The low-tech approach serving the digital resilience of organisations

Adaptation strategies in times of fluctuations

February 2026

Cigref

In partnership with the French Institute

for Sustainable IT (INR)

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EDITORIAL, CIGREF

The low-tech movement emerged in the 1970s thanks to British economist Ernst Friedrich Schumacher, who proposed viewing nature as capital to be preserved rather than simply an inexhaustible source of income. He also suggested creating operations that respect the planet and integrating worker "well-being" and environmental preservation into companies' economic decisions.

In France, the approach gained popularity with the publication in 2010 of "*The Age of Low-Tech*" by Philippe Bihouix and the creation of the "Low-tech Lab" in 2014. The low-tech movement encompasses objects, techniques, services and know-how that are technologically adapted, useful, accessible and sustainable. Since then, this vocabulary has become established in the voluntary sector and environmental movements, which see it as a potential response to the environmental crisis. However, this approach remains marginal within large organisations and companies, which may see it as a backward-looking fantasy or a hindrance to growth.

In 2023, during a training course at Polytechnique Exed entitled "Sustainable Transformation Strategist" led alongside Élisabeth Lucas, Caroline Danancher and Cécilia de Foucaucourt, our dissertation was devoted to exploring this subject. Our objective was to identify its foundations, assess its potential, identify the obstacles to its dissemination within large organisations and companies, and consider the levers that could make it more attractive. Through a series of interviews with a diverse panel of stakeholders, we quickly noticed a growing interest in this approach. This work led to the creation of a Working Group, set up in partnership with Cigref and the French Institute for Sustainable IT (INR), with the active participation of ADEME.

This report marks the end of the first cycle, opening up numerous avenues for future cycles. We hope you enjoy reading it!

Nicolas SCHMITT,

Technology Intelligence & Sustainable IT at BNP Paribas, representative of BNP Paribas at Cigref

EDITORIAL – FRENCH INSTITUTE FOR SUSTAINABLE IT (INR)

For several years, the French Institute for Sustainable IT (*Institut du Numérique Responsable - INR*) has been committed to opening up new avenues for thinking about and practising a more sober, inclusive and resilient digital technology. In this context, the work carried out with Cigref on the low-tech approach marks an important step: it is no longer just a question of questioning the place of digital technology in our organisations, but of asking ourselves how digital technology can continue to exist and serve society in a world constrained by crises and planetary boundaries.

The low-tech approach should not be seen as a step backwards or technological nostalgia. On the contrary, it is an invitation to rethink our priorities, cultivate technological discernment and develop useful, accessible and robust solutions. It asks a simple question: what will remain of our digital systems when energy, raw materials and infrastructure become scarce or intermittent? And above all, how can we prepare credible and desirable responses today?

This report, the result of a year of collective reflection, interviews and forward-looking exercises, highlights three disruptive scenarios for 2035-2040: the fragility of supply chains, the risk of energy and water rationing, and the increasing exposure of infrastructure to climate hazards. Faced with these challenges, low-tech does not appear to be a single solution, but rather a common framework for imagining other trajectories: robust and sober operating systems, manual processes to complement digital tools, territorial pooling of resources, and the development of local repair and reconditioning sectors.

Beyond technical solutions, this report emphasises the transformation of our imaginations. Because low-tech is not just about devices: it is also a culture of simplicity, autonomy and cooperation. It is an invitation to relearn the value of robustness and community in a world where abundance can no longer be the norm.

I would like to thank all the organisations and individuals who have invested their time and energy in this working group, as well as the partners who have contributed their expertise and enthusiasm. Their commitment reflects a shared conviction: digital resilience will not be built in spite of the constraints of the world, but with them.

At a time when we must learn to "do better with less", the low-tech approach is a strategic asset. It paints a picture where innovation and responsibility are not at odds, but reinforce each other. I hope this report will inspire and guide both public and private actors towards a digital world that, far from being fragile, will remain at the service of what matters most.

Richard Bury, President of the French Institute for Sustainable IT

Vincent Courboulay, Head of the Academy and Centre of Expertise at the French Institute for Sustainable IT

SUMMARY

This report explores how the low-tech approach can strengthen the digital resilience of organisations in the face of fluctuations, whether climatic, geopolitical, economic or social. While digitisation has long been seen as a performance imperative, hyper-digitisation now exposes companies to major vulnerabilities. The low-tech approach offers a paradigm for adaptation based on questioning "fair needs", simplifying technological systems and promoting maintainability, all within a systemic approach to economic and social models.

The working group, led by Cigref in partnership with the French Institute for Sustainable IT (*Institut du Numérique Responsable - INR*), has opted for a forward-looking approach aimed at highlighting the major risks that organisations are likely to face between now and 2035-2040. With the support of the consulting firm Futuribles, **three disruptive scenarios** have been identified:

- **The escalation of global conflicts** leading to disruptions in the supply of technology (semiconductors, rare metals);
- **The explosive growth of digital usage** leading to energy and water rationing;
- **The intensification of extreme weather events** damaging digital infrastructure.

These scenarios highlighted high-impact risks, such as **shortages of strategic resources** linked to disruptions in the supply chain, **economic instability** in the value chain, and the **prioritisation of** digital **uses** for energy regulation purposes.

This report then examines how the low-tech approach provides a **conceptual framework and operational lever for strengthening the digital resilience** of organisations by analysing the advantages and limitations of low-tech principles and formulating concrete recommendations for their implementation. These recommendations emphasise the need to relocalise and diversify skills, the potential for developing "hardened" and sober operating systems (OS), and the development of low-tech business continuity plans that incorporate alternative or parallel backup processes. They also address the importance of anticipating resource sharing and access processes by defining and prioritising 'essential' services. Combining these approaches makes it possible to limit exposure to risks "upstream" of crises, improve their management "during" their occurrence, and promote resilience and recovery "post-crisis".

The report emphasises the importance of preparing and transforming mindsets, experimenting in practice, redefining or reorienting business models, investing in skills associated with the development of collaborative ecosystems, and promoting "common goods". Ultimately, far from being a constraint, the low-tech approach is proving to be a strategic, robust and essential asset for evolving in a world of limited resources and an e of increasing risks that are increasingly heterogeneous and difficult to anticipate. It establishes "technological discernment" as the new norm for resilience and innovation, demonstrating that these two dimensions can be combined with a view to progress.

ACKNOWLEDGEMENTS

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AIT DAOUD Marie – VINCI

BESNARD-GUIOL Doralie – MÉTROPOLE ROUEN NORMANDIE

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Anne-Charlotte BONJEAN – ADEME

BOUCHEROT Sara – OCTO TECHNOLOGY

BOURCEREAU Maud – OCI

CALISTI Renaud – GRTGAZ

CAILLAT Jean-Philippe – 3M Group

Amandine Capelle – OCTO TECHNOLOGY

CERDA Roxane – SAINT-GOBAIN

CHARROUF Youri – IJO

CHIRON Jean-Paul – NEW AQUITAINE REGION

CONVERS Ghislaine – Groupe ADP

COMTE Agnès – BANQUE DE France

DANANCHER Caroline – TENNAXIA

DEGUITRE Yuki – L'ORÉAL

DEROUETTE Philippe – BPCE

Denis Didier – ITHENKA

Sousan Dowlatshahi – BNP Paribas

FANGEAT Erwann – ADEME

GALLON Guillaume – MADE-UP CONSULTING

David Heinzer – Edenred

Emmanuel Larocha – Sopra Steria

LAVIRON Francois-Xavier – ADEME

Charles LEDUCQ – BILBEA

LE CALLOCH Marion – ORANGE

Charles LEDUCQ – BILBEA

LOCHON Thierry – MTE

LUCAS Elisabeth – ORANGE

MANAR Karim – SOBRII

MARCHANDISE Jacques-François – ASTROLABE

MARLIN Fabien – MICHELIN

Lucie Marvillat – IJO

MOREAU Wilfried – NEW AQUITAINE REGION

MONTAGUT Adrien – COMMOWN

NITOT Tristan – OCTO TECHNOLOGY

NOTAIRE Thierry – MAIF

Christophe PHAM – INFOGREEN FACTORY

PECCINI Stéphan – STÉPHAN PECCINI CONSULTING

Julie Ribes – Michelin

PINIER Arnaud – ISIA

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Benoît TISSERAND – BPCE

VIEILLEFONT Valérie – TASMANE

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We would also like to express our sincere thanks to all the speakers who contributed to our working group's discussions (in order of appearance):

- **Erwann Fangeat**, Technical Coordinator, Digital Sobriety Department at **ADEME**
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- **Guillaume Boudry**, Telecommunications Futurist, **Orange**
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- **Hacer Us**, Sustainability in Innovation Advisor / Coach at **Michelin Innovation Lab**
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- **Clément Marche**, Co-founder of **Nuageo** and **Fluctu'IT**

This document was compiled and drafted by **Flora Fischer**, Mission Director and Responsible Digital Technology Officer at **Cigref**, with contributions from **Nicolas Schmitt**, Technology Intelligence & Sustainable IT at **BNP Paribas**, co-leader of the working group.

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INTRODUCTION

In a world facing an increasing number of crises – whether climatic, geopolitical, economic or related to resource scarcity – growing dependence on digital systems exposes organisations to significant vulnerabilities. Historically, the main risk identified by companies was insufficient digitalisation, which was not "fast enough, good enough or far enough". However, the current trend towards hyper-digitisation tends to increase the vulnerability of digital services to ecosystem risks, which are becoming increasingly heterogeneous and unpredictable. This development calls into question the notions of service performance and continuity, and calls for a reassessment of adaptation strategies.

It is in this context that the low-tech approach appears to be a promising strategic path that strengthens the digital resilience of organisations. It is defined as an approach to the design and development of products, services, processes or systems that aims to maximise their social utility while minimising their environmental impact, in line with local capacities and planetary boundaries. It is based on a thorough review of needs in order to retain only what is essential, a reduction in technological complexity, and an emphasis on maintainability (through reuse, repair or modularity). Beyond its purely technical dimensions, the low-tech approach takes a resolutely systemic approach, integrating economic, organisational, social and cultural issues. Similar to concepts such as eco-design and the circular economy, it is distinguished in particular by its questioning of what is truly needed, its search for robustness, the accessibility of the skills required for its deployment and the promotion of user autonomy.

At first glance, it might seem bold to consider the contribution of low-tech approaches to the digital sector, given the inherently high-tech nature of the systems involved. However, the opposition between "high-tech" and low-tech needs to be nuanced in light of research and emerging literature on the subject. Digital technology from a low-tech perspective is a rapidly expanding field of exploration, offering promising insights.

One of the major challenges of this report is to move beyond a still widespread perception that associates low-tech approaches with regression or a brake on economic development. It is necessary to reconfigure this perception into an approach that is both desirable and necessary, in tune with a world characterised by constraints and fluctuations. By "fluctuation", we mean the variability of events that generate increasing instability and uncertainty about the sustainability of models or states that were previously considered immutable.

How can organisations, administrations or communities, traditionally structured around models based on short- or medium-term performance imperatives, integrate a low-tech approach that enables them to guarantee the robustness and continuity of their digital systems in an environment marked by growing uncertainty?

This report explores the adaptation strategies that low-tech approaches can offer to strengthen the digital resilience of organisations, administrations and communities. Based on a forward-looking method conducted with the support of Futuribles[1] , it identifies the most plausible future threats likely to affect their digital systems, analyses the strengths and limitations of low-tech principles in the face of these challenges, and finally formulates operational recommendations for their practical implementation.

One of the major contributions of this working group's work is the positioning of the low-tech approach as a relevant strategy to consider in order to cope with a context marked by fluctuations and systemic risks.

[1] https://www.futuribles.com/

1 LOW-TECH: A PARADIGM FOR ADAPTING TO DIGITAL VULNERABILITIES

1.1 DEFINITION AND THEORETICAL FOUNDATIONS OF LOW-TECH

The low-tech approach is not currently subject to any normative definition[2]. The processes implemented vary depending on the actors involved and their level of maturity. However, a growing number of institutions and associations, such as the Low-Tech Lab, ADEME and *La Fabrique Écologique*, are engaged in rigorous work to clarify and formalise the concept, helping to structure the field and define its contours.

Here, we propose adopting the definition developed by ADEME, which itself drew inspiration from the work of several leading figures in the field, in order to construct a faithful and comprehensive approach to the low-tech movement. This definition highlights the main issues that structure it: social utility, questioning needs, accessibility (in terms of use and cost), sustainability, local scale, and autonomy, made possible by a controlled reduction in technological complexity:

"The low-tech approach [...] is an innovative and inventive approach to the design and development of products, services, processes or systems that aims to maximise their social utility, and whose environmental impact does not exceed local and global limits. The low-tech approach involves questioning needs with a view to retaining only what is essential, reducing technological complexity, and maintaining what already exists rather than replacing it. The low-tech approach also allows as many people as possible to access the solutions it produces and to control their content."[3]

Analysis of the various definitions proposed by the actors or institutions mentioned above reveals the recurrence of certain **key concepts** in the characterisation of the low-tech approach:

- **Usefulness**: low-tech solutions must meet **real needs**:
    - The **need** is the fundamental starting point in the low-tech approach. It is the subject of systematic and central questioning, aimed at formulating appropriate, proportionate and truly useful responses. This approach seeks to respond primarily to the "essential needs" of individuals and organisations, breaking with the logic of artificially creating needs, which are then more akin to "desires", often dictated by an exaggerated consumerist dynamic.
    - **Usefulness** is both an essential characteristic and a central objective of low-tech approaches. A solution or service described as low-tech must demonstrate that it brings tangible benefits to individuals or society by providing an optimal response to fundamental needs. The study conducted by ADEME ([4]) on low-tech approaches

[2] It should be noted that the standardisation work currently underway is focused primarily on the circular economy, an economy in which low-tech should play a significant role.

[3] BLOQUEL Marianne, BONJEAN Anne-Charlotte, FANGEAT Erwann, MARRY Solène, ADEME, FORGET Astrid, FUSTEC Alan, HABE Camille, JAEGER Romain, MOIROUD Loraine, MORALES Eloïse, Goodwillmanagement, CHABOT Clément, Low-tech Lab. 2022. *State of play and prospects for low-tech initiatives.* Report - 48 pages. Available online: https://librairie.ademe.fr/industrie-et-production-durable/5421-demarches-low-tech.html

[4] *Ibid*

emphasises the need to maximise the social utility of products, services, processes and systems.

- **Accessibility**: low-tech solutions must be able to benefit as many people as possible. This covers several complementary dimensions:
    - **Comprehensibility**: low-tech solutions, services or processes must be easy to use, modify or repair. This simplicity of use promotes the transmission of knowledge, the sharing of skills and the strengthening of social ties.
    - **Functional simplification**: low-tech solutions are deliberately limited to essential functionalities, i.e. those that have proven social utility and respond proportionately to the specific need expressed.
    - **Affordability**: in order to be truly inclusive, low-tech approaches must remain economically affordable, thus enabling the widespread and equitable dissemination of the solutions offered.
- **Sustainability**: the low-tech approach is also characterised by its intrinsically sustainable objectives. Whether it is an object, a service or a process, its design aims to minimise the use of natural resources and significantly reduce greenhouse gas emissions. It incorporates consideration of the environmental footprint at every stage of the life cycle. By their very nature, low-tech solutions are robust, repairable and often made from reused components, thus promoting a circular and resilient economy.
- **Localisation**: the low-tech approach favours local production in order to limit the environmental impact of transport, strengthen regional skills and contribute to the socio-economic vitality of regions. This approach also promotes better control of value chains and more precise adaptation to the specific needs of communities.
- **Autonomy**: the low-tech approach strengthens individual autonomy by making objects and services accessible, understandable and modifiable, regardless of technical skill level. This capacity for appropriation allows everyone to adapt solutions to their own uses, repair or improve them, while promoting the reappropriation of know-how and the development of practical skills.

To this definition, we propose adding a cross-cutting dimension, considered essential by the working group participants:

- **Robustness:** inseparable from sustainability, this concept is defined by Olivier Hamant[5] as the ability *"to maintain a stable and viable system despite fluctuations"*[6] . Applied to low-tech, robustness implies that elements are designed from the outset to withstand various disruptions over time, depending on the nature of the service, product or system concerned (e.g. the waterproofing of equipment, its resistance to cyber-attacks for a service, the implementation of alternative systems guaranteeing "minimal" business continuity in the event of a generalised failure, etc.).
  Digital systems, due to their intrinsic complexity, are particularly vulnerable. A single component failure can lead to a cascade of malfunctions. Conversely, low-tech systems, due

[5] Researcher at INRAE and Director of the Michel Serres Institute.

[6] https://www.2tonnes.org/post/la-robustesse-appliqu%C3%A9e-%C3%A0-l-entreprise-avec-olivier-hamant

to their simplicity, are often more robust, easier to repair and less dependent on cutting-edge technologies that are sometimes unstable, prone to obsolescence or difficult to access. In crisis situations (component shortages, power cuts), these simpler systems, which are accessible to different types of expertise, are more likely to remain operational. Finally, robustness is closely linked to **resilience**. As Olivier Hamant points out, these two concepts are distinct but complementary: "*resilience in the socio-ecological field is the ability to maintain, adapt and transform oneself in a fluctuating environment*", while "*robustness creates the conditions that prevent us from falling*."[7] It is in this sense that we assert that **the low-tech approach offers many principles that are relevant to contributing to the resilience** of **systems** and organisations.

Finally, the low-tech approach, as we develop it in this report, incorporates **risk management:** this refers to the probability of damage occurring, taking into account the interactions between degradation factors (hazards) and vulnerability factors (level of impact on humans, their activities and the environment). A risk may be natural in origin or result from purely anthropogenic causes (technological or geopolitical, for example), or be linked to natural elements accentuated by human action (climate risk). Risk mitigation and management is achieved by addressing both aspects (hazards and vulnerability).

It is in light of these different elements that we now have a better understanding of how the low-tech approach can be defined as a **proactive resilience strategy** for organisations and societies.

1.2 LOW-TECH AND DIGITAL: BENEFITS OF THE APPROACH FOR ORGANISATIONS

Adopting low-tech approaches in a digital context can offer several advantages for organisations, whether economic, social or environmental. Here are some key benefits to keep in mind:

1. **Financial savings**: Low-tech solutions often require an initial investment and higher operating costs, particularly in terms of human resources. However, this increase must be weighed against the savings generated by eliminating non-essential features, using less energy-intensive infrastructure (because it is technologically simpler), and extending product life through repair and reuse. This will lead to savings in a tense world where the costs of strategic resources and energy are rising.
2. **Reduced environmental impact**: by limiting the use of natural resources and favouring less energy-intensive and more repairable technologies, low-tech approaches contribute to reducing the organisation's resource consumption and greenhouse gas emissions.
3. **Strengthening resilience**: low-tech systems are often more robust and less vulnerable to external disruptions, such as geopolitical crises or natural disasters. They enable organisations to maintain their essential activities even in the event of a failure of traditional digital infrastructure.

[7] https://larobustesse.org/?PourquoiParlerDeRobustesseEtNonDeResilie

4. **Promoting local skills**: by favouring local production and equipment maintainability, low-tech approaches stimulate the local economy and create jobs. They also encourage the transfer of know-how and the development of technical skills within communities.
5. **Social inclusion**: low-tech solutions are often more accessible and understandable to a wide audience. They help to reduce the digital divide by offering simple and affordable technologies that are tailored to the real needs of users.

Low-tech and large organisations: defining a 10-year strategy in three steps

Feedback collected by N. Schmitt, C. Danancher, E. Lucas, C. de Foucaucourt

As part of a thesis for the Polytechnique Exed "Sustainable Transformation Strategist" training programme completed in 2024, we examined the reasons why the low-tech approach remains mainly confined to the non-profit sector or small organisations, as well as **the opportunities and methods for its deployment on a large-scale corporate level**. To shed light on these issues, we conducted a series of interviews with leading figures in the low-tech sector, representatives of organisations such as ADEME, managers of large companies, consulting firms and academic researchers.

These discussions highlighted the benefits of the approach for large companies, subject to the removal of certain major obstacles:

- The difficulty in accepting the approach and the negative perception of the term 'low-tech', often associated with a backward-looking fantasy;
- The difficulty of rethinking economic benchmarks and envisaging a transition to scale;
- The inadequacy or absence of an appropriate regulatory framework;
- Persistent ignorance of the approach and its potential benefits.

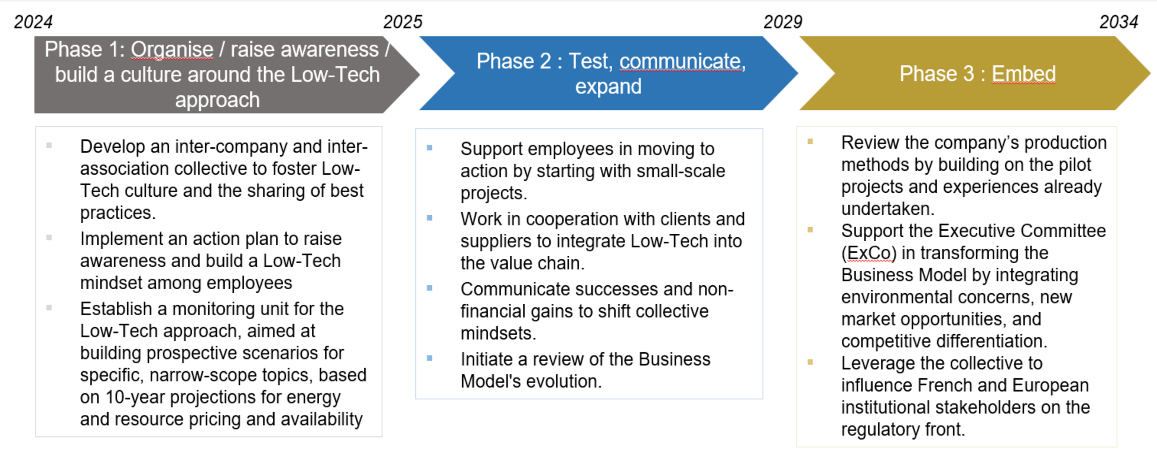
Several success factors have been identified for adopting the approach:

- **Promoting collective intelligence:** the development of low-tech relies on new modes of organisation involving all stakeholders (politicians, associations, investors, businesses, citizens);
- **Adopting appropriate language**: as the term "low-tech" can be jarring in a business context, it may be appropriate to favour concepts such as "techno discernment" or to highlight the principles of "usefulness, reparability and sustainability" without necessarily naming the approach;
- **Comply with regulatory requirements**: low-tech solutions must meet current standards (even if these can sometimes be a hindrance) and guarantee user safety, in order to avoid being equated with "DIY" solutions.
- **Ensure performance or resilience**: the low-tech solution must offer a level of performance equivalent to the existing solution, or respond to an identified risk of fluctuation in order to maximise its acceptability.
- **Guarantee operational reliability**: it is essential to provide for operational maintenance measures, in particular through support teams trained in the repair and maintenance of the solution.
- **Controlling costs**: the overall cost of the low-tech solution must remain acceptable, particularly by incorporating the residual depreciation of the existing solution.

In general, the aim is not to seek to transform an existing solution that has proven its worth, but to embed the approach in a long-term strategy (10 years), anticipating the impacts of future fluctuations, whether in terms of price changes, resource availability or geostrategic risks.

Following this assessment, we developed a vision: "*Make the Low-Tech approach acceptable and desirable in large companies to enable its wider dissemination among their stakeholders and limit our impact.*"

This reflection led to a proposed action plan for the period up to 2034:



The creation of this working group within Cigref and French Institute for Sustainable IT (INR) was the first concrete step in this ambitious plan.

Caroline Danancher, CSR Software Consultant at TENNAXIA

Cécilia de Foucaucourt, CSR Director at GSK France

Elisabeth Lucas, Programme Manager for Group Energy at Orange

Nicolas Schmitt, Technology Intelligence & Sustainable IT at BNP Paribas

1.3 ARE LOW-TECH AND HIGH-TECH COMPATIBLE?

Contemporary discourse on innovation remains largely dominated by a techno-centric vision, in which progress is systematically associated with advances in the high-tech sector. However, this reductive conception deserves to be questioned, since innovation is not limited to technological sophistication. Many innovations may be low-tech or even non-technological, yet still have a significant impact.

In its fundamental sense, innovation[8] refers to the introduction of new ideas, methods, products, services or solutions that are likely to have a positive impact. It also encompasses innovative approaches to problem solving, processes, organisational practices and economic models.

[8] See https://www.universalis.fr/encyclopedie/innovation/

From this perspective, the low-tech approach is not just an alternative method: it is a strategic, evolving and powerful framework for responding to contemporary challenges in a world constrained by resource limitations and multiple crises. By placing principles such as utility, accessibility, sustainability and robustness at the heart of innovation, low-tech offers a credible way to reconcile resilience and innovation, as an alternative to (pure) technological sophistication.

To illustrate the potential complementarity between innovation, high-tech and low-tech, we propose to review several representative examples:

- The Jerry DIT (Do It Together) initiative is a prime example: it involves collectively building IT equipment (computers or servers) from recycled components, assembled in rudimentary containers such as barrels. It provides free access to computers and the Internet in underserved communities, while reducing electronic waste and promoting user education on how computers work.
- The transformation of the *Low-tech Magazine* website[9] illustrates how low-tech principles can be applied to digital services. Now designed with a simplified architecture (static site, optimised images, default font, etc.), the site has reduced the average weight of its web pages by a factor of five compared to the previous version. It is also self-hosted and powered exclusively by solar energy, coupled with a low-capacity battery. This choice means occasional service interruptions during prolonged periods of low sunlight, which are accepted as part of the approach. Although based on advanced technologies (servers, network, etc.), this initiative is part of a logic of energy efficiency and decentralisation. It illustrates a low-tech strategy aimed at minimising the carbon footprint of a high-tech service.
- In the public sector, some services use SMS as their main channel of communication, making them accessible via basic mobile phones or "dumbphones". This example highlights the use of simple technologies to promote accessibility and inclusion. Rather than requiring sophisticated smartphones and an internet connection, this approach favours well-established solutions that are accessible and better suited to the realities of audiences who are digitally excluded.

In light of the above examples and the objectives sought, it appears that high-tech and low-tech approaches can coexist in a dynamic of synergy. High-tech research can, for example, shed light on the choice of the most relevant and suitable materials for low-tech designs, while the latter can steer high-tech development towards greater simplicity, sustainability and reparability. The Fairphone is a striking example of this. Although it is a high-tech product, it was designed according to low-tech principles (robustness, eco-responsibility of components, repairability, modularity, etc.).

Furthermore, high-tech can provide advanced tools, while low-tech offers a more ethical and sustainable framework for their application. Far from being synonymous with "technology of the past", low-tech embodies a form of lucid and responsible innovation. By emphasising efficiency, reparability, sustainability and accessibility, often using local materials and appropriate know-how, it invites us to rethink the use, design and impact of our technologies in order to make them more resilient, equitable and compatible with planetary boundaries. Ultimately, it is a question of "common sense" and balance. The debate between 'high-tech' and 'low-tech' is therefore a valuable opportunity to question the

[9] https://solar.lowtechmagazine.com

purpose of technologies, their hidden costs (environmental, social) and how they can be used to serve 'basic human needs'[10] and greater sustainability.

1.4 DIGITAL TECHNOLOGY IN TIMES OF CRISIS: IDENTIFYING HIGH-IMPACT SCENARIOS AND MAJOR RISKS

In order to analyse the contribution of low-tech solutions, the working group opted for an approach based on risks considered strategic for organisations. This methodological approach aims to reinforce the legitimacy of the discussion among top management and decision-making bodies. This is a deliberate choice that intentionally limits the exploration of low-tech solutions to the prism of risk management. However, this position does not claim to exhaust the subject, and low-tech approaches cannot be reduced to emergency measures: they have a much broader ambition, both creative and social, the dimensions of which will only be partially addressed in this report.

1.4.1 DIGITAL TECHNOLOGY, A SOURCE OF VULNERABILITY FOR ORGANISATIONS

Human activity has already exceeded seven of the nine planetary boundaries defined by the *Stockholm Resilience Centre*[11], illustrating the growing pressure on global ecological balances. Points of tension are increasingly crystallising between different sectors, including digital technology, which depend on the same resources. The digital sector, in particular, is known for its use of 50 to 70 mineral substances from the periodic table of elements[12] . It faces major challenges related to access to raw materials, as well as water and electricity resources. In this context, the imperatives of sobriety and adaptation are essential.

This awareness is corroborated by international analyses, such as that of *the World Economic Forum* in 2025 [13] , which identifies environmental risks (extreme weather events, critical alteration of terrestrial systems, erosion of biodiversity) as the most worrying threats over the next decade.

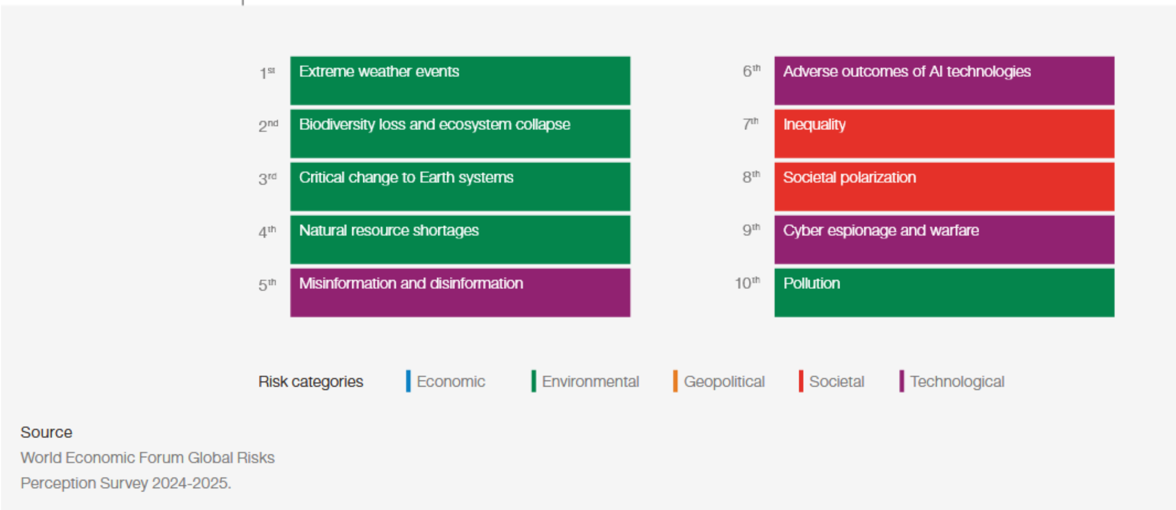
[10] Universal Declaration of Human Rights by the United Nations in 1948

[11] https://www.stockholmresilience.org/research/planetary-boundaries.html

[12] https://www.systext.org/node/1568

[13] https://reports.weforum.org/docs/WEF_Global_Risks_Report_2025.pdf

FIGURE 2.2 | **Global risks over the long term (10 years), ranked by severity**
"Please estimate the likely impact (severity) of the following risks over a 10-year period."



Global risks over the long term (10 years), ranked by severity, World Economic Forum Global Risks, Perception Survey 2024 - 2025

In order to illustrate the specific threats associated with digital technology, **the working group conducted a strategic foresight exercise** over three sessions, with methodological support **from Futuribles**, a partner of Cigref. This approach made it possible to imagine, over a ten- to fifteen-year horizon, major and recurring crisis situations that could affect organisations, forcing them to deploy alternative solutions to ensure service continuity. The objective was to test the resilience of current technological approaches against plausible disruption scenarios.

The objectives of this forward-looking approach were as follows:

- To identify three crisis scenarios deemed likely (geopolitical, climatic, or related to the growth of digital uses and their energy costs) based on several previously analysed risk factors;
- Assess the strengths and limitations of low-tech approaches at time "t_0" of the crisis, with a view to ensuring continuity of services in the short and medium term;
- Analyse their relevance in a "business as usual" context and in relation to high-tech or conventional solutions, in order to assess the relevance of maintaining them in operational condition and their strategic sustainability.

Three scenarios were explored and are presented in detail in the following section.

1.4.2 PROSPECTIVE ANALYSIS: THREE DISRUPTION SCENARIOS FOR 2035-2040

To develop disruption scenarios, the working group was asked to identify current trends that could make certain risks plausible, as well as their impact over the next ten to fifteen years on:

- the organisation's ecosystem (in the sense of 'stakeholders');
- the organisation as a whole;
- and more specifically on its digital systems.

Analysis of these scenarios and their impact on the organisation and its digital systems made it possible to devise the most relevant low-tech approaches to prepare for and even tackle this type of risk, while capitalising on these solutions from a long-term perspective. Although low-tech approaches are not the only possible response, they represent a path that has yet to be fully explored and offers considerable potential.

- **Scenario 1 - Escalation of global conflicts and major disruption to technology supplies.**
  - In this scenario, a major geopolitical crisis crystallises: China's invasion of Taiwan causes a major disruption in technology supply chains, particularly due to the dominant position of Taiwan Semiconductor Manufacturing Company (TSMC), which accounts for nearly 90% of global production of the most advanced semiconductors[14] . This situation gives China considerable strategic leverage over the United States, while catalysing a new dynamic of competition in the field of artificial intelligence. In response, the United States adopts an unprecedented protectionist stance, refocusing its priorities on domestic services at the expense of other regions of the world. Europe, for its part, finds itself in a position of multiple dependency, both on American cloud service providers and on digital equipment produced in Asia, forcing it to make do with degraded digital and AI services.
  - A complementary variant of this scenario is based on the assumption of a resource shortage or a large-scale natural disaster occurring in a strategic geopolitical area, leading to a disruption in the supply of electronic components and thus compromising the production capacity of IT equipment.

- **Scenario 2 - Explosive growth in digital usage leading to rationing of digital services.**
  - In this scenario, faced with the rapid rise in energy consumption driven by digital services, and more specifically by generative and agentic artificial intelligence, public authorities have been forced to introduce restrictions on digital usage, with the aim of promoting a more moderate and efficient use of energy resources. Usage quotas have been defined, and digital features considered non-essential are now subject to suspension at any time.
  - At the same time, worsening climate phenomena are making infrastructure increasingly vulnerable, leading to recurring disruptions in the functioning of digital services. In this context, regulating and prioritising digital uses are the most appropriate means of continuing to access essential services. These usage constraints, which were once exceptional, have gradually become standard practice.
  - Finally, a new regulatory framework is tightening energy consumption requirements while systematising reuse and recycling initiatives.

- **Scenario 3 - Runaway climate phenomena**.
  - In 2035, climate phenomena are much more violent and frequent than was envisaged in the 2025 models, causing repeated damage to infrastructure (data centres, networks, energy production, mines, factories, etc.). The IPCC's forecasts, which were actually very optimistic, underestimated the rise in temperatures, which have already reached +2°C globally over the last eight years. Forecasts for 2100 are now +5 to +7°C if nothing changes fundamentally.

[14] https://www.tresor.economie.gouv.fr/Articles/6e50d790-dc22-453f-9a8b-01fd2c457e10/files/8f24f8f4-abf1-4b5e-bc95-f3891ae98c63

- Organisations are very regularly subjected to degraded operating conditions that have a significant impact on their business models, as energy and water resources are regularly redirected to the most vital and strategic sectors.
- Extreme and recurring climatic events (droughts, floods, storms) regularly damage infrastructure, threatening service continuity and significantly increasing repair costs.
- The working population is particularly exposed to these extreme conditions, and the resulting chain reactions (exposure to high temperatures, health crises due to emerging viruses, etc.) weaken the global economic engine.

The collective development of these **three prospective scenarios** has identified **three types of high-impact risks** for organisations and their digital systems (part 2). The contribution of low-tech solutions, as one option among others, to helping organisations become more resilient and robust in the face of these risks will be analysed in part 3.

2 THREE HIGH-IMPACT RISKS FOR ORGANISATIONS AND THEIR DIGITAL SYSTEMS

The risks identified from the general scenarios were selected because of their criticality, particularly in view of organisations' increased dependence on digital technologies, as well as their high probability of occurrence. For each of these risks, a series of weak signals was identified, providing support and documentation for the hypotheses. The potential consequences for organisations and their digital systems were then analysed in detail.

2.1 RISK 1: DISRUPTION OF THE TECHNOLOGY SUPPLY CHAIN

2.1.1 RISK OVERVIEW

A major geopolitical crisis, a shortage of strategic resources or a major natural disaster occurring in a geostrategic region of the world leads to a disruption in the supply chains for minerals or electronic components, paralysing the production or distribution of all IT equipment.

2.1.2 WEAK SIGNALS THAT MAKE THIS RISK PLAUSIBLE

Several significant geostrategic signals have emerged in recent years. The energy crisis triggered by the Russian-Ukrainian conflict, combined with rising American protectionism (illustrated in particular by legislation such as the *CHIPS and Science Act* in 2022, which aims to strengthen the domestic semiconductor industry in order to limit its dependencies), is a first indicator of the vulnerability of globalised value chains. Added to this is the **strategic positioning of the Sino-Russian coalition in Africa and Latin America**, which is consolidating its **hold on critical metals** such as lithium, tantalum, cobalt and rare earths, while **metallurgical production and refining** capacities remain largely concentrated **in Asia.**

The proven use of rare earths as a diplomatic pressure tool (as in the 2010 Sino-Japanese incident over the Senkaku Islands[15]), as well as the emergence of a veritable "geopolitics of components", marked by the risks of embedded espionage via hardware backdoors or "kill switches ", testify to the growing and sophisticated exploitation of resources and technologies. For example, in response to customs measures initiated by the Trump administration in 2025, China decided to restrict the export of several rare earths (yttrium, scandium, lanthanides, etc.) and metals (indium, gallium, germanium, etc.), which are essential for the manufacture of digital equipment.

Furthermore, **Europe's critical dependence on American tech giants** (GAFAM) for cloud services, operating systems and software architecture constitutes a factor of systemic vulnerability. This fragility is exacerbated by repeated interruptions in rare earth exports from China[16] , and by an intensifying arms race in the field of artificial intelligence. This dynamic is driving exponential demand for advanced

[15] https://www.monde-diplomatique.fr/2010/11/ZAJEC/19832

[16] https://www.latribune.fr/economie/international/restreindre-l-export-des-terres-rares-cette-arme-de-la-chine-contre-les-etats-unis-1022909.html

chips, the production and skills required for which are geographically and politically concentrated in Taiwan, South Korea and China, creating critical breaking points in the event of supply chain failures.

2.1.3 THE CONSEQUENCES FOR ORGANISATIONS AND THEIR DIGITAL SYSTEMS

The direct consequences are difficulties in renewing equipment and an inability to maintain or upgrade existing infrastructure. These disruptions lead to a significant increase in maintenance costs and a deterioration in system reliability. Critical dependencies on single suppliers or specific technologies then become major vulnerabilities, compromising operational continuity and the long-term sustainability of organisations.

In the following feedback, Stéphan Peccini presents his open-source tool for mapping dependencies in the digital manufacturing chain, "FabNum", which is useful for helping organisations understand and anticipate the vulnerabilities of their digital supply chains.

Feedback from FabNum

Identifying and anticipating vulnerabilities in the digital supply chain: presentation of the FabNum tool by Stéphan Peccini

Low tech, a return to the past?

The low-tech approach cannot be reduced to a fad, a technological regression or a simple ideological stance. It is now an essential requirement, a *sine qua non* for the sustainability of human activities. It is an essential lever enabling businesses, organisations and administrations to maintain their capacity to produce goods and services. It also guarantees individuals sustainable access to the most essential and vital functions of our society.

By focusing exclusively on the digital manufacturing chain, it becomes apparent that numerous vulnerabilities exist, and that they are likely to transform hazards into major risks, which is already the case for some.

However, **these vulnerabilities remain poorly understood** and are **rarely included in overall risk plans**. It is already difficult for companies to prepare for local risks (e.g. Porsche, whose production was directly impacted by flooding in Bavaria following an extreme weather event). But what about global risks? Which company anticipates a major flood at the Spruce Pine quartz mine or a maritime blockade of Taiwan, which will indirectly impact it, particularly through shortages?

Preparing for production losses caused by a climate crisis or a geopolitical event occurring on the other side of the world and impacting digital supply chains is not yet a common understanding in today's world. This gap can often be explained by a lack of understanding of systemic interdependencies, and sometimes by excessive confidence in the promises of techno-solutionism.

The FabNum project

It was based on this observation that the FabNum project (an acronym for Fabrication du Numérique, or Digital Manufacturing) was launched, led on a voluntary basis by Stéphan Peccini, Responsible Digital Consultant and member of collect'IF by Infogreen Factory. This project focuses on three areas:

1) Comprehensive mapping of the digital manufacturing chain:

- Identification of the players involved in each stage (extraction, processing, manufacturing, assembly), specifying their geographical location, role and market share;
- Identifying the minerals and metals needed to manufacture components;
- Identifying the components needed to assemble the final product.

This analysis has resulted in a database of nearly 900 players in more than 60 countries involved in extracting and processing minerals, manufacturing components, assembling them and turning them into final products.

2) Development of four vulnerability indices (assessment of the probabilities and levels of impact of risks):

- Geographical or industrial concentration: the higher it is, the more a local disruption can have systemic effects;
- Geopolitical stability: increased instability increases the risk of disruption;
- Criticality of minerals: the more difficult it is to substitute a mineral, the more a disruption affects the production chain;
- Intersectoral competition: strong competition for the same resource increases tensions on the production chain.

3) Development of an interactive application:

This application allows users to manipulate and visualise data, analyse it and identify actions to be taken. It is available online at[17] .

The project has three main objectives:

- Raise awareness of systemic vulnerabilities in order to understand their origins and consequences;
- Assess impacts according to plausible scenarios;
- Prepare appropriate responses based on several strategic approaches.

FabNum is designed as a common good, open source, and is based on a collaborative approach aimed at improving the relevance and reliability of data. Although the collaborative mode is not yet fully operational, the available data already provides a solid basis for analysis, subject to methodological vigilance.

Use case

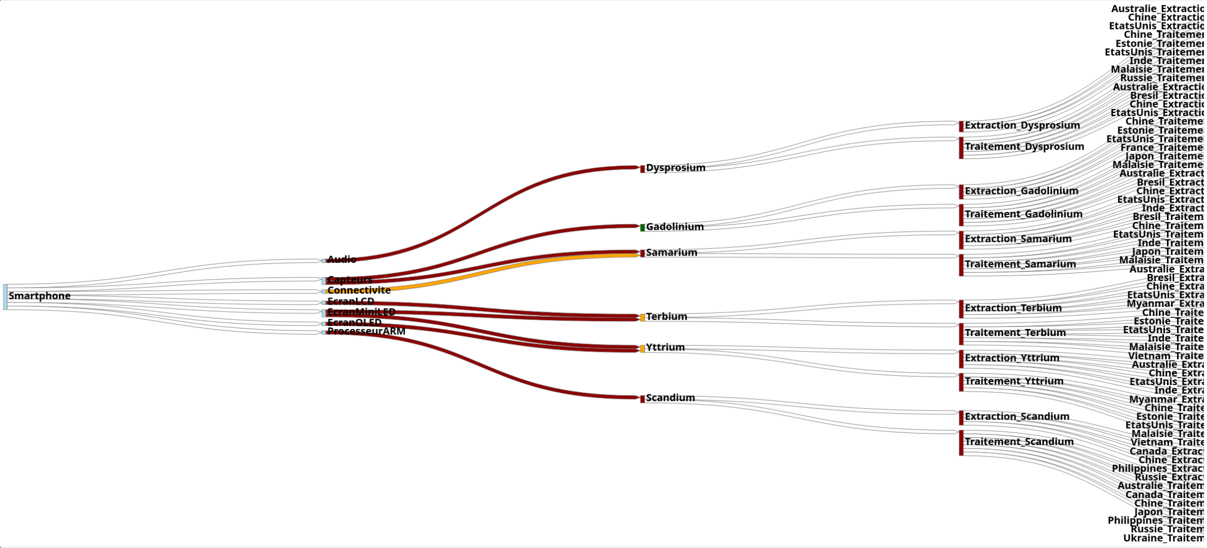
In April 2025, China announced the suspension of exports of several critical metals, mainly rare earths, in response to new tariffs imposed by the Trump administration. This decision directly affects the technology, automotive, electronics, aerospace and energy sectors. The media outlet *Not Like The Others* (NLTO) reported this information in its article "Critical metals: Beijing closes the taps, production lines threatened"[18] .

FabNum enables a more accurate assessment of the extent and nature of this disruption to the digital manufacturing chain.

[17] https://fabnum-maquette.polycrisis-observatory.org/

[18] https://www.nlto.fr/metaux-critiques-pekin-ferme-les-vannes-les-chaines-de-production-menacees/

Let's take the example of the smartphone:



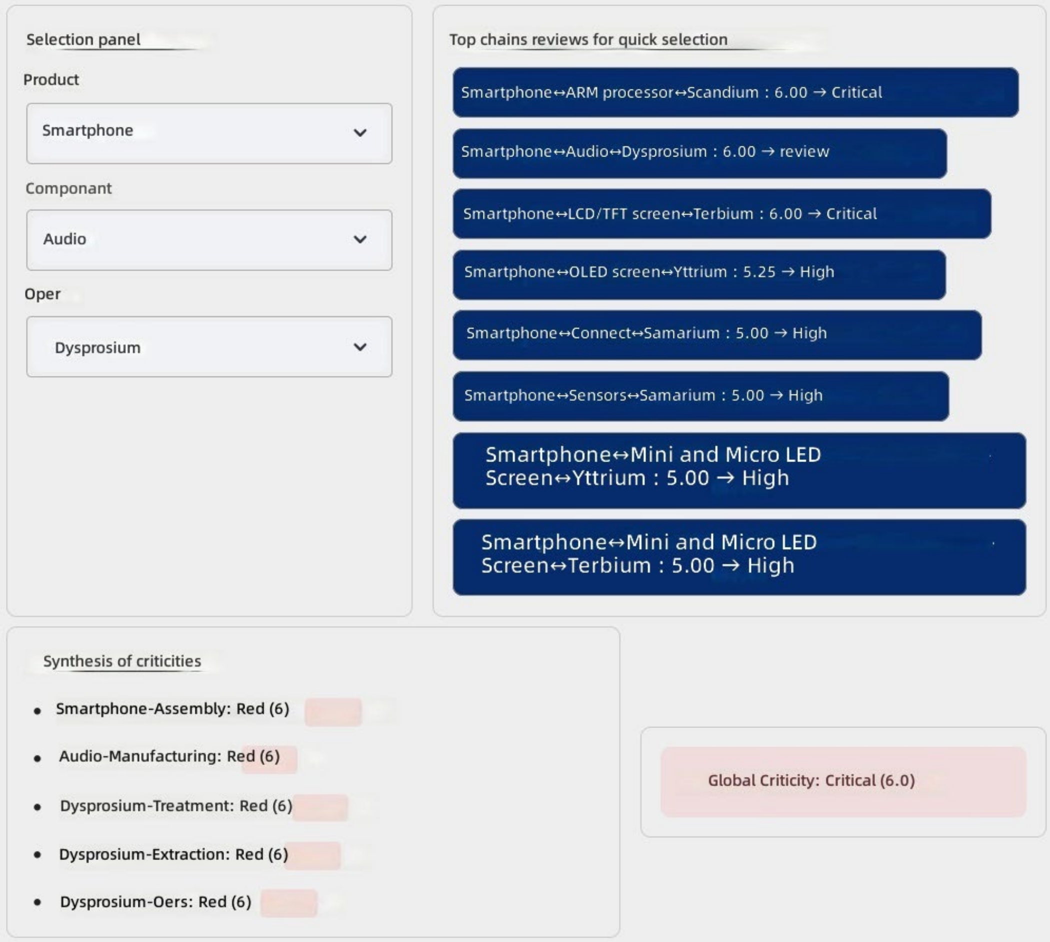
Disruption to the smartphone manufacturing chain_Extract from the FabNum tool

Analysis of the graph gives us the following information:

- All minerals are difficult to substitute, except for samarium for connectivity.
- Dysprosium, samarium and scandium are in very strong competition with other sectors.
- The extraction and processing of all minerals is highly concentrated geographically and even industrially.
- China is moderately unstable.

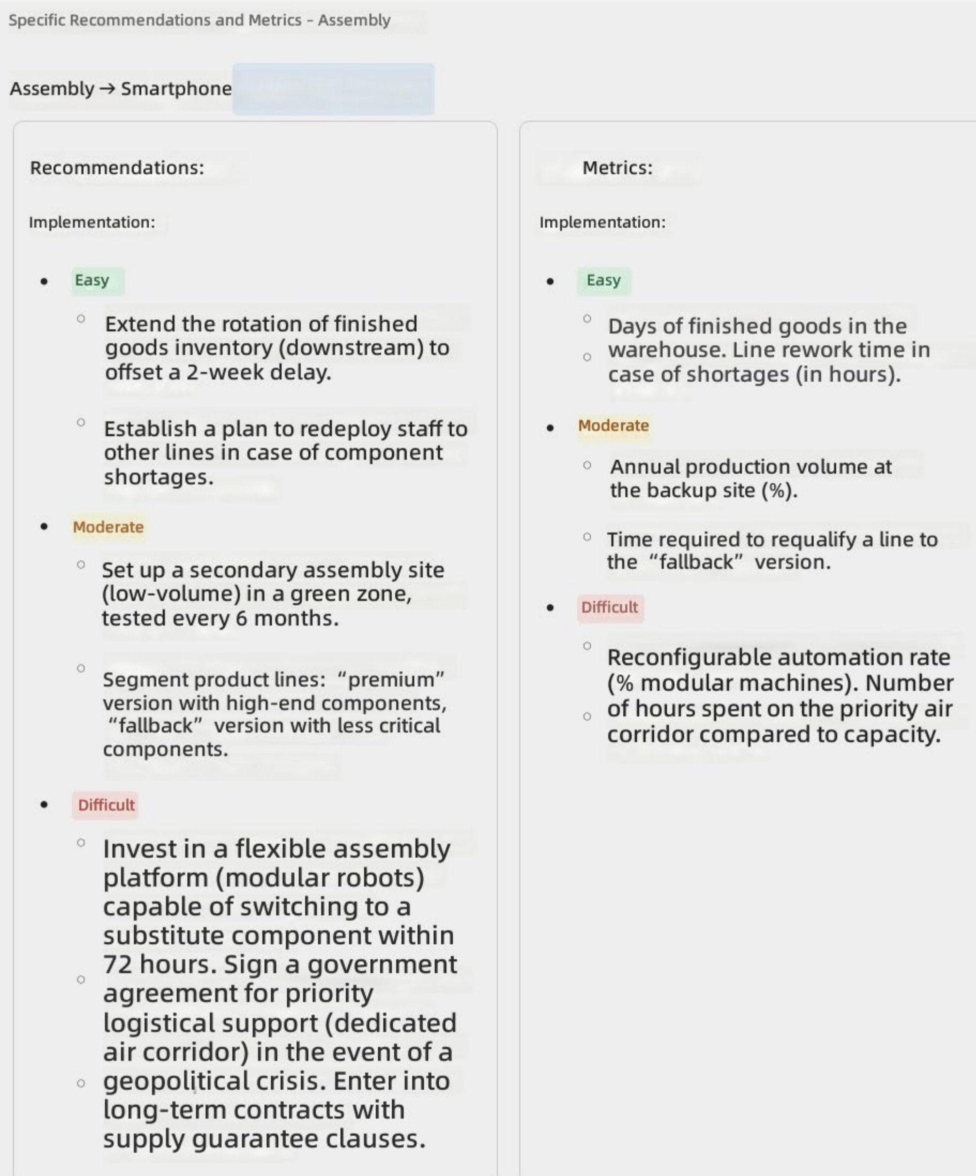
In conclusion, a prolonged disruption in the supply of these minerals would cause real difficulties for the smartphone industry.

All critical paths and levels of vulnerability can also be identified:



Summary of criticalities_Extract from the FabNum tool

Finally, depending on the level of criticality, actions and indicators are proposed:



Specific recommendations and indicators_Extract from the FabNum tool

Depending on the nature of its business, the company will implement the identified measures or request their implementation from its suppliers.

Stéphan Peccini, Responsible Digital Consultant,

member of collect'IF by Infogreen Factory and creator of FabNum

2.2 RISK 2: ECONOMIC AND FINANCIAL INSTABILITY THROUGHOUT THE VALUE CHAIN

2.2.1 PRESENTATION OF THE RISK

Growing supply instability, production interruptions caused by climatic events or geopolitical crises, and the continuous increase in crisis management costs are weakening the entire value chain of organisations. The digital market is more expensive and unstable. In this context, the value generated by digital technologies may prove insufficient in view of the additional costs required for their maintenance and security, exposing companies to the risk of cascading bankruptcies and a loss of investor confidence.

2.2.2 THE WEAK SIGNALS THAT MAKE THIS RISK PLAUSIBLE

Among the weak signals making this risk plausible is **increased volatility in commodity and energy prices**, with a clear upward trend over the last five years. This has a direct impact on the production and operating costs of digital infrastructure. One need only look at the structural disruption shaking the semiconductor market in early 2026[19]: the massive priority given to the production of chips for artificial intelligence has caused a **historic surge in RAM prices** (up 40% to 60% compared to 2025), coupled with longer supply lead times. This crisis is weakening the entire digital economy by sharply increasing the cost of IT equipment and, as a knock-on effect, cloud services for professionals and individuals. As a result, global inflationary pressures, combined with supply disruptions, **are putting unprecedented pressure on the budgets of digital departments,** which are seeing their costs skyrocket. It should be remembered that the concentration of semiconductor production in a few companies (in Taiwan and South Korea in particular) represents a critical vulnerability for the global supply of IT equipment, increasing the risk of shortages and price spikes. Added to this is the cost of cybersecurity, which is now a major and constantly increasing expense. Finally, climate change and the increase in natural disasters are calling into question the very notion of insurability of property and people, reducing social protections and the ability of companies to protect themselves against risks.

2.2.3 THE CONSEQUENCES FOR ORGANISATIONS AND THEIR DIGITAL SYSTEMS

For organisations, the consequences translate into increased demands for return on investment (ROI) for each digital solution deployed, an explosion in the costs associated with the use of digital technologies, and profound questioning of the real relevance of the productivity gains that these technologies are supposed to bring. High-quality digital services could eventually become a privilege reserved for companies with significant financial resources. **The excessive integration of artificial intelligence into business processes** is an **additional vulnerability factor**: organisations risk a significant loss of internal know-how, which could lead to a chain of bankruptcies for those that have become totally dependent on artificial intelligence systems. From the point of view of digital systems, this fragility manifests itself in a loss of reliability due to frequent service interruptions, insufficient

[19] https://www.usinenouvelle.com/electronique-informatique/semi-conducteurs/on-ne-pas-encaisser-ca-tout-seul-comment-lexplosion-des-prix-des-composants-memoire-touche-aussi-les-entreprises-francaises.N16RA4NFSZCOLPR2O2J3MGS3ZI.html

business continuity and disaster recovery plans (BCP/DRP) in the face of prolonged or concurrent crises, and the need for tomorrow's IT departments to design **alternative operational s** capable of "doubling" all their essential digital services with backup processes.

2.3 RISK 3: RATIONING OF DIGITAL USAGE

2.3.1 PRESENTATION OF THE RISK

Faced with skyrocketing energy consumption and increased risks of load shedding, public authorities are forced to implement strict rationing and regulation measures for digital usage. Usage quotas have been introduced, and digital features or services deemed non-essential can now be suspended at any time, depending on the energy priorities defined by the authorities.

2.3.2 WEAK SIGNALS THAT MAKE THIS RISK PLAUSIBLE

Several weak signals converge to confirm the plausibility of this risk. Firstly, it should be noted that the joint study by ADEME and Arcep published in 2022 reveals the actual share of data centres in the digital carbon footprint (rising from 16% in 2020 to 46% in 2022), now including the impact of data centres abroad hosting French usage.

In some European Union Member States, such as Ireland and Spain, bans on the construction of new data centres are being implemented, along with plans for European-wide regulations to control their energy consumption. These bans are also a positive response to growing citizen mobilisation against the installation of data centres.

Furthermore, according to forecasts by Gartner, **electricity shortages could affect up to 40% of data centres dedicated to artificial intelligence** and limit their operations by 2027. The disruption of the American[20] and Irish[21] electricity grids by certain mega data centres is another warning sign of the difficulties that will arise in terms of infrastructure sustainability. Furthermore, electricity grids, which are sometimes outdated, are not always suited to the specific characteristics of data centres specialising in AI (regularly causing significant voltage fluctuations on the electricity grid).

In France, Article 15 of the Economic Simplification Act provides for large-scale or "hyperscale" data centre installation projects to be classified as "projects of major national interest", potentially allowing them to escape restrictions on water use, thus illustrating the growing tensions surrounding resources.

The rapid rise of artificial intelligence in all sectors (economy, infrastructure, home automation, arms and automotive industries, etc.), combined with massive investment plans in data centres, is intensifying energy demand and increasing the risk of rationing. In this context, digital giants are

[20] https://next.ink/brief_article/aux-etats-unis-la-croissance-des-data-centers-pourrait-perturber-le-reseau-electrique/#:~:text=RSS%20feed-,In%20the%20United%20States%2C%20the%20growth%20of%20data%20centres,could%20disrupt%20the%20electricity%20grid&text=More%20than%20three%20quarters%20of,80%20km)%20of%20data%20centres.

[21] https://www.rts.ch/info/monde/2024/article/en-irlande-la-proliferation-de-data-centers-genere-des-risques-nouveaux-28462211.html

tending to become key players in the energy system[22], mobilising colossal resources in nuclear technologies, particularly small modular reactors, installed close to their infrastructure. This development raises **risks of monopolistic concentration and conflicts of use between private interests and collective and public interests**.

2.3.3 THE CONSEQUENCES FOR ORGANISATIONS AND THEIR DIGITAL SYSTEMS

If digital usage were to be rationed, the consequences for organisations and their digital systems would most likely be significant: for example, we could see **frequent interruptions to communication tools**, accompanied by the destabilisation of critical security systems, with particularly severe repercussions for sensitive sectors such as healthcare, electricity distribution and transport, which rely on permanent connectivity to function. The **resilience of** telecommunications **networks** would then be profoundly challenged, requiring a strategic reassessment of the digital services that must remain connected. In this context, **intermittent service would become the norm** for many services, disrupting the availability standards to which organisations are accustomed.

Legislative measures governing digital usage would become inevitable, possibly accompanied by citizens' conventions aimed at deciding on the allocation of resources and democratically defining "**priority uses**". The possibility of violent social conflicts emerging over access to vital resources such as water or electricity, as well as targeted sabotage of digital infrastructure by activist groups, now seems credible given the growing tensions between collective imperatives and private interests.

A general increase in **the costs associated with digital and energy use** would lead to the emergence of a **two-tier digital economy**: on the one hand, players with the necessary resources to guarantee their customers priority and resilient access to digital services; on the other, a majority of companies faced with degraded, unstable and expensive services that compromise their competitiveness. It would become imperative to revise commercial offerings in order to adapt them to new constraints related to usage restrictions and service interruptions.

Furthermore, if high-quality digital services were to effectively become luxury products, then the deployment of resilience strategies, based in particular on maintaining **robust non-digital processes** alongside computerised systems, would become a necessity.

Rigorous governance would require strict prioritisation of digital services, accompanied by the removal of features deemed "convenient" or excessively energy-intensive. Current Business Continuity and Disaster Recovery Plans (BCP/DRP), often designed to respond to localised and short-term failures, would prove inadequate for systemic and prolonged crises affecting resources.

Finally, frequent interruptions to digital services **would erode user and customer confidence**. Maintaining large-scale teleworking, which is heavily dependent on reliable and high-performance connectivity, would become problematic, or even reserved for a privileged minority.

In conclusion, it seems clear that the description of these risks is no longer merely prospective speculation, but **reflects realities that are already observable**. Current geopolitical tensions are

[22] https://www.techniques-ingenieur.fr/actualite/articles/les-geants-du-numerique-achetent-leur-autonomie-energetique-143553/

accompanied by explicit threats, sometimes carried out, of disruptions to the supply of resources and minerals essential to certain industries, particularly digital industries, or disruptions to means of communication (submarine cable breaks, particularly in the North Sea). Furthermore, the rise of generative artificial intelligence **is testing our energy capacities**, while the intensification of extreme weather events is becoming a tangible part of everyday life, threatening to undermine nearly a quarter of the world's data centres by 2050, according to a study by XDI[23] .

By analysing the most salient weak signals of our time, we have sought to illustrate the most radical breaking points that are likely to occur. The forward-looking approach adopted has thus made it possible, based on the identification of major trends, to imagine scenarios of total disruption in one or more aspects of these weak signals, in order to highlight the particularly serious consequences for organisations and their digital systems if no adequate preparation is undertaken. It is now necessary to take a closer look at the strengths and limitations of low-tech principles in the face of these challenges.

[23] https://xdi.systems/news/global-data-centres-face-rising-climate-risks-xdi-report-warns-landmark-analysis-of-nearly-9000-sites-reveals-escalating-threat-to-digital-infrastructure

3 CONTRIBUTIONS OF LOW-TECH SOLUTIONS TO ENHANCED DIGITAL RESILIENCE

This initial stage of reflection, focused on identifying three prospective scenarios and the major risks they could pose to organisations and their digital systems between 2035 and 2040, provided valuable insights into a novel low-tech approach to organisational digital resilience. It also highlighted its structural and conceptual limitations.

3.1 FACED WITH SUPPLY DISRUPTIONS AND TECHNOLOGICAL DEPENDENCIES

<u>Risk overview</u>: A major geopolitical crisis, a shortage of strategic resources or a major natural disaster occurring in a geostrategic region of the world leads to a disruption in the supply chains for minerals or electronic components, thereby paralysing the production of all IT equipment. Such circumstances cause significant disruption and instability in energy networks.

3.1.1 LOW-TECH APPROACHES CONSIDERED TO ADDRESS THIS RISK

In response to these types of risks, several low-tech approaches are being considered to strengthen the digital resilience of organisations:

Firstly, it is essential to **develop skills suited** to a crisis context: expertise in diagnosing and repairing equipment is essential, whether it be microelectronics or ruggedised operating systems (OS). To meet this requirement, it is necessary to strengthen electronics training programmes in order to support the development of skills in component production and reassembly, thereby promoting "upcycling" practices[24] . Anticipating training and maintaining skills at the regional level are crucial to ensuring an effective network of expertise.

Secondly, the establishment of **structured chains for the reassembly and recovery of electronic components** from equipment is recommended. This approach requires the establishment of industrial standards (such as ISO) governing, for example, upcycling practices, as well as the industrialisation of the production of reassemblable electronic chips. The aim is to enable the creation of new digital systems through reuse, avoiding the systematic use of "all-in-one" solutions.

Thirdly, the deployment of **parallel, hardened networks** could be considered, in particular through the use of LoRa (Long Range) infrastructure on smartphones, enabling minimum communications to be maintained in the event of a crisis. The use of alternative communication methods such as VHF (Very High Frequency) with limited range or SSB (Single Sideband) for essential services (security, health, etc.) is also a relevant option. The SSB network offers advantages in terms of energy optimisation and

[24] Unlike recycling, which breaks down materials, upcycling reuses the material as is, or with minimal modifications, to give it a new function. For example, an electronic device can be rebuilt from components from old tablets, or the tablets can be transformed into simple screens.

range, while allowing for the design of repairable transceivers that are less dependent on complex supply chains.

Finally, the **development of hardened and lightweight operating systems (OS)** is recommended. These OSs must combine enhanced security with energy and resource efficiency, while ensuring that only essential functionalities are retained. This involves removing components and functionalities that are not essential to the main function of the OS, optimising the code, designing basic graphical interfaces and reducing the number of components in terminals in order to improve system stability. The design and operational maintenance of these operating systems could be "localised", with a territorial distribution of skills and minimal interoperability focused on basic functions.

3.1.2 ADVANTAGES

These various examples of low-tech approaches offer several advantages.

On a social and educational level, they promote the territorial anchoring of knowledge and skills. At the organisational level, they make it possible to strengthen autonomy from external stakeholders outside France or the European Union, improve system resilience, control costs and limit obsolescence.

For digital systems, these approaches translate into increased robustness, longer infrastructure and electronic equipment lifespans, and a greater ability to quickly restore networks and infrastructure in the event of a crisis. They can also stimulate the emergence of new economic models and promote job creation, particularly in the field of industrialisation of component recovery, reassembly and upcycling chains.

Specifically, **hardened and lightweight operating systems (OS)** allow for better code control, reduced acquisition costs, and decreased vulnerability to cyberattacks (by reducing unnecessary features that increase the attack surface). In addition, they are designed to run on older or less powerful hardware, while promoting standardisation and interoperability.

Finally, the development of **parallel and hardened networks**, such as LoRa infrastructures or VHF or BLU communication for essential services, guarantees minimum communication capacity, decentralisation of use, and greater ability to cope with unforeseen crises, thus ensuring continuity of service for essential, even vital, information.

3.1.3 LIMITATIONS

However, there are some limitations to these approaches. In terms of skills, it seems difficult to achieve a rapid return on investment (ROI) in training, given that the low-tech market is still emerging. Furthermore, interest in these skills may be limited among younger generations, while organisations themselves may not value them as highly as they should. This could reduce the attractiveness of these professions and the associated career prospects.

With regard to hardened and lightweight operating systems (OS), support and maintenance costs can be high, particularly due to a lower scale effect (which is not necessarily inevitable if a common modular solution is favoured for public services, for example). Uncertainties also remain regarding the governance of ownership of these systems and the opportunistic intervention of a hyperscaler, which could reintroduce dynamics of dependency.

Parallel and hardened networks also require significant investment, both for deployment and maintenance, particularly due to the need to regularly test their operational resilience in order to prevent latent failures. Decentralised self-administration can also make attacks more complex to thwart. VHF interference is common and waves are easy to intercept. These networks also pose technical challenges in terms of interoperability (often with reduced bandwidth) or range limitations (short/medium distance) and require the large-scale production of new terminals capable of operating without a connection.

3.2 FACED WITH ECONOMIC AND FINANCIAL INSTABILITY

Risk reminder: Growing supply instability, production interruptions caused by climatic events, and the continuous increase in crisis management costs are weakening the entire value chain of organisations. The digital market is more expensive and unstable, due in particular to the increasing scarcity of certain strategic materials or resources. In this context, the value generated by digital technologies may prove insufficient in view of the additional costs required for their maintenance and security, exposing companies to the risk of cascading bankruptcies and a loss of investor confidence.

3.2.1 LOW-TECH APPROACHES BEING CONSIDERED TO ADDRESS THIS RISK

Low-tech approaches have a legitimate place in the Business Continuity Plan (BCP). Participants therefore devised a "**low-tech Business Continuity Plan (BCP)**", which service availability windows. They also considered the **preparation of backup processes that can be operated manually**, i.e. activated independently of digital tools, as well as maintaining a **"backup" for processes** (automated and manual). In order for an organisation to always be able to execute its essential processes manually, it is necessary to activate this system regularly to maintain operational control and the associated skills. These practices, which aim to strengthen the robustness of systems by limiting the use of technological resources in the design of digital services, thus make it possible to meet the requirement to **do "as well" with "less".** This involves conducting a **detailed analysis of usage patterns** to eliminate anything superfluous, designing **alternative non-digital** or "less digital" **solutions**, and **simplifying architectures**, always with the aim of limiting dependence on critical materials or actors subject to significant geopolitical challenges.

3.2.2 ADVANTAGES

The advantages of the low-tech approaches described above are both operational and strategic: by deploying affordable, simple and diversified solutions and methods, they promote social inclusion and the long-term stability of organisations.

As part of a "**low-tech Business Continuity Plan (BCP)",** these approaches make it possible to preserve a better understanding of activities and know-how, while offering greater adaptability to fluctuations. A BCP based on low-tech principles has the advantage of being less expensive in the long term than a "high-tech" system, due to its simplicity and ease of adoption. It can also be a first step in a gradual transition to low-tech practices within an organisation, thus facilitating the acculturation of stakeholders.

Non-digital alternatives promote social inclusion, simplify usage and contribute to the revaluation of manual skills.

The **diversification of digital solutions and services**, combined with the exploration of alternative avenues, strengthens both the robustness and long-term organisational stability of digital systems.

3.2.3 LIMITATIONS

However, a Business Continuity Plan (BCP) based on low-tech principles may have certain limitations in terms of performance and efficiency. The **coexistence of two parallel systems** (one digital, the other manual) complicates maintenance operations and requires rigorous support from all stakeholders. In general, managing low-tech systems can be more restrictive and costly in the short term, although it contributes to greater stability in the long term, particularly in times of crisis. This situation highlights the contradictory demands of the short term and the long term, which remain largely unresolved.

3.3 FACED WITH RATIONING AND REGULATION OF DIGITAL USAGE

Risk reminder: Faced with exploding energy consumption and increased risks of load shedding, public authorities are forced to implement rationing measures and strict regulation of digital usage. Usage quotas have been introduced and digital features or services deemed non-essential can now be suspended at any time, depending on the energy priorities defined by the authorities.

3.3.1 LOW-TECH APPROACHES CONSIDERED TO ADDRESS THIS RISK

In order to respond to this risk, the low-tech approaches proposed by participants mainly focus on the **development of common goods** (through open source, for example) and the **co-location of production and maintenance capacities.**

These initiatives include **mobilising local structures such as Fab Labs and Repair Cafés**, which offer manufacturing and repair workshops, as well as implementing simple educational tools designed to spread low-tech culture. The creation of platforms or catalogues listing low-tech alternatives applicable to professional services is also a possibility.

Another major approach is to **reaffirm the place of humans** in interactions, replacing digital devices in certain convenience functions (such as chatbots or automated information terminals) with direct human relationships.

Additional proposals include the reintroduction of paper media in the administration, health, banking and commerce sectors, as well as the use of "dumb phones", landlines and the maintenance of the copper network. The **pooling of resources between players** in the same sector for similar services is also essential.

The **strengthening of local recycling and reconditioning networks**, the creation of a **"self-repairability" index** when purchasing equipment, and the strengthening of **public education** on digital and low-tech practices are also widely supported. In this context, it is necessary to create and consolidate simple, reproducible and repairable production chains, and to favour the use of standard electronic components that are interoperable and easily accessible and understandable to the general public.

Finally, the **TELED method** (for "Essential Tasks When Energy is Available"), presented at a workshop by **Arnaud Crétot**, founder of NeoLoco and co-founder of the TELED method collective, could be a relevant lever for **adapting organisations to the variability of energy access**.

3.3.2 ADVANTAGES

Low-tech approaches offer many advantages in the face of this risk. The development of common and local goods makes it possible to structure **approaches that are both mobilising and empowering**, by moving production centres closer to the places where the products are ultimately used. This relocation promotes the **preservation of skills associated with** tool **maintenance and repair within the territory**.

These approaches facilitate **innovation based on cooperation** rather than competition alone, while contributing to the emergence of an accessible technical culture. They enable citizens to reclaim simple technological tools and mobilise knowledge, thereby strengthening their autonomy. Furthermore, they contribute to the creation of **shared knowledge bases**, promoting the principles of open source and open hardware culture applied to low-tech approaches.

The establishment of simple, reproducible and repairable production chains simplifies recycling and reconditioning, **curbs "disposable innovation"** and planned obsolescence, while **reducing** strategic **dependence** on external actors. It **promotes greater interaction** between different actors.

Finally, strengthening human and territorial ties between those involved promotes **societal resilience** by promoting mutual aid practices. It contributes to the revaluation of trades and skills, while increasing confidence in the services offered.

3.3.3 LIMITATIONS

However, low-tech approaches remain very marginal today and require **significant financial support** to promote the research, training and investment essential to their development. **The lack of economies of scale** in the production process is an additional obstacle, as is the need to ensure **compliance with safety standards** applicable to the protection of persons.

Furthermore, the risk of fragmentation of initiatives and **regional disparities** calls for greater coordination, without which these approaches could lose their effectiveness or even become counterproductive. The removal of certain digital services that provide convenience could lead to **isolationism** or communitarianism, undermining social cohesion.

Finally, these transformations entail significant **organisational costs** and require targeted investment in adapting business processes and strengthening the security of hybrid processes that combine human intervention and digital solutions.

Feedback from the TELED Method Collective

Adapting to variability in energy access

The **TELED method**, initially an acronym for "Energy-Intensive Tasks When Energy is Available", has evolved to refer to "**Essential Tasks When Energy is Available**". It was co-founded by **Arnaud Crétot,** a computer engineer specialising in energy issues and founder of Neoloco, and **Loïc Perrochon**, an engineer and co-creator of the method. To date, it brings together around twenty professionals.

The main ambition of the TELED method is to establish a **culture of variability within organisations**. This concept stems from the observation that our society is based on the assumption of unlimited and continuous access to resources, whereas it is becoming necessary to integrate the variability of energy supply, particularly in the case of renewable energy sources that cannot be controlled. The guarantee of continuous access to energy is in fact increasingly variable: disruption of Russian gas supplies, risk of blackouts (as in the Iberian Peninsula in April 2025[25]), fragility of supply chains linked to geopolitical tensions, instability of energy prices, cyber-attacks, strategic infrastructure being targeted, etc.

Principles and application of the TELED method:

The method is based on Arnaud Crétot's practical experience at Neoloco, a solar-powered bakery and coffee roasting company whose operations depend on the availability of solar radiation to power its ovens. This operational framework has enabled the testing of business models compatible with variable energy access.

A tangible illustration of the application of this method is that of the industrial carpentry company ADAM, which powers part of its operations with solar energy. By identifying that the main source of energy consumption came from the sawmill workshop (comprising four employees out of a total workforce of seventy), the TELED method made it possible to separate this workshop from the rest of the factory's energy flow and proposed a different distribution of operating hours (shorter days spread over six days instead of five, and a shift in the lunch break to take advantage of peak sunlight hours). This reorganisation leads to a potential improvement in the utilisation rate of solar panels, from 25% to over 50%.

Application of the TELED method in the digital sector:

The method offers the ability to adapt in the event of a disruption in access to digital services or the internet, relying on several levers:

- **Managing service interruptions**: several examples already demonstrate practices that make it possible to easily manage variability in access to digital services . Websites for one-off events are often subject to high traffic. They are therefore regulated by a queue, thus avoiding service saturation and oversized infrastructure. The Low-Tech Magazine website, hosted on a solar-powered server based in Spain, is another example of this deliberate intermittency. During prolonged periods of low sunlight, the service is cut off. The remaining operating time before the cut-off is clearly displayed on the page so that users can make arrangements.

- **Task** planning: more strategic use of data and macro-level task planning would make it possible to anticipate variability in the consumption of servers and digital infrastructure and to schedule certain operations, such as updates, at times when energy is more abundant. The aim is to reduce energy consumption while maintaining continuous access to services in the vast majority of cases.
- **Integration into risk management**: the TELED method also aims to enhance risk management and business continuity plans in the digital domain. It offers a structured operational approach, based on a graduated action plan (from the simplest to the most restrictive) to manage variability in access to resources and energy.

How the TELED Collective works:

Although the TELED methodology is not available as open source, the collective behind it is committed to creating a shared resource with no commercial purpose. It does not offer services for sale, but professionals from the collective carry out TELED assessments and provide support for organisational transformation. The Collective also offers training courses and qualified facilitators to support learners in their adoption of the method. In return, users commit to sharing the main lessons learned from their use cases, thereby contributing to the collective enrichment of practices.

Arnaud Crétot, Founder of NeoLoco, Co-founder of the TELED method collective

The low-tech initiatives favoured by participants to address the three types of risks identified have highlighted many advantages, while revealing certain weaknesses inherent in the way organisations and their digital systems operate.

Let us now consider how to instil these issues at the heart of organisational culture and how to realise these ambitions.

[25] https://www.connaissancedesenergies.org/afp/black-out-en-espagne-et-au-portugal-ce-que-dit-lenquete-des-experts-europeens-251003

4 CONVINCING ARGUMENTS: HOW TO TAKE ACTION?

As we reflected on the issue, it became clear that the concept of low-tech remains relatively unknown and, due to its shifting meanings, suffers from a lack of consensus on its definition. This plurality of understandings makes it difficult to grasp, particularly for decision-makers. The subject, often perceived as theoretical or even utopian, seems to lack tangible arguments or concrete demonstrations. This is why the working group chose to focus on **developing clear points of conviction**, as well as **collecting concrete and operational examples** that could shed light on the subject, overcome resistance and promote acculturation.

4.1 IDENTIFYING RESISTANCE

Any attempt to convince or argue requires a detailed understanding of the points of disagreement and factors of resistance. Discussions within the working group, enriched by the thesis work carried out by Nicolas Schmitt, Caroline Danancher, Elisabeth Lucas and Cécilia de Foucaucourt, identified **three categories of resistance**:

- **Endogenous**, i.e. internal to organisations: the low-tech approach raises concerns about a possible loss of productivity, the complexity of replacing existing systems, and the difficulty of industrialising an approach that is local in nature. However, this apparent paradox between locality and large-scale implementation can be overcome by drawing precisely on local resources.
- **Cultural**: the term "low-tech" is often perceived as synonymous with regression. In the collective imagination, innovation remains closely associated with cutting-edge technologies, which hinders acceptance of more modest solutions.
- **Exogenous**, i.e. external to organisations: regulatory constraints, or conversely the expectation of a normative framework to legitimise action, are obstacles to engagement in the low-tech approach.

4.2 DEFINING CONVICTIONS AND SUCCESS FACTORS

Several strategies have been proposed to overcome these obstacles:

- **Adopt a risk management approach**: risk management departments within organisations are natural partners for addressing issues of IT system robustness and continuity. As our work has shown, geopolitical crises, resource shortages and extreme weather events can directly compromise the sustainability of digital activities. Low-tech approaches, by reducing dependence on global supply chains and simplifying systems, strengthen resilience to these shocks.
- **Develop a ten-year forward-looking vision**: by taking into account changes in resource prices and availability, a forward-looking approach makes it possible to identify vulnerabilities in the

value chain and initiate a gradual transformation towards more sober and resilient services and products.

- **Embrace corporate codes**: it is important to adapt the discourse to the language of decision-makers, highlighting the contribution of low-tech approaches to the resilience, stability and sustainability of organisations and their digital systems. Presenting low-tech as a methodology that complements existing approaches allows it to be seen as an enrichment rather than a disruption.
- **Simulating crises**: organising scenario-based exercises (such as energy or component supply shortages, prolonged network connectivity outages, etc.) is a powerful way to raise awareness. These "stress tests" provide a practical opportunity to experiment with low-tech solutions, stimulate team creativity and help managers better understand the risks associated with a lack of foresight.
- **Experiment to convince**: demonstrating the relevance of low-tech through action, pilot projects and concrete feedback, is particularly effective. Some organisations have appointed a low-tech representative, responsible for educating project teams and capitalising on initiatives from the ecosystem to drive them internally. Sharing successes and lessons learned is essential to overcome resistance.
- **Redefining the lexical framework**: if the term "low-tech" provokes reluctance due to connotations perceived as backward-looking fantasy, resistant to innovation, it may be appropriate to use alternative expressions such as "fair tech", "right tech" or "technological discernment". The aim is to promote a desirable and innovative image of these approaches, thereby facilitating their acceptance by decision-makers.
- **Develop** "**avoidance accounting**": this involves highlighting the costs avoided thanks to low-tech approaches, whether financial, environmental or related to critical dependencies. The economic argument, in particular, is a major lever for persuasion.

4.3 SHARE CONCRETE EXAMPLES

The discussions were illustrated by several concrete examples demonstrating the feasibility of the low-tech approach:

- **Railway trace**ability: in order to improve the traceability of a railway company's wagons, an initial high-tech proposal envisaged the integration of Internet of Things (IoT) devices, coupled with GPS and 5G technologies, as well as an automated coupling system. This high-performance solution enabled real-time location tracking, the collection of large amounts of data and easier coupling operations. However, its cost, estimated at between €30,000 and €50,000 per wagon, proved prohibitive for the fleet concerned.

  The study was refocused according to low-tech principles, starting from actual needs, identifying the most suitable technologies and analysing value. The automated coupling system was abandoned because it did not offer any significant advantages over the existing system (the engines push the carriages and the operator lowers a handle). With regard to localisation, the analysis showed that real time was not necessary, as the carriages were either parked for long periods or coupled to a moving locomotive. The solution adopted is based on a device consisting of a Raspberry Pi microcontroller, a GPS chip and a LoRaWAN transmitter, which transmits the position every 30 minutes. This reduces the unit cost to €150 per carriage. Real-time sensors are now concentrated in the locomotives, where their usefulness is proven. The company has made this innovation available as open source so that it can be widely adopted.

This alternative, which is more resource-efficient, less costly, well-suited to needs and made available to as many people as possible on a sharing basis, illustrates the ability of a low-tech approach to respond to industrial challenges.

- **Low-tech online banking**: a banking group has developed a prototype for its "online banking" website based on low-tech principles. It has been streamlined, stripped of advertisements, pop-ups and superfluous features. The cohort of users who tested it found it to be "simpler and faster" than the standard application. This prototype was also more streamlined and secure due to its reduced exposure to multiple features. However, the project was not pursued because the marketing department was not prepared to give up advertising.
- **Service continuity in the absence of a network**: systems such as "El Paquete" in Cuba, which relies on the distribution of content via hard drives to circumvent censorship, or the use of radio networks or Mesh WiFi [26], demonstrate that it is possible to maintain access to information even when telecommunications infrastructure fails.
- **Alternative economic model**: NeoLoco, a company specialising in solar roasting, has designed a model that takes weather variability into account. Its business is based not only on product sales, but also on the transfer of know-how and training, thereby promoting the spread of resilient practices.

[26] "The Mesh consists of a set of Wi-Fi terminals, each of which relays data flows." (source: https://www.cnetfrance.fr/produits/wifi-mesh-qu-est-ce-que-c-est-et-comment-l-installer-pour-etendre-facilement-la-portee-du-reseau-sans-fil-39934811.htm)

Feedback from ORANGE

Building network resilience, towards adaptation to climate change

Orange has undertaken extensive work to strengthen the resilience of its telecommunications infrastructure to the effects of climate change, drawing inspiration from low-tech approaches. This research was conducted by **Émile Burckard** as part of an internship between March and September 2024, supervised by **Guillaume Boudry**, Telecommunications Futurist, and **Marc Vautier**, Lead for the Orange Energy & Environment Expertise community. Interviews were conducted with Orange's operational departments, particularly in the Grand Ouest region, which was severely affected by Storm Ciaran in 2023.

Findings and challenges following the incidents caused by Storm Ciaran:

- **Heavy dependence on electricity networks**: during Storm Ciaran, nearly 90% of mobile phone service interruptions in the Grand Ouest region were directly related to power cuts. This figure highlights the critical nature of the interconnection between energy and telecoms infrastructure.
- **Structural interdependence between networks**: telecoms and electricity networks form a closely intertwined technical ecosystem, where the failure of one can have a knock-on effect on the other.
- **Complex trade-offs linked to the diversity of networks and uses**: the multiplicity of technologies (copper, fibre, mobile) and associated services makes it difficult to prioritise interventions in the event of a crisis. For example, Orange has sometimes chosen not to repair the copper network when fibre deployment was feasible, illustrating a long-term optimisation approach.

Needs identified in crisis situations:

- Access to reliable, clear and up-to-date information;
- Ability to establish contact, particularly in emergencies or when assistance is needed;
- Increased vigilance with regard to vulnerable people and life-threatening situations;
- Proximity and support for affected populations.

Measures taken by Orange:

- Use of generators, often loaned by Enedis, to compensate for power cuts;
- Distribution of Airboxes (small devices that provide Wi-Fi) and data allowances (limited amounts of internet data allocated to mobile or fixed-line plans) to temporarily restore connectivity;
- Use of satellite solutions, particularly for isolated areas;

One major observation emerges from this situation: volunteers (farmers, Orange employees, etc.) spontaneously came forward to help. However, their participation remained limited due to safety constraints and a lack of organisational foresight.

Recommendations for strengthening resilience:

- Mobilise and train volunteers, providing them with a secure and structured framework for intervention;
- Anticipate crises by incorporating their intensification into continuity and risk management plans;
- Share and make information visible, using tools adapted to different audiences (mapping, alerts, collaborative platform);
- Train and equip teams, particularly those in direct contact with local authorities and customers, to ensure effective coordination and an appropriate response.

Designing resilience in the era of climate change:

The concept of resilience, originally used in materials science, refers to a system's ability to absorb a shock, limit its effects and return to a normal state within a reasonable time frame. It encompasses both the intensity of the shock that can be withstood and the speed of recovery.

In the context of climate change, this definition needs to be broadened: resilience is not only about the immediate response, but also about the ability of future generations to cope with increasingly frequent and intense shocks. It is essential to recognise that systems themselves, through their complexity and environmental footprint, can exacerbate the effects of crises. Thus, by limiting its environmental impact, a system can influence its own resilience, thereby enhancing its sustainability.

Resilience must be considered on a socio-technical scale, i.e. by integrating technical dimensions and their interactions with society. Two sociological aspects are particularly decisive:

- The tendency to want to return quickly to the previous state, without questioning structural vulnerabilities or considering more sustainable reconstruction;
- The vulnerability perceived by society, which often differs from expert analysis. This social perception, based on collective representations, must be integrated into resilience strategies.

Resilience is not limited to a technical or operational approach: it must aim for sustainability and be based on a detailed understanding of the interactions between technology, society and the environment.

Orange's proposals for more resilient networks:

- **Strengthen operational proximity**: deploy teams as close as possible to local areas and communities in order to facilitate coordination, responsiveness and adaptation to local specificities;
- **Anticipate crises**: set up simulation exercises, develop contingency plans, organise targeted training and conduct regional studies to better understand vulnerabilities and levers for action;
- **Involve volunteers**: build a pool of volunteers, whether from the local area or within the company, and train them in resilience tasks in a secure and structured environment;
- **Co-develop solutions**: organise brainstorming and design workshops involving stakeholders (local authorities, operators, citizens, experts) using a socio-technical approach that integrates human, organisational and technological dimensions.

These initiatives must be implemented in two complementary contexts:

- Upstream of crises (anticipation): this involves preparing the conditions for reconstruction, defining frameworks for intervention and strengthening adaptation capacities;
- After crises (post-crisis): capitalising on the data collected, mobilising stakeholders to improve existing systems and resisting the temptation to return to "business as usual".

Guillaume Boudry, Telecommunications Futurist, Orange

Marc Vautier, Orange Energy & Environment Expertise Community Lead, Orange

4.4 THE CONTRIBUTION OF LOW-TECH SOLUTIONS TO CRISIS MANAGEMENT

Crisis management, whether anticipated or unexpected, requires organisations to take an approach that is both methodical and adaptable. In this context, the principles inherent in the low-tech approach can prove particularly useful in each phase: upstream, during the event and in the post-crisis period. Adopting a step-by-step approach, based on these different time frames, therefore seems to be a sensible way of identifying, at each stage, the points of vulnerability on which efforts need to be focused.

4.4.1 BEFORE THE CRISIS: REDUCING EXPOSURE AND PREPARING

Anticipating and preventing crises is a fundamental part of a proactive approach for organisations. Early integration of low-tech principles into preparedness measures significantly reduces areas of vulnerability, consolidates the mobilisation of strategic stakeholders and operationalises the system. In this regard, several best practices can be implemented:

- Prioritise digital services based on their essential nature, both for operational continuity and for the collective interest;
- Strengthen internal and regional skills to ensure a robust and responsive network;
- Deploy resilient infrastructure and processes, such as alternative networks or stocks of critical components;
- Raise awareness and train decision-makers and employees, in particular through crisis simulation exercises.

OCTO Technology feedback

Focus on the "*Disruption Game by OCTO*": an immersive awareness-raising tool for customers

OCTO Technology has developed a fun and immersive experiment called the "disruption game", which aims to change customers' perceptions of their resilience and level of preparedness in the face of crises. This tool places participants in a simulated context of extreme constraints, whether climatic, energy-related or other, right from the product scoping phase. It aims to bring about a paradigm shift by encouraging them to consider solutions that are not exclusively digital, but which incorporate low-tech alternatives. By immersing them in this constrained environment, the "disruption game" stimulates a dynamic of great creativity and innovation, going beyond conventional models.

Sara Boucherot, Sustainable Digital Change Maker at OCTO Technology

4.4.2 DURING THE CRISIS: MANAGING AND ADAPTING

When an organisation faces a crisis situation, whether it be a disruption in technology supply chains, severe economic instability, restrictions on digital usage or cyberattacks, **low-tech approaches offer levers for rapid adaptation** while ensuring **minimum service stability.** This facilitates the deployment of corrective measures, provided that contingency plans and procedures have been defined in advance, particularly as part of a Business Continuity Plan (BCP) based on low-tech principles.

Recommended actions include:

- The activation of alternative solutions such as the use of manual processes, or the switch to low-tech networks based on renewable energies or data mules[27];
- Maintaining essential services in operational condition;
- Mobilising skills acquired upstream and pooling material resources and expertise between different organisations, local authorities, civil society, etc.;
- Reusing old or reconditioned equipment to perform certain basic tasks.

4.4.3 POST-CRISIS: RECOVERING AND BUILDING LASTING RESILIENCE

At the end of a crisis period, organisations have a strategic opportunity to consolidate the lessons learned and embed their transformation in a sustainable dynamic. In this regard, low-tech approaches provide a framework conducive to capitalising on the efforts made, contributing to the development of sustainable resilience and a profound redefinition of how value is created and preserved. This approach is reflected in particular by:

- Capitalising on feedback and best practices;
- The structured integration of low-tech principles into organisational strategy;
- Recognising and promoting cross-functional skills and internal expertise;
- Promoting a culture based on digital sobriety, sharing and cooperation;
- The evolution of economic models towards a logic of qualitative growth, based on sustainability and societal impact.

Beyond simply responding to the emergency, **low-tech principles are emerging as levers for systemic transformation**, capable of steering digital systems towards greater resilience. It is now up to organisations to turn this vision into reality by translating intentions into tangible, structural actions.

[27] Examples of low-tech networks, such as the HopScotch project in Scotland and the Indian Daknet network, are described in the article by Eva Morgand, Frenoux Emmanuelle, and Marceau Coupechoux: *Low-tech and networks: an impossible combination?* [Internship] Telecom Paris; Paris Saclay University, 2021 [https://universite-paris-saclay.hal.science/hal-03697720/]

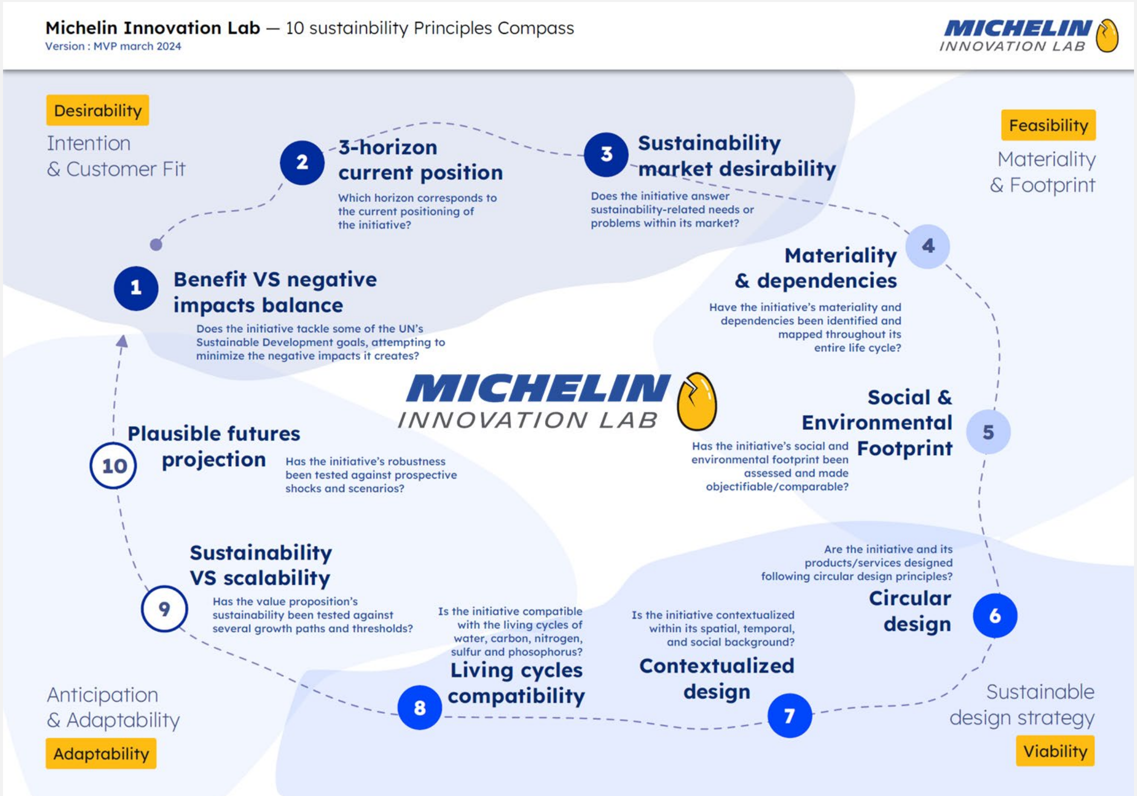
Feedback from MICHELIN

A sustainability compass for the business models of the future

Since 2018, Michelin has shifted its strategic focus from "Planet, Profit, Performance" to an integrated "All sustainable" approach, thereby broadening its scope of action.

While low-carbon policies are relevant levers for convergent actions, they can nevertheless lead to a reductive vision by obscuring certain equally important impacts.

With this in mind, the *Michelin Innovation Lab* has designed a "sustainability compass", an open-source methodological tool designed to stimulate reflection on the sustainability criteria applicable to the company's new economic models and to evaluate its innovations according to different time horizons. It incorporates ten key principles, divided into four structural areas: desirability, feasibility, viability and adaptability.



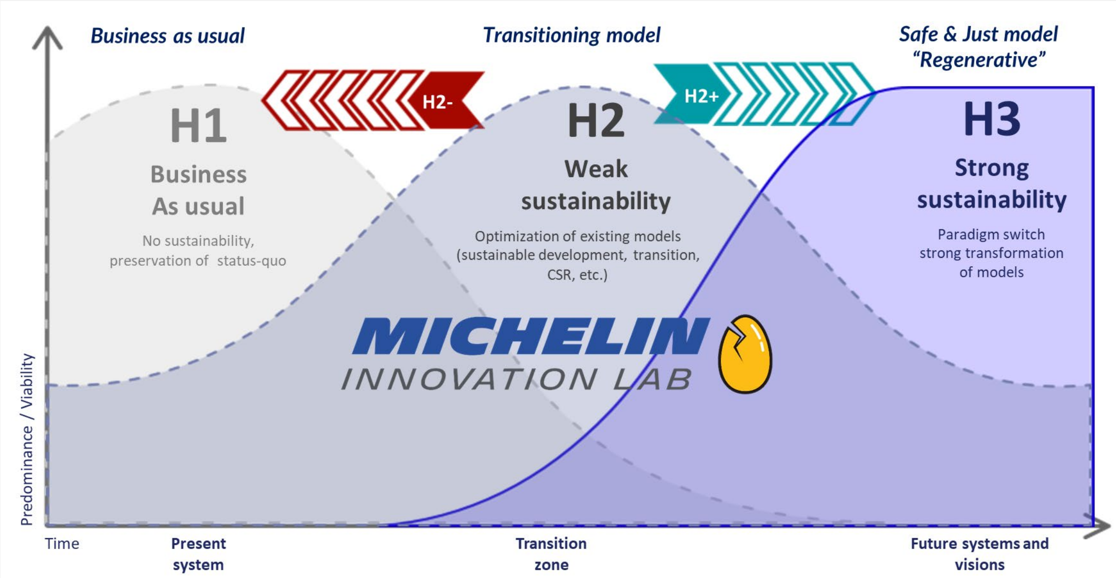
Compass and 10 principles of sustainability - Michelin Innovation Lab

Inspired by the work of Bill Sharpe and Kate Raworth[28] , three horizons have been defined in this model:

- H1: unsustainable, corresponding to maintaining the status quo;
- H2: efficiency of existing models focused on optimisation, taking into account the purpose of projects, in line with the requirements of sustainable development, the CSRD (Corporate Sustainability Reporting Directive) and transition initiatives. It is

primarily the assessment of the project's purpose that will lead either to a return to H1 or to an attempt to explore H3;

- H3: complete circularity, based on life cycles and involving a profound transformation of the model.



Model of possible horizons in terms of sustainability – Michelin Innovation Lab

Although this framework is still being tested by the teams, it provides a valuable opportunity to redefine the foundations of sustainability in a demanding industrial context and to explore concrete ways of applying the principle of "fair need" on a large scale.

Fabien Marlin, Digital CSR Officer / Head of Digital CSR,

Hacer Us, Innovation Sustainability Advisor / Coach at Michelin Innovation Lab

The working group's work has highlighted several levers of conviction that can be used to raise awareness among organisations of the potential of low-tech approaches: the risk management approach, crisis simulation, experimentation through pilot projects, and the development of "avoided cost accounting" that values the economic and environmental costs saved are all examples that help legitimise the low-tech approach. Furthermore, analysis by crisis phase (anticipation, management, reconstruction) confirms that these approaches are not limited to sustainability issues alone: they structure a genuine organisational resilience approach. These findings now need to be translated into concrete actions. What operational recommendations can guide organisations in this transformation?

[28] https://www.iffpraxis.com/3h-approach

5 BEST PRACTICES FOR DIGITAL PLAYERS

The working group's forward-looking workshops have resulted in a set of key messages designed to serve as benchmarks to guide organisations in their approach. These messages, which are both operational and practical, aim to provide decision-makers and project teams with clear and actionable guidance for initiating, structuring and sustaining the integration of low-tech principles as a strategic axis of resilience for their organisations and digital systems.

The initial findings **are structured around the** following **seven key messages**, which are then broken down into practical courses of action:

- Integrate low-tech into the resilience strategy of organisations and their digital systems
- Develop sustainable digital technology by design, based on moderate use;
- Investing in low-tech and digital skills, promoting them and maintaining them over time;
- Build regional and collaborative digital ecosystems;
- Create simple, reproducible and repairable production chains;
- Strengthen the robustness of systems through pooling and diversification;
- Promote common goods, local solutions and social inclusion.

5.1 INTEGRATE LOW-TECH INTO THE RESILIENCE STRATEGY OF ORGANISATIONS AND THEIR DIGITAL SYSTEMS

Key message:

In a global context marked by increasing complexity and ever more pronounced fluctuations, **it is becoming imperative for organisations to rethink their operating models**. Adopting low-tech approaches to address digital vulnerabilities is a strategic response to ensuring the continuity of essential activities and services. This approach calls for a shift from a short-term, performance-only mindset to a longer-term mindset that incorporates a focus on robustness.

Call to action:

The courses of action are shown in the diagram below:

Integrate low-tech into the resilience strategy of organisations and their digital systems

Visual summary of best practices for integrating the low-tech approach into organisations and their digital systems

5.2 DEVELOPING SUSTAINABLE DIGITAL TECHNOLOGY BY DESIGN AND PROMOTING MODERATE USE

Key message:

Integrating the principles of sustainability and digital sobriety from the design phase of systems and services is an essential lever for **mitigating the risks associated with energy overconsumption and resource shortages**. It is no longer just a question of optimising existing devices, but of calibrating solutions by questioning the underlying usefulness of each feature and structuring them according to actual needs.

Call to action:

- Design technical and organisational solutions aimed at minimising the use of resources, whether energy, materials, water or data;
- Implement eco-design practices and use life cycle analysis to assess and optimise the environmental impact of systems;
- Develop specific eco-design approaches as part of low-tech initiatives, ensuring their simplification;
- Develop performance indicators focused on the sustainability and resilience of digital systems;
- Promote a culture of rational use and essential functionality. As mentioned in section 4.1, the development of low-tech business continuity plans (BCPs) provides an opportunity for acculturation.
- Experiment with product or service framing under constraints in order to stimulate low-tech creativity and innovation, thereby challenging the common perception that innovation can only be high-tech.

5.3 INVEST IN LOW-TECH AND DIGITAL SKILLS, PROMOTE THEM AND MAINTAIN THEM OVER TIME.

Key message:

Organisations' ability to withstand shocks and recover from them depends fundamentally **on** their **mastery of their tools, as well as their ability to repair and adapt them**. In a context where supply chains can be disrupted and access to cutting-edge technologies is becoming more uncertain, **skills** in **diagnostics, repair, upcycling and management of ruggedised, eco-designed** and, where possible, open-source **operating systems** are becoming strategic assets. **Investing in local human capital**, far from being a one-off expense, represents a real guarantee of independence and resilience for organisations.

Call to action:

- Anticipate the skills needs related to low-tech approaches at the regional level and promote a stronger network of this expertise.
- Develop training programmes dedicated to synergies between low-tech and digital technologies, including specialised courses in the production, reassembly and maintenance of components;
- Set up continuing education programmes for professionals to maintain and enhance their skills in diagnosing, repairing and managing ruggedised operating systems. "Self-repair" workshops may be particularly relevant in this regard.
- Promote these professions to younger generations by emphasising their social utility and future potential.
- Raise awareness in schools and academic circles of the importance of integrating low-tech principles into their curricula, in conjunction with other digital issues.

5.4 BUILD REGIONAL AND COLLABORATIVE DIGITAL ECOSYSTEMS

Key message:

In the face of crisis situations, turning inwards is not a viable response. Resilience relies **on collective strength and local roots**. The creation of local production and maintenance networks, as well as the **development of partnerships between different actors (businesses, local authorities, citizens)** are essential for **pooling resources**, sharing low-tech know-how and contributing to the building of distributed, inclusive and shared resilience.

Call to action:

- Support the development of local sectors dedicated to production, maintenance, repair and recycling in order to strengthen local autonomy.
- Encourage the creation of digital commons and resource exchange platforms, drawing on the expertise of local ecosystem facilitators (such as the ALOEN model[29] in Lorient, which is linked to low-tech approaches, third-place training centres, etc.);
- Encourage cooperation between Fab Labs, Repair Cafés and other citizen initiatives as levers for pooling expertise and distributed innovation.
- Establish shared governance and collective decision-making mechanisms to ensure the inclusiveness and sustainability of the initiatives undertaken;
- Develop local public policies aimed at structuring low-tech and digital ecosystems in the region;
- Rely, whenever possible, on local renewable energy sources. For example, using low-tech principles to install solar power [30] to power offices with renewable energy.

[29] Local Energy and Climate Agency of Southern Brittany: https://aloen.fr/qui-sommes-nous/

[30] In addition to so-called "passive" or photothermal solar solutions such as solar dryers or ovens, solar panels can also be part of a "low-tech" approach if they are small, sized to meet specific needs, and dedicated to a specific, autonomous use (such as recharging a battery for lighting).

- Raise awareness among public funding bodies of the need to recognise that innovation is not limited to 'high-tech' technologies. Low-tech approaches must be fully eligible for innovation support programmes.

5.5 CREATE SIMPLE, REPLICABLE AND REPAIRABLE PRODUCTION CHAINS

Faced with increasingly complex digital systems and technological dependencies affecting the European continent, organisations are confronted with both technical and geostrategic vulnerabilities. In this context, it is imperative to **shift equipment design and production models towards more robust value chains** based on principles of sustainability. This means prioritising simplicity, repairability and interoperability.

Call to action:

- Prioritise the use of simple, standardised and interoperable electronic components, while ensuring that they are easy for the general public to understand.
- Combat disposable innovation and planned obsolescence by incorporating sustainability and repairability criteria from the design stage onwards.
- Establish standards (possibly in the form of ISO standards) to regulate the upcycling of electronic components, particularly chips, in order to guarantee quality and interoperability.
- Invest in infrastructure and industrial processes dedicated to the production and reassembly of components, moving away from the integrated "all-in-one" model;
- Simplify equipment recycling and reconditioning operations by facilitating disassembly and component separation, including for network infrastructure. To this end, the integration of low-tech criteria into relevant eco-labels (such as TCO, EPEAT, Blue Angel, etc.) could be a significant step forward;
- Make manufacturers' technical documentation available to the public to enable "self-repair" or redesign of parts, thereby contributing to extending the life of equipment and promoting personal autonomy.
- Reduce strategic dependence on external actors by promoting the relocation of production and the pooling of resources at the local level;
- Encourage interaction between different actors (businesses, local authorities, citizens) in order to share production equipment and optimise the use of industrial tools at the local level.

5.6 STRENGTHEN THE ROBUSTNESS OF SYSTEMS THROUGH POOLING AND DIVERSIFICATION

Key message:

The robustness of systems can be improved through **the pooling and circularity of resources, a return to local production and the diversification of solutions**. However, this transformation requires forward planning and a long-term strategic vision. Such an approach would limit points of failure, reduce dependence on global supply chains, and strengthen the security of organisations in the face of geopolitical, climatic or economic risks.

Call to action:

- Explore opportunities for resource sharing and circularity at the local level to optimise asset utilisation and reduce operating costs.
- Establish monitoring and control mechanisms to identify weak links and ensure system robustness, while avoiding the pitfalls of hyper-control.
- Diversify cloud solutions and service providers to limit the risks of dependency and "single points of failure"[31];
- Organise internal crisis simulations, and with other partner organisations, based on common scenarios (power outages, network loss, cloud unavailability, extreme temperatures, etc.) to identify vulnerabilities and define adaptation plans that strengthen their resilience;
- Sustain LoRa-type infrastructure and extend its use, particularly for communications with smartphones, in order to ensure a minimum level of connectivity in the event of traditional network failure;
- Maintain and modernise VHF and BLU communication systems for essential services.
- Develop hardened and lightweight operating systems, favouring regional control while ensuring minimum interoperability and focusing on essential functionalities.
- Implement digital services on cloud-agnostic platforms (i.e. environments that are independent of providers), recognised for their ability to be migrated quickly, in order to enhance the flexibility and resilience of digital infrastructures.

[31] A single point of failure (SPOF) is a point in a computer system on which the rest of the system depends and whose failure causes the entire system to shut down.

NUAGEO feedback

How does robustness serve the "low technicisation" of information systems?

In a context marked by the proliferation and unpredictability of shocks, where uncertainty tends to supplant quantifiable risk, particularly for digital systems, robustness should no longer be seen as a constraint, but as a strategic opportunity. It paves the way for the "low technicisation" of information systems, based on simplicity, resilience, local control of tools and a desire to use digital technology for purposes that contribute to the common good.

To initiate a robustness approach applied to so-called "fluctuating" information systems, it is necessary to adopt the following fundamental principles:

- Integrate shocks and disruptions as constituent elements of the company's nominal functioning;
- Go beyond the logic of optimisation alone, whether financial, social or environmental, and adopt a systemic approach;
- Regulate digital uses through deliberate and thoughtful restraint;
- Aim for short-term stability, sometimes referred to as "sub-optimality", while ensuring long-term viability. For example, introducing heterogeneity in the choice of suppliers, although not optimal in the short term, strengthens the robustness of the system;
- Activate the levers of robustness, which are heterogeneity, redundancy, circularity, accepted imperfection, interactions and architectural modularity.

Ultimately, robustness must be considered a prerequisite for the long-term viability of information systems.

To initiate a concrete transformation of information systems, it is necessary to move from a "**fortress**" model (based on a monolithic architecture) to an "**agile village**" model based on a micro-services approach:

- A **monolithic information system** is characterised by its stability, linked to a design that meets predictable needs. However, its architectural rigidity and extensive optimisation can make it vulnerable to unforeseen events. This model is mainly geared towards performance and efficiency.
- Conversely, **information systems based on micro-services** are distinguished by their adaptability, offering flexibility in the face of unpredictable challenges. They are based on a modular architecture, comparable to "autonomous neighbourhoods", and promote flexibility. However, this approach involves increased complexity, particularly due to the sheer number of actors to coordinate. It focuses on resilience and adaptability.

Please note that this is only one example: in some cases, and often on a small scale, a monolithic model can be less complex than a microservice architecture. There is no dogma; the right technological solution must be sought in relation to the right need.

The Fluctu'IT workshop is a collective intelligence tool designed to help companies understand and address issues related to the robustness of their information systems. It aims to facilitate a comprehensive mental representation of risk mapping and possible courses of action:

- This collaborative workshop focuses on analysing the robustness of information systems in a context of variability and uncertainty.
- It enables the identification and classification of the main risks (environmental, supply-related, technological, regulatory, social, energy-related, geopolitical, economic, commercial or business model-related) according to their impact on the information system.
- The approach adopted encourages a constant focus on the end goal, avoiding pitfalls such as "green energy deforestation", i.e. solutions that claim to be sustainable but are not sustainable overall.
- The workshop helps define levers for action to promote low-tech digitalisation, while integrating the principles of circular economy and sobriety into organisations' digital strategies.

Clément Marche, co-founder of Nuageo and Fluctu'IT

5.7 PROMOTING COMMON GOODS, LOCAL SOLUTIONS AND SOCIAL INCLUSION

Key message:

Digital resilience cannot be reduced to a simple technological issue; it is deeply embedded in the social fabric and relies on the collective capacity for innovation and solidarity. Given the diversity of risks to which organisations are exposed, it is essential to adopt collaborative and decentralised approaches, leveraging local resources and the expertise of employees and citizens. **The low-tech approach is** thus **emerging as a vehicle for inclusion**, **promoting the reappropriation of the tools and knowledge necessary for collective and resilient adaptation**.

Call to action:

- Mobilise Fab Labs and local manufacturing and maintenance workshops to promote the production and repair of tools and equipment, while spreading a culture based on low-tech principles.
- Train citizens and organisation employees in low-tech technologies, with a view to reappropriating digital tools and developing their autonomy in terms of repairability, maintenance and rational use;
- Build a collaborative knowledge base, accompanied by catalogues of low-tech alternative solutions designed to meet the needs of business services;
- Decentralise production centres in order to bring manufacturing closer to actual usage, while preserving local maintenance and repair skills;
- Encourage innovation based on cooperation, promoting collective dynamics rather than competition alone;
- Organise hackathons dedicated to resilience strategies, to stimulate collective intelligence and develop robust and adaptable solutions;
- Strengthen the culture of maintenance, both in terms of hardware and software, considering it a pillar of digital sustainability;
- Draw inspiration from CUMA (Coopérative d'Utilisation de Matériel Agricole[32]) to promote the sharing of equipment and optimise its use.

[32] This cooperative enables farmers to pool the resources (machinery, labour, sheds, etc.) necessary for their agricultural activities.

CONCLUSION

In an environment marked by increasing fluctuations and unprecedented hyper-digitisation that creates vulnerabilities, this report highlights the strategic and essential role of low-tech approaches in strengthening the digital resilience of organisations. Far from being a brake on innovation or a nostalgic return to the past, the low-tech approach is establishing itself as an enlightened paradigm of adaptation, based on the search for the "right need", functional simplicity, sustainability, accessibility, local anchoring and autonomy, all consolidated by systemic robustness.

The prospective analysis conducted as part of this work identified three major risks that could compromise service continuity and organisational viability: disruptions in technology supply, economic instability and rationing of digital usage. In the face of these threats, low-tech approaches offer concrete and operational solutions: developing repair and upcycling skills, implementing alternative communication networks and hardened operating systems (OS), pooling resources, and developing Business Continuity Plans (BCPs) that incorporate manual processes. These levers make it possible to reduce exposure to risks upstream, optimise crisis management in real time and promote sustainable post-crisis recovery.

The successful integration of these practices depends on a profound shift in collective narratives, broader recognition of their value (economic, social and environmental), and collective commitment. Organisations are therefore invited to rethink their resilience around these principles, to structure collaborative and local ecosystems, to invest in versatile skills, and to promote a culture of digital sobriety and sharing.

The concrete feedback presented in this report attests to the feasibility and relevance of these approaches, constituting case studies that are likely to overcome resistance and encourage their implementation.

The working group concludes that the low-tech approach is fully compatible with digital systems and represents a proactive and creative strategy that is essential for evolving in a world of limited resources and growing uncertainty. It calls for "technological discernment" which, far from hindering progress, reorients it towards greater sustainability and resilience.

Cigref is a network of major French companies and public administrations whose mission is to develop its members' ability to integrate and master digital technologies. Through the quality of its thinking and the representativeness of its members, Cigref is a unifying force in the digital society. Cigref was founded in 1970 under the French law of 1901, and does not engage in any profit-making activities.
To achieve its mission, Cigref relies on three core businesses that make it unique.

Membership
Cigref embodies the collective voice of France's leading companies and government agencies on digital issues. Its members share their experience of technology use within working groups, to help identify best practices.

Intelligence
Cigref participates in collective reflection on the economic and societal challenges of information technologies. Founded nearly 50 years ago, Cigref is one of the oldest digital associations in France, and draws its legitimacy from both its history and its mastery of technical subjects, the foundation of skills and know-how that underpin the digital world.

Influence
Cigref promotes and respects the legitimate interests of its member companies. As an independent forum for exchange and production between practitioners and players, it is a benchmark recognized by its entire ecosystem.

www.cigref.fr
21 av. de Messine, 75008 Paris
+33 1 56 59 70 00
cigref@cigref.fr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