policies.

Digital practices management is a public policy issue

- **The current digital overconsumption** is the result of well-identified psychological and social trends. This goes beyond individual "good practices": there is an urgent need to firmly recover and **maintain control over our digital interactions on a collective scale.**

- A better **understanding of the structure and impacts of our current digital practices** is essential to ensure that digital technologies fit with our collective goals and address the challenges of the century.

- **A whole array of public actions should be implemented**, from basic digital education, to the regulation of design techniques, and prevention campaigns against "digital obesity".

Bring about a discussion on digital sufficiency

- The discussions and possible solutions to achieve digital sufficiency can also be applied to developing countries. While the baseline contexts and reference pathways are different, the dynamics governing both uses and supply are broadly similar.

- It is essential to nurture social debates on collective technological choices with objective facts. Keeping this in mind, *The Shift Project* plans to update the prospective scenarios elaborated in 2018, in order to shed light on the potential impacts of the technological innovations currently being implemented (IoT, Artificial Intelligence, edge computing, 5G etc.).

A methodology to assess the energy relevance of connected projects

How efficient are connected technologies?

- At the local level, **technological choices are intertwined with societal decisions.** The emergence of new practices, the influence on other activities (mobility, consumption channels etc.), the interdependence between local governments and private actors in service or maintenance... are dynamics that involve trade-offs that must be understood by local actors.

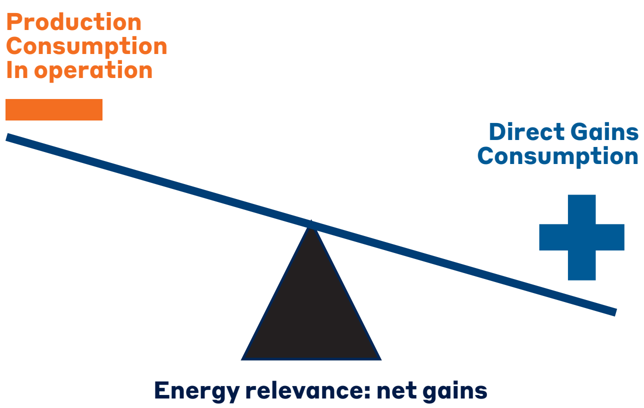
- Connected solutions, commonly referred to as "smart", are no longer self-contained ("standalone") solutions; they are components of a whole "digital system". **They should be implemented in a fully informed manner**, i.e. by computing all relevant factors. These include technology costs (mostly energy costs and resource consumption), their actual benefits as compared to non-connected technologies, and the indirect effects of their implementation (maintenance costs, the need to create new infrastructure, etc.). Besides, the "need" they are supposed to address should be reappraised and compared to the importance of other unfulfilled "needs".

- Assessing the energy relevance of a new connected layer means being able to measure the net decrease or increase in energy consumption allowed by this layer (taking into account both the energy cost of the production phase and the consumption of the connected equipment in operation).

A methodology and a collection of case studies

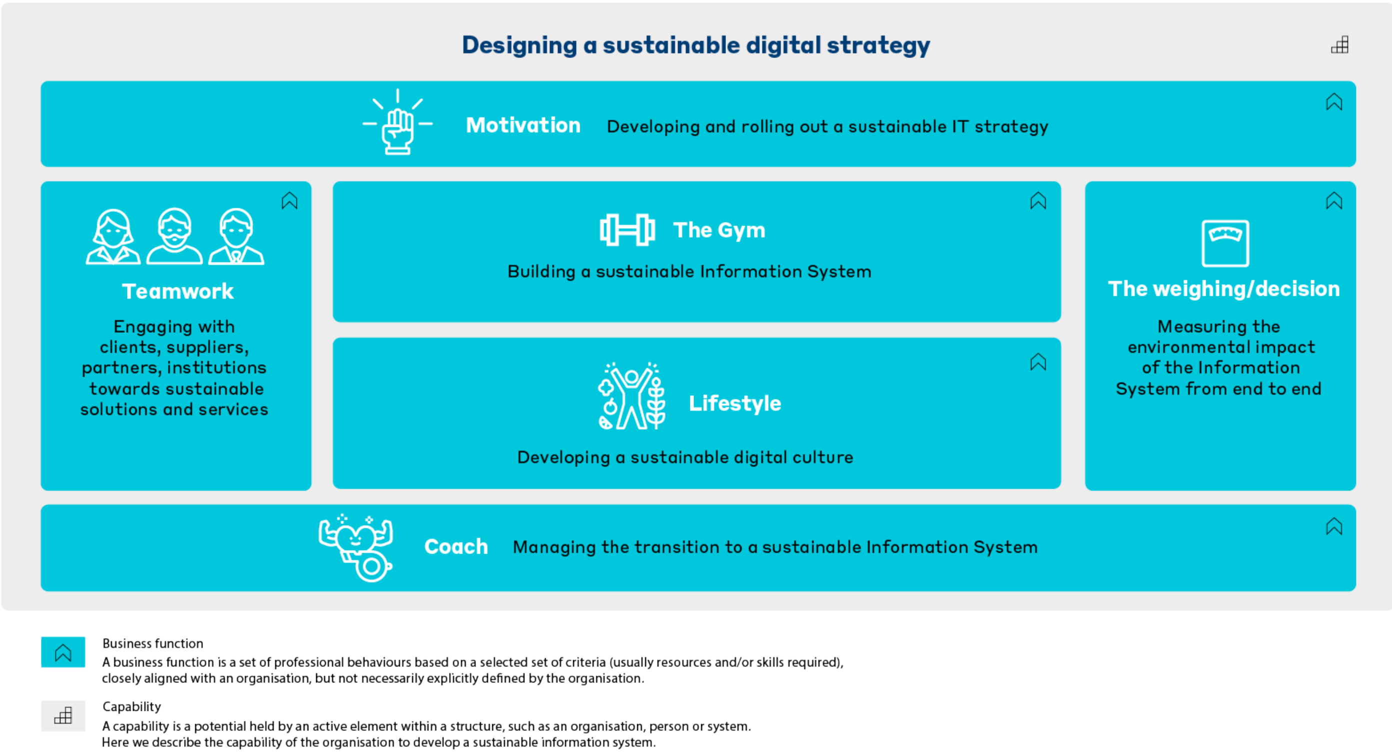
- The Smart Technologies Energy Relevance Model (STERM), developed by *The Shift Project* working group, makes it possible to assess the net energy-saving contribution of connected solutions for specific case studies.

- This model is only the embryonic version of a tool, and is intended to be used by both private and public actors to develop genuine operational tools, appropriate for their policies. At *The Shift Project* we decided to implement this mathematical model using Python and to make the code freely available.



- **Three case studies** provide an illustration of the practical application of this tool and of the required methodology. Two of these case studies are focused on connected lighting (private residence and tertiary office buildings). The third one presents a communicating power meter.
- These studies reveal that a **system may be "smart" even though it is not connected.** This feature should be assessed, considering the additional services it provides, the transversal gains it can generate, and the situations in which these gains can materialise.
- Often, a connected technology may only be a relevant solution where it is part of a broader program. For example it can be aimed at supporting a change in consumption behaviour.
- **The relevance of a technology should not be assumed according to general rules, but assessed for each type of operational case.** Only then will we be able to deploy solely those tools that we know to be truly useful given their environmental cost.

A Guide for the environmental management of Information System



Reference model - high level view - "Get the Information System back in Shape". [Source: The Shift Project, production of the working group]

- **Considering the increasing environmental impact of digital technology, organisations should implement policies for sustainable digital use.**
- Many digital service providers have **greatly optimised their electricity consumption.** This has been done through early initiatives focused on the direct costs of power consumption in server facilities, the introduction of more efficient hardware, and intervention of energy experts...
- **Maximising the digital sector's contribution to carbon neutrality requires us to** not only **optimise the use of energy and natural resources,** but also **to reduce the turnover of equipment and to dedicate resources to the uses with the highest societal value.**
- So far, only a few organizations have **looked holistically at the scope of their information systems**, considering among other things, outsourced services, the impact of infrastructure hardware manufacture, the electricity efficiency of both manufacturing and operating sites, training and management of sustainable digital skills, and choices in software architecture and development. **Where such a comprehensive viewpoint is lacking**, blind spots will lead to option decisions and trade-offs which hide highly significant impacts.
- The digital sector is currently experiencing a **growth dynamic** that is incompatible with physical limitations. As with individuals who need to manage increasing obesity, organisations also need **a program to get their information systems "back**

in shape". The aim of this report is to establish **a common language across industrial sectors** that will guide such programs based on the organizations' knowledge of their information systems.

- The proposed framework can be used to classify initiatives already under way, assess their maturity, strengths and improvement areas, and to benchmark them against the market. This framework, inspired from the practices of a major insurance group and the Open Group standardisation consortium, needs to be adapted to the specific context of each organisation.

A study of our digital practices: improving our understanding in order to make wiser decisions

We need to regain control of our digital practices

- Implementing digital sufficiency requires a better understanding of how our technological choices involve genuine societal choices. **The choice of specific infrastructures and their relevant technologies favours, if only by default, certain types of uses** (whether already existing or emerging).
- **Today, our digital choices tend to rely on automatic behaviours, attention-grabbing designs and business models that generate profit from continuous consumption of pervasive contents.**
- Technologies are not mere tools: they are an additional, structuring dimension of our daily lives, our professional, academic, family, individual and even intimate spheres, and in public spaces.
- **The solution has to be elaborated on the collective scale.** An individual perspective is useful to understand the practical impacts and effects (both positive and harmful) of our practices. However, this individual understanding should fuel debate about collective solutions making it possible to implement actions with a real, large-scale systemic effect.

Public policies that remain to be designed

- **Our digital practices must be addressed in terms of public health policy since they involve health-related risks** (on child development, school and academic performance, information overload, etc.). It is crucial that we build coherent tool-sets adapted to each specific field of our lives (educational, academic, professional, private etc.).
- Several key stakeholders should be involved: public authorities, private actors, national and European regulators, com-munities of designers and consumers, and experts studying the health and sociological consequences of our chosen prac-tices. Working with them, we need to build:

– **Training tools for public institutions** (in education and public administrations) to evaluate the consequences (both positive and harmful) of technological choices.
– **Support materials for people with educational roles** (parents and other educators).
– **Levers to regulate attention-grabbing designs** (autoplay, etc.) and schemes that take advantage of automatic/impulsive consumption behaviours.
– **Reflections on the changes to be made in the economic models of digital product and service providers.**

This report has benefited from the contribution of a number of experts, brought together in a working group led by Hugues Ferreboeuf.

A list of the working group members and the methodology are available in the foreword of the long version of the report.

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Foreword

The Shift Project, a carbon transition think tank, aims to tackle the key issues of the carbon transition. Its mission is to provide the factual and quantitative elements that will make it possible to deliver the trade-offs necessary for the success of this transition. The exponential development of digital technology, and how this interacts with our societies' attempts to decarbonise, is one of the essential dimensions of these issues.

In April 2017, *The Shift Project* asked Hugues Ferreboeuf to set up a working group to lead a collective reflection on the possibilities of synergy between digital and energy transition. This first step gave birth to the report **"Lean ICT - For digital sobriety"** (The Shift Project, 2018), published in October 2018, supplemented by a second report on online video usage, **"Climate: the unsustainable use of online video"** *(The Shift Project, 2019)* published in July 2019. This report constitutes a new stage in these discussions, carried out within a new working group convened by Hugues Ferreboeuf since March 2019.

The objective this work is to **identify how digital technology contributes towards the energy transition** and to compare it with the environmental cost of its implementation so as to develop quantitatively relevant and effective strategies in the long term. In view of the many contradictory theories circulating on these subjects, *The Shift Project* tries to provide research and findings that are objective, so that practical, systemic and long-term recommendations can be made to contribute towards the goal of decarbonisation.

The term *digital sobriety* has a long history, since its first use by GreenIT in 2008 (Bordage, F., 2018). Over the past two years, *digital sobriety* has established itself as a unifying concept amongst those working towards the development of resilient digital technology. It is now regularly put forward as a central approach by public authorities (in France such examples include the Senate and the National Digital Council) as well as by professional associations or organizations.

In our first two reports in 2018 and 2019 we were able to clearly define the concept of digital sobriety. In **this third one we propose operational and methodological frameworks that can be put in place** both in public strategies and policies, as well as in companies, as systems that can be used in the private sector.

The conclusions and recommendations of our working group target stakeholders in economic, social and political life, and will help in making decisions in order to evolve towards a resilient society. As part of the French Economy Transformation Plan (FETP), *The Shift Project* is in the process of building a thorough and systemic vision on issues of resilience that are prevalent in our society, in order to identify the inevitable trade-offs that we as a society may have to make as a result from them. This report "*Deploying digital sobriety*" is part of the sectoral discussions carried out upstream of this work and which will serve as a basis for the next steps of the FETP.

The Shift Project Digital team

SUMMARY FOR DECISION MAKERS

Rethinking the digitalisation of low carbon transition

- Meeting the challenges of the 21st century requires a better understanding of the physical constraints limiting our physical and economic systems. Global warming and the gradual depletion of our fossil fuel resources combine into the "twin constraints of energy".
- In order to comply with commitments aiming to protect our global survival (such as the Paris Agreement), we need a drastic reduction of energy consumption as well as the resulting greenhouse gas emissions. Since we have limited resources it is mandatory to understand that each physical process, including information transfer, processing or storage as well as the relevant Information and Communication Technology (ICT) device production, is energy consuming.
- As a result, digital technologies are both a tool and a challenge to shift towards a low carbon economy: while digital technologies do provide tangible opportunities, they are subject to the same constraints as any global system. Therefore, we ought to design digital practices and infrastructures that are resilient and sustainable.
- The innovation challenge we are currently facing requires measuring the energy costs and environmental footprint associated with the expansion of digital technologies. The digitalisation of our economy ought to be sustainable from an environmental standpoint.
- As of today, our digital growth is not sustainable: the energy consumption of digital activity increases by 9% per annum. Most business models behind mass digitalization require a constant increase in content and data consumption and in the associated infrastructure to remain profitable on the long run. A phenomenon fuelled by the "attention economy."
- Digital sufficiency involves switching from an instinctive or compulsive use of digital systems to a more controlled use of digital technologies, built from measuring both the associated risks and opportunities.
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– Reflections on the changes to be made in the economic models of digital product and service providers.

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[1] Axis 1: "Analyzes the energy relevance of connected projects" | Axis 2: "Guiding organizations towards a sustainable Information System" | Axis 3: "Digital uses: a societal construction"

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Technical information on the report

Abbreviations

IoT	Internet of Things
LED	Light Emitting Diodes
CFL	Compact Fluorescent Lamp
PUE	Power Usage Effectiveness
lm	lumen

List of symbols used in calculations

T_{PB}	Payback time, or amortization
α	Energy saving coefficient
β	Fraction of the number of hours of use authorized over 24 hours
$E_{savings}$	Reduction in energy consumption enabled by the introduction of the connected layer
E_{smart}	Total energy consumption associated with the connected layer
$E_{smart, embodied}$	Energy consumption associated with the production phase of the connected layer
$E_{smart, funct}$	Energy consumption associated with the use phase of the connected layer
E_{ini}	Energy consumption of the initial system in operation, ie without connected layer

Interpretation of bibliographic references

Bibliographical references are cited in this report according to a code showing the main author and the year of publication of the source. The reference (Byeon H. et al., 2015), for example, means that one must refer to the article *"Relationship between television viewing and language delay in toddlers"* published in the scientific journal PLoS One in 2015 by Byeon H. et al. Full information is available in the bibliography, listed by authors in alphabetical order.

Introduction: Digital technologies, rethinking the transition

A. Digital technologies: a tool and a challenge for the low carbon transition

Information technology, nowadays central and essential in all aspects of our society, has a crucial role to play in the low carbon transition of our economies. However, if such technology and the uses it enables and promises seems to be designed to meet ever greater challenges, **we must nevertheless reflect on howit is used and consider its relevance.** In a world with limited resources, it is important to remember that every physical transformation and every action requires energy, including the sending of information. **Digital technologies are thus not purely virtual tools, but are also physical and material mediums, even if we do not directly perceive their materiality through the actions they enable.**

Digital technologies form a global system: devices (such as smartphones, computers, tablets, etc.) connect to each other via network infrastructures (through terrestrial and submarine cables, mobile network antennas, optical fibers, etc.) to exchange information stored and processed in data centers, the beating heart of this system. However, each of these elements requires energy not only for it to function (the "operation phase" of such technologies) but also at the time it is created: the **mining of raw materials, and the industrial processes required to process these and then deliver them to consumers require very substantial resources, which are far from negligible.**

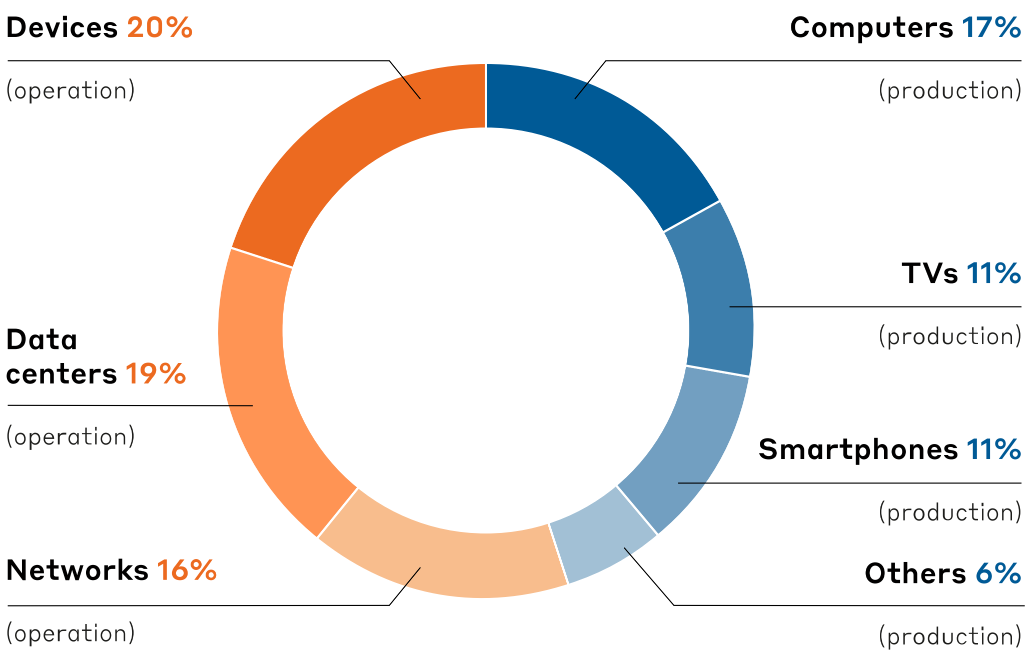

Figure 1 – Final energy consumption of digital technologies by item for production (45%) and operation (55 %) in 2017
Source: Lean ICT, (The Shift Project, 2018)

Digital services rely on physical infrastructures and therefore require energy and material consumption, which in turn create carbon emissions. Consequently, the introduction ofdigital technology – even if it is to reduce energy consumption, carbon emissions or to work towards energy transition in any way – must be thoroughly considered and thought must be given to the physical and material cost it implies. Whilst digital **systems and technologies are tools of undeniable value in view of the challenges of the 21st century, they remain subject to the same physical constraints (availability of energy and mining resources, climate constraints, vulnerability of ecosystems and other environmental constraints) that apply to every system on our planet.**

Faced by these constraints, the digital ecosystem is in danger. The physical nature of such constraints mean they cannot be ignored and must be confronted. **Since our technologies are, at the same time, crucial tools in energy transition they need to be based on a foundation of rigor and objectivity so that we may best meet the challenges of this transition.**

Meeting such challenges means, above all, creating resilience against the risks and disruptions that we expect to face in the coming decades: climate change, the unavailability of fossil fuels and mining resources, the general geopolitical and health risks of our globalized society are all situations for which our current systems and ways of working are not designed. The COVID-19 health crisis has highlighted the extent of the possibilities that digital tools offer in terms of adaptability and responsiveness for our activities.

However, this observation is twofold: information technology can be an incredibly valuable asset, but the stability of our economy is completely dependent on digital tools. In a context of increasing physical and globalized risks, thinking about the resilience of our societies and activities is essential if we want to preserve them. **In the context of this century, it is inevitable to think about the strategies to deploy to ensure the resilience of our digital infrastructures.**

B. Growth is currently unsustainable

The digital world as it is conceived today is developing in a manner that is incompatible with a world of finite resources.

In 2019, nearly 4% of global carbon emissions were caused by production and use of the digital technology and the digital system. This is more than the 2% usually attributed to civil aviation and, with a projected increase that is now standing at 8% per year, this figure could double by 2025 to reach 8% of the total of all global carbon emissions - matching the emissions currently caused by cars and two-wheelers (see Fig 2).

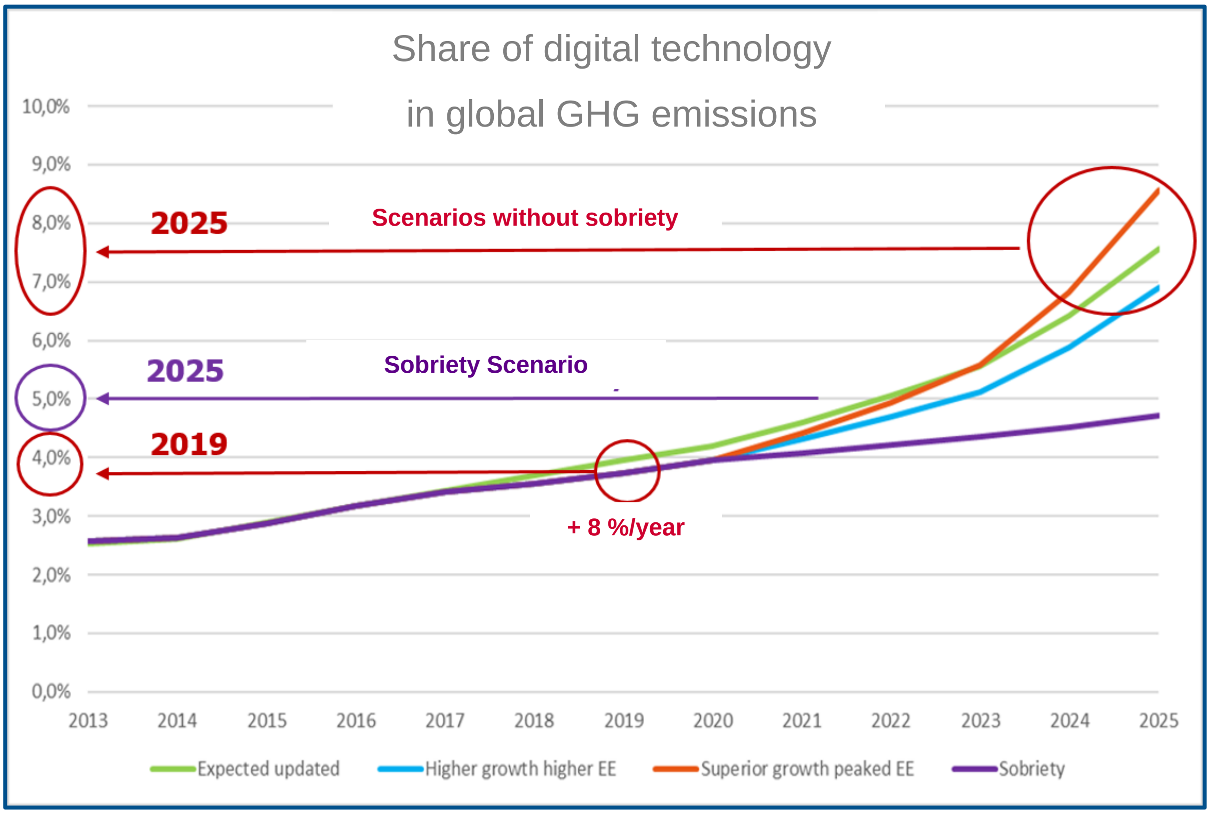

Figure 2 - 2013-2025 evolution in the share of digital technology in global GHG emissions
Source: (The Shift Project, 2018)

To ensure the resilience of our current societal systems, compliance with the Paris climate agreements, including the self-imposed 2°C target, requires a decrease in global emissions of at least 5% per year. Yet, currently global emissions continue to rise despite the intensive digitization of our activities.

During the production of our first report (The Shift Project, 2018), we proposed a "sobriety" scenario, and argued that it is possible to adjust the dynamics of digital technology for the first time without challenging the principle of a digital transition itself[2]. Although the “sobriety” scenario would enable us to rein the increasing impact of digital technology back in line with current global trends that include all sectors[3], it would not be enough to make the digital transition compatible with the Paris agreements.

Despite not being sufficient in and of itself, such a scenario does demonstrate that the emissions trajectory followed by our digital world is strongly dependent on the way we choose to use these tools, more so than the fact of technological progress itself: **despite the prodigious technological advances of recent years, an effective reduction in the total energy consumption of technology can only be achieved through considered and well thought out use.**

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[2] In this scenario, the volume of data passing through data centers still increases by 17% per year, traffic on mobile networks by 24% per year, and the number of smartphones and TVs produced each year stabilizes at 2017 levels - while markets in Western countries are now close to saturation.

[3] In this scenario, the increase in digital energy consumption is limited to 1.5% per year.

Preserving the positive impact of digital technology requires the careful management of its development: in terms of generalizing new uses, deployment of new infrastructures, marketing of new devices and technical solutions. At a time of strong politicization and polarization of debates on digital technology - such as the one surrounding the deployment of 5G, for example - it would be a mistake to continue to consider these services as simple solutions to current and future problems.

Our understanding of digital systems, their challenges, their potential but also their vulnerabilities has now reached a new stage of maturity. We must move from a carefree use of digital technology to a more long-term and resilient one, by understanding the trade-offs that we have implicitly made until now and by building the conditions enabling its continued development.

C. For digital sobriety

1. Digital sobriety - its objective

"Digital sobriety" calls for using our analytical capacities and tools to build and use a digital system that, by reducing its consumption of material and energy resources to a level compatible with environmental constraints, preserves its essential contribution to society.

2. Digital sobriety - its problem

The central question when thinking about digital sobriety is how we use technologies.

Digital systems are intrinsically linked to the physical infrastructure that supports them: for example, the growth of the volume of data produced leads to the development of additional infrastructure that transport, process and store it, which in turn supports this digital technology and enables it to be used in new and additional ways, themselves more data-intensive thanks to this new usage.

It is this chain of rebound effects that, today, governs the growth of the global digital system and that the idea of digital sobriety brings into question (The Shift Project, 2018) (The Shift Project, 2019):

How do we build our digital systems and the technical and practical infrastructure that supports it in a resilient and long-term manner?

3. Digital sobriety - a paradigm shift

The "digital sobriety" approach consists of **moving from a way of using technology that is purely instinctive to one that is conscious and considered.** As part of this it is necessary to identify the positive social contributions of digital technology that need to be preserved and developed.

The question of "utility" is, of course, a subjective one, but it needs to be asked collectively if we want to ensure the resilience of the digital world[4]. A paradigm shift such as the one we are advocating will always be a social as well as a technical project, despite its complexity. It therefore raises questions that are eminently political in the primary sense of the term. This shift would also concern all actors that use or are part of the modern digital world and therefore would also be systemic in nature.

4 The relevant players in online usage issues (regulatory bodies, public authorities, design communities, online content distribution platforms, consumer groups, etc.) already exist at the national and international levels. Bringing them together in a reflection discussion on the use of digital technology is both possible and essentiale (The Shift Project, 2019).

Objectives and approach of the working group

The objectives of the project

The aim of this study is to explore the questions that arise when it comes to putting digital sobriety into practice. Our first report, "Lean ICT - For digital sobriety" (*The Shift Project*, 2018), made it possible to draw up the quantitative findings essential to understand and characterize the environmental impact of digital technology. Our second report, "Climate: the unsustainable use of online video" (*The Shift Project*, 2019), began to identify the questions essential to the practical realization of a system based on thoughtful and considered use.

This report provides a set of findings and methodological frameworks that can be used by the general public, businesses, public authorities and the State to define and deploy strategies that both reflect and help to achieve "digital sobriety".

Axis 1: assess and strengthen the energy profile of connected technologies

The concept of the "connected city", "intelligent city", or even "Smart City", today brings together many different realities and ambitions. Both a slogan of public policiy and an infatuation of the private sector, the "connected city" aims to be part of a future that it often struggles to characterize.

One of the objectives of this report is to build a methodological framework illustrated by case studies (mainly around connected lighting) enabling participants (public policy players, companies in digital transformation and other private actors) to assess the energy profile of their digital projects, by helping them to identify the essential characteristics to give to their analysis and decision-making tools.

Axis 2: drive the digital transformation of an organization to make its IT system sustainable

All organizations (companies, associations, institutions, etc.) use digital tools in their activities. Their development, optimization or transformation strategies rely heavily on digital projects but no measurement or predictive assessment of the environmental footprint of these projects is generally made.

One of the objectives of this report is to propose a methodological framework that fits into a company's existing decision-making processes (in particular by means of Enterprise Architecture repositories) and which makes it possible to accelerate the measurement and reduce the environmental footprint of an organization's information system, in order to ensure its sustainability and the resilience of related activities.

Axis 3: explore and understand the links between human uses and digital tools

Digital infrastructures and equipment underpin a system of uses that justify and legitimize them. Implementing digital sobriety in practice therefore involves understanding how these two components of the digital system, “technologies” and “human uses”, interact with each other.

One of the objectives of this report is to build a factual vision of the construction mechanisms of our current digital uses as well as their effects, at both individual and collective scales. This makes it possible to raise certain societal questions that are essential to address in order to discuss digital sobriety in practice, to identify levers for transforming our systems of use and to direct public policies towards digital sobriety.

The working group's approach

The “Deploying digital sobriety” working group brings together 25 people from academia, companies in the digital sector, associations and various spheres of expertise in the issues addressed. Through regular meetings, collaborative work and interviews with external actors and experts since March 2019, its members have been able to produce the models, analyses, conclusions and recommendations that are brought together in this report.

This working group was organized around three main axes which structure the reflections and objectives of this report: **energy relevance of connected technologies**, the **digital strategy of organizations**, and the **question of uses**.

I. Analyzing the energy relevance of connected projects

A. Understanding when a connected technology is relevant: a simple modelling tool

1. Background and objectives

a. Digital sufficiency: to know why and how to deploy innovative technologies

The "Smart City" is today both a public policy slogan and a private sector infatuation, seeming to cover many realities and ambitions, which are often not clearly defined.

Commonly found within discussions on urban planning, it is one of the two current imperatives of public authorities: the "city of the future" strategy deals with digital transition on the one hand and environmental transition on the other. Yet these dynamics can become conflicting rivals and if the design and quantitative evaluation of their implementation are not carried out with sufficient rigor or scale.

Therefore, creating a smart city requires much more than rolling out an accumulation of connected services and infrastructures. A smart city should understand the impacts of the technologies it uses. It should be able to identify which parameters it should measure and then adjust to ensure that its digitalization is compatible with natural constraints. Last but not least, it should be a quantitative asset for its environmental transition strategy.

Building a sustainable and resilient smart city requires assessing the energy and carbon suitability of a technology or a service systematically before they are implemented. Any digital solution expansion must be subject to a quantitative assessment of its energy use and effect on the reduction of carbon emissions because generally adding a “smart” layer to a service or an activity generates indirect or counterintuitive consumption and emissions (e.g. at production or standby stage). Quantification is therefore necessary to ensure the city and its components are resilient.

Making the choice to expand the use of technology means choosing a particular path for the development of the said technology. Expanding a particular infrastructure in a given area means supporting specific usage dynamics; in other words, it means conditioning the subsequent expansions in all the sectors affected, which will need to be consistent with these developments. Thus, making technological choices without giving oneself the means to evaluate their relevance in the long term may make the territory and its actors more vulnerable to the risks of the coming decades.

The cost of deployment (environmental, energetical, carbon, in terms of maintenance requirements, training, external inputs…) must be assessed systematically and comprehensively. Only then will local authorities be able to build relevant and sustainable strategies for the future. These assessments and strategies must be carried out at the different levels by various stakeholders: company, organization, administration, household or territory.

b. Characterizing the conditions of relevance of a "Smart" technology

"Connected" technologies increasingly rely on the terminology of so-called "smart" technologies. However, it is important to question the true meaning of this lexical field: are these objects just connected to each other? Or do they enable the delegation of the management of the system in which they are integrated to some specific electronics? To some digital “intelligence”? Does this imply that the addition of this delegated management is really offset by the savings and advantages that it claims to guarantee?

Adding a smart layer to an infrastructure means delegating its management to microcontrollers through the introduction of electronics, sensors, inter-communication devices as well as decision making and optimisation algorithms. Although the direct energy savings from the introduction of the smart layer are often quantified, three key dimensions are often overlooked:

- The quantification of the energy consumed by the smart layer itself is not sufficiently systematic,
- The grey energy[5] is very rarely quantified and taken into account,
- The consequences of the "rebound effects"[6] are rarely studied and difficult to model.

However, it is essential to quantify the overall and total energy cost of the technology and the system of which it is part, from production to implementation: this is achieved by comparing its total energy and carbon cost with the reduction permitted by the technology. By doing this comparison, the impact of the new technology can be objectively assessed.

The aim of this work is to produce a methodological framework illustrated by some applied examples that should enable connected city stakeholders (at different scales within a geographicl territory, from public institutional actors to households and businesses) to assess the energy footprint of a connected technology and its contributions to consumption reduction. This will enable them to develop their connected infrastructure strategies in practical and relevant ways.

We present here a model clarifying the parameters necessary to assess **energy** relevance. The case studies described are not intended as generally applicable templates, but to illustrate:

- The central issues that emerge when relevance is treated objectively;
- The way in which this model can be taken up, used and even adapted by actors who would like to build their own assessment tools and methodologies.

It is essential to understand that there is no general answer to the question "is this technological solution relevant to energy challenges?". The solution has to be built by actors who wish to expand the technology, for each type of situation, in order to understand:

- In what framework and under what condition this technology becomes relevant;
- How to create and promote this framework of relevance.

[5] Energy consumption related to the production phase (raw material extraction, components and manufactured product production and delivery to points of sale), upstream of the use phase.
[6] The term "rebound effect" refers to the historically observed phenomenon whereby improving the efficiency of a technology or service in terms of resource consumption leads to an increase in its use, which will offset the direct savings achieved and result in reduced savings or even an increase in the total net resource consumption.

2. Approach and presentation of the model

a. The STERM model

As part of the production of this report, we have developed a model intended to enable assessment of the energy relevance of a connected technology.

The approach developed here has already been explored in relevant scientific literature. The work carried out here was done to build a clear methodological framework from which to construct the model and its possible applications.

This work is intended to be taken up by public and private actors likely to make technological choices, to:

- Build their own tools from the model presented here, by supplementing it, making it more complex or adapting it to the needs of the actors concerned;
- Acquire the methodological reflexes and habits essential to exhaustively assess the relevance of a particular expansion of any technology in a given context.

The model to which our work has resulted, **the STERM model – Smart Technologies Energy Relevance Model –** is built according to a methodology and a mathematical formulation, whose details are available in an exhaustive manner in the body and appendices of this report, along with a description of the Python codebase used to perform the calculations presented[7] hereafter.

b. The "Smart, connected light" study object

In the work presented in this report, the case studies and the model are built on an example of connected technology: the **connected light**.

This example was selected for several reasons:

- Its simple but illustrative architecture of a connected object: the connected layer added to the initial lighting system.
- The range of situations in which it is illustrated: residential premises, professional environment, public lighting etc.
- The ability to observe the preliminary issues surrounding the introduction of connected technologies: direct energy savings, the motivations for deploying a connected layer, the place of the connected layer compared to direct optimization of the initial system etc.
- The simplicity of the modelling, which enables its use as a support for the development of a model which can be made and then further developed to become applicable to other technologies and case studies.

Thus, connected light will be studied here not to demonstrate the relevance of the technology in particular, but to develop methodological tools, which will then enable stakeholders to build approaches for their own case studies and technologies.

[7] cf. Appendix

c. Hypotheses

- The end-of-life phase is not taken into account: in line with the methodologies adopted in our previous work (The Shift Project, 2018) and in view of the available data, only the equipment production and use phases are considered.
- The impacts of the installation phase of the system (at a private home, for example) have not been taken into account.
- The quantification of the grey energy for the electronics in the system is established by mapping the best candidate in the "GaBi Electronics XI" database of the company SPHERA-THINKSTEP[8], by comparing the orders of magnitude obtained with the existing literature. Quantification is carried out for the main and structural components[9].
- The quantification of potential energy gains is expressed in primary energy. An average conversion factor (ie. C=3) was considered between kWh_{elec} and $kWh_{primary}$ (Taylor, 2015).
- The power profile in use has been defined by a low limit, confirmed by the electrical measurements performed by our working group[10].
- The dynamic data exchange in the local system is not considered and communications to a possible cloud or external network (e.g. the internet) are not considered.
- Whatever the chosen configuration, a gateway[11] must always be active since it functions as a coordinator of this connected network. Also, in accordance with the technical specifications of the considered system, a gateway can manage a maximum of 50 connections (lights, sensors, etc.).
- The potential energy savings made possible by the integration of this type of system were evaluated via an analysis of the available literature. (Martirano, L., 2011), (Lin, et al., 2019), (Tejani, Al-Kuwari, & Potdar, 2011).
- The system lifetime has been set at 5 years.
- The considered connected lights are only LED types.
- Three cases are considered for the use phase and for the production phase:
    - A "low limit" case: for the use phase, a standby consumption resulting from a measurement is considered[12] for connected lights when they are off. We consider that the gateway is on standby 99% of the time. For the production phase, an optimistic quantification was carried out[13].
    - An "average" case: for the use phase, we consider standby consumption that meets the connected lights manufacturer specifications when they are off, except for the gateway which never seems to go into standby mode in practice. For the production phase, a "best candidate" quantification was carried out.
    - A "high limit" case: for the use phase, we consider standby consumption that meets the connected lights manufacturer specifications when they are off, except

[8] http://www.gabi-software.com/support/gabi/gabi-database-2020-lci-documentation/extension-database-xi-electronics/
[9] Details of the assumptions in Appendix.
[10] The details of the measurement campaign we carried out available in the Appendix.
[11] See definition in the description of the system: section B.1 of this section.
[12] Link to the measure we used: https://www.anandtech.com/show/6805/philips-hue-automated-home-lighting-gets-colorful/6.
[13] Details of grey energy evaluations available in Appendix.

for the gateway which never seems to go into standby mode in practice. For the production phase, a broader quantification was carried out.

- The presence sensor switches the lights to "on" and "off" positions depending on the presence of movement in its detection zone. The *dimming* function, which consists of a dynamic adaptation of the light based on the current illumination detected by the sensor, is not considered here[14].

d. Mathematical formalization of energy relevance

In order to assess the energy suitability of introducing a smart layer into an environment, an overall cost function *G(t)* can be defined (approach similar to (Kumar T., 2017) and (Van Dam, 2013))[15]:

$$G(t) = C.E_{savings}(t) - E_{smart}(t)$$

This function evaluates the net energy saving (in primary energy) *G(t)* as a function of time, taking into account:

- The conversion factor C of electrical energy into primary energy[16].
- The reduction in energy consumption enabled by the introduction of the smart layer (better management of the infrastructure) – this reduction is modeled as a percentage of the initial energy consumption of the lighting system:

$$E_{savings}(t) = E_{ini}(t).\alpha$$

, where $.\alpha$ is called "energy saving coefficient".

- The operating energy as well as the grey energy necessary to produce the various elements of the smart and connected layer:

$$E_{smart}(t) = E_{smart,embodied} + C.E_{smart,funct}(t)$$

The analysis of this function enables us to obtain the so-called **energy neutrality** point, which corresponds to the amortization time, or **recovery time**, from which the savings made possible by the introduction of the intelligent layer offset the energy cost of its production and operation.

This energy neutrality point is defined by $G(T_{PB}) = 0$, where T_{PB}[17] is the recovery time (i.e. "payback time") previously mentioned. Therefore, the lower T_{PB} is, the more interesting it is to introduce a smart layer in the considered environment, provided that some net savings are achieved at the same time at the end of the lifetime system[18]. It is important to note at this point that this indicator alone does not capture all the information necessary to fully establish the relevance of a smart project. However, it **motivates a more systemic and life cycle**

[14] However, the model built enables to integrate a simulation of this type of use: playing on a lighting attenuation will vary the consumption of the light, which can be reflected by a variation in the energy saving coefficient (as detailed in this report).
[15] Details of the calculations and formalization are available in the appendix.
[16] A value of C = 3 has been considered in this report (Taylor, 2015)
[17] Mathematical expression of T_{PB} available in appendix.
[18] The effects of a variation over time in the savings generated by the smart layer (especially when linked to changes in behavior) can indeed make a system inefficient at the end of life despite a positive balance at the start of its life (explored below in this report).

methodology-based approach, which is essential to build a strategy for **net and real** emission reductions from our value chains.

e. Modelling the variability of savings potential

In practice, however, the savings achieved thanks to the introduction of the smart and connected layer are not systematically constant over time. In particular, as explored in the remainder of this report, when energy savings are obtained by behavioral changes generated by the use of new connected tools. This temporal variation of the savings made possible by the technology can be modeled by introducing a time dependence for the energy saving coefficient α, which becomes $\alpha(t)$.

Several models can be used to describe the variations of the α coefficient, and their relevance will depend on the type of phenomenon being modeled (type of behavioral change, for example). In this report, the model we chose to explore and implement is the so-called "staircase evolution" (cf. Figure 3 – Evolution of $\alpha(t)$). There are two main reasons for this choice:

- As this modelling has already been studied in the literature available today (Van Dam, 2013) it enables us to assess its relevance on the basis of previous work.
- The mathematical development behind this "staircase" model remains simple and accessible, which will facilitate the understanding and subsequent reuse of the model presented in this report[19].

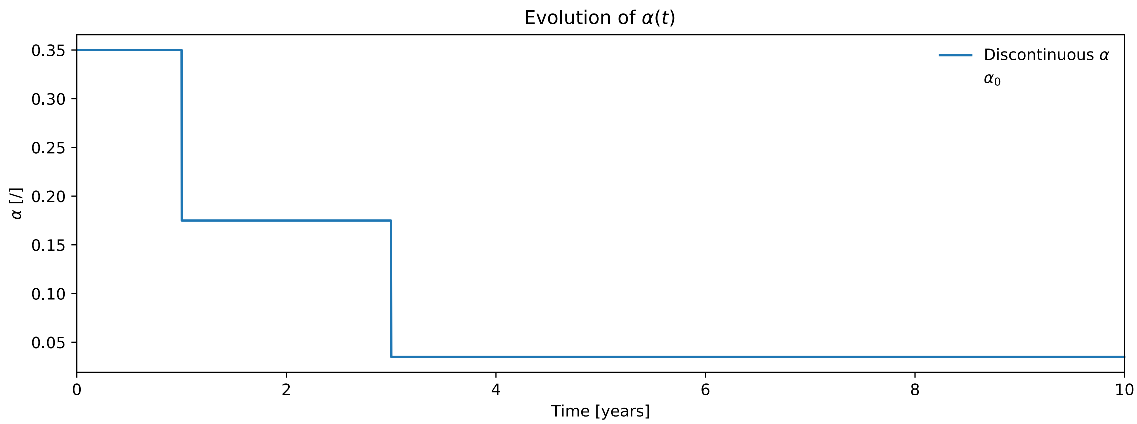

Figure 3 - Evolution of α(t)[20]
Source: The Shift Project

[19] The modelling of $\alpha(t)$ by a decreasing exponential has also been developed and implemented by the members of the working group within the framework of the research carried out (referents: David Bol, Thibault Pirson), but is not published in this report. However, these are ways of making the model more complex, which could be explored by the actors taking up this issue.

[20] The modelling uses here the following settings: $\alpha 0$ = 0.35, r0 = 1, r1 = 0.5, r2 = 0.1, t1 = 1, t2 = 3, t3 = 10. List of settings and exhaustive description of the modelling available in Appendix.

B. Analyzing the context that makes technology deployment relevant: several case studies about connected lighting

Three families of figures are presented in this report:

1. The recovery time T_{PB} as a function of α,
2. The net energy savings over the lifetime of the system as a function of α,
3. The cumulative energy savings curves as a function of time.

Visualizing the recovery time T_{PB} as a function of α for the entire range of α – rather than for a single value of the coefficient – mainly enables us to observe:

- The lower limit of α below which the recovery time is less than the lifetime and thus assess the practicability of making the system relevant.
- The influence of user behavior on recovery time (through the change of the coefficient value).

The different curves that can be observed in the figures in this report are as follows:

Recovery time curves T_{PB} as a function of α :

- Typical : estimate corresponding to the "average" case previously defined (see "A.2. Assumptions")
- *Upper boundary*: estimate corresponding to the "upper limit" case previously defined
- *Lower boundary*: estimate corresponding to the "lower limit" case previously defined
- *Influence of a varying α on the typical scenario:* estimate corresponding to the "average" case previously defined but with α varying over time
- *System's lifetime*: system lifetime (maximum limit for recovery time T_{PB})
- *W-savings boundary:* lower limit for α in order to ensure a zero-energy balance over the system lifetime

Curves of net energy gains over the lifetime of the system as a function of α:

- *Best case savings:* energy savings over the system lifetime for α constant over time
- *Worst case savings:* energy savings over the system lifetime with α variating over time
- *No savings:* zero energy balance over the system lifetime
- *W-savings boundary:* lower limit for α in order to ensure a zero-energy balance over the system lifetime

Curves of cumulative energy gains as a function of time:

- *Grey energy:* energy consumption due to the production phase
- *Use-phase energy:* energy consumption of the entire system during use

- *Energy for the smart layer:* energy consumption of the connected layer during use
- *Energy saved thanks to the smartness:* energy savings due to the connected layer
- *T_PB:* amortization time
- *T_lifetime:* system lifetime

1. Case study: the residential room – The "functional *only*" and comfort technologies

a. Description of the case study

- **Situation described by the case study**

This first case study focuses on smart connected lighting designed for residential areas. This is a field in which several products already exist on the market, thus enabling any individual to obtain them. The interest of this case study also comes from current trends concerning the IoT and, in particular, their automation applications within "connected homes" (which participate in the forecasts of exponential increase in the number of devices of this type) (CISCO, 2019).

The objective here is to question the interest of introducing a so-called "smart" technology within a household, in the domestic environment. By applying the **modelling methodology** described in the previous section of this report, the aim is to check whether energy gains are possible **over the lifetime of a smart lighting system** for an infrastructure representative of a typical household.

In other words, it is about **questioning the usefulness of a connected and smart lighting technology for private use.** One of the primary selling points for this kind of system is usually an improvement in the level of comfort (Strengers & Nicholls, 2017) (Salman, Easterbrook, Sabie, & Abate, 2016), which is not an objectively quantifiable quantity, and therefore incomparable in a direct way with the associated energy consumption. Sometimes, however, the energy saving argument is also used. In this case, it is justified to test the energy relevance of this system.

As a reminder, **the central goal of the methodology developed in this report is to compare the energy cost of production and use of the infrastructure enabling "smartness" against the energy gains made *in practice*.**

- **Construction of the case study**

The models carried out are based on the typology of a system of connected and "smart" lighting available on the market for private use[21]. This system consists of:

- A connected light bulb (i.e. equipped with a communicating layer),
- A motion sensor,

[21] A real system has been obtained in order to study the operating mechanisms of this type of technology, among others through measurement campaigns. Exhaustive description of the system and the measurement campaigns available in Appendix.

- A gateway [22].

Three scenarios are considered in this case study:

- **The first scenario is a functional lighting scenario, modelling a typical use in a typical household.** The infrastructure includes 1 *gateway*, 2 motion sensors and 8 connected light bulbs. This installation provides about 5800 Lumens, which gives a correct average level of illumination of 100 Lux for a dwelling, although no normative text applies to the dwellings[23], for a living space of about 58 m^2 (living room, kitchen, small open office). An illumination of 1000h/year is considered[24].
- **The second scenario aims to model a recreational lighting overlaid on the functional lighting of the first scenario.** 12 connected lamps and 5 motion sensors are considered here, as well as an illumination time twice as long (ie. 2000h/year) so as to model a more important occupation and lighting use. This scenario represents the use of smart lighting for comfort and entertainment (e.g. lights behind the TV screen, inside cabinets, etc.) in addition to functional lighting[25].
- **The third scenario consists in modelling an entirely recreational or comfort-related use.** This results in the implementation of only a few lamps (4), no motion sensor and a *gateway*. An illumination of 1000h/year is considered.

b. Results of the modelling

- **Scenario 1: functional lighting only**

The application of the STERM model to this case study enables us to obtain the results presented here.

[22] Centralizer, or communication gateway: enables to centralize and distribute the communications of the various communicating elements.
[23] The French standard NF EN 12464-1, which applies to indoor workplaces, recommends an average of 100 lux in standard use areas, i.e. areas where no specific or complex tasks are performed.
[24] No reference document indicating the lighting duration lighting in the residential sector, hypothesis based on technical data sheets of general public equipment – for example: lifetime of 15000 hours for 15 years. This scenario is equivalent to replacing the existing lighting in a typical living room with PHILIPS HUE E27 White lights and using the lighting system without abuse.
[25] This scenario is quite close to the configuration proposed on the PHILIPS HUE website, which offers to visit a model living room in 360° immersion (Philips HUE (website), 2019).

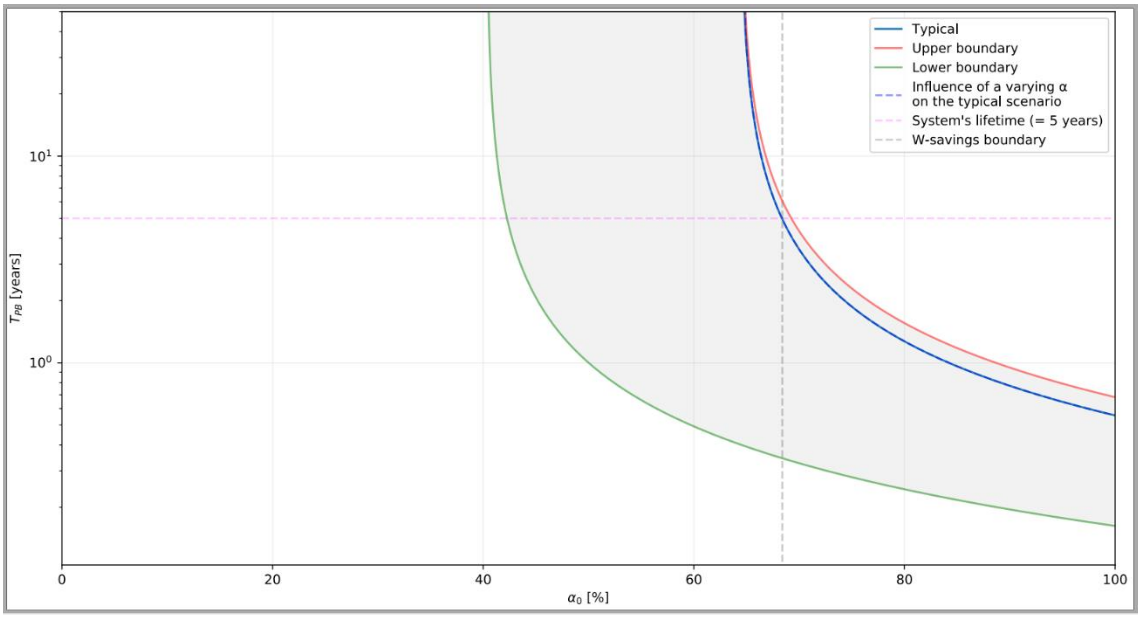

Figure 4 - Recovery time T_{PB} as a function of α, scenario 1
Source: The Shift Project, working group production

The first conclusion which can be drawn (Figure 4) is that it is impossible to achieve a recovery time below the system lifetime if α < 40% for the lower limit and approximately α < 65% for the medium case.

In practice, 40% energy savings with this system configuration would correspond to a situation where the introduction of the smart layer would save about an hour of illumination per day. 65% would correspond to an illumination saving of about 1h45 per day. In the current scenario, i.e. domestic use and considering the usual illumination profiles, such a saving would seem difficult to achieve in practice[26].

[26] That is to say that considering the total duration of residential rooms lighting, over a day (in the order of a few hours), to be able to decrease the lighting from 1h to 1h45 would mean that the rooms are unnecessarily lit for as much time over this period.

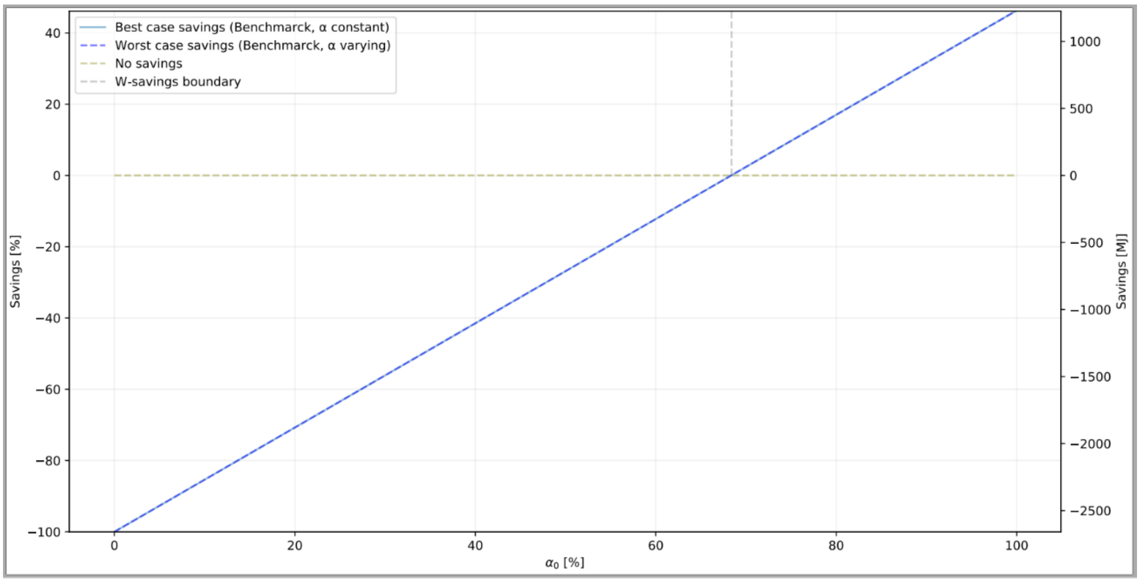

Figure 5 - Net energy savings at system lifetime as a function of α, scenario 1
Source: The Shift Project, working group production

As presented in *Figure 5* for the average case, it is necessary to have approximately α > 65% (i.e. the layer provides 65% savings on lighting consumption) in order to achieve net energy savings over the system lifetime.

Thus, the energy curves have been plotted with an energy saving coefficient value of α = 70% (Figure 6): the net energy savings remain small, although positive from a T_{PB} lifetime of about 3.5 years. This is because the savings enabled by the connected layer evolve with the technology usage: therefore, they evolve similarly with the energy required to run the smart layer.

Furthermore, it is important to notice that a value of α = 70% seems unachievable in practice, given the studies now available in the literature (Martirano, L., 2011), (Lin, et al., 2019), (Tejani, Al-Kuwari, & Potdar, 2011). **Therefore, in practice, it appears impossible to make energy efficient the introduction of a smart layer in the lighting system studied in this case.**

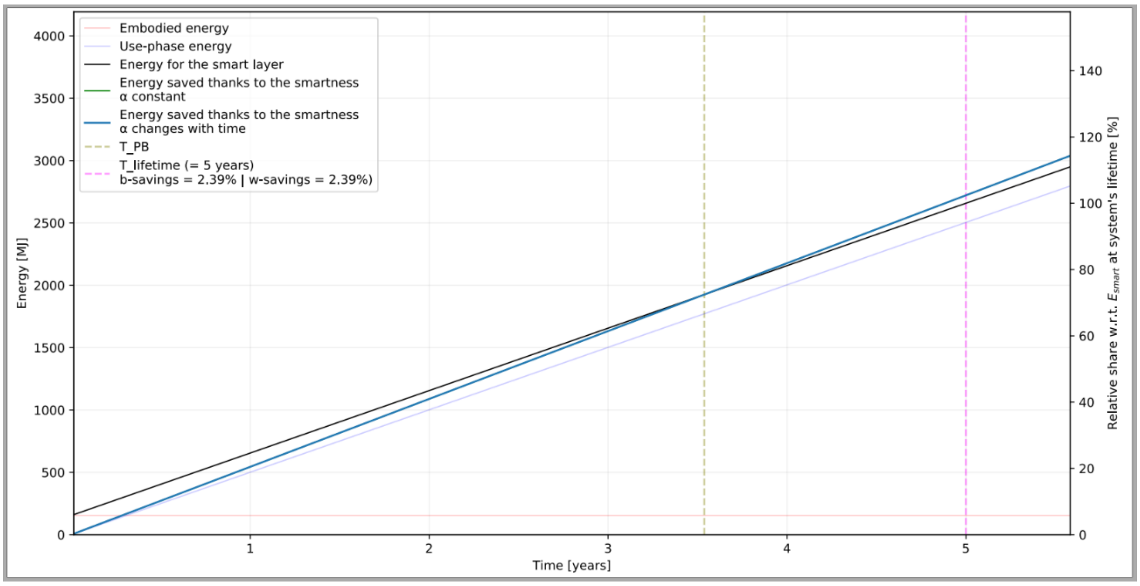

Figure 6 - Cumulative energy curves as a function of time, scenario 1
Source: The Shift Project, working group production

- **Scenario 2: functional and recreational/comfort lighting**

The results for this scenario are available in the Appendix.

The analysis of this scenario reveals an essential paradoxical effect. Net energy savings are possible in this configuration, contrary to the previous scenario with only functional lighting. However, these savings are only possible because the total cumulative lighting time has increased significantly (considering that the number of lights is higher in this scenario than in the previous one, the annual lighting time is doubled from one scenario to the other). Indeed, the energy savings provided by the connected layer are indexed to the electrical consumption of the system in usage: the greater the lighting hours, the greater the potentials of energy savings.

In other words, this scenario shows the paradoxical effect of making a system efficient by saving on direct consumption: **a connected system can only become relevant from an energy perspective if the initial system consumes a important enough amount of energy. It will therefore be relevant to deploy connected technology on this initial system only if the initial consumption is both high enough and can be optimized as much as possible.**

- **Scenario 3: lighting recreational/comfort only**

The results for this scenario are available in the Appendix.

This scenario does not aim to achieve any energy savings: as connected lighting is implemented here for entertainment purposes only, its relevance is not related to the effect of the connected layer on energy consumption. It is therefore not surprising to see that this system will probably lead to deadweight energy losses. The interest here is to be able to objectify the energy cost of the comfort increase.

This matches the modelling case where α = 0%. The total energy consumption will then be in the order of 400 kWh over the system lifetime (5 years).

c. Conclusions and discussions

Connected lighting as used and marketed today does not provide clear or automatic energy savings over the system lifetime when used in a domestic environment. In the current context, with objectives aimed at reducing the energy impacts of our lifestyles, it is therefore appropriate to question the relevance of this type of system for private use. The methodology here developed can only evaluate the energetic relevance, not benefits in terms of recreational applications or comfort. **However, it is essential to be able to calculate and to visualize the additional consumption associated with the introduction of a comfort system, by integrating not only the direct consumption, but also the energy used throughout the entire value chain, particularly during the equipment-manufacturing phase.**

To our knowledge, the conclusions presented here have not been discussed in any literature on connected lighting systems like this. Some studies on the benefits of smart lighting present opposite conclusions (Dubberley, Agogino, & Horvath, 2004), but they generally focus on systems that are not accessible to the general public and on older lighting technologies with higher power consumption (e.g., CFL rather than LED).

An important factor impacting the system is the consumption of the connected lights during the use phase. Indeed, in order to ensure continuity of connectivity, the communicating part of these systems must remain powered even when the light is off. The grey energy of the system modelled in this work seems to be relatively low (less than 10% of the total energy needed for the smart layer over the system lifetime). These results should be verified on other private lighting infrastructures. Indeed, considering already existing results on the quantification of the grey energy of electronic devices, it would seem that the share of impacts attributed to the production phase is often non-negligible or even more important than the use phase, a result that seems to be more pronounced if the observed systems are small[27] (Ryan, Smith, & Wu, 2019).

Given the significant hypotheses made for the quantification of grey energy in this case study[28], the conclusions should be understood as defining the lower boundary. Furthermore, **a clear difference in energy consumption profiles was observed between battery-powered nodes (presence sensor) and grid-connected nodes (gateway and light).** In the latter case, it seems that the specifications are not always respected and that constraints for the consumption in use are relaxed, while autonomy problems do not arise[29]. **This could partly explain the relatively low contribution of grey energy for this type of system.** In any case, a more advanced sensitivity analysis should be carried out for any recovery and adaptation of the model.

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[27] Of course, these trends cannot be generalized to all devices and the framework in which they will be employed also has a strong influence

[28] Details available in appendix.

[29] Details available in appendix.

2. Case study: Tertiary work office – different topologies and different conclusions

a. Description of the case study

- **Situation described by the case study**

This second case study focuses on the integration of connected lighting within workspaces hosting tertiary-type professional activities.

The objective here is to question the value of introducting of a "smart" technology within a workspace. Our approach explores the potential energy savings offered by a connected control of lighting for a usual infrastructure of such offices. The methodology developed here is built in two stages: it relies on standardized models carried out using the software *DIALux®*[30] in order to assess the potential for direct energy savings[31], to then assess the net savings using the STERM model.

Similarly to the previous case study, the energy relevance of connected infrastructure will be studied here, that is to say their relevance with respect to an objective of reducing energy consumption.

- **Construction of the case study**

The models have been built for four types of offices, illustrating different professional uses in the tertiary sector[32]:

- The individual office (around 10 m²),
- The collective office (2 to 3 people, around 25 m²),
- The open space (around 150 m²),
- The classroom (around 70 m²).

The main hypotheses used are as follows[33]:

- The windows run the entire length of the wall. The sill is 80 cm and the height of the window is 1.25 m.
- All four studied office topologies are oriented in the same way such that this parameter does not influence consumption variations.
- The studied cases were computed in Marseille, Paris and Brussels to see the impact of latitude on the different conclusions[34].
- The luminaires used are brand-new recessed luminaires. These are standard models dedicated to the tertiary sector, therefore suitable for lighting offices and educational premises.

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[30] Free software, financed by manufacturers of lighting equipment and published by the company DIAL (Deutsches Institut für angewandte Lichttechnik) https://www.dialux.com/en-GB/about-dial
[31] Corresponding to the energy saving factor α.
[32] The exhaustive descriptions of the chosen parameters are available in the Appendix.
[33] Exhaustive details on the assumptions and standards used are available in the Appendix.
[34] Details available in the Appendix.

- For each topology, the most suitable photometry was selected. They all have a unit flow of 2700 lm, and depending on the photometries, their luminous efficiency ranges from 100 to 122.7 lm/W.
- The configuration of the smart layer, which is used to control the lighting infrastructure, is as follows[35]:
    - A sensor or set of sensors, making it possible to detect movements (infrared sensors) and to measure the level of illumination (with a nominal power of the order of 1 W);
    - Radio communication modules (transmitters and receivers) associated to luminaires and sensors (mostly with a power between 20 and 30 mW);
    - Possible functionalities:
        - Automatic ignition when a user is detected;
        - Automatic switch-off if no user is detected after a delay of a few minutes (adjustable according to the use case);
        - Dimming of the luminous flow emitted by the luminaire depending on the daylight entering the office;
        - Dimming of the luminous flow of the luminaire throughout its lifespan to limit the electrical power consumed at the start of its lifespan and increase it gradually to compensate for the loss of luminous efficiency linked to ageing and clogging.

The lighting levels used here are defined on the basis of standard NF EN 12464-1[36], applicable to the case studies defined here, which enables to characterize the premises' illumination on the basis of quantified factors (average illumination, uniformity of illumination, glare threshold, etc.)[37].

Once the case study is built, the software *DIALux*® computes the consumptions associated with the lighting infrastructure, taking into account[38]:

- The direct electrical consumption of the luminaires,
- The power consumption of the auxiliaries (only auxiliaries present in the luminaires and the batteries of the emergency luminaires);
- The parameters influencing these consumptions (lighting factor, emergency lighting charging time, natural lighting, occupancy rate, etc.).

An important hypothesis, inherent in the standard regulating the implementation of the software *DIALux*®, considers that the regulation auxiliaries are integrated into the luminaires and switched off whenever the luminaires are. The consumption of remote sensors and communicating modules has therefore explicitly been added. The potential savings have been computed with standard NF EN 15193[39] and can therefore be modulated depending on the actual use and should thus be considered in order of magnitude.

[35] The tables of technical specifications, in particular the nominal powers taken from the manufacturer's data, of the various components (sensors, communicating modules), are available in the Appendix.
[36] NF EN 12464-1 norm July 2011: "Light and lighting – Lighting of workplaces – Part 1: Indoor workplaces"
[37] Exhaustive list of parameters and quantitative values available in the Appendix.
[38] Exhaustive list of parameters and mathematical formalization used available in Appendix.
[39] NF EN 15193-1 norm of May 2017: "Energy performance of buildings – Energy requirements for lighting – Part 1: specifications, module M9"

b. Modelling results

Two calculations were carried out on each of the four topologies:

- The first one with luminaires controlled by a simple switch;
- The second one with the gradation of lighting depending on the contributions of natural light and presence detection for switching on and off the lights.

For each topology, in accordance with standard NF EN 15193, the total annual consumption of luminaires in kWh/year for the entire office as well as the surface consumption, total consumption reduced per m² of the office, are computed.

By way of example, the results for the Marseille site are summarized in the following table[40]:

Office topology	Simple switch		Gradation and detection		Energy saving [%]
	Total consumption [kWh/year]	Surface consumption [kWh/m²/year]	Total consumption [kWh/year]	Surface consumption [kWh/m²/year]	
Individual office	141,03	11,75	71,69	5,97	-49,17
Collective office (2-3 people)	257,66	10,74	165,53	6,90	-35,76
Open space	2117,05	14,11	1795,63	11,97	-15,18
Classroom	901,05	13,04	646,41	9,35	-28,26

Table 1 - Results of direct energy savings modelling for "tertiary work office" case study (calculations by DIALux®)

Source: The Shift Project, production of the working group

The introduction of the connected layer – with the functionality of presence detection and adaptation of the brightness according to natural lighting – makes it possible to obtain energy savings in use, which can directly translate into quantitative values for the energy saving coefficient α.

First developing these case studies on *DIALux®* enables extracting coefficient α values corresponding to each topology, which are then used as parameters for our STERM model.

So when *DIALux®* makes it possible to evaluate the energy saving on the direct consumption enabled by the connected layer, the application of our model enables it to add the grey energy and effective consumption from the whole smart layer[41].

[40] We notice that even if the latitude has an influence, it has relatively little impact on consumption using the calculation of NF EN 15193 (less than 10% between the extremes). However, the difference in cloudiness over an entire year, not taken into account by the standard, can amplify this difference. Results for the other sites available in the Appendix.
[41] Exhaustive details of the configuration of the model available in the Appendix.

Office topology	Direct energy saving	Net energy saving
Individual office	- 49 %	- 41 %
Collective office (2-3 people)	- 36 %	- 31 %
Open space	- 15 %	- 13 %
Classroom	- 28 %	- 24 %

Table 2 - Results of direct economy models (calculations by DIALux®)

and net energy savings (by the STERM model) for the "tertiary work office" case study
Source: The Shift Project, production of the working group

The application of the STERM model on these four case studies leads to the conclusion that the savings predicted by NF EN 15193 and the ones computed with *DIALux®* seem overestimated, given that the continuous activity of the smart layer as well as its grey energy are not considered. However, despite this overestimation, taking into account the impacts of the smart layer does not fundamentally change the conclusions.

c. Conclusions and discussions

In our case studies of "tertiary work office" as they are defined, the introduction of a connected layer enables clear energy savings over the device's lifetime. **These are therefore cases in which these technologies are relevant**. From there come some essential conclusions:

- The difference between these conclusions and those of the residential case studies illustrates the fact that it is essential to conduct a complete and transparent relevance study for each type of deployment, rather than letting a technological choice be driven by general impressions or observations that cannot be formulated in a meaningful way.
- The production phase is not predominant here, particularly with regard to the long lifespans of our devices (15 years). In most cases, it will again be essential to deploy new systems in situations where their lifespan is important[42].

The quantitative findings formulated here are of course not general findings, but only valid in the context of our case studies and our models, some of the main limitations and nuances to be provided below:

- The surplus impact due to maintenance over the 10-year lifespan is not taken into account here,

[42] It will thus be useful to analyze the types of obsolescence to which the different types of technologies are subject, for example between recreational technologies (subject to marketing obsolescence, for example) and professional activities (where functional obsolescence is more often predominant).

- The grey energy and operating consumption hypotheses that were used here are extrapolated from our case studies in the context of domestic systems, therefore for technologies that may differ in certain dimensions. It would thus be crucial to evaluate in details the real grey energy carried by these systems,
- It is useful to remember that only the energy impact is taken into account here. However, producing and disposing of these devices entail other environmental impacts (soil pollution, water consumption, consumption of mineral resources with finite reserves, etc.).

If the quantitative analysis shows here that introducing a smart layer enables effective net energy savings, it is essential to underline one thing: **the implementation of a connected layer is not a pre-requisite for obtaining these results**. The functions truly responsible for energy savings (management of depending on the presence of users and light gradation) can be fully fulfilled by wired systems and sensors[43].

The "connected" function brings an additional supervision service, which can be useful for the management of large or remote lighting infrastructures, and which could have the advantage of improving the quality of service (fault detection, hour counter, maintenance planning, etc.).

The value of the deployment of a connected infrastructure for lighting systems cannot be justified by an argument of energy efficiency. Technological judgements must be carried out in an informed manner:

- By taking into account the real contributions of the connected technology (which therefore do not fall within the scope of energy saving, non-connected systems being able to fulfill this function),
- By taking into account the energy cost of adding these functions: integrating a connected layer results in additional consumption,
- By ensuring that are taken into account the training requirements for dedicated operators, qualified to manage and exploit this type of technologies.

More generally, any technology deployment must be made with full knowledge of the facts. And this is the objective of the methodologies developed in this document: **all connected systems have an energy cost and this must be taken into account in order to fully understand the judgement that is made when choosing to deploy them.**

3. Case study: Renovation of a tertiary premises – a methodology for assessing the relevance of solutions

a. Description of the case study

- **Situation described by the case study**

This third case study concerns the integration of lighting equipped with regulation in **existing** tertiary premises, whose transition between traditional lighting and regulated infrastructure was observed. The infrastructure installed here is not "connected".

The objective here is to compare the theoretical conclusions formulated through the previous case studies with feedback in a real situation. Based on documentation of observations *in situ* carried out on a demonstrator, the goal here is to validate the relevance of

[43] The most common form today in professional lighting systems.

the models developed in the previous case studies and to understand the decisions that arise in a real situation. The integration, here, of an unconnected controlling infrastructure enables us to illustrate our observations about technological choices in real situations.

- **Description of the case study**

The considered premises are a classroom within the Thermal Engineering and Energy Department of the Rouen University Institute of Technology. This room has all the usual characteristics of teaching premises, namely a wall with a large number of windows, the other three having none[44].

The lighting of the room was rehabilitated in 2005 with equipment available commercially at the time, which provides feedback over several years.

The original installation dated from 1993, the year the building was constructed.

After study and simulations, the selected and installed solution was:

- 9 ceiling-mounted fluorescent tube (CFL) luminaires, divided into 3 lines (window side, central and corridor side);
- 2 light sensors on two of the luminaire lines (window line and central line)[45] directly connected to the luminaires to inform them of a lighting level;
- 1 presence sensor for the whole room;
- 3 energy meters, 1 per phase, each phase being dedicated to one of the three lines of luminaires.

b. Luminaires' renovation results

After several months of use, the meter readings made it possible to observe a two thirds reduction in energy consumption as a result thanks to this renovation. It also showed that the gradation alone results in a direct decrease in consumption[46] of the order of 35 to 50% here, respectively for the central line and the window line compared to the indicator line on the corridor side, the lighting of which is fixed[47].

c. Conclusions and discussions

The results obtained with the 2005 technology are consistent with the orders of magnitude obtained in the simulations of our previous case studies on tertiary professional premises. As the savings observed here are due to the integration of a non-connected control technology, this case study also shows that the connected equipment is not essential to save energy in such a case: regulation requires first and foremost compatible sensors and luminaires. As developed in the analysis of the previous case study, the connected layer has the advantage of providing new services such as remote management or the crossing of data between several businesses.

It should also be noted that the renovation of the room has led to an increased attendance by teachers and students, compared to other rooms. In addition to performance, therefore, the issue

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[44] The plan and the source documents are available in the Appendix.
[45] The corridor side line is not equipped to serve as a control in order to quantify the gain of the gradation.
[46] Decrease corresponding to the direct consumption economy, i.e. to the factor α of the STERM model.
[47] The reduction in consumption is strongly linked to the configuration of the premises, the building environment and the number of visitors. It is therefore to be considered in order of magnitude.

of comfort is an important factor here in the assessment of the value of implementing the technology.

When considering the introduction of a connected control system thought must be given to the lighting equipment itself, as to its current relevance, the optimization possibilities for the luminaire itself, as well as the appropriateness of the equipment that will be proposed by default with the connected solution.

4. Public lighting – an example of key questions for local authorities

Public lighting represents 10 to 13% of the energy consumed by all lighting in France according to sources[48]. In addition, lighting represents 10 to 12% of the total electricity consumed in France. Consequently, the consumption of public lighting represents approximately 1% of the electricity consumed in France. The configuration of public lighting helps to structure public spaces, which makes any technological choices concerning lighting essential for communities.

Since the beginning of the 2000s, the world of public lighting has experienced major changes. The twentieth century objectives were to give access to lighting to all urbanized areas, then to improve the level of service by increasing the quantity of light supplied. Communities now aim to lower the costs[49], which goes along with a decrease in electricity consumption.

LED technology, which large-scale deployment was launched ten years ago, has been and remains one of the pillars of this strategy to reduce electricity consumption. The presence of electronics in these new lights offers new functions, including the possibility of controlling the luminous flux more precisely and securing this control thanks to information sent by sensors.

As a public lighting installation is highly dependent on the location where it is deployed, the objective here is not to propose a predictive model for calculating energy savings or CO_2 emissions. Instead, it is to raise the questions that arise when the ideas elaborated in our different case studies are deployed on a wider scale.

Initial feedback regarding the introduction of control technologies in public lighting are emerging, such as the example of a street in Strasbourg discussed hereafter[50]. They enable us to formulate some questions that echo the points of concern highlighted in this report[51]:

- The interest in presence sensing technologies depends on the use rate of the space in question: it will tend to be greater in areas with little traffic (residential, pedestrian paths or isolated areas) than in areas with a lot of traffic during the night (bars, restaurants, theaters, etc.). **It is therefore essential to answer the question of situational relevance for the deployment of such technology.**
- From the experience of rue Saint-Dié in Strasbourg, implementing pedestrian detection enables to achieve savings similar to an hourly basis pre-programmed variation technology, while guaranteeing a better level of service (pedestrians always having sufficient light as they pass). **It is therefore essential to answer the question of the true additional costs of this technology when compared to the other available solutions.**

[48] ADEME, 2013 - French Lighting Association AFE, 2019 - Lighting Union - Syndicat de l'Eclairage, 2014
[49] ADEME, 2014
[50] Details and documentation available in appendix.
[51] The experience feedbacks used here concern unconnected controlling technologies. However, they offer public lighting control services also deployed by connected solutions, which raises the question of additional services enabled by the connected layer, as mentioned earlier in this report.

- **The evaluation of the true relevance of these devices is not carried out with a "life cycle" approach**, since neither the energy associated with the production phase nor that associated with the control of operations are taken into account.

Today, the challenge for public authorities is to understand the real trade-offs they have to make when taking technological decisions. Choosing to deploy a technology means choosing a direction for your territory: this is because the digital tools deployed form a system, and a system necessarily orders and influences the dynamics of other related sectors. Thus, building your digital strategy means also building your strategy for mobility, buildings, consumption circuits, etc.

When the local authorities choose among the accessible solutions, it is therefore essential that they give themselves the means to understand the real justifications behind the project:

- What new services, which can only be guaranteed by the use of digital tools, does the community really need?
- What are the energy and environmental costs for their production and installation?
- What technological implications do their deployment have for future years and cycles?

Within the public space, the digital world is presented as a way to “make everything possible”. However, it is still necessary to define exactly what is expected from this digital world and how communities can be orientated towards using its services so as to justify the additional enery expenditure which they entail.

C. Diversification of the model for other technologies – the example of the Communicating Meter

1. Description of the subject of the study

- **Context**

The "smart meter", or "communicating meter", is a relevant case study to understand the implications of digital sobriety for the so-called Internet of Things (or IoT). It combines a large-scale industrial strategy with an adoption by the public of new functionalities, which do not always have an obvious added value.

It is therefore important to methodically analyze both the technical and societal dimensions of the environmental impact of such a deployment, within the framework of physical constraints to which our choices of digital strategies are subject.

At a European level, the political will to deploy a new generation of electronic meters for the various fluids such as electricity, gas and water dates back more than ten years now. The objective put forward was to avoid the annual visit of a technician and to inform the consumer in near real time of his consumption, thanks to an electronic metering and a frequent radio reading. It was assumed that with the consumer being informed regularly, savings would be established in individual or family households.

Another objective was to measure the quality of the distribution network for these flows. In fact, the electro-mechanical meters read once a year did not make it possible to monitor all the incidents that could appear over the last few meters connecting the customer's installation to the general network. The search for better network efficiency and better controllable consumption inspired the specifications of such communicating meters.

In this study, we only tackle the measurement of electrical flows in homes (and not the meters associated with other flows)[52].

Through this study, we would like to answer the question of the **environmental impact of the communicating meter, limiting ourselves to the scope of its impact on energy usage.** To enable a better quality of distribution networks for these flows, and an incentive for citizens to have greater and better control of their consumption, it was decided to install new electronic equipment directly in homes (home automation technologies within the framework of "connected homes") and in the networks themselves.

This new equipment, although potentially enabling energy savings, will increase energy consumption items both in their daily use and in their manufacture and production (grey energy). It is therefore necessary to question the conditions under which the sum of this additional consumption might be compensated by the savings made by operators and consumers.

- **Establishment of a "smart meter" network**

In addition to the data collecting network constituted from meters installed in the homes of consumers or in businesses, European specifications demand that the communicating meter must also provide the following services:

- To the consumer:
    - Direct reading of his consumption (in kWh and in €) with updates every 15 minutes;
- To the electricity distribution operator:
    - Data collection on a regular basis (at least once a day and up to every 15 minutes depending on the customer's contract),
    - Provision of a bidirectional channel to facilitate network management (adjust supply to demand in near real time);
- To operators selling electricity:
    - Be able to implement several tariff systems (8 loops on the Linky system in France),
    - Enable an on/off control of electricity supply, and in any case the ability to limit consumption (prepayment).
- Of security:
    - Provide a protected data transfer system,
    - Ensure the prevention and fraud detection.

[52] It is interesting to note that certain European countries have taken the decision to deploy the technical infrastructure for connecting these electronic meters, which are common to gas and electricity.

To achieve all of these functions, the smart meter integrates the following modules:

- The meter,
- The display, giving the electricity consumption directly in kWh but not valued in € (such a figure would depend on the prices of the provider)
- A long-distance communication module enabling it to be connected to the collection network chosen or required by the energy provider:
    - In France, data collection from the Linky system is done using PLC[53] on the energy network, then in GPRS[54] up to the servers of the electricity operator, Enedis;
- In the United Kingdom, the collection network is operated by an operator independent from the energy providers. The network is a dedicated GSM network[55]. The meter's long-distance communication module is then provided by the dedicated operator.
- Local communications modules (wired or ZigBee radio[56]) to the sensors and actuators of any home equipment to be remotely controlled.

Architecture of the "Communicating meter" network

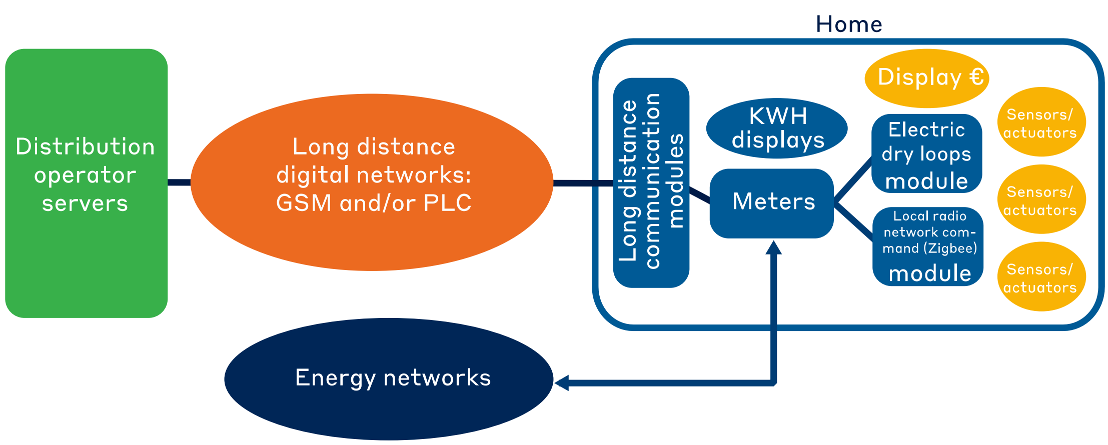

Figure 7 - Architecture of the "Communicating meter" network. In blue, modules making up the communicating meter.
Source: The Shift Project, production of the working group

In the analysis of the energy impacts which we detail below, only the consumption of the four modules described above is taken into account.

The sensors, actuators and the display in € are optional and therefore not evaluated in this study.

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[53] Power line carrier (PLC)
[54] General Packet Radio Service
[55] Global System for Mobile communications
[56] Communication protocol

a. Modelling: adaptation of the model and of the set of hypotheses

As indicated earlier in this report, our methodology consists of evaluating the energy consumption of all the electronic modules which make up the connected layer of the communicating meter over their complete life cycle so as to analyze the conditions under which this consumption is compensated by any savings made.

The evaluation of the suitability of the equipment takes the following parameters into account:

- The grey energy necessary for the production of the various parts of the communicating meter,
- The life cycle of the equipment,
- The energy consumed by this equipment during use across its lifecycle,
- The annual savings in the household's electricity consumption enabled by the system,
- The household's attitude towards savings measures recommended by the energy provider in regards to the actual consumption (that is to say, the adoption of new energy consumption behaviors).

- **Modelling behavior change**

In the case study of the communicating meter, the behavioral change is a structuring variable regarding the energy savings actually achieved. The savings enabled by the communicating meter do not mechanically result from its installation in the home. **They result from the modification by individuals of their consumption habits (choice and use of their household equipment), triggered by the visualization of the household's consumption and the advice of the energy supplier.**

According to some studies now available (ADEME, 2018) (TBH Alliance, 2016), this attitude is variable. The changes in behavior, if they do indeed appear for most households when the meter is introduced, attenuate either more or less rapidly over time, often to the point of disappearing if they are not supported by educational and support systems. In this case, the household members return to their initial consumption habits once the “novelty” effect has passed, nullifying the direct gains made possible by this connected technology.

Within the STERM model, the implementation of this change in behavior and of the evolution of the efforts made by the household can be done by using the integration of a time dependence in the energy saving factor, as presented earlier in this report.

The approach presented here aims to illustrate the way in which the STERM model can be reused and reappropriated by the concerned actors (public authorities, organizations, service actors, etc.) to describe more complex and precise situations than those presented in this report. Thus, the objective of this work is once again part of a **methodological approach aimed at highlighting the questions and elements to be integrated into the construction of energy relevance assessment tools of a technology**. However, this evaluation can only be carried out for each group of specific and correctly defined cases to limit the number of average assumptions to be made, and ensure the relevance of the models and conclusions.

b. Modelling and conclusions

- **Description of the case study**

To analyze the energy impact of the smart layer of the communicating meter, we have chosen three scenarios for a household with an average annual electricity consumption of 4,590 kWh:

- **The first scenario (1) is characterized by an average attitude of the household** regarding the behavior evolution during the meter lifetime. Savings of 3% over the first period, lasting one year, and of 0.69%[57] over the second period, which covers the rest of the life of the meter (14 years).

- **The second scenario (2) corresponds to a home where no new habit is established in a sustainable way** despite the information given by the communicating meter. The novelty encourages behavioral changes (3% savings) over the first period, lasting 6 months, followed by a 0% gain over the second period, which covers the rest of the life of the meter (14.5 years).

- **The third scenario (3) characterizes a household maintaining its efforts to change behavior**, which leads to savings of 1.5% each year over the life of the meter (15 years). When compared to real-life observations available today, this scenario is more theoretical than realistic.

Each of the three scenarios serves as the basis for a parameterization of the STERM model, which will enable us to apply the methodology for evaluating the energy relevance developed in this work.

- **Modelling results**

The modelling of the three scenarios above, carried out using the STERM model, makes it possible to observe the impact, on the final conclusion[58], of changing the value of the energy-saving coefficient. The non-persistence of the behaviors initially implemented by the household to reduce its electricity consumption will indeed *at least* increase the amortization time T_{PB} (see the results of the first scenario, in the appendix), or even make it impossible to amortize the production impact of the new technology through the savings made during the use phase (cf. *Figure 8*, blue curve[59]).

This means that the non-persistence of the change in behavior over the entire life of the meter has an impact on the total savings made: by increasing the time from which the savings made compensate for the grey energy of the meter, or even making this compensation impossible over the lifetime of the device.

[57] (Taylor, 2015)
[58] Exhaustive results and figures available in the Appendix.
[59] The inflection of the curve after a period of 0.5 years reflects the end of behavioral changes in the household, as well as the effect of the return to initial behavior on the savings made which become zero in this scenario. The green curve represents the evolution of energy savings (cumulative) if the changes in behavior are maintained continuously.

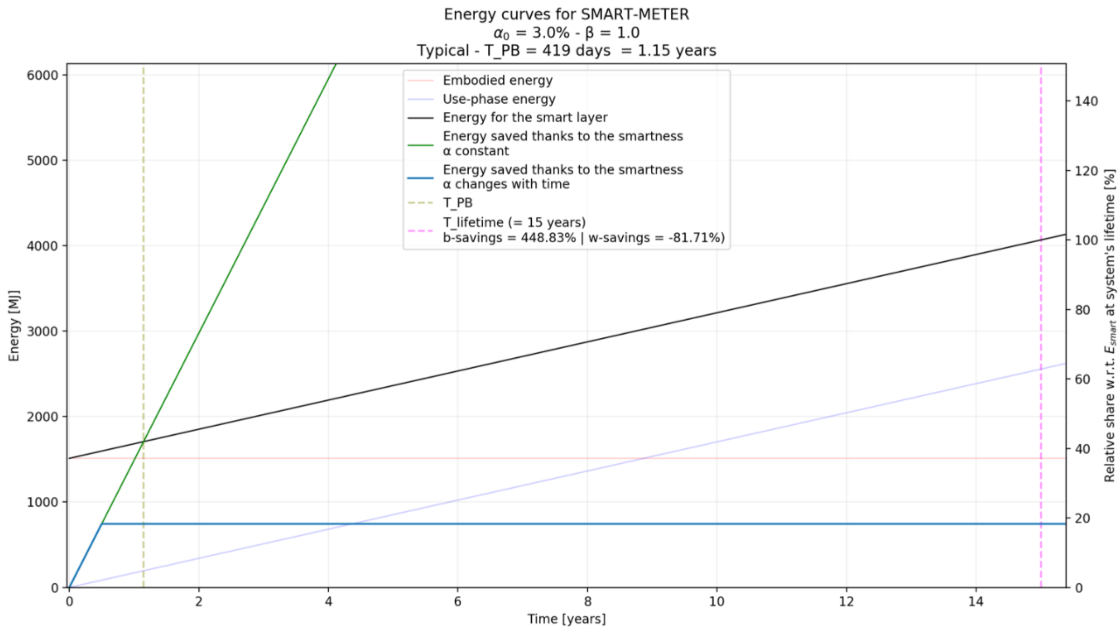

Figure 8 - Cumulative energy curves as a function of time, second scenario
Source: The Shift Project, production of the working group

- **Conclusions and discussions**

The conclusions that we can formulate at this stage focus on a single area: the effectiveness of the meter as an energy saving tool at the household level, and without additional support. **We did not take into account in this study the savings and the positive impacts achieved thanks to the meter communicating on the distribution network (better management of the network, elimination of trips linked to the annual reading of indexes by technicians, etc.). The conclusions formulated here are only intended to feed further discussions so the real conditions of relevance of these systems can be studied.**

As in the other case studies explored in this report, there is no basis to conclude that there is an automatic gain in terms of domestic energy consumption when the technology is introduced. The savings enabled by the meter are directly linked to changes in household habits and so depend on human behavior.

The opportunity to visualize the energy consumption associated with consumption habits can however be useful or even essential for behavior change. Near real-time information about household consumption can thus become an asset to encourage citizens to better manage their energy consumption. If we want to exploit its potential, the deployment of these new tools must be accompanied by strategic thinking, some of the key points being:

- The deployment of a tool in order to follow the household consumption only brings about a behavioral change if it is appropriate and integrated into a defined approach. **It is therefore essential to develop and disseminate approaches to support households.** Beyond simple awareness, changing the habits of a household requires the implementation of specific advice on the objectives to be achieved, the actions to be implemented and a **clear explanation of the new trade-offs implied by these changes in behavior.**
- The deployment of these new tools, which can enable households to change the way they manage their fleet of domestic appliances (purchase choice, way of using the

appliances, etc.) **should not encourage the thoughtless generalization of the idea that connected tools offer new services**. It has been reaffirmed through the various case studies of this report that the impacts of the production step are often significant in the assessment of the energy relevance of connected tools[60]. Allowing the development of obsolescence triggered by the introduction of a tool aimed at reducing energy consumption would therefore be an error, which would cancel the potentials of the tool.

- It would be more useful to push the development of tools which operate without the need to renew the stock of household appliances, and to analyze precisely, according to the methodology used in this report, what are the real savings enabled by the tools designed for "household energy management".

D. General methodological conclusions and recommendations

When we try to create energy resilience, the essential issue to address when making decisions related to the deployment of connected technologies is its **appropriateness**: relevance to the resilience challenge, relevance to the compatibility between environmental and digital strategies of territories or organizations, relevance to the indirect challenges caused by the deployment (maintenance, multi services, essential role of external/private actors, etc.)

The model built by our working group (the STERM model) provides a first neutral approach to energy suitability. It embeds the following critical parameters:

- Energy cost of production of connected layer components,
- Device lifespan,
- Electricity consumption caused by the operation of connected devices,
- Energy savings made possible by the implementation of the connected layer,
- Parameters that could impact these energy savings (i.e., the context of relevance)[61].

Integrating these parameters is essential for an evaluation that is not partial. The case studies developed here have indeed shown that the integration of a true “life cycle” approach can shift the final conclusion in regards to its value. **It is thus common for a smart system to generate savings in electricity consumption during the operation phase. Given the importance of the energy required to produce these technologies, it is however less obvious to find the right deployment conditions that effectively lead to a reduction in total emissions.** Yet, failing to take into account emissions throughout the entire value chain means failing to understand that it is essential to adopt systemic considerations such as "life cycle analysis" if the challenges of decreasing the carbon emissions caused by our activities are to be tackled seriously.

The case studies illustrating our work enabled us to list the most important recommendations regarding the deployment of technologies enabling energy savings:

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[60] Once again, the generalization should not be done in an absolute way. It is only the trend observed in the case studies as well as in the previous works of The Shift Project. (The Shift Project, 2018).
[61] Room attendance rate for connected light, persistence of changes in behavior for the smart meter, etc.

- A connected system becomes valuable from an energy point of view only **if the initial system consumes a important enough amount of energy**. So it will be **worthwhile to deploy the connected technology on this initial system only if the initial consumption is both sufficiently high and already optimized as much as possible**[62].
- **The deployment of smart technology, if it leads to the installation of other technologies or infrastructures, greatly or even totally reducespossibilities that it will bring actual energy savings.**[63]
- The resulting changes in behavior usually subside over time. **Introducing a new tool is therefore not enough to change a habit** if it requires effort from individuals. It is therefore essential to think about the type of support that a real change in consumption patterns requires. The introduction of new tools can be an essential asset to achieve this goal, but only **if its deployment is designed to fit into an environment where it can deliver value and is then supported (training, support in piloting, etc.) to create and promote this value.**

These conclusions can be considered as guidance to the reflections of concerned actors by enabling them to **build their own analyses**. It is impossible to build an objective answer to the general relevance of connected technologies to the energy transition. It is however possible to produce consistent estimates of the costs of their deployment, which makes it possible to develop a clear and explicit vision of whether a given technological choice will deliver against given objectives.

The aim of this work is to produce illustrative examples of an approach enabling local authorities and their (private and public) stakeholders to ensure the relevance of their choices.

The work carried out here focuses on the evaluation of the impact of connected technologies on direct energy savings, i.e. when the connected layer enables a saving directly on the consumption of the object on which it is integrated. For indirect processes (connected layer to optimize mobility flows for example, or to optimize management of material or waste flows, etc.), it will be necessary to update the modelling of the generated energy savings (by integrating a more complex conversion of the associated processes, within the modelling of the energy saving factor α). Still, the assessment must absolutely integrate the assessment of the direct consumption of the connected layer and the associated grey energy. Beyond energy consumption, **the development of these tools will have to integrate environmental criteria, which are not studied here and whose consideration is essential (carbon impact, pollution indicators associated with the production, at the usage and the end-of-life stage of the digital tools)**.

The model developed here aims to be the embryo of a tool that is adopted, understood and adapted to the needs of actors, **in order to develop the range of tools necessary for the implementation of mutually developed and consistent dynamics within given territories**.

[62] In the example of connected light, it appears that improving the energy efficiency of lighting technology (by switching from incandescence to LED for example) often makes the introduction of a connected and intelligent infrastructure irrelevant, the consumption then becoming too optimized for the connected layer to become efficient.
[63] Deploying new tools means having to produce them and make them work, which has always historically led to the development of larger infrastructures and to a greater material impact.

E. The "connected city": from slogan to smart district strategy

The connected city needs to be clearly defined. As it is part of how planners and local authorities intend to built the “cities of tomorrow”, it has to reach the right level of ambition.

Digital and connected technologies offer real opportunities but are not free from the risks that the coming decades pose to the resilience of our systems: climate risk, risks related to the sourcing of fossil resources, health and geopolitical risks. It is essential that the so-called city of tomorrow accepts its responsibilities so as to become truly “responsible”. It is now responsible for the strategic choices it will make, and therefore it must also be able to understand the effects and implications on its transition to resilience.

Technological choices are no longer simple choices between tools. **The deployment of a technology generates a whole new range of uses linked to it** that call for further deployments in the future. Any technological choice is therefore a societal and systemic choice, which will have impacts on the other systems and infrastructures of the area in which it is implemented (mobility, social and societal systems, distribution channels, etc.).

Making our districts resilient will not require a “digitalization” of all the activities taking place in them. The actors of our digital systems must develop in-depth consideration of the data, produced in such cities, its volume, the dynamics (which must no longer be simply expansionary) they provide, the infrastructures needed to store and distribute them, the energy related them, the question of their availability and use in the long term, the question of their end-of-life stage and of their true value.

Resilience will require us to build a clear vision of the objectives that need to be achieved, the solutions available to reach them, the role of connected technologies in these combinations of solutions and how to promote the development and maintenance of their relevance frameworks. **It is the duty of district level public authorities to determine quantified objectives regarding their district’s environmental transitions, in order to be able to build explicit, workable strategies in intensive collaboration with local actors** (companies, organizations, associations, households, etc.).

Developing these strategies and collaborations require us to anwer the following essential questions:

- What policies and which tools are needed to support the inhabitants of the district when using digital tools?
- What real end-of-first-life policies need to be put in place for digital tools (repair, reconditioning, recycling, etc.)?
- What strategies are required to contain the dynamics of rebound effects caused by digital uses and likely to negate any positive effects?
- What are the real motivations of the district’s technological projects (effective energy savings or increased connectivity, customer profiling, etc.)? What is the relevance of these motivations when considering energy and environmental costs, in terms of loss of resilience, etc.?
- What dependencies between actors appear during the deployment of new infrastructures and technologies (especially dependencies between public and private actors on the operation or maintenance of systems, tools, infrastructures)? Are they compatible with the other high priority needs of the district?

“The connected city” will only be “city of the future” if it is thought through by a given district, so as to create consistent dynamics with the actors working within it, which will build a digital strategy that will truly become an asset with respect to its environmental trajectory, and which will translate this strategy at the different levels constituting it (companies, households, institutions, public authorities). **Because building a connected city without giving any consideration to the resilience of the technological infrastructures deployed within it means missing one of this century’s great the technological opportunities. Today, true innovation is that which takes into account full knowledge of the facts.**

II. Guiding organizations in their efforts towards a sustainable Information System

A. Context and objectives

1. Objectives

From the environmental point of view, Information & Communication Technologies (ICT) contribution to CO_2 emissions, the use of natural resources and the pollution of water and soil are such that **each organization, whatever its size, will have to change its digital approach to contribute to the collective reduction of the environmental pressure of human activities**.

This chapter aims to promote **the vision of an organization’s Information System (IS) whose operation is sustainable.** It presents a **methodological framework and some specific tools to set up to boost the measurement and reduction of the IS environmental footprint.** The goal is to guide digital actors so that they can contribute to the journey towards global carbon neutrality, described in France's National Low Carbon Strategy [9], which aims to achieve carbon neutrality by 2050 and to contain by 2100 global warming below 2 °C with respect to pre-industrial levels, according to the Paris Agreement (COP21) signed in 2015.

Several authors have been engaged in the writing of this report, partly during a lockdown period due to the impact of COVID-19. During these strange times, the use of digital technology in society has increased and we have seen how much it can act as a tool for resilience in the world of tomorrow. It is up to digital professionals to make this technology evolve quickly towards a sustainable model, combining sobriety in use, as well as in system and operation optimization.

☝ **N.B.**	In this chapter, **the term organization** refers to a group organized towards a common goal. This can be a company in the industrial or service sector, an administration or an association. Suppliers such as digital hosting service or equipment manufacturers are included as well. **The term information system** or **IS**, refers to all the IT infrastructures that an organization uses or manufactures to support its activities and provide its customers with its sold product or service. Neither greenhouse gas [GHG] emissions from buildings such as data centres or facilities that house IT human resources, nor those of transport and food for staff working in the Information System management department, nor those of buildings and air conditioning systems required to house servers for IT professionals are covered in this chapter.

The framework defined here should enable an organization to **deploy a sustainable digital policy.**

It revolves around 6 main activities:

- Develop and deploy a sustainable IT strategy,
- Develop a sustainable digital culture,
- Measure the environmental impact of the end-to-end information system,
- Build a sustainable information system,
- Engage with customers, suppliers, partners, institutions towards sustainable solutions and services,
- Govern the transition to a sustainable information system.

The following, non exhaustive, **benefits** can be expected from this approach:

- Reduce GHG emissions and the use of resources,
- Improve operational efficiency, reduce IS costs by being more frugal, and by being more concerned with minimizing digital resources with low added value,
- Abandon strategies leading to environmental and financial deadlocks,
- Be ready when legislation enters into force concerning these issues, which is imminent in France and the EU,
- Be ready when rare metals become scarce, and IT equipment is impacted,
- Be attractive to newly hired collaborators and help motivate their company's employees by enabling them to put their professional activity at the service of a strong societal concern,
- Offer customers, shareholders and employees a vision and an approach in line with their civic concerns.

☝ **N.B.**	In addition to this chapter, the following are provided as an appendix and on the website of *The Shift Project*: ▪ A list of good practices to help transcribe the various initiatives of the framework into explicit and concrete actions ▪ A PowerPoint with this report's diagrams to facilitate their reuse ▪ The XML export of Archimate models® that can be imported into all modelling tools compatible with The Open Group® standard

2. Targeted actors

This chapter is intended for:

- **Directors of organizations**, who define and support the IT strategy,
- **Professions using digital services** such as application owners, managers, decision-makers and others who are responsible for the use of the information system and who will have to rethink these uses with respect to their environmental impact,
- **Marketing or sales professionals** responsible for designing the services used by the organization's clients, which will promote more frugal use cases and consumption behaviors,
- **Information systems directors** who are responsible for developing and operating the Information System,
- **Enterprise architects** responsible for designing future architectures and contributing to the decision-making process, either to optimize the digital assets of the organization, or to develop its capacities,
- **IT professionals**, business and application owners, managers, decision-makers and others, who are responsible for this system for their organization,
- **Teachers in digital fields** in universities, research laboratories, high schools or vocational training organizations,
- **Corporate Social Responsibility (CSR) professionals** because of their role in the transformation towards sustainable organizations,

And more broadly **anyone involved in the digital transformation of an organization.**

B. The information system has an environmental impact

- **We've got the wrong idea about digital dematerialization**

At first glance, digital technology appears to dematerialise physical flows, and seems to "lighten" organizations and make them more flexible by reducing the use of paper and the number of proxies required to access a service. But in reality it materializes flows of data, which are stored on servers and travel through real physical channels. It generates another form of managing data that is very intensive in energy, space, and sometimes scarce hard commodities: server rooms, terminals, networks, etc.

- **Our information systems are bloated**

Driven by decades of internal process digitalization, implementation of indicator calculation (regulatory governance, control, key risk, or decision-making) and business growth support (digital economy), computing systems are now used in every organizational process. The success of this digitalization and the related growing number of innovations leave no room for rationalization. **Almost all organizational entities suffer today from technological bloat due to partially controlled stacking of different architectures, applications, data, and technologies.** These strategic information systems can act as constraints on any business that would be otherwise willing to adapt to new financial realities. Until now, the rationalization phase of the information system paradigm has been something to be "endured": a state of affairs that was partly triggered by the bursting of the dot-com bubble in 2001 and the financial crash in 2008. However, **the transformation of an entire information system is time consuming**, a fact that is often incompatible with the expectations of customers and different business actors. Understanding that new environmental requirements will have a similar effect implies **the implementation of a new strategy in a short time** to avoid the impact of a transition that is too abrupt.

- **... and it shows on the scale!**

In our first report published in 2018 (*The Shift Project*, 2018), we were describing the environmental impact of digital technology at a macro level. Today, the fact that curves of data usage show tremendous growth, demonstrating the consumption driven by so-called Big Data raises substantial questions.

According to a recent study led by IDC, an international research company specialized in information technology, the volume of stored data will reach 175ZB (zettabytes) in 2025, i.e. **5.3 times more than that which was stored in 2018**. However, each additional byte requires energy to be stored, and therefore generates additional carbon emissions. Given today's goals of stabilizing and reducing CO_2 emissions[2], we must try to stabilize this trend by dedicating our storage capabilities to only the most meaningful data.

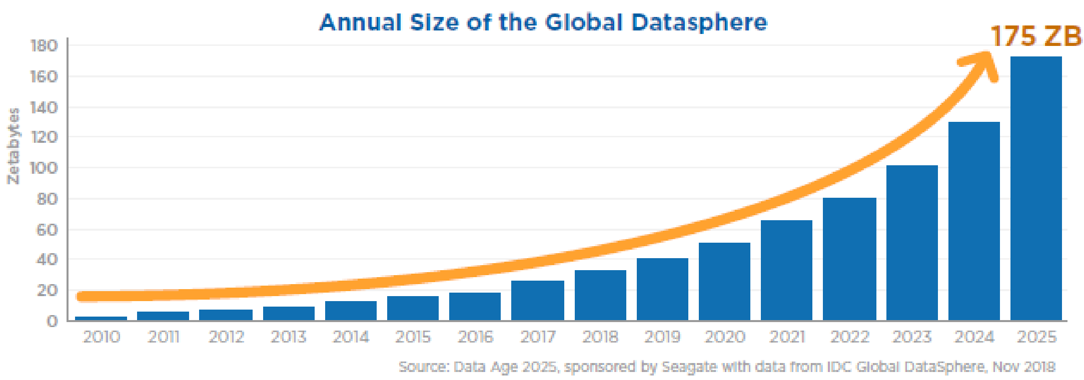


Figure 9 - once depicting growth, data explosion curves are becoming really worrying
Source: (Reinsel, D., Gantz, J., Rydning, J., 2018)

While the increase in data volume is a corollary of the digital boom, other indicators such as the quantity of digital waste and network flow, the amount of digital equipment, available digital services, data streams, and available solutions, electricity consumption etc. all follow mutually sustaining growth dynamics.

The diagram below is an illustration of the positive feedback loops at work. It illustrates how the increase in data volume mechanically increases the available services, which themselves create new needs in devices that generate new data.

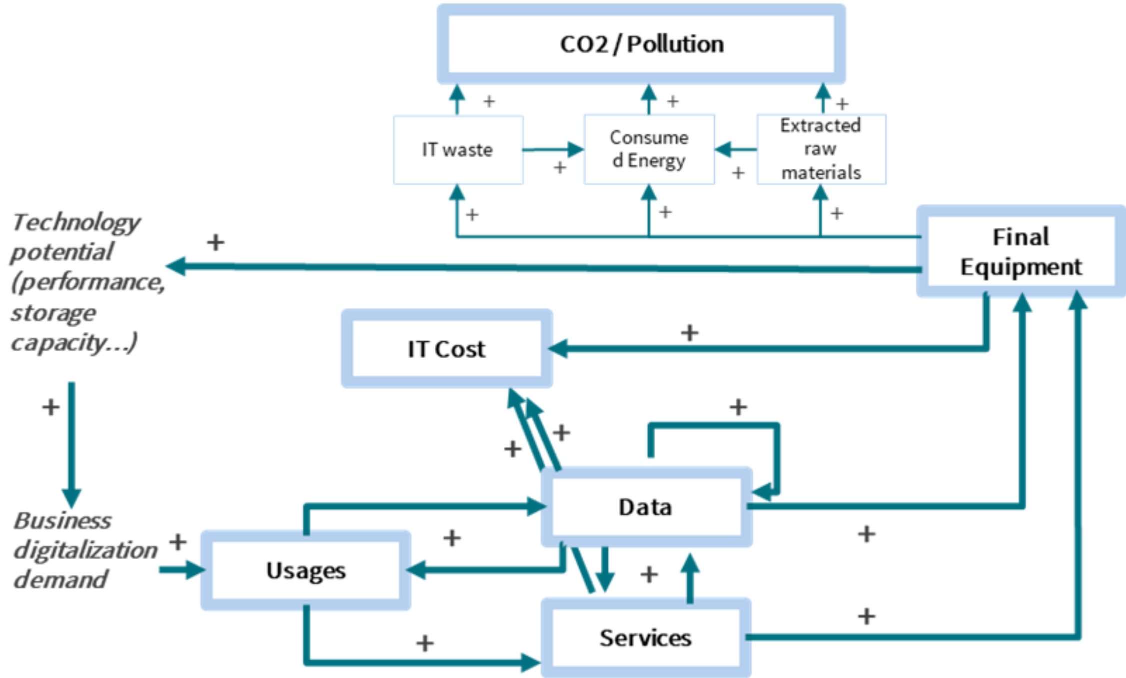


Figure 10 - System Thinking applied to the Information System of an organization –

inspired by Thinking in Systems by Donella Meadows (Meadows, D., 2008)
Source: The Shift Project, production of the working group

☝ **N.B.**	Measurement of the global environmental impact of digital technology has been established in the report "Lean ICT: Towards digital sobriety" (*The Shift Project,* 2018). The contribution of ICT in greenhouse gas emissions has increased by half since 2013, from 2.5% to 3.7% in 2018 to reach **4% in 2020**: it is more than civil aviation. The digital transformation of society has resulted in an intense increase in energy needs from the ICT sector. This footprint includes the energy required for the production and use of digital devices such as servers, networks, terminals and is growing by 9% each year. In a context where global greenhouse gas emissions must be globally reduced by 5% each year to keep the projected temperature increase below 2°C, it is necessary to stabilize the energy needs of the digital sector, as mentioned in the report " Lean ICT: Towards digital sobriety" (*The Shift Project*, 2018), and if possible, reduce them. Some orders of magnitude are specified below. Note that depending on the considered baseline, there may be some variations, but the orders of magnitude stay the same.

N.B.

Examples	KG equ CO_2	Source
Paris – NY roundtrip by plane		
Per passenger	1,047	http://eco-calculateur.dta.aviation-civile.gouv.fr/
Per passenger	2,870	Carbon footprint calculator from the Good Planet Foundation, https://www.goodplanet.org/fr/calculateurs-carbone/particulier/
A car, Peugeot 208 II model		
Produced in Europe	8,870	ADEME*: 1,1T x 7.643 = 8,407 Kg
40,000km/year for 8 years (life cycle)	33,280	40,000 x 8 x 0.104 = 33,2380Kg (manufacturer data)
A car, Sedan		
Fabrication	7,100	https://www.fondation-nicolas-hulot.org/quelle-contribution-du-vehicule-electrique-a-la-transition-energetique/
25,000km/year for 10 years (life cycle)	3,840	https://www.fondation-nicolas-hulot.org/quelle-contribution-du-vehicule-electrique-a-la-transition-energetique/
A 1,000 m^2 data center, installed capacity 1 MW, PUE 1.7		
kWh fabrication (without considering the building, the cables, the air-conditioning …)	7,119,000	7,119 Kg CO_2/w x1,000 m^2 x 1,000w/m^2 = 7,119,000 Kg CO_2e
Annual operation kWh – PUE 1.7	14,892,000	1,000 KW x 1.7 x 24 x 365
Annual operation in France – PUE 1.7	850,333	Energy mix data from the ADEME*: Formula = 1,000 KW x1.7 x 24 x 365 x 0.0571 = **850,333**
Annual operation in India – PUE 1.7	13,581,504	Energy mix data from the ADEME*: Formula = 1,000 KW x1.7 x24 x365 x0.912 = **13,581,504**
Professional mobile phone fleet (1000 units) for 3 years (life cycle)		
iPhone 8 fabrication	141,000	Manufacturer data from Apple: 1,000 X 3 x 47
Use in France, 1 charge per day and per mobile phone	938	Manufacturer data from Apple: 1,000 X 3 x 5.475 x 0.0571
Professional mobile phone fleet (1000 units) for 3 years (life cycle)		
Fabrication	61,000	The Shift Project, lean ICT v1 (2018)
Annual use in France	200	The Shift Project, lean ICT v1 (2018)
1 server in data for 3 years (life cycle)		
Fabrication	588	The Shift Project, lean ICT v1 (2018)
Annual use in France	200	The Shift Project, lean ICT v1 (2018)
Video		
30 mn (for instance, e-learning session 100% for 30 mn)	9	The Shift Project, lean ICT v1 (2018)
Email		
10 emails with 1 MB attachment sent daily	66	The Shift Project, lean ICT v1 (2018)
Paper		
1 printer white paper ream 80g/cm^2	2	(same link (the redirestion is actually not working))
1 French citizen for 1 year		
For 1 French citizen on average	11,900	https://www.gouvernement.fr/indicateur-empreinte-carbone
*Sources: GreenIT, NégaOctet, The Shift Project, *ADEME: French Agency for the Ecological Agency 1 KwH éléc. France = 0.0571 kg eq CO2*		

• A fitness program for information systems

At the organization level, managing and reducing the environmental impact of the information system means:

- measuring the dependence on specific resources that may become scarce and expensive;
- assessing the financial risk related to future regulatory changes that may be imposed;
- evaluating if the information system is in "good or bad shape", i.e. its efficiency (value/energy ratio).

It is about **retaking the control of the digital environment footprint with a continuous fitness program!**

C. Deploying a sustainable digital policy to reshape Information Systems

- **Designing a sustainable digital policy**

Many digital service providers have **optimized their electricity consumption**. The earliest initiatives focused particularly on the direct costs of power consumption in server facilities: introduction of more efficient hardware and the intervention of energy experts...

Maximising the digital sector's contribution to carbon neutrality requires not only **optimizing the use of energy and natural resources**, but also **dedicating resources to the uses with the highest societal value**.

So far, only a few organizations have adopted a **holistic view of their information system**, which should include, among other things:

- outsourced services,
- the impact of manufacturing the hardware that makes up the digital infrastructure,
- the performance of the electrical mix of the manufacturing and operating sites.

Where organisations lack such a global view, decisions and trade-offs regarding the numerous uses of the Information System will suffer from blind spots that may hide impacts significant enough to affect decisions and outcomes. This framework aims to support organizations in this transformation.

New or existing activities to be developed are to be implemented to **deploy a sustainable Information System policy**. Those described below are common to all organizations using an **Information System**. It is important to describe them in a reference framework to define **a common interprofessional language**.

This "fitness" framework of the Information System is intended to serve as a starting point. It is used to classify activities already undertaken, to evaluate their maturity, their strengths, the weak points to be addressed and how they are placed in comparison to others in the market. **It should be adapted to the specific context of each organization**.

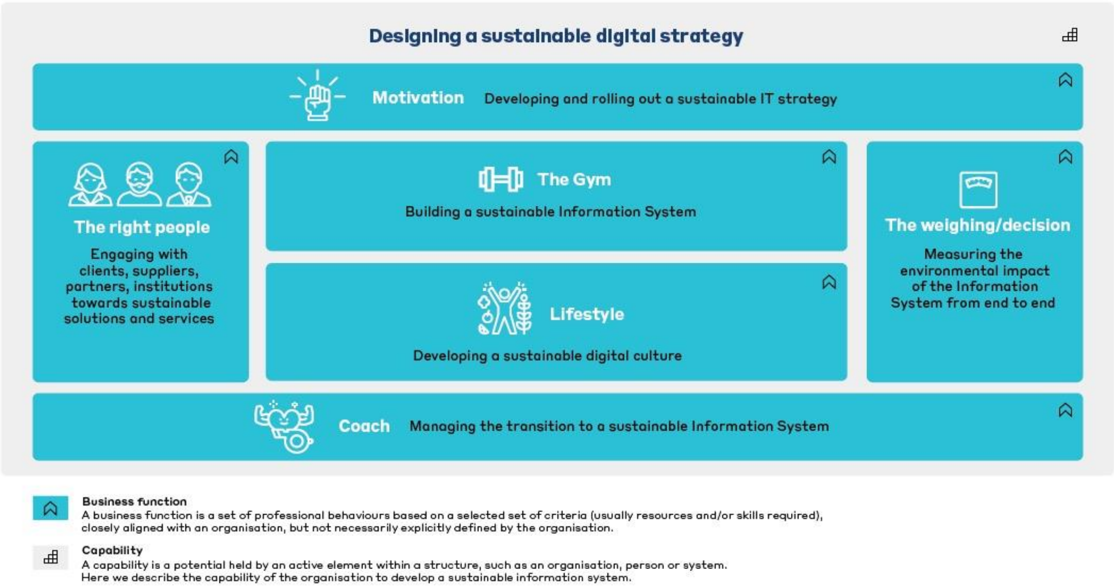


Figure 11- Reference model - top level view - for a reform of the Information System
Source: The Shift Project, production of the work group

- **Developing and rolling out a sustainable IT strategy**

An information system needs an **ongoing long-term sustainability program**. This requires the **support of management** and a strong sponsor such as the director of operations or the director of ICT. It involves formulating and sharing motivations and objectives for transformation towards a sustainable Information System. These objectives must be part of an overall sustainability strategy across the organization and be integrated into the general IT strategy.

They must also be rolled-out in enterprise architectures with approaches that encourage mutualization and simplification of the Information System.

Once the **sustainable IT strategy** has been defined, it is then necessary to **identify an actor and a team that will be responsible for leading the transformation** through the activities described below.

- **Developing a sustainable digital culture**

The lack of awareness about the complex **energy-climate issue** and the environmental impact of digital technology is probably one of the root causes of our difficulty in dealing with these issues. This program needs the support of all employees, who must be trained and made aware in order to embody a sobriety and sustainability culture that will become part of the long-term DNA of the organization.

- **Measuring the environmental impact of the Information System from cradle to grave**

Measurement is **the key tool required to lead a quantitative reduction**. The tools must be developed to control and measure the progress of an effective reduction of the impact of the Information System on the environment across the whole life cycle of hardware components "from cradle to grave". The production of devices is responsible for more than half of their CO_2 emissions, it uses rare metal resources, and it generates waste and pollutes the soil and water. The search for the optimization of power consumption is leading to intense hardware renewal rates (*The Shift Project*, 2018). To build a sustainable Information System we need to take into account all end-to-end impacts, including "scope 3" of the carbon balance method of the CSR standards. For the implementation of such measurement in an organization, this report focuses on the organization's efforts on CO_2 emissions, on a global basis, and on the initial efforts to reduce emissions. Developing this new capability implies significant effort, but it is essential for tracking the transformation and achieving meaningful reduction targets.

- **Designing & Building a sustainable Information System**

Methods for creating digital tools must be adapted to minimize their environmental impact at all stages of their lifecycle, from design to implementation. This new framework will help feed the agile inspired methodologies used for the creation of IT solutions. The architectures will be chosen depending on their environmental impact. All architecture levels are concerned:

- **Businesses units** will question the basis of all digital solutions. From among those offers that provide real business value, they will select those which are most environmentally efficient from the manufacturing stage to consumption.
- **Applications** on the organization's servers and end-users' terminals will be resource efficient.
- Stored **data** will be managed in a rigorous and economical way, and their presence justified by quantifiable utility.
- **Technical solutions** will be chosen taking into account their repairability, durability, energy efficiency, and the origin of their components (e.g. considering whether they encourage the circular economy).

- **Engaging with suppliers, partners, institutions towards sustainable solutions and services**

To date, Information Systems are characterized by rapid obsolescence. It is at the core of the current economic model of the sector, and we must move towards **planned sustainability**. Furthermore, the energy mix of countries in which IT employees and service providers work is rarely taken into account when choosing services, even though it can vary the environmental impact by several orders of magnitude.

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

The ecosystem surrounding an organization appears to be a key point in its transformation.

To achieve sustainability objectives, it will be necessary to choose partners who wish to be part of a sustainable framework, to define a strategy taking into account the environmental impact of suppliers, to get involved in the interprofessional interactions on environmental issues in order to to create peer pressure concerning the transformation of the sector.

Finally, if the organization that promotes services or purchases solutions does not then implement them, it remains responsible for the amount of produced data which they generate, their processing, network usage and the choice of suppliers who share their values. An external supplier cannot be the organization's "carbon trash can" to filled up in order to reduce the scope of its own obligations. Intense collaboration with various subcontractors is necessary to ensure completeness of the measurement and actions to reduce indirect emissions from these third parties driven by the organization.

- **Governing the transition to a sustainable Information System**

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

The activities that make up this governane are detailed in the reference model below and in the following chapters.

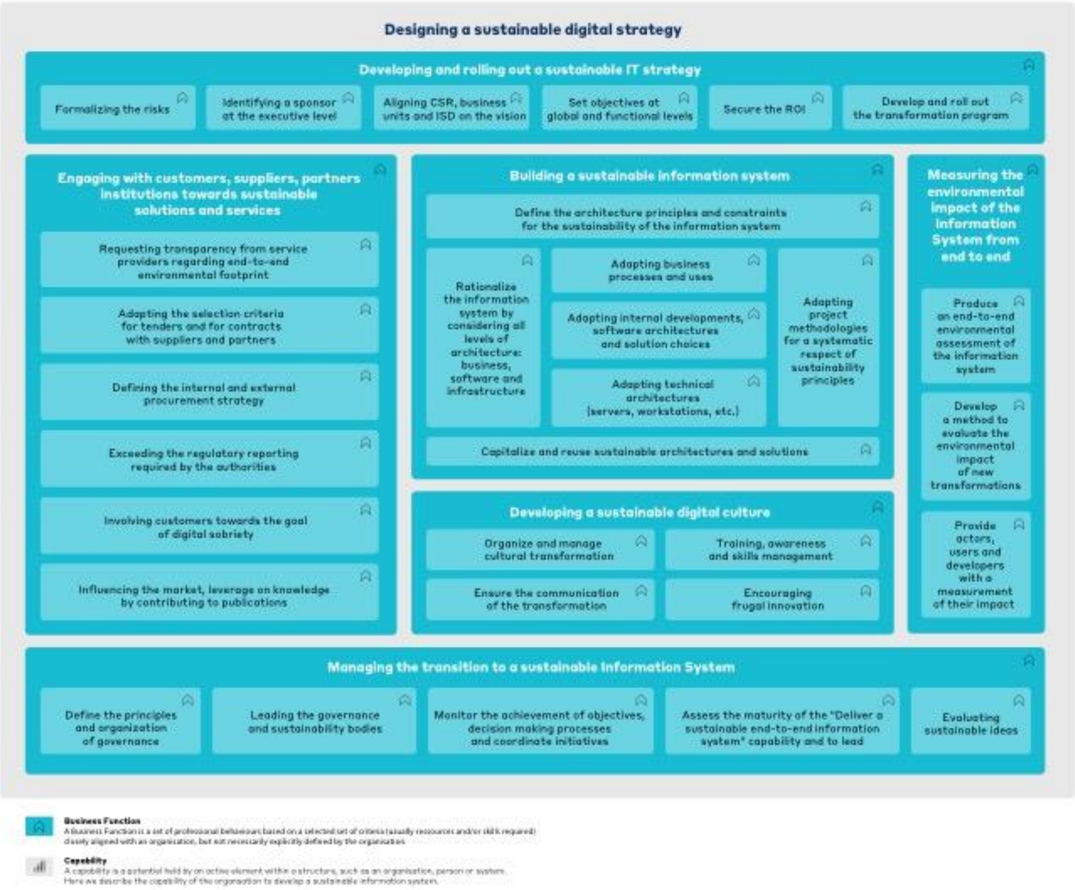


Figure 12 - Reference model - detailed view - For a redesign of the Information System
Source: The Shift Project, production of the work group

This model is also made available in the Open Exchange XML file format defined as part of The Open Group's Archimate standard. Each function is documented with a description and the xls file of best practices lists the actions to be carried out in relation to each of them.

D. Developing and rolling out a sustainable IT strategy

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 can take 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 twofold between 2006 and 2018 (IDC, 2017) (1).

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 (Cybersecurityventures, 2019), and these risks are now overseen directly at the executive management level.

2. Environmental risk linked to digital technology: the need for executive awareness

The expression "**infobesity**" is used to express the risk that a company is not able to adapt quickly to new market conditions because of its ever growing Information System. Companies must know whether their Information Systems constitute a threat when facing tomorrow's new environmental constraints and requirements, or will aggravate the climatic risks that the company is facing. These are listed below.

<table>
<tr><th colspan="2">TRANSITION RISKS</th><th>PHYSICAL HAZARDS</th></tr>
<tr><th>Regulations</th><th>Markets</th><th>Acute</th></tr>
<tr><td>• Increase in the price of GHG emissions
• Increase of reporting obligations
• Regulations on existing products and services</td><td>• Changes in consumer behavior
• Uncertainty of market signals
• Increase in raw material costs</td><td>• Increased intensity and frequency of extreme events:
– Cyclones
– Hurricanes
– Flooding
(Causes of damage on facilities, reduction in production capacity)</td></tr>
<tr><th>Technologies</th><th>Reputation</th><th>Chronic</th></tr>
<tr><td>• 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</td><td>• Changes in consumer preferences
• Stigmatization of a particular sector
• Increase in negative comments from stakeholders (e.g.: greenwashing...)</td><td>• Changes in precipitation patterns and increased variability
• Increase in average temperatures
• Rising sea levels
(Causes of damage on facilities, increased operating costs, impact on employee productivity)</td></tr>
</table>

Table 3- Typology of transitional and physical climate risks
Adapted from I4CE, based on (I4CE, 2017)

It should be noted that this official taxonomy is not limited to energy-climate issues, but that the risks induced by the Information System and its physical construction go beyond that: pressure on finite mineral resources, water and soil pollution, social and political tensions.

Consequently, **raising awareness and initiating transformation at the executive level** is the first act of a sustainable IT strategy.

Figure 13 - Risks, responsibilities and role of the ISD
Source: The Shift Project, working group production

3. Sustainable IT strategy: expression of a responsible corporate strategy

All these risks go far beyond the simple perimeter of the company: becoming aware of one's share of responsibility, as an organization is a societal issue, which is displayed in one's "**mission statement**". This notion was recently institutionalized by the French PACTE law (Ministry of the Economy, Finance and Recovery, 2019), which legally allows companies to "specify a mission statement. This consists of the principles which the company adopts and to which it will allocate resources and to which it intends to allocate means in the transaction of its business and is enshrined in its statutes. The growing influence of this mission statement on strategy is increasingly cited. (BCG, 2019).

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 any external impacts outside of the company**. This must be considered as a whole: its external constraints, business model, organization in the broadest sense – geographical locations, processes, governance, functions – its partners and suppliers, its culture and, of course, its Information System. In this respect, the scope of the transformation is comparable to the so-called "digital" transformation one, which has also needed strong sponsorship and has been officially represented at Executive Committees, in the form of, for example, a "Chief Digital Officer".

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 overall cohesion with both the other environmental aspects (travel, buildings, etc.) and the development of the company's activity.

4. Ambition of a sustainable digital strategy

Determining the ambition of this strategy requires a rather complex measurement exercise, which aims first of all to identify and quantify the company's current digital footprint in its entirety. This includes its direct electricity consumption (known as "scope 2") but also the upstream and downstream indirect impacts (known as "scope 3") – from construction and hardware delivery to its use in an external supplier's data center, for example. These represent by far the largest part of the equation (French Ministry of the Environment, Energy and the Sea, 2016).

Modelling and redistributing this global footprint across the company value chain will help in the second exercise of defining reduction objectives, quantifying them and choosing the means to achieve them. This involves questioning the uses of each function with regard to their economic gain/environmental impact ratio. The global objectives can be compared with the Paris agreements (COP21), **which commit to a reduction in global emissions of 5% to 7% per year** (*The Shift Project*, 2018). In France, the ambition of the National Low Carbon Strategy is to divide emissions by 6 by 2050 (French Ministry of Transition and Solidarity, 2020).

As with the implementation of any strategy, investments secured by senior management are required. Some of the initiatives may have positive economic impacts, others negative impacts, and while it is difficult to assess the initial impact of the actions as diverse as streamlining the Information System, changing suppliers (to more responsible ones), and relocating specific operations (to countries with a clean 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 ones must lead to the formulation of acceptable limits for the possible increase in the operating budget, which must be clearly presented as a limiting factor of the ambition. It should be noted that initiatives to ensure the financing of such a strategy (CAPEX and OPEX impact) start to emerge with internal carbon tax mechanisms, charging the business lines according to their CO_2 footprint (Société Générale, 2020).

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 in this way:

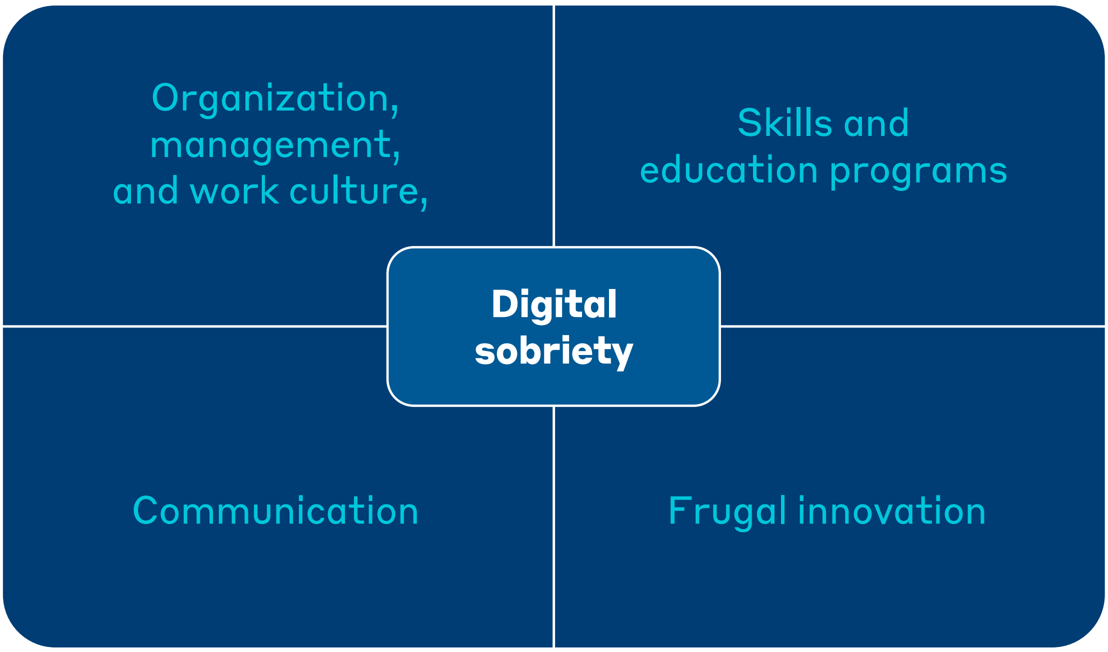
R	A	C	I
Responsible	Accountable	Consulted	Informed
CIO (CIO)	Member of the EXCOM having authority over the ISD: CEO (Chief Executive Officer), CDO (Digital), COO (Operation)	CSR, Business professionals, Support functions, Partners, Suppliers	Clients

Note the growing importance of purchasing departments within this program given the amount of IT outsourcing and the strong trend in the XaaS ("*everything as a service*") 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, so as to achieve the culture change that will make this paradigm shift long lasting and sustainable.

E. Developing a sustainable digital culture

As previously mentioned, digital pollution is multifactorial. Nowadays within businesses, it is not really the right time to think about reducing technology uses. But this growth is not sustainable. These limits must make organizations act to **support their staff** and **develop their organization's digital frugality transversally**. These are true organizational and cultural transformations that must be carried out to ensure the adoption and integration of climatic and environmental issues into the (internal and external) uses and work methods.

This transformation can be carried out and evaluated according to 4 main axes depicting the digital frugality common goal:



1. Organization, management and work culture

To develop a legitimate and lasting transformation, **the climate crisis must be understood at the highest level of the company and included into every decision**. The principles and orientations taken within the frame defined by the CSR must still be relied on, but they must as well be overachieved. By committing to this transformation, management encourages their employees to contribute actively to a transformation meaningful enough to transcend the organization.

This **motivation towards 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 this in her or his daily activities. At the operational level, the objectives must be available at the individual level, but the commitment to the global climate goal must be, more than ever, collective.

More informal methods can also be considered to create positive peer pressure. 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, coworker, business activity or IT professional to act at their level by defining their own objectives and management indicators.

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

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 should get involved. Thus, depending on their positions, they must:

- Be included in 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 reference regarding the new digital temperance practices at different levels (development, business activity, etc.) and at any time during the whole information system life cycle.

Additionally, because of their key role between ICTs and business units, **product owners** will have to build a bridge between two very different worlds to solve a common issue. Their daily activity will have to evolve to include sustainable digital objectives over their entire action range: it is up to them to question environmental value and to establish a balance between business activity value and environmental goals.

Finally, the processes that make it possible to address the transformation of an organization, such as enterprise architecture, which is particularly suitable because of its systemic approach, along with the tracking and governing bodies set up within the organization will have to be adapted to integrate digital frugality as an objective, as described in sections G-Building a sustainable Information System and I-Governing the transition towards a sustainable Information System.

2. Skills and education programs

Processes to raise awareness and to educate must be implemented within each organization to support understanding by all coworkers of the strategic low carbon objective and foment recognition of the need for change. Energy-climate/resource scarcity issues as well as the digital technology contribution to the current disruptions must be pointed out. Therefore, workshops such as Climate Colleges[64] or Digital Colleges, conferences led by coworkers, pointing out daily actions etc. are recommended initiatives. Although it is possible to involve external contributors**, priority should be given to initiatives initiated by coworkers to maximize adoption and impact.**

These education programs should not be managed just by ICT communities: every single employee must be educated so that they can understand the environmental impact of ICT resulting from their uses and their decisions or expressions of needs. To do that, it is possible to imagine widely broadcasted MOOCs or online communication, like that undertaken for GDPR or the risks related to cybercrime.

Example	"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 at the "company engagement" initiative of the company and made it possible to raise more than a thousand coworkers' awareness. It is the building block of a series of initiatives at the group level set up since the beginning of 2020.

Beyond raising awareness and education program initiatives, digital sobriety 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 for **ICT positions**, especially for architects and senior developers, whose role is, among other things, to guide and implement ICT practices. **These skills will have to be included into HR processes and added to job descriptions or standard jobs** for the involved ICT communities. They must then be developed by specific education programs depending on the targeted public.

Buyers, whose activity covers a large part of the **scope3 of the organization's carbon footprint**, must be the subject to special attention in terms of education programs and skills because they will 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 IS.

[64] https://climatefresk.org/

At the **hiring** level, it is essential that businesses ensure that the candidates' profile and skills match their new needs. Hiring young graduates from schools and universities that have been the subject of targeted initiatives is a great help, but it must go beyond this by integrating into the recruitment process questions related to digital frugality for everybody, then ensuring that new coworkers will be able to adapt to the new work culture and the ongoing transformation.

3. Communication

Internal communication with respect to **eco-communication** (ALEC Lyon, Hespul, 2017) (French Agency for the Ecological Transition) and digital sobriety principles must reflect the challenges and efforts made at every level. **It must start and sustain the movement and motivation towards the goal of digital sobriety**. It can highlight challenges (lean ICT hackathons…), praise significant progress, animate corporations, or support communities during this digital temperance process. The communication intensity and the transparency about the actions of the organization such as the evolution of the carbon footprint, of the overall electricity consumption, of the WEEE (waste from electrical and electronic equipment) management sector processes will be one of the proofs illustrating the involvement of management towards digital frugality.

External communication will lead to peer-pressure between companies and an acknowledgment within the organization of the need to target talents who care about environmental issues. For instance, it can organize conferences or meetups about digital frugality initiatives, **preferably led by employees to have more impact and generate more motivation**, or even set up public communities based on the open-knowledge principle.

4. Frugal innovation

The challenge is "how to do as well, or even better, with less? ". Since ICT lies at the heart of digital transformation, it is not about stopping or slowing down innovation. By relying on the transformations carried out along the previous axes, innovation must also evolve and become frugal: frugal in its stakes, frugal in its means, frugal in its objectives, frugal in essence.

Frugal innovation is an approach that aims to **develop efficient solutions that are devoid of complexity and superfluousness, using as few resources as possible but without any compromises regarding the quality** of the service provided. This approach also anticipates the life cycle of the service and the way it will be used. It must be based on values (simplicity, temperance, etc.) and rely a range of skills. ICT skills are especially suitable as the ability to innovate and cope with recurring challenges is common among professionals working in digital business. To deliver the approach, **the innovation capabilities of the organization** must be **deployed at every level**: every suggestion must be considered as long as it meets the objective of digital frugality. Therefore, it is necessary to implement tools and methods that will enable innovation to emerge, be deployed and be accepted by integrating the Lean ICT methods and practices. ICT projects will then have to be challenged and evaluated by taking into account digital frugality criteria.

Even frugal, innovation can be a source of major changes and disruptions, especially when it changes the way an organization works or simplifyies processes or structures: every coworker must accept the need for change and the change itself. **To develop a digital frugality approach,**

we must not just optimize the current information system but also change the direction which our digital technology is taking and the path to get there.

5. Transformation towards digital sobriety

To implement a cultural transition towards digital sobriety consistent with the previously mentioned approaches, we extended Kotter's 8-step change management method (Kotter, J.) (Kotter, J., 1996) with the following approach:

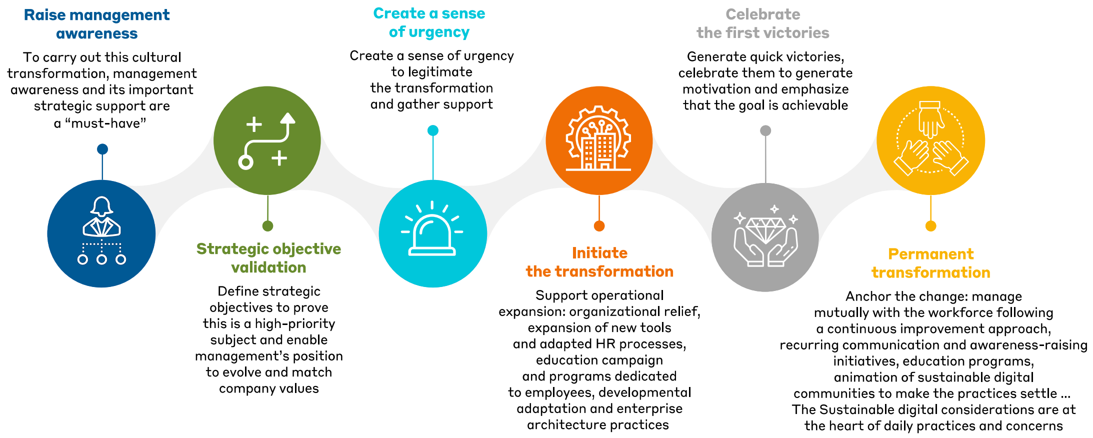


Figure 14 - Transformation towards digital frugality
Source: The Shift Project, method developed by the work group

This approach must be implemented knowing that the level of consciousness of a company cannot go beyond the one reached by its CEO (Laloux, F., 2014).

In the face of the climate emergency, a culture transformation is required within organizations. They must **start with small victories, gradually gather their troops, and then structure their approach to move towards digital sobriety together**.

F. Measuring the environmental impact of the Information System from cradle to grave

Establishing a **measurement of the environmental impact of IT** that is **exhaustive**, has **the right orders of magnitude** and is **calculable** is crucial to implementing the strategy properly, and to maintaining the effort over time. The deadlines and extent of the effort required to mitigate climate change leave little room for error and measurement ensures that **new initiatives make a quantatative contribution to sustainability goals**. Measurement is **a prerequisite to implementing governance**.

N.B.	In France, providing a **carbon footprint** is mandatory for legal entities governed by private law and employing more than 500 people in metropolitan France or 250 peoplein overseas France. This **legal obligation** 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", indirect emissions related to electricity consumption, heat, or steam, needed for the activities of the legal entity. The declaration of "scope 3", that is other emissions indirectly produced by the activities of the legal entity, is recommended but not mandatory. http://apc-climat.fr/bilan-ges/reglementation/

Compared to the greenhouse gas emissions balance of all activities of an organization, the environmental assessment of the information system has the following features:

- It is only **partially affected by the regulations**: there is very little focus on **"scope 1"**, direct emissions (e.g. leaks of refrigerants from air conditioning), and more on **"scope 2"**, i.e. indirect emissions related to consumption of electrical energy purchased directly by the organization (e.g. electrical consumption of data centers).
- As demonstrated in our previous report "Towards digital sobriety" *(The Shift Project,* 2018) and detailed in the report “Quelle est l’empreinte environnementale du numérique mondial ?”- ("What is the environmental footprint of global digital technology?"), published by Green IT.fr in 2019, **more than half of digital technology’s carbon balance is in "scope 3",** which means that it is related to the purchase of goods and services from suppliers. This category is not affected by regulatory obligations and is more opaque because operated by other stakeholders.
- The environmental assessment of the information system is made of greenhouse gases, **used metals,** which are natural resources whose stocks are finite, the **volumes of soil moved** to extract them, **water** resources, generated **waste** and **pollution**. For most organizations, all other impacts are proportionally related to greenhouse gas emissions in "scope 3”.

Figure 15 Diagram of the different sources of emissions related to the activities of an organization.

Source: (French Department of Environment, Energy and the Sea, 2016)

The information system reshaping program should start with establishing an annual environmental assessment taking into account the greenhouse gas emissions related to:

- The electricity consumption of the data centers operated by the organization taking into consideration emissions in kg CO_2/kWh of the electricity mix of the electricity production area,
- The manufacture of servers and network equipment operated by the organization,
- The use of services available on the public cloud: related both to electricity consumption and manufacture of equipment,
- The outsourcing of digital services such as marketing campaigns, counseling, data processing, etc.

- The use of the public Internet network,
- 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 balance over 2 to 3 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.

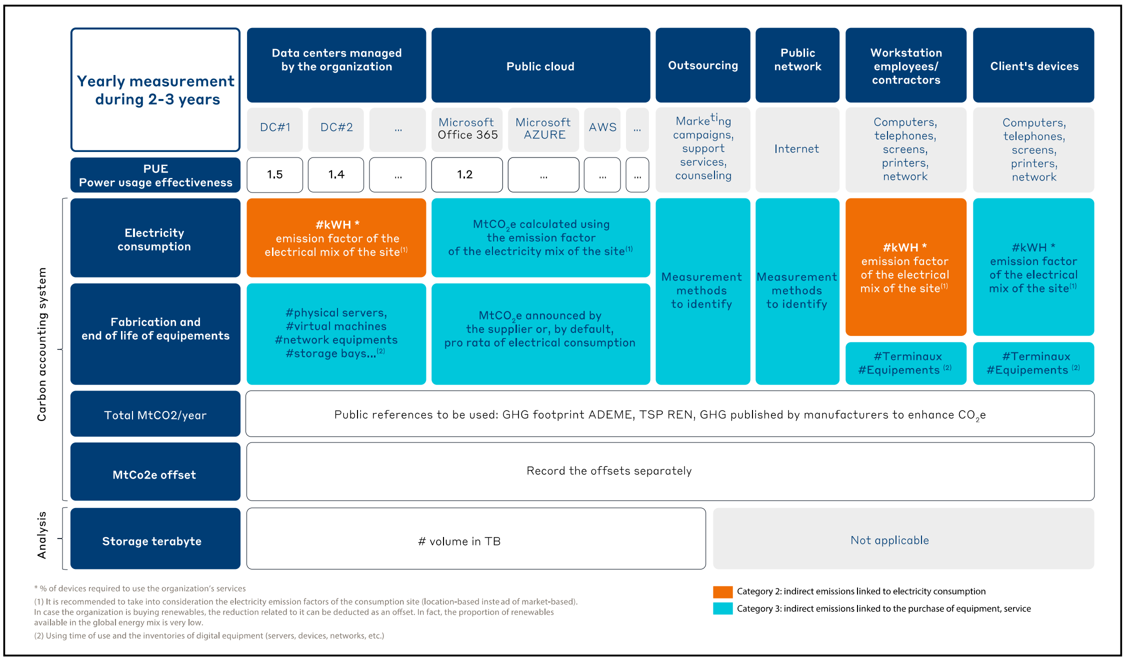


Figure 16 - Yearly environmental assessment of the information system - model inspired by the work carried out by the AXA group in 2020 as part of the "Digital Sustainability" program to measure and manage the impact of IT
Source: The Shift Project, production of the working group

Calculating a carbon footprint can be complex, thus it is recommended that a pragmatic approach that highlights trends and orders of magnitude be taken. This will enable the entity to initiate effective reduction actions quickly, rather than to get bogged down in detail:

- Some data, in particular for "scope 3", can be difficult to obtain. In such cases, it will be necessary to calculate orders of magnitude while waiting for data to be provided by suppliers. The absence of precise data should be dealt with through reasoned and justified estimates rather than the absence of an evaluation.
- Once organizations reach this stage, of maturity, **it is better to focus on CO_2 emissions as a steering indicator**. These represent a central indicator which, when shared, enables comparison with others and with national objectives. It represents a first significant effort to be established on a complete scope by the organizations. 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 relevant to manage **Offsets but this should be done as a separate activity** Under no circumstances can these justify an absence of frugality, or an increase of

usage or electricity consumption. Keeping them separate in GHG accounting is aligned with the methodology to produce a carbon footprint. Offsets should not be deducted from the carbon footprint. (French Department of Environment, Energy and the Sea, 2016).

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. Thus, market trends **switch allocations between scopes depending on regulatory obligations**:

- 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 labor is lower presents financial advantages from which a large number of organizations have tried to benefit. But these countries are often not very involved in the 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 the chapter *H. Engage with customers, suppliers, partners, institutions towards sustainable solutions and services.*

<table>
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<td>Tools</td>
<td>
Data repositories

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 the Ecological Transition), provides freely accessible data on its website https://www.bilans-ges.ademe.fr/fr/accueil/:

About electricity - "scope 2": mix of electricity network, means of production
About goods purchasing - "scope 3": emissions from the "cradle to the grave" of products such as electrical, electronic and computer equipment.

Digital Environmental Standard (REN) made available with the report “Towards digital sobriety” (The Shift Project, 2018). The REN provides everyone with data on GHG emissions and metal use for the production and execution phases.
Ecoinfo is a Services Cluster (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 (Information and Communication Technologies)". Among

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<td>Tools</td>
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other things, with Ecodia, they provide a freely available service, which can be used to calculate the carbon footprint of an IS (https://ecodiag.osug.fr/) and the data on which the service is based. (https://ecoinfo.cnrs.fr/wp-content/uploads/2019/12/ecodiag-v19.12.html).

On the supplier side, even if the methods are not yet standardized, audited and auditable, the following are worthy of mention:

Data in kg of CO_2e provided by Apple on devices, including production, use, transport and recycling.
Data in kg of CO_2e 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 $MtCO_2e$ 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 greenhouse gas emissions, materials, etc.

The project Negaoctet winner of the APR PERFECTO Award from ADEME, has the ambition to develop and test an evaluation repository of environmental performance of software solutions in anticipation of their eco-design around 2020.
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- **How to calculate?**

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

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

- **data of computer equipment inventories,** by using, for example, the CMDB - Configuration Management DataBase set up by IT operations as part of ITIL procedures[65],
- **electricity consumption** of data centers and GHG emissions related to digital services purchased
- **history of digital material purchase,** ideally over 2-3 years to be able to reveal a trend,
- **public cloud providers data and reporting**.

[65] ITIL – Information Technology Infrastructure Library

- ### How to make different stakeholders and functions of the organization accountable for their impact?

Once the measurement of greenhouse gas emissions has been done for the technical components, it must then be **applied to the main functions of the organization,** the value chain production of goods and services, finance, human resources support functions or customer relations functions. This breakdown aims to identify the lines of business with the highest impact, which will then make it possible to determine emission reduction goals for each function.

To achieve this, **intermediate measures and indicators**, something common to IT professionals, can be implemented. Thus, the increase measured by these indicators is related to GHG emission growth: volumes stored, volumes passing through the network, treatments carried out. In case of services rendered by third parties such as *cloud computing*, when the details are not known to the user company, these intermediate measures can enable management to begin while waiting for the publication of standards and obligations of this data to be implemented.

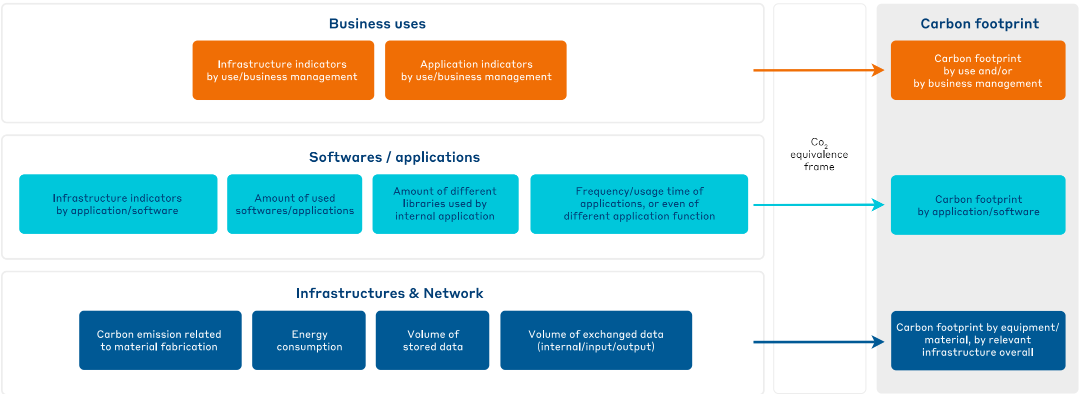


Figure 17-- Measuring the environmental impact of the Information System at different levels
Source: The Shift Project, production of the working group

G. Designing & Building a sustainable Information System

- ### Actions for reducing the company's information system carbon footprint

The design of a sustainable Information System must coherently reshape the business processes and use of the associated systems, applications and data, as well as the technical infrastructures supporting these components.

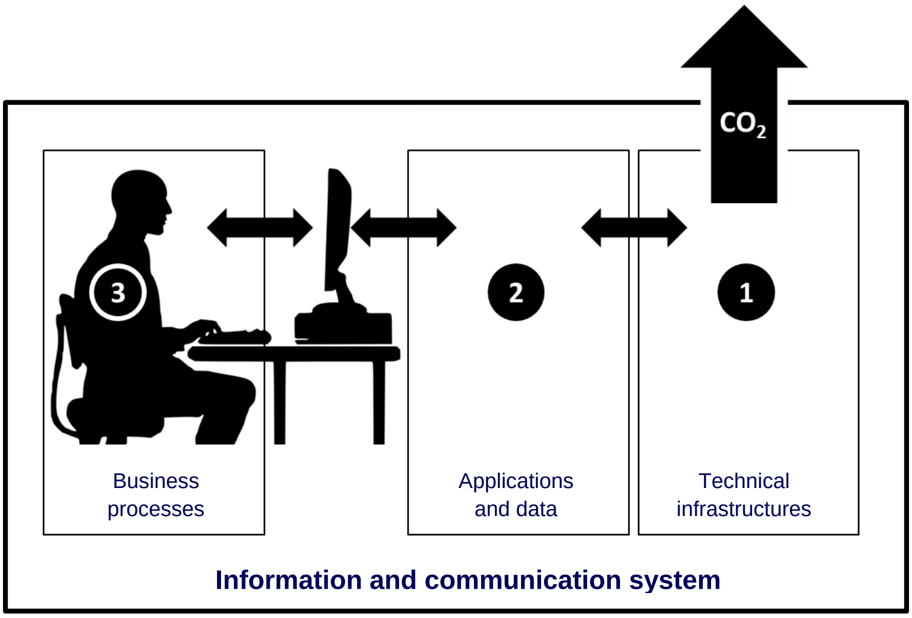


Figure 18-- Information and communication system
Source: The Shift Project, production of the working group

❶ The carbon footprint of the company's Information and Communication System (ICT) consists of its technical infrastructures: equipment components, servers, storage units, network controllers, screens, fixed and mobile devices, and the software operating them.

- This footprint is not limited to electricity consumption during operation, it also includes energy consumption for construction and installation of components, maintenance and end of life after reform.
- It is not limited to nationally produced emissions as it also includes foreign emissions due to the construction of many components and the operation of many servers.
- It is not limited to the components owned by the company, it also includes the emissions of external IT resources (cloud for example) and of functional subcontractors (advertising agencies for example) who operate on the company's behalf.

The **"carbon footprint"** expression summarizes all these dimensions. Their combined system design must be addressed to mitigate carbon emissions.

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

❸ The Information and Communcaton "System" is also characterized by business processes, which manipulate information in oral, written or digital formats, all of which can be more or less structured. Application software automates part of the procedures included in business processes.

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

- Informing departments of the environmental footprints of the digital services they request, and offering choices favoring services with high societal value;

- Optimizing business processes and automation procedures with application software;
- Optimizing application level and its technical requirements;
- Optimizing technical level.

We suggest a dual approach to identify mitigation requirements at all levels.

1. A dual approach to identify mitigation requirements at all levels

To identify these different mitigation levers, two approaches can be implemented simultaneously:

- **A business use-based approach:** centered on business use and specific to business resources, with reduction of the footprint of identified business use cases (eg: "sending emails", "sharing documents" or the use of a business application as a whole) as a goal. As seen previously in the chapter about measurement, initial footprint measurements aggregated at the level of business functions/business applications can designate priorities among business use cases.
- **An infrastructure-based approach,** whose goal is to reduce the footprint of IT systems identified as consuming resources and data (and potentially used for several purposes). Likewise, initial footprint measurements of existing infrastructures should help guide the identification of highly emitting systems.

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

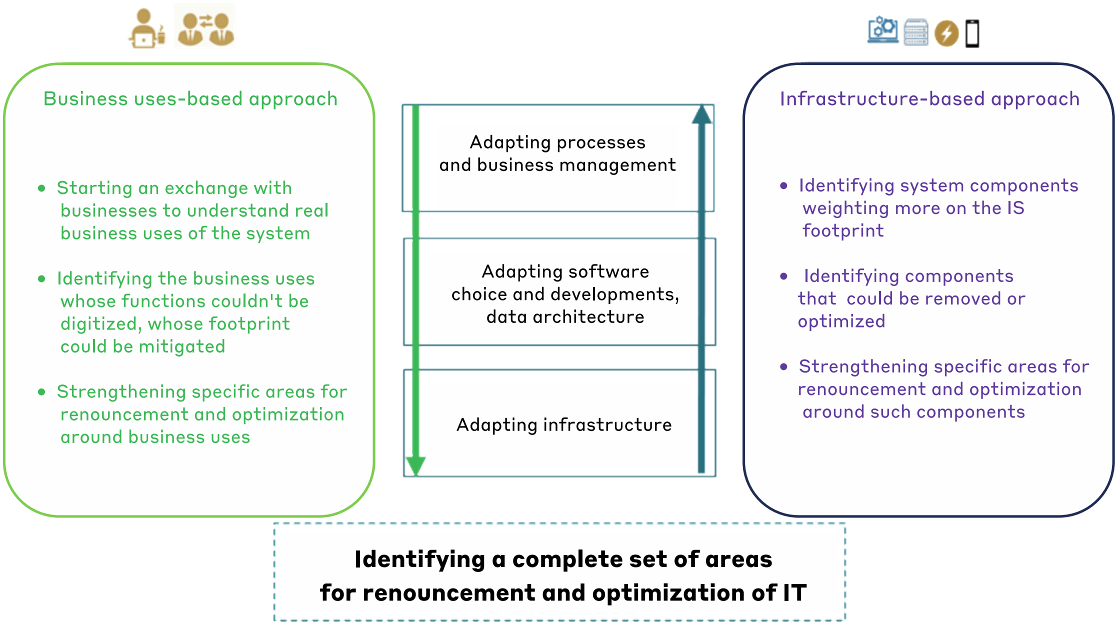


Figure 19 - A dual approach to identify mitigation requirements: business uses-based and the infrastructure-based
Source: The Shift Project, production of the working group

- The business use-based approach must lead to a clearly identified and prioritized list **of business functions that should be forsaken or optimized**. It requires :
    - An exchange between business units, in particular, with system end users,
    - A clear and validated mandate to work on these topics with business resources,
    - Initial metrics, for example by business unit or business application, to target systems for which business use cases must be developed as a priority.

- The infrastructure-based approach must lead to a clearly identified and prioritized **list of computer systems that should be forsaken or optimized**. It requires:
    - An inventory of the existing architecture of the information system,
    - The implementation of a set of initial actions to identify the relevant systems (for example those with the highest footprint, or the highest footprint per user).

In both cases, decommissioning and optimization opportunities may be found in the existing infrastructures, developments, software architecture, data, or the real definition of the business use of the system. **The goal is in no way to decouple business usage from infrastructure as this would not make sense.** The entry point is the only changing parameter in these two approaches: the optimization of a business use requiring solutions to "go down" to the technical system, and the optimization of a technical system requiring solutions to "go up" to its business use (for example to ensure the acceptability of the potential impact of a reduction or an optimization of the system to the business unit).

These decommissioning and optimization opportunities identified by business use or infrastructure are the design backbone of an information system with lower emissions.

Overall, the implementation of these mitigation and reduction opportunities must result in revision of the non-functional requirements of the systems and in new IT projects, with the following main trends:

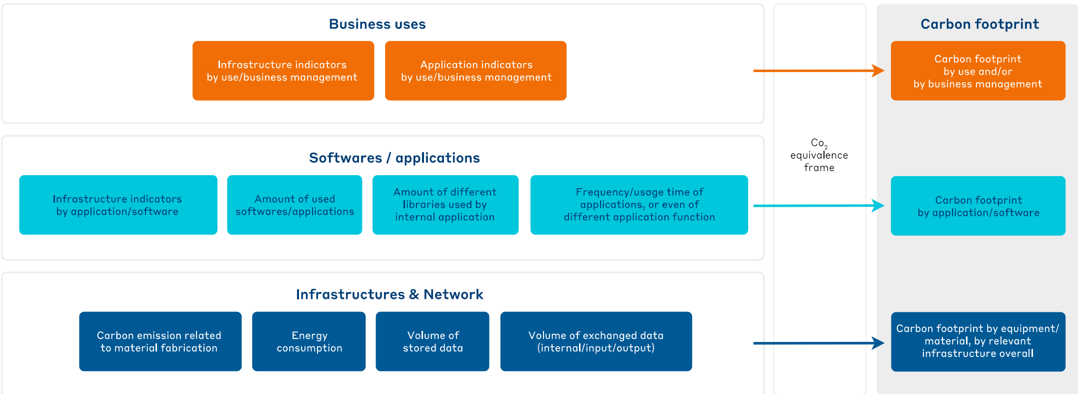


Figure 20 - Influence on the achievement of the requirements of the reduction of the environmental impact of IT

Source: The Shift Project, production of the working group

Overall, availability demands, storage capacity and energy needs will be reduced. Requirements in terms of longevity, maintainability, dismantability-repairability, portability and interoperability, and robustness of the systems will increase.

2. Daring to constrain the Information System and its use

Beyond the individual use-by-use and system-by-system mitigation options, it is important to dare to constrain the system as a whole so as to promote a low-carbon trajectory over time.

Setting constraints may seem like an unpleasant exercise, but it is a powerful and essential lever for the architect:

- We are moving towards an increasingly constrained ecosystem (resources, regulations, etc.). In order 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/Business Usage, by explicitly limiting uses, infrastructures and data (volumes, location).

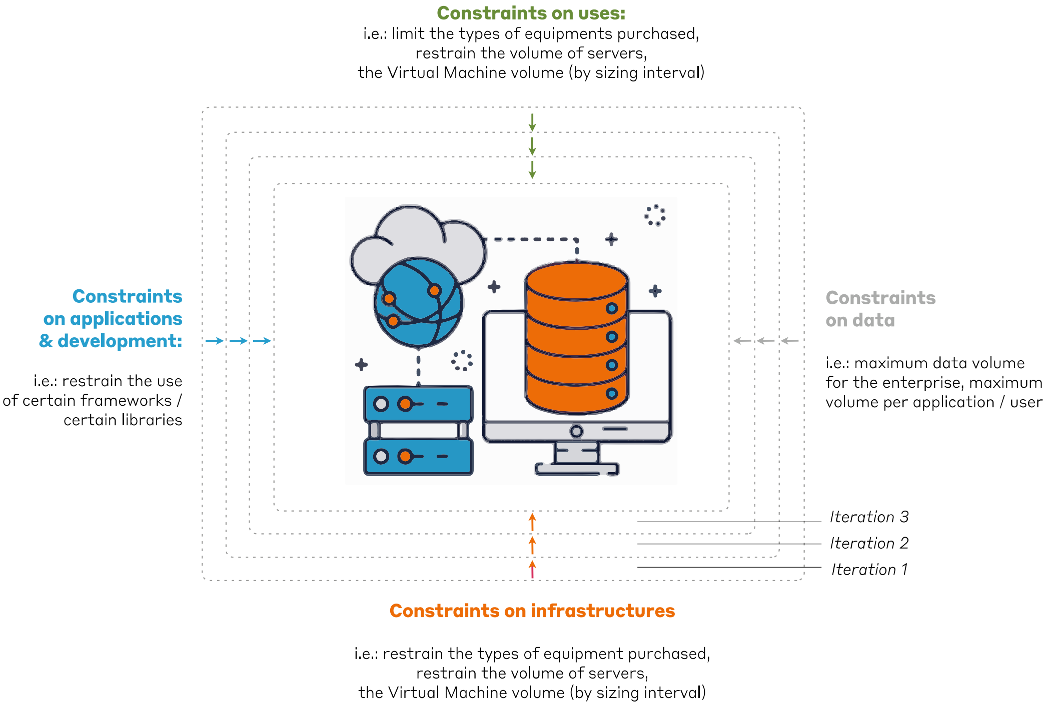


Figure 21 - Build an information system under constraint
Source: The Shift Project, production of the working group

How to do it? The system must be constrained gradually. The constraints installed by the architecture must take several forms:

- **Constraints on data:** for example, set a maximum volume by 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).

- **Constraints on applications and developments:** for example limit/restrict the use of certain frameworks or libraries.
- **Constraints on infrastructure/devices:** for example, restrict the types of equipment purchased, the volume of servers, the VMs/containers, the maximum number of technical objects used (by sizing intervals), and also limit the energy consumption of certain infrastructures.
- **Constraints on usage :** for example limit the volumes associated with some specific use cases (volumes of attachments sent per day and per person in an email, volumes of video consumed per day, etc.), limit the frequency of certain usage (number of web pages opened per day and per person), limit certain usage (restrict access to social media, streaming sites, etc.)

The IT architect must formalize and validate a path towards a system that operates under selected constraints by involving all stakeholders. The exercise is of course more complicated than it seems. It is not about imposing "blind" constraints. Being able to design a relevant constrained system requires having metrics in place. This involves combining constraints at different levels while ensuring, often 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, in particular within the framework of the governance activity, in the same way as the architectural principles.

	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 France					

3. Rethinking architectural practices to meet mitigation and optimization requirements

Overall, to meet new requirements, the evolution of the architectural practice of IT will have to evolve, gaining in focus and maturity. It must learn to facilitate the optimization opportunities emerging from the use-based or infrastructure-based approaches.

- **Optimizing the technical level**

The technical level of IT is made of subsets of hardware and software components rendering a more or less coherent technical service: database, backup, execution of application software, display, data transfer, etc. The subset providing a given technical service assembles its components according to a standard architecture.

Some examples of key optimization actions:

- For each technical service (storage, website hosting, etc.), identify typical technical architectures with a lower carbon footprint, and generalize these implementations.
- Choose suppliers wisely (see the chapter *H. Engage with customers, suppliers, partners, institutions towards solutions and sustainable services*): server renewal rate (case: *On Premises*), choice of “Green” cloud suppliers capable of providing carbon footprint measurements 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 2-year history, for what value?"
- If the organization manufactures or maintains digital material, strive for “programmed sustainability” (as opposed to rapid obsolescence). Opt for lifecycle management at a more granular level (at the component level of a machine) by increasing the requirements in particular for interoperability and durability (eg MTBF - Mean Time Between Failure).

Reduction and optimization at the application level will lead to a decline in sizing requirements at the hardware level.

- **Optimizing the application level and its technical requirements**

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, once again, the supplier must be required to provide transparency and the tools needed to furnish a clear vision of the software’s carbon footprint and development processes (e.g. concrete precautions taken by the software company in terms of code optimization, performance report/footprints of different configurations),
- Or an internal development process within the organization: in this case it is essential to initiate a frugal approach around the digital products of the organization; this implies adopting repetitive cycles, challenging existing functionalities or new requirements (value vs. footprint). With reference to this topic, see our focus on “agility and DevOps” in the chapter *Adapt project methodologies*

At this level, it is a question of ensuring a functional reduction but also of reviewing non-functional requirements, in particular those for user interfaces (eg: avoid automatically launching videos on a new page, limit animations, etc.).

- **Reducing data volumes**

Data architecture offers significant leverage in this area. Data managers (the *Chief Data Officer* if the function exists) should integrate the control of data volumes and the reduction of the associated footprint in their *"Data Strategy"*, and initiate the organization's data governance processes:

- **Generalize *"Data Minimization"*:** the principle to be applied here is well expressed in the GDPR rules for personal data: "*personal data must be adequate, relevant and limited to what is necessary for the purposes for which they are processed*". This principle must be generalized to all data across the entire 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 in the same way has quality controls and security controls.

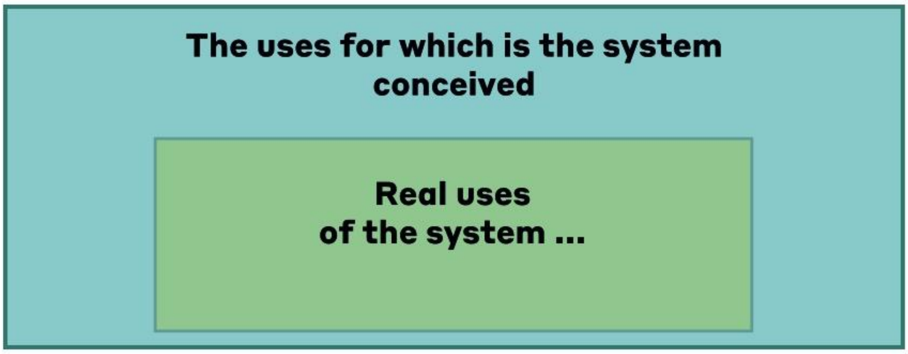
Finally, the desire of business units to focus on essential functions, to eliminate unnecessary ones, and to adapt processes to reduce the footprint of the systems, will lead to a reduction in the functional gluttony of applications, and thus that of the underlying systems.

- **Optimizing business processes and their use of application software**

In an approach familiar to CIOs, application capacities – data and processing – are determined by negotiating with business units. In the event that reducing the company's carbon footprint is a major strategy for upper management, decisions involving trade-offs between business units on whether or not information and procedures should be digitized, provide leverage to reduce IT carbon footprint.

The level of information includes processes specific to each business unit of the company, and cross-functional processes: sharing of product line data, internal operating data (messaging, reporting), etc.

- **The challenge here is to decide which information should be digitized and which processes should be automated**. This decision should be specific to a given scope and life cycle depending on the carbon footprint of the infrastructures required.
- **The challenge is also to identify those digital tools and functions which, in practice, do not serve any use, or are no longer in us** (due to obsolescence, discrepancy between intended design and user experience of the system).



- It is also about measuring the real gain of digitization when compared to analog (flexibility, staff involvement, operational gain, reduction of the analog footprint, financial gain, costs reductions, etc.).

4. Simplification of IT management

Along with the main objective of reducing IT carbon footprint, an architectural approach optimizing all levels of IT provides secondary gains: **simplified installation, maintainability, end-of-life**

management and, on a daily basis, better management of the application and technical assets.

Thus today, part of the efforts of CIOs are devoted to setting up and above all keeping up-to-date interfaces between "silos" of information, applications and technical components, whose functional and technical incompatibilities originate in the absence – even the refusal – of coordination between business units. However, the purchase by a business unit, through its own budget, of a software package to digitize one of its processes creates data flows involving the rest of IT, as well as requirements of the common technical infrastructure or even the acquisition of new technical capabilities that may be more or less interoperable with existing ones.

At a company level, these practices multiply the volumes of data, processing and technical components that could be shared if functional and technical interoperability were ensured. They complicate all types of IS interfaces and contribute to increasing its carbon footprint. This legitimizes reducing them.

This reduction also involves, as we mentioned, a systematic "challenge" of new needs in order to develop and deploy only what brings value: this is the subject of the next section devoted to **agility**.

5. Adapting project methodologies: agility serving frugality requirements

As in fitness programs, we cannot plan everything in advance, and have to react to contingencies and changing realities. The **Agile method**, with an empirical approach based on continuous improvement, was developed precisely to meet this challenge. Agility ultimately ensures that the digital product is produced as close as possible to its actual use, in particular through strong integration of the business in short development cycles. It prevents the production of applications, of which a large part of the initially desired functions are never used. This approach has been formalized under 4 values and 12 principles. Six of these principles seem particularly relevant in the context of sufficiency:

- **Useful value**: it is at the center of the approach. The role of the Business Owner has changed: they no longer simply request things 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 approach**: short cycles with frequent releases to production. The delivery and demonstration of functions developed are essential measuring tools: specifications, documentation, theoretical indicators have no value until tangible proof of operation is demonstrated. In case of error, we pivot faster.
- **Simplicity**: the system must meet needs in the simplest way – this system is also expected 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**: this is free to choose solutions and implementations for which it has full collective responsibility, a freedom exercised within a framework defined by Enterprise Architecture standards and requirements.
- **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**: the measurement of "value points", complexity, velocity, quality… To steer product development, many of the used indicators are intended to be factual and public.

Within the framework of digital frugality, **limitation of environmental impacts** must be supported by the business unit in the same way it supports the generation of **use value**, and be integrated – like a complexity assessment – into decision-making processes (acceptance, prioritization, etc). **Repetitive deliveries** enable rapid **measurements** of these impacts, by automating these measurements 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.

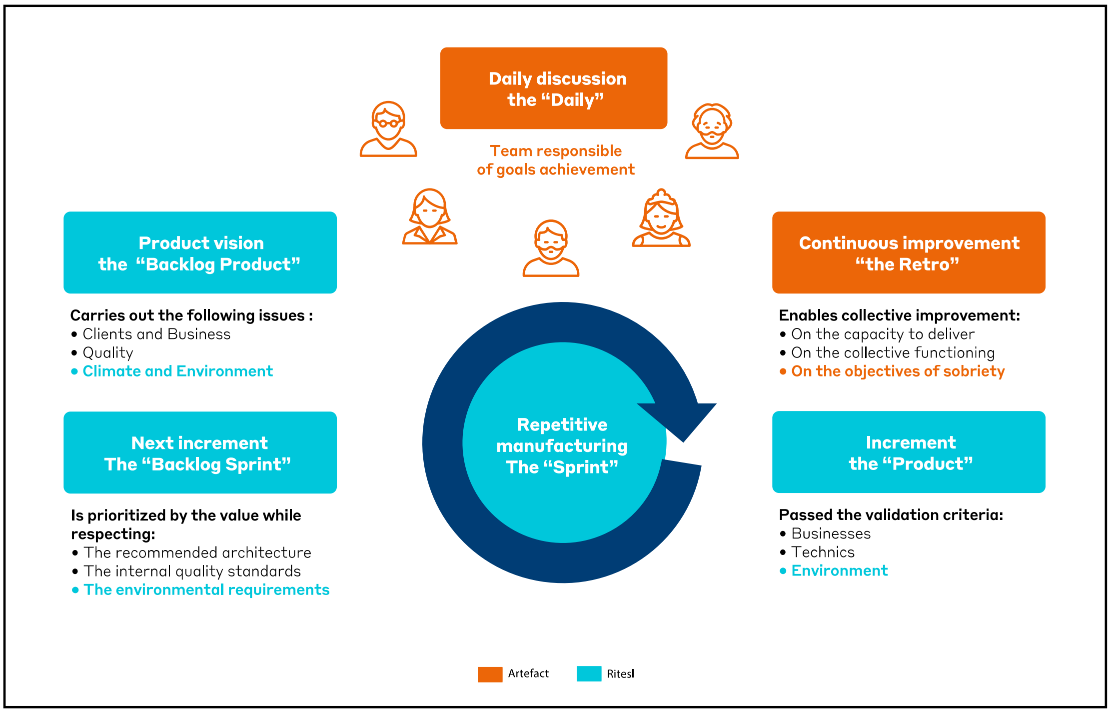


Figure 22 - Source: The Shift Project, production of the working group

- **What are the conditions to implement a "sufficient" Agile approach?**

In order to implement this new approach, several tools and catalysts are necessary, stemming from the strategic desire of the company to implement sobriety. We mignt, for example, mention:

- 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, possibly even through a mandate from the head of IT to put them in charge.

But the key to success remains **to drive forward in a way that is aligned with this new environmental requirement**. This is a necessary and sufficient condition to immediately initiate eco-design approaches, whose feedback will help roll-out and adjust the deployment on a larger scale. These elements constitute the reference architecture proposed above.

Regarding the need for continuous measurement, readers should be aware that there are specific and repeatable measures to show that the same functional internet browsing service provided, some internet browsers consume almost twice as much energy (on the user side) as others (Greenspector, 2019).

- **DevOps at the crossroads of IS implementation and operation**

When considering **DevOps**, we must remain focused on the probem that the approach seeks to resolve. Remember that DevOps consists of integrating the constraints and non-functional needs resulting from *Operations* (production and support) into the process of choosing, prioritizing, developing IT and ensuring the operability of the system before deployment.

As continuous integration and development are components of a DevOps strategy, they pose a fundamental question: they involve an integration of the source code into IT on the fly, end-to-end environments that are persistent or created on the fly, and multiple processing chains operating 24/7. These things increase energy consumption for a more frequent and more qualitative "*delivery*". We will limit ourselves here to asking questions to frame the problem: how to control this rebound effect due to the low-cost availability of ever more powerful computer racks and deployment automation software? How to vary the level of service according to the criticality? How to automate the small footprint verification? How to make DevOps a key asset to IT sustainability, under construction or renovation?

The following example shows that, at the very least, we must not throw out the baby out with the bathwater: new tools exist to balance the reproducibility of IT on the one hand, and its carbon resilience on the other hand.

Example *Source Greenspector*	Website of a large banking institution. During a major version of the website (14 million monthly connections), a campaign to measure the environmental impact and injection into the backlog of optimizations produced the following results: ● -22% energy consumed on the user side, ● -68% display time in 2G connection (from 46 s to 15 s), ● -74% requests to servers and therefore a possibility of greatly reducing the server infrastructure for the same level of service.

6. Developing in a sustainable way

At the heart of the Information System, we find digital equipment for material parts and the code enabling interfacing and organizing this equipment 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. It is clear that this acceleration has often been done to the detriment of quality and that languages have become more accessible but also more resource intensive.

However, it is in the code that equipment use optimization can be achieved, whether for data storage, processing or network flows.

Some good sustainable development practices are available on the market but they are far from being complete and used systematically. Tim Frick's book *"Designing for Sustainability"* (Frick, T., 2016) or the work of Frédéric Bordage *"Ecoconception web: les 115 bonnes pratiques" (Web eco-design: the 115 best practices")* (Bordage, F., 2019) offer, for example, best practices for website development. Chapter E. *Develop a sustainable digital culture* proposes an approach to reach developers.

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

Sustainable development practices will call for:

1. Establishing 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;
2. Systematically considering frugality before embarking on a new development: ensuring that the functionality is not already coded and that it will be used once it is;
3. **Implementing and automating environmental impact tests of the code** during its use: as such, Greenspector offers solutions for mobile applications (Greenspector, 2019);
4. **Using and contributing to open source projects** to avoid unnecessarily increasing the environmental costs of software manufacturing;
5. Capitalizing and sharing **good practices,** not only for the development of **mobile apps**, **web front-ends,** but also for **data processing and AI**.

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

To favor quality and sustainable coding, and therefore more time-consuming projects, it is necessary to focus on demonstrating energy gains, improved service quality and maintenance during operations (i.e. beyond the cost of the project, often over several years). Finally, the decisions described in chapter 6-*Adapting project methodologies: agility in the service of frugality requirements* 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**.

H. Engaging with customers, suppliers, partners, institutions towards sustainable solutions and services

Many stakeholders are involved in the development of a digital solution. In order to successfully deploy its policy, the organization will need to work in **partnership with the different players involved in the sustainable IT ecosystem**. These stakeholders could be customers, service or equipment suppliers, regulatory and informational institutions such as ADEME in France, higher education or non-profit organizations acting as catalysts and enabling citizens' mobilization when corporate funding is scarce.

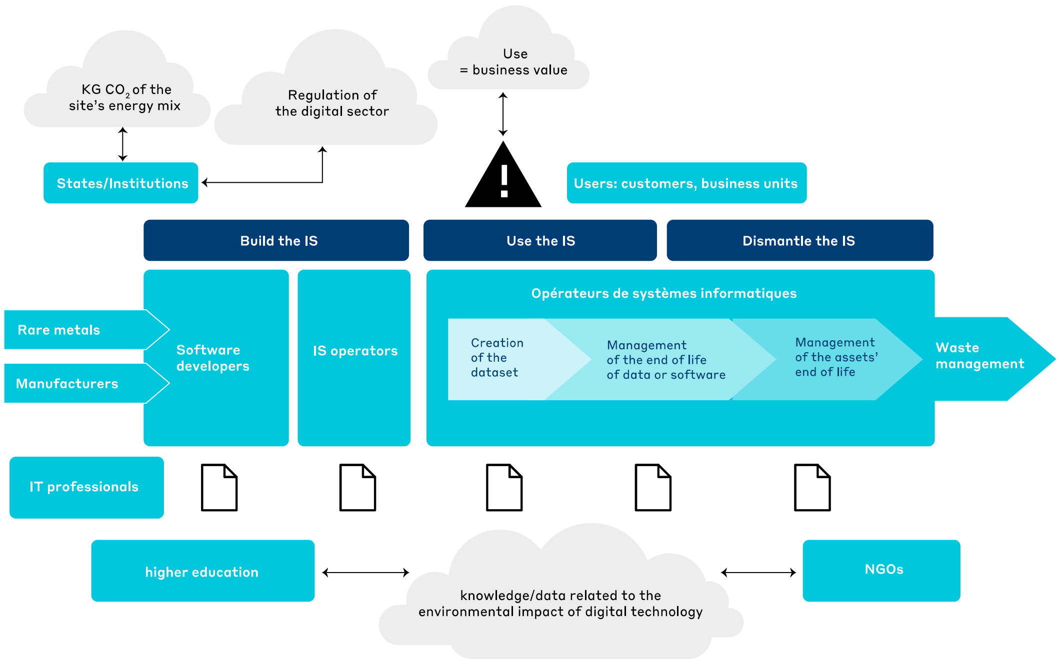


Figure 23 - Actors involved in the production line of a digital solution
Source: The Shift Project, production of the working group

In this chapter, different activities are discussed in order to interact with this ecosystem.

1. Asking service providers for end-to-end environmental footprint transparency

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

In the "non-financial results" section 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"*, an international NGO, collects and publicly shares said carbon footprints in a standardized format. Enabling the organization to read these reports easily, as a first step to working with suppliers.

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 life cycle, from "cradle to grave". However, although service providers communicate on the optimization of electricity consumption, only a few approach the full life cycle and publish compensations and purchases of renewable energy separately.

Transparency on all these indicators must be reached quickly, by emphasizing that **environmental impact management is a significant competitive advantage**. Optimization should be seen as the supplier's duty, decisions regarding the use of technology made within each organization and require precise data. The following actions can be considered:

- Publicly announce via the sponsor that transparency and environmental impact reduction plans are competitive advantages;
- Identify the main suppliers of IT services and equipment, set up a dialogue on the issue of sustainable IT, work in partnership on IT 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: management, technicians, business units;
- Decide to make a purchases based on environmental factors, even if costs are higher. This will send a strong signal to suppliers.

2. Adapt the selection criteria for requests for tenders and contracts with suppliers and partners

In tender requests, **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 IT selection: maintenance contracts enabling extended product lifetime, purchases of robust and repairable equipment with low consumption, description and qualification of the recycling/reuse process...

New contracts signed with suppliers must reflect these commitments on these issues even though these 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. https://www.matinfo-esr.fr/ecoinfo https://ecoinfo.cnrs.fr/2018/12/04/enseignement-superieur-et-recherche-achats-informatiques-et-developpement-durable/

Lastly, when renewing contracts, clauses related to corporate responsibility will have to be reviewed.

Concretely, for instance, it is feasible to add the following to tender requests or contracts:

- Obligations of means: raising awareness or training staff, adapting working methods, committing to respect specific good practices, setting up measures and indicators, etc.;
- Obligations of result: maximum amount of data, energy consumed during the user process, ability to operate on low-power equipment, etc.

N.B.

Demand planned durability of electronic products: how to reduce material obsolescence and increase lifetime?

Equipment obsolescence describes cases where the product is no longer working due to component failure. This can occur during normal use of the product, after an accident or misuse. Cases where a functioning product is replaced with a more modern one (technology obsolescence) or due to incompatibility with the environment it is integrated in (functional obsolescence) are not addressed here.

This involves getting inspiration from feedback received from a “panel PC” (industrial version of a tablet) used in the railway, energy production or defense industries for which planned durability is obtained through two types of requirements:

- **No breakdown for the first 10 years of use**

This is commonly assessed by the mean time between failures (**MTBF**). It indicates the reliability of a component, product or system, expressed in hours, under defined conditions of use (temperature, humidity, etc.).

A product with an MTBF of 100,000 hours, standard for a panel PC in the mentioned industries, will therefore be able to operate 24 hours a day for 11.4 years on average, without failure.

- **Be repairable for 20 years**

The components needed to repair the panel PC must be available for 20 years. The component manufacturers selected during the design process commit to keeping them available for purchase or to replacing them with a new, compatible model. It is sometimes up to the panel PC manufacturer to stock components covering end-of-life replacements for the last years of its commitment, or to extend the lifetime of the product.

In both cases, reliability and availability of components need to be taken into account right from the design phase. These constraints limit the number of suppliers of electronic components and increase the price of the product, which will be sold in smaller quantities. It is therefore a change in the business model of manufacturers, whose income will be partly generated by services extending product life cycles.

Two levers enable manufacturers to implement these practices:

- the legal constraint in which durability is mandatory to sell the product
- the economic constraint, or the impossibility of selling without sustainability due to consumer demands.

French Law № 2015-992 of August 17, 2015 on energy transition for green growth, as well as the report of the DG-CCRF to Parliament in November 2019, begin to take into account the fight against planned obsolescence. The regulations are set to be strengthened in years to come. Some European manufacturers are trying to anticipate what will become the norm in a few years. Fairphone (Netherlands) thus markets a phone made from recycled materials, repairable for 5 years, made up of easily replaceable blocks. In 2019, it captured 0.1% of the Western European market. There is still work to do!

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

- Considering total cost of ownership over the full lifetime – until waste treatment – for the purchase of equipment (PC, smartphones, servers, etc.) will tend to take into account all environmental criteria rather than just considering acquisition impacts;
- 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. Offers like these 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.

3. Define the procurement strategy

The procurement of equipment or services faces two strategic choices:

- Insource the capacity or outsource it;
- Choose the location of the assets: *onshore* (French territory), *nearshore* (Europe) or *offshore* (America, Asia, Africa, Oceania).

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

The example below illustrates the consequences of choosing different service suppliers in terms of CO_2 emissions.

CO_2 emissions from use of a developer's laptop depending on location:

	Onshore (France)	Nearshore (Europe)	Offshore (India)
kg CO_2 /kWh	0.0791 kg CO_2 /kWh	0.42 kg CO_2 /kWh	0.912 kg CO_2 /kWh
1 developer's laptop for 1 year of operation (*)	1.81 kg CO_2	9.62 kg CO_2	20.88 kg CO_2
Multiplicative factor	**1**	**5**	**11**

Equipment – for example: HP EliteBook 840 G6 Notebook PC - Annual electrical energy requirement 22.9 kWh

(*) excluding manufacturing-related emissions

Example

These numbers focused on the consumption of a laptop are simply illustrative, as many factors impact the relocation of an internal IT development service. The two main types of impact break down into:

- **Collaborative** (impact of remote work): increased digital footprint (video conferences, emails, electronic whiteboards, etc.), transport footprint (business trips between sites), and multiplying effect *offshore-onshore* (compensating lost productivity by increasing staff and associated equipment),
- **Physical** (impact of local energy mix): IT equipment electricity consumption (terminals and servers), air conditioning of the buildings hosting them.

Source: https://www.bilans-ges.ademe.fr/ for kg of CO_2/kWh under Electricity \\ Electric network mix; HP IT ECO Declaration and "Energy consumption of IT equipment in a professional environment" for the annual consumption in kWh per user in services p. 24 of the whitepaper. *https://www.connaissancedesenergies.org/sites/default/files/pdf-actualites/livre-blanc-consommation-energetique-equipements-informatique-2015.pdf*

Beyond the carbon footprint, changes in the choice of suppliers will be necessary to minimise the number of intermediaries between producer and consumer. The objective will be to limit logistics flows, pinpoint unnecessary links so that these can be dealt with and ensure maximum proximity and access to the supplier's activities. From a corporate accountability perspective, the further away a supplier is, either physically or through intermediaries, the more difficult it is to ensure their ethics.

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

4. Involve customers in the goal of digital sobriety

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

The emulation of such announcements across the market cn be seen as positive. However, it should be remembered that **it is counterproductive to communicate on CO_2 emissions**

reduction solely by talking about the consumption of renewable electricity or by including carbon offsets. To do so gives **the illusion that it is possible to extend usage without environmental impacts** which is incorrect, dangerous, ineffective, and poses a reputational risk to the organization of *greenwashing*. In fact, optimizations in electricity consumption come at the cost of very frequent hardware renewals. It is only useful for an organization to communicate on its objectives and results if the full scope is taken into account.

☝ **N.B.**	Behind the **so-called 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, consumption is not linked to what is bought, but rather 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 in turn strongly depends on national policies. Reference: - http://www.carbone4.com/wp-content/uploads/2018/12/Publication-Electricite-verte.pdf - https://ghgprotocol.org/scope_2_guidance

It will therefore be necessary to develop this activity for it to have a positive impact, as recommended by the Net Zero Initiative of Carbone 4[66]:

- 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 IT 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 (eg: 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. The “Environmental and digital roadmap” in Measure 11 conveys this aspiration (CNNum, 2020) and ADEME - French Agency for the Ecological Transition - has been commissioned to implement it by 2021 (MTES, 2020).
- More broadly, to support customer efforts towards digital frugality (for example, by enabling customers to self-impose limits to their use of the provided services).

5. Going beyond the regulatory environmental reporting requested by authorities

Any organization will have to carry out the regulatory environmental reporting defined by the local authorities.

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66 https://www.carbone4.com/publication-referentiel-nzi/

In France, companies must carry out their carbon footprint (MTES, 2019) or **Regulatory GHG report** which only concerns emissions from scope 1+2.

These regulations will be reinforced in France, but also in Europe and in the world, as already observed in the regulations related to personal data management (GDPR). Various studies show that regulations will be strengthened in France and in Europe, in particular:

- **France Stratégie**: autonomous institution under the authority of the French Prime Minister, which concluded in the study called "La consommation de métaux du numérique: un secteur loin d'être dématérialisé" - (The consumption of metals for digital applications: a sector far from being dematerialized) published in June 2020: *"Given the environmental challenges, recycling metals contained in digital equipment cannot be the only response and must be accompanied by policies aimed at reducing our consumption of primary materials"* (France stratégie, 2020).

- **The Senate** published in July 2020 the results of the "Mission d'information sur l'empreinte environnementale du numérique" ("Information mission on the digital environmental footprint"), and concludes among other things: *"According to the results of this study, digital technology is a major source of greenhouse gas emissions in France (15 million tonnes (15 MtCO$_2$eq), or 2% of total emissions in 2019), which could increase considerably in the years to come if nothing is done to reduce its impact (+60% by 2040, to reach 24 MtCO2eq). By 2040, if all other sectors achieve carbon savings in accordance with the commitments of the Paris Agreement and if no public digital frugality policy is deployed, digital technology could reach nearly 7% (6.7%) of France's greenhouse gas emissions, a level much higher than the one currently emitted by aviation (4.7%). This growth would be driven in particular by the boom of the Internet of Things (IoT) and of data center emissions."* Different measures to avoid this scenario are suggested. (Sénat, 2020).

- **The national digital council** published in July 2020 its "Roadmap on the environment and digital technology" and proposes 50 measures for **a national and European agenda** on responsible digital technology, i.e. sufficient and in the service of ecological and inclusive transition and sustainable development goals (CNNum, 2020).

- **The citizens' convention for the climate** communicated its goal to "Support the evolution of digital technology to reduce its environmental impacts" (CCC, 2020).

While awaiting regulatory changes, and given the urgency to act, it is desirable that organizations anticipate and go beyond regulatory obligations. This allows them to publish and share with their customers **the necessary measures to reduce the GHG emissions of IT.**

Half of IT's environmental impact is driven by manufacturing (*The Shift Project*, 2018), which does not necessarily take place in the country where the resource is used. As a result, satisfying local regulatory reporting does not make it possible to move towards sustainable IT. This trend is reinforced by the use of digital hosting services to replace data centers directly operated by organizations.

6. Influencing the market, capitalizing 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 IT practices**. The objective is to make them freely available to higher education teachers, all organizations using digital solutions and all suppliers of IT equipment and services. The goal is to enable the emulation of good practices across the sector, enabling collective acceleration towards sustainable IT.

This activity can be broken down into different actions:

- Contribute to inter-organization working groups capitalizing on good sustainable IT practices;
- Share data related to the environmental impact of one's 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.

<table>
<tr>
<td>Examples</td>
<td>Examples of non-profit organizations involved in the transformation towards sustainable IT.

In France:

1. The Shift Project through the Lean ICT working group sponsored by organizations and associated publication work.
2. Cigref, an association representing the largest French companies and public administration organisations 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.
3. The INR (Institute of Responsible Digital Technology) is a think tank bringing together experimentation and promotion of good practices for more regenerative, inclusive and ethical digital technology.

In the world:

- The Open Group©: international organization dedicated to the development and deployment of standards in the digital world.</td>
</tr>
</table>

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

All stakeholders in place must now weigh in to make digital technology sustainable and make it evolve towards an economic model focused on **planned sustainability** and delivering **the tools of frugality**. This model must **enable all stakeholders, customers, businesses and developers to "reduce their usages" and "play their part"**. This new approach is intended to evolve from current economic models based on the infinite availability of resources and which see equipment renewal as an externality available in an infinite way.

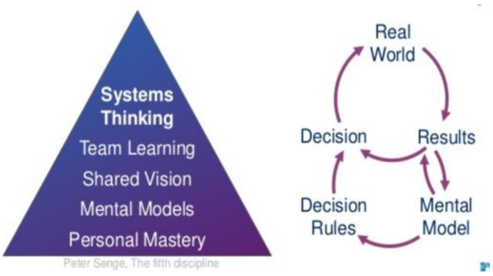
I. Governing the transition to a sustainable information system

Implementing a strategy for Information System durability requires a business 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 means **setting up strong governance**.

N.B.	**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 concerns in the decision-making process requires using new indicators, related to greenhouse gas emission potential, rare metals mining, or drinkable water usage, which will inform decisions and enable the monitoring of the transformation process. (See chapter *E*.)

The point is to treat the business ecosystem as a whole, by taking the environment of the company into account instead of maintaining a narrow point of view (which may threaten the balance and sustainability of the organization). In other words, it is about “Systems Thinking”. (See chapter *H.*)



Systems thinking is the process of understanding how those things which may be regarded as systems influence one another within a complete entity, or larger system. In nature, systems thinking examples include ecosystems in which various elements such as air, water, movement, plants, and animals work together to survive or perish. In organizations, systems consist of people, structures, and processes that work together to make an organization "healthy" or "unhealthy".

(Meadows, D., 2008)

This chapter partly sets out a governance approach that is suggested in the following standard: *The Open Group Architecture Framework* (The Open Group®).

1. Making decisions with the environment in mind

At every level of the company decisions impacting the environment are made, directly or indirectly, formally or informally. Making such decisions compatible with Information System sustainability requires stalwart decision management that favors balance.

☝ **N.B.**	**Decision-making** is the key element of governance, and must be handled accordingly. Decision-making is critical to come up with design choices that meet requirements and have 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;
- the repository of decisions.

- **The decision log**

The decision log makes it possible to list the various criteria that the organization wishes to prioritise in its decision-making. In this case one of these is the environmental criterion. The decision log enables the company to track decisions, share information among staff, and update this information.

Here is a decision-making (#1) example where a company wishes to set up a new mobile application for its customers:

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[67] solution**
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

[67] A progressive web app is a type of application software delivered through the web, able to provide the user with the same interface as a native or mobile app.

			environmental impact; compatibility with continuous deployment.
Owner	Business		
Stakeholders	Business, IT, Finance, Environmental Management Person		
Validation	Executive Committee		
Scope of application	Customer channels		
Field	Business & Information System		
Environmental criteria			
eqCO_2 (manufacturing)	1,200 TCO_2e	890 $kgCO_2$	400 $kgCO_2e$
eqCO_2 (use)	580 $kgCO_2$ /year	360 $kgCO_2$ /year	170 $kgCO_2$ /year
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			

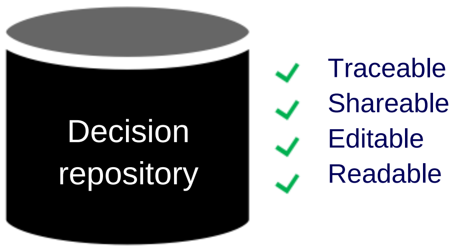
NB: The above case is only an example; the development of a mobile application requires in-depth case-by-case analysis.

N.B.	In order to add the environmental criterion to decision-making, it is important to have reference tables enabling fast and efficient measurement of CO_2eq emissions, rare metals extraction, and drinkable water use, according to the company's assumptions (see chapter *E.*).

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

- **The decision repository**

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



2. Setting up decision validation bodies aligned with environmental issues

Governing the Information System in the 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 or not a decision should be submitted to a governance body.

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

- **Examples of criteria for submitting the decision to a decision committee:**

Criterion	Substantiation
New application hosting service	Changing the hosting service is a critical choice with regard to 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 CO_2eq	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 similar to the one used in budget impact-based decision-making.

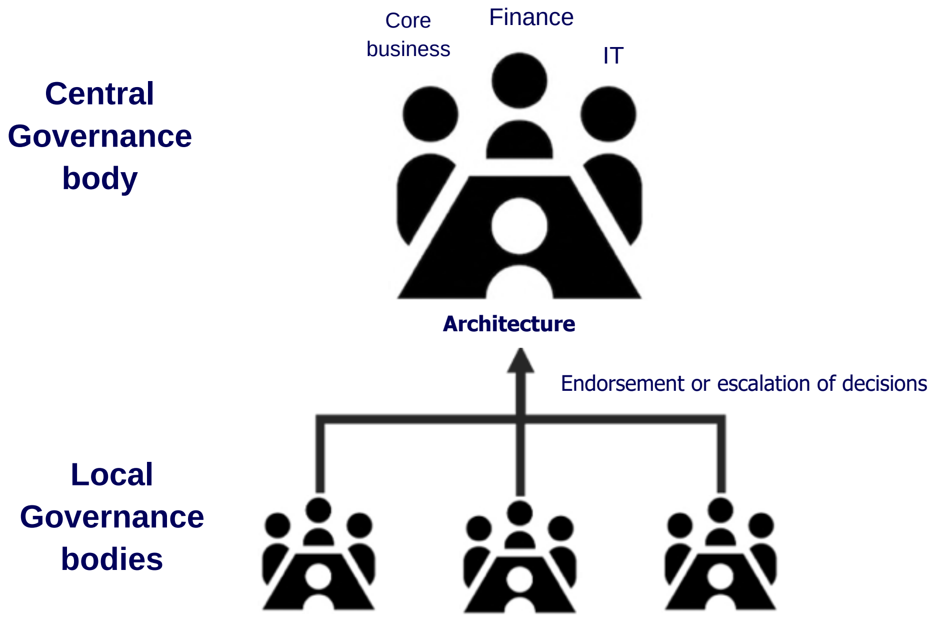


Figure 24 - Diagram of a distributed governance model
Source: The Shift Project, working group output

3. Setting up guidelines for eco-responsible decision-making at all levels

The vast majority of 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.

☝ **N.B.**	***Architecture principles*** *define general properties that should apply to every system in the company.*

- **Examples of company architecture principles:**

Figure 25 - Governance principles for a sustainable information system

Company architecture principle	Description	Justification
1 **Training, internal and external communication**	Provide employees, managers and shareholders with training on the energy/climate problem and the environmental impact of digital technology. Rigorously communicate, internally and externally, on the sustainable IT 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_2 over the entire product life cycle and move towards other indicators as 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:** ADEME is tasked with defining a methodology on the obligation to make it possible for a user to see the carbon impact of their digital consumption, by the end of 2021 (MTES, 2020).
3 **Responsible use of digital services and equipment**	Avoid anything that is not necessary; avoid rushing into adopting new technology (which often turn out to be no 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 (Sénat, 2020).
4 **Use of shared, sustainable digital services**	For instance, encourage renting IT 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 handle digital waste. Choosing suppliers committed to their products' entire life cycle will naturally make suppliers evolve towards sustainability.
5 **Knowledge sharing**	Use Open Source, Open Data, Open Architecture, Fab Lab. Encourage and contribute to "Open" initiatives. Learn to share, instill a culture of sharing: document, build architectures by separating generic structure from specifics (Continuum principle of TOGAF©) (The Open Group®). Get involved in standardization processes.	Share everything that can be 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 **Optimisation 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...	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© enterprise architecture standard (The Open Group®) 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.
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 traveled, 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 made to move the Information System towards a sustainable state. It is based on the principles explained in:

- Enterprise Architecture standards (TOGAF© - The Open Group®)
- *Leverage points: places to intervene in a system* (Meadows, D., 1999)
- *The Symbiotic Economy* (Delannoy, I., 2017)

There are also reference to principles, submitted by digital sufficiency actors:

1. **Software eco-design principles**, offered by the Green IT association (GreenIT.fr, 2020)
2. **Principles of green engineering**, offered by the United States Environmental Protection Agency.

Governing on the basis of principles and patterns is one of several good practices fostering the self-governance and autonomy of **agile teams**. It is up to every architecture organization and to every architect to make them their own, 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.

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 next section).

"Acceptance criteria" are a means of confirming the consistency of the implementation with the architectural decision, by providing proof.

- **Example of acceptance criteria:**

Acceptance criterion	The "delivery" service of application X is indicated as decommissioned within the CMDB (database centralizing the components of an information system)
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.

☝ **N.B.**	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 CDN. Use of these patterns can be automated via software production lines (CI/CD).

5. Managing environmental debt in the information system

An information system built without considering environmental concerns will almost inevitably lead to debt.

☝ **N.B.**	**Environmental debt** is the consequence of a decision misaligned with the trajectory of the company aiming to establish a sustainable Information System.

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

- **Examples of debt criteria**

Criterion	Duplicated functionality in the Information System
Justification	See the "Maximize the reuse of functions and application data flows" principle

New decisions can lead to intentional or unintentional debt, and must be identified, tracked and measured.

It is important to be aware of the creation of intentional debt when making a decision – it may be due to time constraints, legal constraints, etc. 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 that describes how that debt will be reduced over time. Debt should be reviewed on a recurring basis to ensure the proper execution of 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 amount of required resources by the number of channels
Elimination plan	Coalesce delivery functionality into a service that is atomic enough to meet all specificities
Environmental cost	1,000 kgCO_2e/year
Risk	1. Failure to meet the annual target of a 30% reduction in CO_2 emissions 2. Carbon tax

☝ **N.B.**	**Technical debt measurement** has always been an elusive Holy Grail. To this, we now add **environmental debt measurement**. New native cloud architectures and increasingly automated software production chains now enable to envision function redundancy-based, or data flow-based, debt identification.

III. Digital uses: a social development with collective and individual dimensions

A. Digital sufficiency is a matter of usage

Deploying digital sufficiency requires a strategy compatible with designing and using our digital system within the physical constraints of nature. This system is made up of two interacting subsets:

- **The system of usage**, encompassing the actions made possible by digital tools (sending emails, watching online videos, processing data, writing this report, etc.) as well as the resulting behavioral and social dynamics (i.e. how often people uses their smartphone, what kind of content they consume, what data is consumed and stored in the process etc.).
- **The technical system**, encompassing the physical components of the digital system which support and enable this usage. User terminals, network infrastructure and data centers are the three elements of this technical system and are the physical parts of the digital technology covered in this study.

We therefore cannot avoid reflecting upon the development of system use. To implement digital sufficiency in practice, we need tools giving us insights into the behavioral processes that have contributed to making the digital system what it is *today*.

Our previous report "Climate crisis: the unsustainable use of online video" (The Shift Project, 2019) has shown the necessity of calling for a public and collective debate on how digital technology is used. Public, because it falls upon public authorities to initiate it, given the sheer magnitude of the social issues at stake. Collective, because properly developing it requires bringing together all the relevant stakeholders and tools at our disposal: regulatory bodies for online use, online platforms distributing online content, representatives of consumer associations, and designer communities (qualified regarding interactions between design and behavioral orientation), etc.

Any public debate questioning day-to-day behaviors must inevitably comprise digital usage at the societal scale, how it develops and the consequent results. As such, the core objective of the present work is to understand that **digital frugality, given its structural effect on usage, raises issues extending beyond the sole aspect of energy consumption.**

The approach we have chosen consists of exploring the most direct effects of digital use upon individuals, i.e. **health and behavior issues.** The subject of health lies outside of the Shift's primary domain of expertise, which is why we have aimed to provide a survey of today's academic knowledge on this topic, as established by research in medicine and behavioral sciences (psychology, sociology, etc.), while relying on the expertise of our working group members in order to understand and synthesize it.

With these results, we do not aim to be exhaustive; we aim to illustrate the relationship between the issues arising from questioning digital usage. The most immediate benefit of studying various noxious effects of today's consumption of digital services is to **describe some of the main social dimensions of current digital use.** This analysis will then lead us to explore the **synergies and mutual benefits** that may exist between reducing digital energy consumption and the public health implications of using digital tools.

Reflecting upon health consequences requires using all available approaches to gain insights on how digital uses develop in and affect society. This report cannot hope to drive such an analysis to its completion, which is why we call once again for the only viable approach to handling the complexity of this matter: brainstorming with all stakeholders, using their expertise and tools, in order to **explicitly** raise unavoidable questions.

B. Digital uses are a collective development

A question underlying the issue of digital use is that of responsibility: this is what makes it so difficult to have a collective debate on what digital sufficiency entails in practice.

Studying how use cases develop reveals that **calling for a behavioral change is a collective endeavor, not just an individual one** (The Shift Project, 2019). Developing a low-footprint system is not simply asking users to limit their video consumption hoping that it will make a significant difference to related energy consumption.

Developing a sustainable system of use requires reflection on the mechanisms that shape it: why do we consume so much digital content? Which social and psychological phenomena are involved? What sorts of use are encouraged by the designs of our digital tools, and how? Developing a sufficient system of use and behaviors means acting at both individual and collective levels, with different implications:

- **At the collective level:** some individual actions do result in direct reductions on the environmental footprint of our usage, such as reducing device turnover, using wifi over 4G, etc. Many of these actions, on the other hand, have a different but complementary goal: to understand and identify our real needs.

  Individual actions enable us to feel the complex issue of the environmental impact of our digital habits daily, thus helping us understand it. They give us the opportunity to regain control over our own digital use, so that we can make personal and subjective assessments about which ones are essential. Essential uses are those uses we want to prioritize when facing constraints, as is the case when running into the physical limits of energy consumption and emissions.

  For instance:

  - When someone lowers video quality to the minimum definition that lets them enjoy what they are watching, this will make no significant difference to their **direct** footprint (data throughput has but a small *direct* influence on the energy consumption of networking infrastructure[68]), but it will help them figure out what

[68] There are two approaches to accounting for the energy consumption of data transfer (e.g as a result of watching online video). The power consumption of networking infrastructure breaks down into a constant part (the power baseline which keeps the infrastructure running, even when no data goes through it) and a variable part (the additional power required to convey data through the network when required). The first method consists in accounting only for direct

video definition they **really** need in this situation. They will then be in a position to tell what definition they need, for what type of content, on what terminal, etc.

  - Likewise, turning off autoplay will only incur marginal savings on someone's energy consumption, but it enables them to tell which content they watch purposefully (out of need) from the content they watch mechanically (as a habit fostered by their uses).

- **At the collective level:** our use does not result solely from individual choices, but is also strongly influenced by the way tools are designed, the algorithms chosen by online platforms, the advertising messages and positioning of brands, the commercial offers of network service providers, etc. Understanding which of these mechanisms come into play when we choose to watch a video or change smartphones enables us to identify the collective opportunities for orienting our uses into a low-footprint, quality-first, and resilient trend.

  A digital system is resilient if it preserves essential use when facing external constraints. Making the digital system resilient means collectively adjusting the scale of various digital use cases and their supporting infrastructure in a way that **preserves the most valuable uses**.

Today, it has been established beyond a reasonable doubt that we need to make our systems compatible with the constraints of the physical world. Now is the time to take the next step: **listing and characterizing those uses that society deems valuable and high-priority.** Prioritizing digital uses requires a collective debate based on individual insights. Only when individuals have learned to tell which of their digital uses are essential to their needs will society be ready to reflect on the most relevant ways of preserving the fundamental benefits of the digital system, in view of the physical constraints it faces.

1. How digital usage develops

a. User / Vendor influence effects

A digital use (for example, sharing a picture online) consists of a person using a system, i.e. a jointly operating a set of tools (in our example: the smartphone – used to take the picture and connect to the network – and the social media platform the picture is shared on). What we call the development of digital use is the set of mechanisms leading us to use our systems in a certain way.

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consumption, i.e the variable part of power consumption, that is the additional energy required in practice for the data to reach the terminal. The second method consists of accounting for direct consumption as well as a share of the constant consumption of the network. This amounts to taking the view that if the network infrastructure has been deployed with the intent of conveying data, including my video, and therefore that the total consumption of the infrastructure is in part due to my video passing through it at some point.
Thus, in practice, reducing data transfer does not immediately influence the consumption of networks in any significant way, because the constant baseline of power consumption is very important. However, including that baseline in the allocation makes it possible to understand how and why our networking infrastructure was deployed, in relation to the digital uses they support.

Digital useage develops along two dimensions *(The Shift Project*, 2019): through user actions, and through the architectural choices made by tool vendors. There are thus reciprocal influences between digital uses, how they evolve, and the professional practices shaping them (design, advertising choices, etc.).

The user influence effect refers to the influence user behavior exerts on tools design. For example, individuals favoring video as a communication medium encourage the development of platforms entirely focused on video content.

The vendor influence effect refers to the way architectural choices of online platforms influence user behavior. For instance, embedding video content in online newspaper articles encourages readers to watch more videos.

It is important to understand that today's digital tools have been designed in a thoughtful and technical way, with the aim of meeting certain objectives. However, as will be shown in the following analysis, these objectives are not compatible with the physical constraints surrounding the digital world.

b. Designing for addiction

The past two decades have seen the emergence of new dynamics in the distribution and consumption of content. During this period, the development of digital use came along with the improvement of tools to monitor online activity (amount and distribution of consumed content, browsing behavior, etc.). This has enabled economic players to create new metrics to evaluate platform performances: what is measured is no longer the explicit satisfaction of users so much as their implicit satisfaction. The metrics for user experience are now the amount of content they consume sequentially, and the profile and evolution of their usage (*The Shift Project*, 2019).

The first direct effect of this paradigm shift is the development of new tools for maximizing performance as described by these new metrics, leading to the emergence of so-called ***addictive* designs**. These refer to design techniques enabling online media to **capture user attention as effectively as possible** (autoplay, embedded videos, ads, pop-up windows, *thumbnails* [69], etc.) then **keep it for as long as possible** (auto-playing the next video, skipping opening and ending credits in TV shows, unsolicited video previews, endless scrolling, re-populating news feeds just before the user leaves, etc.).

These design techniques originate from well-known neuro-psychological phenomena, which they leverage through deliberate technical tools. For instance, offering an uninterrupted content feed (playing one video after another without pause, avoiding separations between social media posts, etc.) maintains the user's brain in a consumption mode, circumventing the natural stopping behavior occurring when users realize the content is coming to an end (*The Shift Project*, 2019).

c. Incompatibility with physical constraints

The new paradigms for evaluating user experience are thus built on very sub-conscious components of individual behavior, via user profiling. Such profiling requires large amounts of data and becomes all the more effective as uses intensify: it gets continuously refined and updated by integrating new data from online activity. **Business models built on these metrics will thus naturally foster an increase in data consumption, the creation of new use and the**

69 Refers to thumbnails of images redirecting to other content (article, video, post etc.)

development of the media that supports it. Over the past decades, the significant proliferation of business models leveraging user profiling and large-scale data-processing (*big data*, artificial intelligence, attention economy, etc.) has established and reinforced these dynamics, making the related innovations economically viable.

The development of online usage has material consequences: the growing place of digital usage in our daily lives favors the emergence of new tools, devices and networks, supporting increasingly energy-consuming usage patterns. Combined with the fact that the environmental footprint of digital terminals lies mainly in their production phase – for example, 90% of the direct carbon impact[70] of a smartphone is attributable to its production phase – *(The Shift Project*, 2018), accordingly **the current trend of development in digital use drives a massive increase in the material footprint of our digital system** (more connected devices, larger screens, higher computing power for increasingly mobile uses, pervasive deployment and scaling of network facilities - e.g public Wi-Fi, 4G in public transportation etc.).

The uncontrolled expansion of our digital system is not viable given the physical constraints surrounding it. Ensuring the preservation of its essential benefits requires resizing its internal dynamics to make it a resilient and managed system. Therefore, we must ask what we must change to challenge the currently-predominant business models of the online economy. Digital stakeholders must take up these issues to avoid putting the very system they are helping build at risk.

2. How to question the relevance of digital usage

Digital usage is developed collectively, but must be understood at the individual level.

By understanding how design choices influence the way we use our systems, we make it possible to re-orient these processes towards more resilient use. Designing to encourage low-footprint use, inventing new business models creating value by other means than exploiting increasingly large data amounts, subordinating the deployment of networking infrastructure to social relevance and reduced emissions, etc. are all strategies to build by bringing together all parties involved.

These parties are:

- **Economic agents in the digital sector**, who control the orientations of systems and platforms;
- **Designer communities**, who hold the techniques to design tools in view of the desired objectives;
- **Public authorities**, who have the ability to build public policies matching the new ambitions of our systems;
- **Regulatory bodies**, to provide direction and build a holistic view of our digital system[71];

70 That is to say without taking into account the consumption of the network infrastructures incurred by using the terminal.

[71] Regulatory bodies like the Arcep are in a position to combine the various different approaches and available data and to centralize the exchanges between the parties so as to propose relevant and substantiated strategic orientations for digital systems (Arcep, 2020).

- Individuals, consumer associations, experts in digital uses and their effects (sociologists, psychologists, health professionals), and all other **relevant stakeholders to understand digital usage and its benefits.**

As we have seen, although significant change can only be effected at a macroscopic and collective level, individual actions remain essential to devising a relevant system of usage. This is where input from stakeholders involved in understanding usage are essential. Consumers, sociologists and health professionals are able to carry out two essential tasks for the deployment of a truly low-footprint system of use:

- Describing digital use cases as they exist today,
- Analyzing their effects on individuals.

It is mainly through noxious effects analysis that we can identify, among the multiple dimensions of digital evolution, the things which call for vigilance. For instance, the increasingly prominent need for offline time is a **symptom of supply exceeding demand, as services no longer accurately fulfill the needs they were made to target** (*The Shift Project*, 2019). Only by understanding these phenomena can we discuss the relevance of letting our system of uses follow certain trends or not.

This report is meant to be illustrative: the following sections aim to illustrate some of the possible noxious effects of current digital use, more specifically **health-related effects**. As this is a complex subject involving multiple fields of expertise, we do not aim to cover these issues exhaustively, rather to initiate work along two directions: **describing the limitations of current digital use, and understanding how they have developed through successive technological deployments – without preemptively and systematically studying their relevance.**

C. The penetration of digital: unmanaged ubiquity

Digital technology is omnipresent in our activities today. Our connected tools support a majority of these activities, structure our private as well as professional or academic spheres, and occupy a significant place throughout our lives (adult life, adolescence and childhood).

This ubiquity could not have been built without the massive deployment of terminals, infrastructures and commercial offers enabling appropriation, by a growing part of the population and collective structures[72], of services offered by industry players.

The following reflections aim to explore the manifestation of these societal dynamics in individual daily lives, as well as the undesirable, or even noxious, effects they can have on individuals when they are neither understood nor managed. **In the context of this report, it is by no means intended to build the demonstration of a net assessment of the societal effects of digital technology.** The ambition here is to explore and illustrate different types of pitfalls stemming from automatic and ubiquitous development of digital consumption.

Answering these questions is essential if we want to be able to build an effective collective debate on the trade-offs to be made between types of digital usage. Given the ubiquity of these

[72] Companies, organizations, communities, administrations or other public bodies etc.

technologies, the noxious effects of uncontrolled use of digital technology fall under **public health**. **Because choosing a given technological future is in fact choosing a given societal future.**

1. Screen exposure: historical example of consumption not preemptively analyzed

Screen exposure is not a new phenomenon. Since the arrival of television screens in domestic homes in the 1950s, researchers have identified the effects of these uses and of this new form of entertainment on individual viewers and social entities (Hemmelweit, H. et al., 1958) (Wartella, E., Reeves, B., 1985). In 1977, the American journalist Marie Winn published "*The Plug-In Drug: Television, Children, And The Family*" (Winn, 1977), a book in which she described the addictive influence of television screens on toddlers and shed light on the exclusive experience of television: *"We always watch television when we watch television rather than having another experience*".

For some specialists (Baton-Hervé, E., 2020) (Bihouix, Ph., Mauvilly, K., 2016) (Duflo, 2018) (Dieu Osika, S., 2018), the arrival of digital screens in everyday life operates a shift towards a consumption profile for screens **which has not been thought out or analyzed a priori.** However, this consumption leads to misuse and irrelevant use of digital devices, resulting in risks of noxious effects on different levels (societal, health) and for different populations (children, adolescents and adults).

Screen time has become a routine activity among teenagers. On average, 13-18 year olds get 6.40 hours of screen time a day, which represents 40% of their normal awake time (Rideout V., 2015). This exposure represents the equivalent of "2,400 hours per year, 100 days, 2.5 school years, or even the combined amount of time a French scientific student would spend studying French, mathematics and natural sciences throughout middle school and high school." (Desmurget, M., 2019). Every day, adult or adolescent smartphone owners[73] endure between 50 and 150 interruptions on average, or one every 7 to 20 minutes (excluding sleep) (Gazzaley A., 2016) (Markowetz, 2015).

In addition, recent work examines the way digital content penetrates reception spaces of adults, adolescents and children (Baton-Hervé, E., 2020) (*The Shift Project*, 2019). This type of approach, combined with data, constitutes a reliable knowledge base capable of assisting and guiding public authorities and civil society (including parents and educators) to provide relevant support to users of digital tools, particularly the most vulnerable among them.

2. Digital technology in our private spheres: ubiquity risk management

- **Ubiquitous communication tools**

The ubiquity of digital tools in daily life manifests itself differently depending on populations (age, sociological characteristics, professions, etc.). Among them, contemporary adolescents are key

73 77% of the French population aged 12 and over have a smartphone in 2019, and 95% have a mobile phone (Credoc, 2019)

to understanding the mechanisms at work in the construction of our usage as it exists today. Among adolescents, the use of social media and digital tools cut across different spheres of daily life from the beginning of adolescence; for example in France, in 2019 (Génération Numérique, 2019):

- 82% of girls and 73% of boys between 11 and 18 years old are registered on one or more social media (including 56% of 11-12 year olds);
- 64% of 11-18 year olds have a digital device with them at all times;
- 35% of them wake up to check it.

In this context, it would be a mistake to consider that virtual activity does not intersect with real life: in 2017, for example, 50% of girls and 60% of boys aged 15 to 18 had already had contact with strangers and nearly 45% of them had met them physically (Génération Numérique, 2017). On the other hand, almost 80% of girls and 60% of boys between 15 and 18 years old use their real identity as well as real photos on their online profiles (although a large majority of them say they lie on their age).

A teenager using a smartphone at home is exposed to external dangers within an environment often considered safe, since he can go online from inside the family sphere, from his bedroom. This virtual universe becomes one of the main links between a teenager's intimacy and the outside world (Tisseron, S., 2011) (Génération Numérique, 2019). Therefore, digital uses development must be understood and managed as **behaviors being integral parts of daily activities and real life.**

Digital tools and their content are ubiquitous in family, professional and even public spheres (advertising screens, flat screens in stores, etc.). These tools are all built around the attention-grabbing strategies and designs mentioned above, with the intent to capture user attention and retain it for as long as possible. The fact that the accessibility of all content, everywhere and at all times, has become generalized will lead to the inclusion of our digital practices in all societal organizations (including the private and family spheres). **This ubiquity will influence the structure of interpersonal relationships within our private spheres and can disrupt intra-family relationships:** continuous content consumption, digital tools interrupting real life exchanges, ubiquity of solicitations and disruption of classic communication rhythms are now constitutive to building family relationships.

The work of E. Baton-Hervé explores these phenomena, which are difficult to quantify, and enables us to move towards identifying key points regarding digital use within a family unit, and with children. This to understand "the conditions in which modern parents must perform their tasks as educators" (Baton-Hervé, E., 2020).

The scarcity of interactions within families is one of the potential noxious effects of building up unmanaged digital use. These types of effects require caution since they do not take place suddenly or visibly. According to the testimonies collected, scarcity of family interactions builds gradually, without the awareness of adults in the household. (Baton-Hervé, E., 2020).

The lack of digital use management therefore generates a risk to interactions and to family sphere stability (Lardellier, P., Moatti, D., 2014), as well as to shaping the building blocks of a child – "a lack of exchanges with parents has direct consequences on the overall development of the child, on self-esteem and on the quality of the connections to others".

- **The different phases: production, distribution and reception of content**

The effects of online content consumption are illustrated at the three levels of media use[74]:

- Content production;
- Content distribution, provide content via a platform (social media, streaming video etc.)
- Content reception, viewers consume and seize content

Each of these phases interacts with different spheres of users daily life, but all are interdependent.

The content production phase by users will impact behaviors in private spheres, specifically and in very particular ways for social media content. Each platform having specific characteristics and privileged frameworks (short message, short video, tone of messages, etc.), they will influence content creation and therefore certain behaviors (*The Shift Project*, 2019) – specifically, social media content is often closely linked to users day to day lives.

Some research (Rodgers, R.F., 2017) highlights the fact that the use by young people of certain applications (such as Snapchat or Instagram for example) induces self-awareness and body-image relationship changes (the body being a tool and the object of content subsequently made public), up to being able to influence young girls (4 to 5 years old) eating behaviors.

The content distribution phase involves users making their productions available on networks and platforms. Since these productions regularly involve the identity of interested parties, it raises questions about the ability to control content, once broadcasted. However, to take the relatively well-documented example of adolescent populations, and contrary to a commonly accepted idea, younger generations do not have expert computer skills by default or systematically. They master simple functions (such as downloading and using mobile applications) but often find themselves helpless when faced with complex rules regulating social media profiles, especially when it comes to restricting or controlling access to content concerning them. Thus 57% of 11 to 18 year olds find it really complex to delete content concerning them published by other Internet users, which is accompanied by fears of harassment, concerns for their reputation, etc. (Génération Numérique, 2019).

The content reception phase is, historically, the most widely documented. Questioning its effects dates back to the first concerns about screens appearing in family spheres, before the presence of tools enabling daily homemade content production. Content accessibility, of all kinds and virtually anywhere, makes it difficult to moderate information, images and messages accessible from within the family sphere.

Thus adolescents are frequently exposed to violent, sexual and hateful images, with an average of nearly one in two children having already been exposed to content of this type on streaming platforms (Jehel, S., Gozlan, A., 2019). Documentation of different types of possible attitudes adopted by adolescents facing non-moderated content access (adhesion, indifference, avoidance or autonomy) (Jehel, S., Gozlan, A., 2019)[75] shows different impacts based on individuals and populations concerned.

Also, research shows that digital content access inequalities exist (digital and social divide) (Pasquier, D., 2018) just as there are currently inappropriate content exposure inequalities.

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[74] This three-step description is valid for all online media uses, for children as well as adults.

[75] S. Jehel identifies four main categories of attitudes (not exclusive): (1) adherence which is accompanied by a fascination with violent, sexual and hatefulhate images; (2) the indifference which pushes the adolescent to "go his way" without however pointing out these contents; (3) avoidance of such content; (4) autonomy which consists in taking a step back, the ability to talk about these images with their relatives and to become more likely to become a platform moderator afterwards.

Figuring out how social environments influence the way content is understood and processed, and how representations broadcasted by the media and digital platforms lead to real public health questions, highlights the need to understand and control our use.

3. Digital technology in the early stages of life: learning tools for the digital world or risks to children's development?

- **Overexposure definition**

Digital technologies are now structural elements of daily life. Children are a focal study point, as they are a population whose development mechanisms are heavily influenced by their environment. It is essential to identify what degree of exposure to digital technology leads to the impact on children doing more harm than good. The developmental phase in children is in fact governed by mechanisms constructed over the course of evolutionary history and adapted to a world without digital technology. It is therefore essential to understand the influences these new ways of interacting with information can have on real world learning phases.

Defining “overexposure” means identifying the threshold not to be exceeded if we wish to protect children from the harmful effects of screens. Some studies documenting the causality between exposure to screens and language delay lead to the conclusion that any regular exposure to screens (even under an hour) influences children’s development. It is therefore essential to understand the exposure risks as soon as digital tools infiltrate the family sphere and children’s development (Van den heuvel M. et al., 2019) (Chonchaiya W. et al., 2008) (Birken, C., 2017) (Masur, 2016) (Pempek, T. et al., 2014) (Tanimura, M., 2007) (Zengin-Akkuş, P. et al., 2018) (Byeon H. et al., 2015) (Walsh J. J. et al., 2018) (Takeuchi, H. et al., 2016) (Takeuchi H. et al., 2015) (Desmurget, M., 2019) (Chiado L. M. et al., 2007).

Every moment of day-to-day life impacted by overexposure must be analyzed. Our digital use enables us to access all content types, anywhere and at all times, infiltrating our spaces and sleep. Given that children and teenagers have their self-regulatory capacities under construction during their development period, studying the effects of attention-grabbing tools on their nocturnal behavior seems relevant. A study observes that nearly 45% of girls and boys between 11 and 18 years old admit staying awake or waking up to go online at night, even though they already have ignificant daily use. 33% say they spend more than 4 hours a day online and up to 40% of their time at weekends (Génération Numérique, 2017).

These behaviors, stemming from children and adolescents significant self-regulation difficulties when facing technology addictive designs, generate significant sleep deficits, in quantity and quality (Carter B. et al., 2016). Lack of sleep has significant consequences on the brain and motor development of children and adolescents. For example, it disrupts the reactivity and connection of brain circuits involved in the construction of emotional stability or in cognitive construction (memory, creativity, attention, etc.) (Desmurget, M., 2019). According to studies documenting the phenomenon, overexposed children and adolescents thus exhibit more irritable behaviors and more chaotic emotional self-management than those with little exposure (Gujar N. et al., 2011) (Yoo S. S. et al., 2007).

- **The real world cannot be learned like the virtual world**

“Child development is holistic, it involves language, intelligence and motor skills. These three components are themselves conditioned by psycho-emotional development” (p. 132 of Baton-Hervé, E., 2020). Child development suffers when ordinary exercise conditions are thwarted during their early years – for example when handling a puzzle in 2D on a tablet rather than in 3D in real life. Interacting with the environment, objects or people, is a necessary condition for brain construction and to acquire a logical and analytical understanding of the world.

The building blocks of children's learning are based on their interactions with the three-dimensional world and human interactions (for language, simple tasks and gestures, logic, etc.), according to a test-failure-correction logic and through a wide variety of experiences (games, activities, communication attempts, trips, etc.) (Baton-Hervé, E., 2020). Therefore, digital tools cannot replace diverse developmental experiences shaping world comprehension and must be made available in a thoughtful and managed manner. Deploying them ubiquitously in children’s learning spheres risks making them compete with direct and material interactions and standardizing experiences accessible to children during formative years, leading to potential noxious effects on their learning building blocks (motor skills, logic, languages, etc.).

As detailed earlier in this report, digital tools are integral parts of our private spheres today, their effects reducing direct communication spaces within families are identified and command attention. Furthermore, decreasing parent-children interactions harms growth, language learning for example, which quickly suffers from the uncontrolled introduction of digital media into the family environment (Baton-Hervé, E., 2020).

Once again, managing and controlling the introduction of digital technology is essential in a given system of use, indirect and undesirable effects being complex to predict but no less impacting. In private and family spheres, children require special attention, given the importance of their formative experiences and their inability to ensure any type of self-regulation when faced with the content on offer. It is essential to **build management tools for parents and educators**, to enable them to measure the relevance and risks of digital content. The development of these management tools requires the mobilization of all available scientific documentation and a cross-referencing of different types of expertise regarding the construction of uses and their effects. This complexity calls for the inevitable involvement of public authorities, to be able to correctly inform and guide individual decisions in light of collective considerations and observations.

4. Digital technology in professional and training spheres: false ally if not managed

- **Digital tools, learning and academic performances**

Introducing digital tools in learning and school processes once again casts doubts on the conditions of relevance. At a time of strong support for the digital transition in academic and school circles, nothing indicates the intrinsic effectiveness of digital tools for school learning.

Since the 2010s, some education institutions have shifted from books to tablets to relieve the weight carried by students, others offer free tablets and computers to undergraduate freshmen. Such education and training policy decisions are not trivial. They must take into account the behavioral and societal impacts caused by such generalized expansions.

A large-scale observational study conducted by two researchers focused on the impacts these tools have on student behavior (Rodhain, F., 2019). Based on substantial observations (1,600 hours) of students in higher education courses[76], they mapped the uses of tablets, originally distributed by the university as a learning tool.

80% of the uses are recreational. Only 20% are linked to learning and knowledge integration activities.

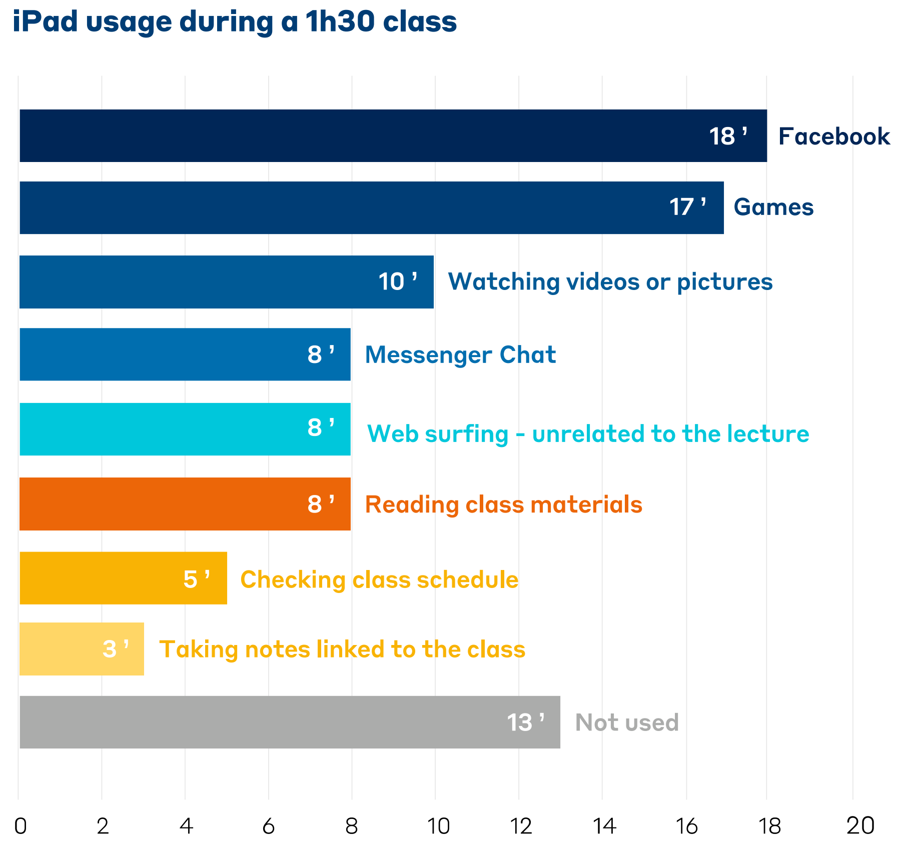

Figure 26 - Use of iPad during an 1h30 class
Source: Rodhain, F., 2019

During a 90 minute class, students spend about "an hour using the iPad for pure entertainment (Facebook for 18 minutes, various games for 17 minutes, watching videos for 10 minutes…), (…) a quarter of an hour during which they do not use it, and (…) a quarter of an hour during which they use it in connection with knowledge or learning" (Rodhain, F., 2019).

Usage being mainly recreational, it means introducing these tools as is done today, rather than supporting an educational approach, amounts to supporting a use model based on online content being accessible and consumed continuously. Many students consider these tools to be harmful but addictive and fail to restrain themselves (Rodhain, F., 2019). Considering the ways these technologies and platforms are designed, it becomes clear that betting on individual self-control

[76] The observer, Dr S. Kakavand, "posed as an Erasmus student, infiltrated various courses, attending all the classes and tutorials, systematically sitting at the back of the class or lecture hall, and with infinite patience, she noted the actual use made of the iPad distributed at the start of the first year. In this way, over a total of 1,600 hours, she observed the behaviour of students from Bac+3 to Bac+5 in several higher education schools". (Rodhain, F., 2019)

to make the tools relevant is a mistake. Consequently, it is essential to develop educational processes facilitating tool uses within a controlled framework and consistent with learning objectives.

These field observations are in line with macroscopic considerations on the effects of introducing digital technology in international level learning processes. The PISA survey (Programme for International Student Assessment) carried out by the OECD, provides benchmarking international data, enabling to assess changes in school performances around the world according to several variables[77]. Some data relative to digital technology from the 2015 PISA report confirm certain conclusions made in the study cited above (OECD, 2015).

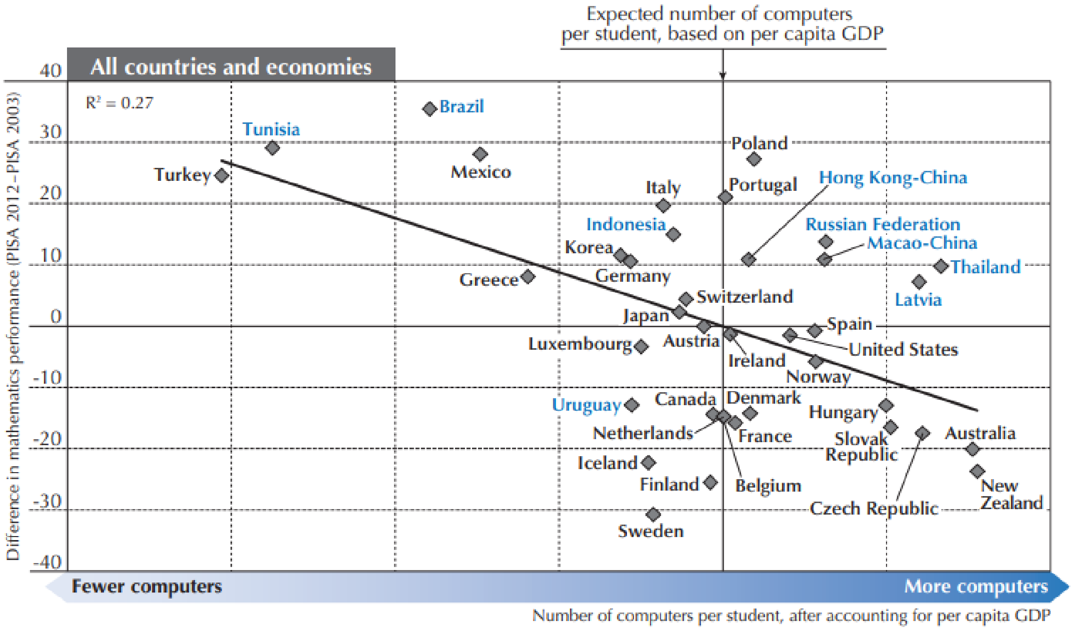

Figure 27 - Correlation between mathematical performance and the number of computers per student
Source: (OCDE, 2015)

The negative correlation between digital investments in schools and the improvement of student performances as well as the analysis of the PISA report, lead to the conclusion that "technology can amplify great teaching but great technology cannot replace poor teaching" (OECD, 2015). It confirms that introducing new technology in classrooms, is itself not an educational strategy, as the effects of these tools on usege are complex and regularly paradoxical. **Rolling out digital tools cannot escape a reflection on the deployment framework and on the prerequisites to align their use with the educational approach** (use management, risk identification of paradoxical and counterproductive effects, teachers training needs, maintenance and training needs for school staff, etc.).

[77] « The Program for International Student Assessment (PISA) is an international assessment that measures 15-year-old students' reading, mathematics, and science literacy every three years. First conducted in 2000, the major domain of study rotates between reading, mathematics, and science in each cycle. PISA also includes measures of general or cross-curricular competencies, such as collaborative problem solving. By design, PISA emphasizes functional skills that students have acquired as they near the end of compulsory schooling. » (National Center for Education Statistics – US Department of Education)

- ### Unmanaged digital practices impairing professional spheres

Digital transformation in the professional sphere enabled companies to adapt to current socio-economic challenges. The deployment strategies of tools assisting this transformation (email, intranet, company social media, collaborative tools on cloud infrastructures, remote work, hybrid conversion from physical to virtual tools, remote training, etc.) intended to harmonize digital technology use, erase or reduce the professional digital divide and increase businesses economic performance, missed the emergence of new challenges stemming from them.

Use management shortages throughout the lifecycle of online content (production, distribution and reception phases) can have negative impacts on employees' mental and physical health. For many businesses digital technologies are now vital. However, "best practices" associated with workplace digital tool use are not instinctively implemented and employees often lack the specific skills to implement these retrospectively.

The professional environment is above all a social environment (Depolo, M. and al., 1998). It means that beyond the technical use performance of tools or work processes, behavioral and social dynamics exist within the organization. The design of some professional tools incorporating attention-grabbing models and models built around public activity (sharing of achievements, avatars design, etc.), common in social media and entertainment tools, influence these dynamics.

Beyond the indisputable positive impacts of digital tools when used properly, negative effects must be expected under deficient management[78]. An example identified by Orse (Observatoire de la Responsabilité Sociétale des Entreprises, 2011 – *"Observatory of Societal Accountability of Enterprises"*), poorly managed emails: create a sense of urgency, increase interruptions, generate information overload and accumulation, complicate information processing and prioritization, invade privacy through the feeling of constant availability and reduce productivity.

Tools evolve, unlike our information processing abilities. Managing development and deployment is therefore critical to ensure tools are adapted to our capacities and **help us achieve our objectives rather than becoming an unsuited source of information overloading our cognitive abilities**[79].

Another influencing factor is the high continuity of use that digital technology enables. Being reachable at any time makes individuals "extensible" (in the sense of (Janelle, D., G., 1973)) and prompts a feeling of constant availability. Private and professional spheres overlap more and more, and the massive increase in remote work following COVID 19 health constraints clearly revealed ambivalences and paradoxes of digital tools. Remote work proved to be an essential facilitator of continued activity, productivity-wise it can be an advantage or pitfall but it also constitutes an information overload risk. The results of an implementation cost-benefit analysis depend largely on management of tool use.

Unmanaged usage leaves room for undesirable phenomena, such as mobile technology addiction, already a reality facing employees (notion of "crackberry" (Mazmanian, M. et al., 2006)). The "Fear Of Missing Out" favors more and more intense and regular, even compulsive, usage.

Employees feel the need to "disconnect" from digital tools when they are no longer at work to genuinely feel on a professional break. However, other studies highlight a new paradoxical

[78] The term "technostress" (Brod, C., 1984) was already used in the 1980s to characterize the difficulties linked to the use of new technologies, particularly in the professional environment.

[79] As our cognitive abilities are designed to rather apprehend the sequential and localized unfolding of events, the construction of a networked society offering a simultaneous and global influx of information carries the risk of information overload and cognitive saturation (Castells, M., 1998) (Isaac, H. et al., 2007) (Lahlou, S. et al., 2000) (Shenk, D., 1998).

phenomenon: this need to “disconnect” is sometimes felt by employees when they have to tackle a specific task. Thus, being reachable anytime and anywhere makes notifications and calls (including professional ones) pervasive, disrupting concentration and effectively interfering with task performances (Fernandez, V. and al., 2014) (Marrauld, L., 2012). These phenomena are consubstantial with digital services designs and identified in literature as the **paradoxical nature of mobile digital technology** (Jarvenpaa, S., L., Lang, K., L., 2005).

Once again this illustrates the ambivalence of technology designed to interact with our attention mechanisms. It reasserts the need to manage technology, regularly leading to counterproductive effects, including in the professional sphere, when deployed without strategic planning.

D. Conclusions: choosing a technological future is choosing a societal future

- **The need for management and restraint**

Our digital use has been shaped by platforms with attention-grabbing designs and the goal to constantly increase content volume and availability. Today, our tools no longer enable us to access information at specific times, but to be connected to all virtual spaces anytime and anywhere. Understanding that connected technologies are no longer simple tools but an additional dimension encompassing our private and intimate spheres, enables us to understand the need to manage uses developments. Today we are platform users, consumers of information, and content producers. Content involving our daily, personal and private lives by publishing parts of our image.

Managing use development means identifying the relevant limits to build to avoid negative effects on our private, family, professional and academic spheres. As management involves understanding how use is shaped and its effects on individual daily lives, it can only be implemented through collective tools. Public authorities, private actors, regulators, designers, consumer communities as well as experts in health and the sociological impacts of our use choices. All of these are essential stakeholders to bring to the table. This is to **understand how our technological choices entail real societal choices**. **Deploying infrastructure and associated technologies means choosing to favor a certain type of use (whether existing or new).** Building a resilient digital system requires giving ourselves the tools, information, data and space to organize collective debates, suitable to make trade-off decisions between opportunities offered by technological choices and paradoxical, undesirable or even detrimental effects. **So the question should no longer be “is this new technology an unmissable opportunity?”, but rather “under which deployment conditions and management of usage does this technology present a real opportunity?”.**

Steering the evolution of our use means questioning the constraints (of an energy, climatic, environmental, societal nature) to comply with and identifying the resulting trade-offs and the services to prioritize.

However, the quantitative solution is not found at the individual level. At the individual level, systemic thinking can accompany concrete elements of daily life, which can then feed the collective debate. The public debate then enables actions (public policies, economic models adaptation, private sector regulations and their consequences on governance) which can have real large scale quantitative effects.

This is the only way for us to make choices preserving our digital services physical and societal beneficial effects, without ignoring the negative ones and without endangering their own sustainability, which today is essential to the challenges of the21st century. Meeting the challenge to build resilient and relevant collective digital technology dynamics cannot be done without **questioning the economic models currently governing the evolutions of our online activities.**

- **Public policies to be built**

Societal reflections on technology use must be fact-based and systemic. To build a relevant and resilient system of digital usage, it is necessary to understand the dynamics at work within different spheres (private, family, professional, educational, academic) and the way they interact. For example, deploying tablets in educational spheres impacts the constitution of student's digital habits (because these tools and the content they give access to are designed to induce behaviors leading to increased and uninterrupted information consumption). As these behaviors are now structuring parts of our daily lives, private lives and habits will inevitably be impacted.

It is also essential to think about our digital uses **in terms of public health policy**, to be able to build a range of tools and actions not only adapted to each sphere but also consistent between them. **Without thoughts of this type and level, our digital policies and strategies will remain wasted opportunities of a digital transition missing its objectives:** to help us meet the physical and societal challenges of this century.

These public policies, built with public health communities at large and stakeholders involved in design of uses and their effects, will constitute the cornerstone of the deployment of a system of well managed usage:

- **Awareness programs, teaching tools and training programs enabling collective actors (schools, academia, public administrations) to build real strategies to roll out digital tools**: by identifying expected benefits, building frameworks ensuring relevant, and not harmful, deployment (particularly necessary educational innovations, training needs, etc.), monitoring results to steer frameworks development and tools roll out.
- **Awareness programs and educational materials for individuals in education roles (parents and educators)** enabling families to balance and manage digital technology infiltration at home and avoid negative impacts.
- **Information programs adapted to companies and best practices tools for all sectors** aligning business digital cultures with the issues at stake.
- **Regulatory tools** controlling attention-grabbing designs and automatic consumption.
- **Incentives and initiatives, initiated or supported by public authorities, to trigger the required evolutions of digital services economic models** moving from a paradigm encouraging intensification of digital use to goals compatible with the physical and societal resilience constraints of our digital systems.

Conclusions

In October 2018 we published "For digital sobriety" reporting that "the current global digital overconsumption trend was not sustainable regarding the supply of energy and materials it would require" (*The Shift Project*, 2018).

While at the time this assertion appeared strange, even provocative, nowadays it is more and more accepted by large parts of public opinion[80] but also by companies (CIGREF made digital frugality one of its strategic axes[81]), administrative and political authorities[82], and even some key digital stakeholders[83]. It is also regularly confirmed by the quantitative studies conducted on the subject[84]. While confidence in the inherent ability of technology to solve technology-driven problems continues to be observed, as the slowdown of energy efficiency gains in the coming decade takes shape, it is becoming increasingly clear that only a moderation of our usage, limiting growth in digital volumes, will enable us to return to a manageable trajectory.

Our call to **"Adopt digital sobriety as a foundation for action"** was therefore - and remains - fully justified.

This call received media coverage, making it possible to inform different audiences and to raise awareness of a necessary paradigm shift within society. It will only become truly audible to a majority of stakeholders if it is **communicated** on a large scale and embodied in **policies,** especially by public authorities.

For communication and policies to have a sufficiently rapid and significant impact on people, it is essential to rely on precise understanding of behavioral mechanisms generating digital technology hyperconsumption in order to identify the levers for change.

This is why we devoted a significant portion of this report to the societal construction of digital uses. Identifying psycho-societal mechanisms at work shows that **what is at stake is not, in the first place, to implement individual "good practices" but to regain and maintain control over our digital interactions on a collective scale.** An entire field of policies, particularly public ones, need to be developed and implemented to do this. These cover the whole range from initial digital education to design technique regulations, including prevention campaigns against digital overconsumption.

Regarding organized structures (companies, public agencies, local authorities)[85], it is essential to give them tools enabling **the integration of environmental dimensions into the strategic and operational management of their digital technology initiatives.**

We favored a systemic approach because each organization, no matter its size, should **change its digital approach and not just to acquire and use new optimization tools as strategies and policies remain unchanged**.

[80] https://www.bva-group.com/sondages/numerique-et-environnement
[81] According to Cigref's 2018-2019 activity report/2019-2020 work program
[82] For example, the Senate in its information report on the environmental footprint of digital technology for an ecological digital transition, published on June 24, 2020
[83] Roadmap on the environment and digital of the National Digital Council, published on July 13, 2020
[84] (GreenIT.fr, 2019) ; Further efficiency gains vital to limit electricity use of data, ING Economics department, November 2019; Powering the data revolution, HSBC Global Research, May 2019; New perspectives on internet electricity use in 2030, Anders Andrae, June 2020
[85] Referred to for convenience of language as "companies" or "organizations" in this report

This change is a corporate approach to be carried out under the guidance of upper management and with the drive of the IT department, as Cigref describes in its working group report on digital frugality[86]. The challenge is not only reducing the carbon footprint of Information Systems as holistically as possible[87], but also applying this goal to all (significant) digitization projects.

The methodological framework we built enables **steering this transformation and establishing operating processes consistent with this paradigm shift within companies**. As such, this framework is complementary to more operational eco-designs and expanding of good practice approaches.

Deploying digital frugality, also requires distinguishing digital technology innovations to prioritize investments accordingly. Some show potential environmental gains, but some structurally lack this ability.

These innovations, often identified as **"smart",** are generally presented as significant energy or environmental gains and are the main focus of intensive and ubiquitous marketing campaigns, especially to local authorities.

The detailed analyses we carried out on smart lighting led to the conception of a model (STERM[88]), enabling to highlight the significant impact of the digital layer energy consumption, particularly of grey energy (used during the production of equipment constituting the digital layer), and the carbon footprint dependence on weakly predetermined use cases and under conditions *ex-ante* depending on the complexity of the system to be optimized.

Without claiming to be either exhaustive or universal, this approach enables us to highlight the necessity **to carry out ex-ante environmental assessments** of these so-called "smart" projects, without relying on their simple name. It also shows that in many cases, **the environmental benefit will not ultimately come from the technology employed but rather its resulting usage, user behavior, and thus the ability to set up governance steering behavior**.

The guidelines and ideas we provide here to public and local authorities, companies, and users or suppliers of digital services, to deploy digital frugality do not only apply to developed countries. The needs for **environmental management of the digital transition** also exist in the developing world: although the initial contexts and reference trajectories are different, the dynamics governing use and supply remain substantially similar to those in developed countries.

We are working on updating the prospective scenarios developed in 2018 (*The Shift Project*, 2018) to shed light on potential impacts of technological innovations being deployed (Internet of Things, Artificial Intelligence, *edge computing*, 5G in particular), to help improve the objectivity of the social debates gradually emerging around them.

We are also considering launching new discussions to enable us to continue developing a systemic approach of the environmental impacts of the digital transition, especially around the digital economy (business models in place, contribution to growth, alternative business models) and linking both digital and environmental transitions.

Finally, we will participate in public debates taking place and being prepared, in France and in Europe, on the role, place and purpose of digital technology in our societies, by providing insights emanating from our work.

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[86] To be published at the end of October 2020
[87] By adopting an approach that understands the impacts of scope 3.
[88] Smart Technologies Energy Relevance Model

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The Shift Project

The Shift Project is a think tank working in favor of an economy free from carbon constraints. Association law 1901 recognized as a “general interest group” and guided by the requirements of scientific rigor, our mission is to enlighten and influence the debate on the energy transition in Europe.

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