Energy and digital transitions

Preface
Gérard Roucairol, president of the digital pole of the Académie des technologies

Introduction
Olivier Appert, Académie des technologies, IFRI Energy Center, and **Richard Lavergne**, Conseil général de l'Économie

Towards increasing electricity and digital needs

Why data is vital to build a better energy future for the world
Dr Fatih Birol, Executive Director of the International Energy Agency

In this contribution, Dr. Fatih Birol, Executive Director of the International Energy Agency (IEA), highlights how data is essential to understand and map progress in clean energy transition, to bring down global greenhouse gas emissions, achieve key international Sustainable Development Goals on universal access to modern energy and ensure energy security worldwide. The article depicts how the IEA produces, maintains and continuously improves essential datasets, indicators and data-based projections to help countries navigate this challenge.

Energy consumption of digital uses in France
Michel Schmitt, Engineer General of Mines, member of the General Council of the Economy

In 2018, the Conseil général de l'Économie estimated the electricity consumption resulting from digital uses in France at 35,750 GWh, which was a clear drop from the figure in the previous 2008 study. This same report anticipated that, for similar uses, this consumption would be 31,843 GWh in 2030. In light of the last two editions (2020 and 2022) of the Digital Barometer, in this article we analyze the trends observed since 2018, compare the data anticipated at the time for 2022 with the current data, and update the 2030 forecast. In particular, containment has changed behaviors, with computers and tablets making a strong comeback during telecommuting periods.

Comparative strategic autonomy in energy and digital
Grégoire Postel-Vinay, General Economic Council

The three largest world blocs have divergent situations when it comes to energy autonomy: the United States has become an exporter, China is dependent on energy for about 21% of its primary consumption, the European Union is dependent on energy for 57% of its primary consumption, and this figure has been rising for the past twenty years, while France is dependent on energy for 44%. A major effort is required by both the EU and France to improve these figures, which implies, among other things, a reversal of the trend for nuclear power. In the digital sector, the EU's dependence on the United States in particular is even greater. An awareness, aggravated by recent crises, is leading to major inflexions. In both cases, the order of magnitude of private and public investments required is one trillion euros over the decade. Similarly, new skills are needed, as well as long-term planning. Finally, the efforts to be made are closely linked between the two areas.

How is Europe organizing itself to ensure the convergence of efforts in favor of green and digital transitions?
Valérie Drezet-Humez, Head of the European Commission Representation in France

Achieving the twin green and digital transitions is a major challenge for the European Union. In its latest strategic foresight report on "Coupling the Green and Digital Transitions", the European Commission stresses that the implementation of the two transitions must be coordinated and coherent, in order to identify opportunities, trade-offs and compromises between the two ambitions. To this end, it identifies ten key areas of action to improve synergies while minimising the potential risks that arise from the coupling.

Making the necessary adjustments for a sustainable and digital transition will enable the emergence of a new, regenerative and climate-neutral economy. The European Commission is committed and determined to move Europe forward in this direction, while combining this twin transition with its democratic and social justice values, benefiting all citizens and territories.

Energy and digital: preparing for another battle
Jean-Pierre Hauet, Chairman of the Scientific Committee of Équilibre des énergies

Today, digital technology is often singled out as an unbridled consumer of electrical energy. However, considerable progress has been made, but the extension of the services offered, the rebound effect and the excesses of a few gluttonous applications mean that consumption will probably continue to increase in the future.

It is in the general interest to contain this consumption while decarbonizing it. But we must also look at

their primary cause, i.e. the very efficiency of electronics as a means of processing bits of information. We then realize that electronics is a particularly inefficient process in terms of thermodynamics, but that there are also ways of progressing in this area that could constitute a real revolution, as was the arrival of LEDs in the field of lighting.

This is the challenge posed to spintronics, which proposes to control electrons not only by their electrical charge, but also by their spin. This is a field in which France has good assets, which must be preserved and exploited.

Digital technologies are both part of the environmental problem and solution

Patrice Geoffron, LEDa, Université Paris-Dauphine, Université PSL, IRD, CNRS

The debate on the environmental impact of digital technology is complex and cannot be approached simply by observing the increase in its weight in CO_2 emissions or electricity consumption. Recent work has made it possible to improve the understanding of induced effects, in particular by establishing the extent to which the uses of digital technology influence the emissions trajectory of States or act on the co-benefits of climate action (such as air quality). Furthermore, these analyses must be placed in the context of the health crisis (and the development of 'remote' socio-economic activities), as well as the energy crisis (which involves optimising systems that are becoming increasingly complex due to the accelerated development of renewables, efficiency efforts, etc.). This work leads to a contrasting assessment of the environmental impact of digital technology (which, however, does not invalidate the need for sobriety efforts).

What about beyond the Moore's and Koomey's laws?

Dr Vincent Mazauric, Principal Scientist, Schneider Electric, **Alexia Auffèves**, Director of Research at the CNRS, Director of the international laboratory MajuLab of the CNRS and co-founder of the Quantum Energy Initiative, **Olivier Ezratty**, Consultant, author and co-founder of the Quantum Energy Initiative and **Sergio Ciliberto**, Director of Research at the CNRS, École normale supérieure de Lyon

For nearly fifty years, Moore's and Koomey's laws symbolized the continuous progress in the computing performance of microprocessors and accompanied – even founded – the exceptional growth of the semiconductor industry. Thus, computers have become smaller and cheaper, while being faster and more powerful; thus fueling a perpetual "rebound effect" in the information and communication technologies (ICT) sector which has still not reached "fullness"! Nevertheless for a few years, the manufacturers of microprocessors are faced the physical limits of the assumptions which had made possible to conjecture the Koomey's law; so that the future of the semiconductor industry and more generally of the ICT sector must now be considered beyond Moore's Law.

At the same time, the current massification of data has led to identify the ICT sector as being largely intensive in electrical energy, and therefore highly emissive in CO_2, but also extracting critical materials, while it was viewed as "immaterial" few years ago. To consider the role that information and communication technologies can play as a response to the sustainability challenges, it is necessary to relativize the notion of computational performance and to turn back to the link between information and energy, which has been stated, including in the digital context, long before Moore's Law. Moore's and Koomey's laws then only appear as contextual "paths" leading to thermodynamic maturity, which is measured by a tendency to reversibility. In order that the "data deluge" does not turn into an "energy wall", other paradigms will have to be considered to accompany the journey towards sustainability of the information and communication technology sector.

Decarbonization of the economy in the context of new models

Digital, an underutilized solution to power system management challenges

É**tienne Beeker**, Scientific advisor at France Stratégie

The Ukrainian crisis has revealed the double fragility of the European electricity system: a very high exposure to gas and to Russia, its main supplier, but also an under-capacity in controllable production means. This crisis, which only concerns Europe, can be blamed on the adventurism of European energy policy, which wanted to set up a new system based on intermittent renewable energies, leading to the overly rapid elimination of the old system and forgetting the imperatives of security of supply and competitiveness. Many controllable production facilities have been shut down, without thinking about compensating for the resulting flexibility deficit. The use of digital technology could fill this gap. However, although the corresponding technologies are mature, they are still notoriously underused, as is the case with Linky in France, which is practically deployed throughout the country and is designed to control electricity demand.

The place of digital technology in the energy transition

Gilles Guérassimoff, Professor at the Centre de mathématiques appliquées (CMA) at the École des Mines de Paris

The energy transition is on all fronts to work towards limiting the effects of climate change. Digital technology is an obvious candidate to contribute to the success of this transition, given the match between the climate emergency and the sector's dynamic development. To attempt to assess the place of digital technology in the energy transition, it is important to first define the scope of the concept of digital technology. Next, it is necessary to quantify its energy impact to evaluate the applications that will be beneficial to the transition.

Finally, the risks and limits to its deployment must not be overlooked. A few examples are given to illustrate the preferred areas of application.

The role of flexibility in today's and tomorrow's power system

Alain Burtin, Head of Energy Management activities in the EDF Group's R&D department

Electricity cannot be stored. It must be produced, transported and distributed when needed. This requires flexibility margins and levers to ensure the physical adjustment of electricity supply and demand at every moment, while respecting predefined criteria for the security and reliability of electricity networks. The decarbonization of the electricity mix with the massive development of renewable energies is profoundly changing the fundamentals of power system operation, whose flexibility needs are increasing in order to manage the variability of renewable energies, while the main sources of flexibility constituted by conventional power plants are decreasing. In this article, we discuss the rise of flexibility issues in today's power system and the levers used to meet them, the adaptations needed to meet the European objectives for 2030, and the post-2030 outlook.

Is blockchain good for the climate?

Paul Jolie, Engineer General of Mines, General Council of the Economy

The public blockchain is a recent technology that allows trust to be created without a centralized body. Blockchain is based on a peer-to-peer network. The damage or loss of one node will not affect the functioning of the whole system. With its properties of tamper-proofness, traceability and transparency, the blockchain enables the creation of notarisation services in a digital world between actors who do not a priori trust each other.

Recent applications using blockchain technology include crypto-currencies, two of which have been very successful: bitcoin and Ethereum. Yet, between 2018 and 2022, the annual amount of electricity from global crypto-assets has increased significantly. As of August 2022, published estimates of total global electricity consumption for crypto assets ranged from 120 to 240 billion kilowatt hours per year, a range that exceeds the total annual electricity consumption of countries like Argentina or Australia. This is equivalent to 0.4% to 0.9% of the world's annual electricity consumption and is comparable to the annual electricity consumption of all data centres in the world. This consumption is mainly due to mining activities (which are used to establish a consensus between players) using the so-called "Proof of Work" (PoW) method, used in particular by bitcoin.

In this sense, the blockchain, the core technology of bitcoin, is a major contributor to greenhouse gas emissions. Fortunately, there are other consensus mechanisms that consume less energy, such as the "Proof of Participation" (PoS) mechanism used by Ethereum.

On the other hand, the new services offered by blockchain are particularly attractive for combating global warming.

For example, blockchain can facilitate exchanges between energy producers that are difficult to store. It is also very suitable for helping to create decentralised and distributed infrastructures, while guaranteeing the origin of energy thanks to its traceability properties, reinforcing consumers' confidence in the real origin of the energy they consume.

Thus, through blockchain, a collaborative process between states should become possible to develop effective and evidence-based environmental performance standards.

Digital technology as a vector for the decarbonization of economic activity sectors

How can Europe's "industrial" reclamation of digital technology contribute to carbon neutrality?

Aurélie Picart, General Delegate of the Strategic Committee on New Energy Systems Industries

To ensure that the contribution of digital technology to carbon neutrality is not offset by an increase in the use of digital technology, it is necessary to take coherent action on three major levers: research, changes in behaviour and the development of decarbonised and competitive energy.

But more broadly, achieving our decarbonisation objectives and our ability to influence international climate negotiations depend on our industrial, digital and energy sovereignty.

We must therefore strengthen and decarbonise our industrial sectors and secure our supplies, while mobilising the demand of the European internal market and developing key technical skills. Europe has begun to shift its policy in this direction. A consensus must quickly be reached between the European countries to build a coherent and ambitious policy to meet the challenges posed by the American Inflation Reduction Act and inflation.

How to reconcile decarbonization and industrial competitiveness?

Romain Bonenfant, Head of the Industry Department at the Directorate General for Enterprise

Containing climate change requires decarbonizing our industry. This structural transition calls for an appropriate regulatory framework to ensure a level playing field for both EU industry and third countries', and create favorable conditions to foster private investment for decarbonization projects. Breakthrough technologies are needed to reach emission reduction targets compatible with climate objectives. The private sector will not be in a position to finance entirely these innovations, considering associated risks. In this context, industry decarbonization should be planned to optimize

transition costs and focus public funding where it is most required.

Digital, ally or enemy of the ecological transition?

Claire Tutenuit, General Delegate of Entreprises pour l'Environnement (EpE), and **Benoît Galaup**, Head of Digital and Environment at EpE

Characterised by an extremely rapid pace of innovation, the ongoing digital revolution is transforming our notions of time and space and profoundly changing our ways of accessing knowledge and consumption, and reaching others. Used wisely, these technologies can bring many benefits, but today, they are mainly at the origin of significant impacts on the environment. Therefore, the new challenge for companies is to reduce their environmental footprint while continuing their digital transformation. Within EpE's Digital and Environment Commission, nearly sixty large companies have analysed the conditions for accelerated adoption of digital technology with a reduced footprint as well as being useful for their ecological transition and that of society. The publication "The digital, ally or enemy of the ecological transition?" Summarises this work and shows encouraging results. It suggests the adoption of frugal behaviours to drive ecological and digital transition at the same time.

The contribution of digital technology to the decarbonization of mobility: the case of the automobile

Christophe Midler, Director of Research Emeritus, Management Research Center of the École Polytechnique-i3, CNRS-IPP, member of the Académie des technologies, and **Patrick Pélata**, Former Chief Operating Officer of Renault, former Chief Automotive Officer of Salesforce, member of the Académie des technologies

Digital technologies have had a major impact on CO_2 emissions from cars, mainly through improved engine management, since the early 1990s. The cumulative effect of these 30 years of innovation is about 200 $MtCO_2$ per year for Europe.

However, apart from electric vehicles, where most of the innovation comes from chemistry and power electronics, the innovations we are seeing today, which are based on digital technology (telecommuting, e-commerce, car-sharing, VTC, shared mobility, whether soft or not), have a much lesser impact on decarbonizing mobility.

What the future holds for us is still very uncertain. But autonomous driving, especially when applied to shared robot cabs, could make a significant contribution to and even accelerate the major transformation that is the electrification and reduction of the car fleet.

The contribution of digital technology to the decarbonization of buildings

François Bertière, President of Foncière Fiminco Reim

The building and real estate industry is undergoing a profound change as a result of the energy transition. In this respect, digital tools are powerful assets to take up the related challenges in a sector that was lagging behind the industry in the digital field.

In this article, we present the current advances made possible by digital technology in the fields of new construction, renovation and operation of buildings and neighborhoods, giving examples of innovative solutions. It highlights the importance of regulation and the perspectives opened by the Building Information Model, life cycle analysis and the digital twin. It concludes that regulatory constraints must be accompanied by a policy of training, support and incentives.

How to reduce the environmental impact of microelectronics in a rapidly changing semiconductor field?

Sébastien Dauvé, Director of CEA-Leti, and **Léa Di Cioccio,** Fellow and research director at CEA-Leti

Microelectronics is now an integral part of many countries' strategies, and the global landscape is likely to change in the coming years to rebalance the value chain. It is in this unprecedented context that the question of the environmental impact of microelectronics is increasingly being raised through the production of its components, but also through its uses. Industry and research players are fully mobilized to achieve the objective of reducing its carbon footprint through concrete actions. They are also integrating this dimension into the design of future microelectronics technologies and components. In this article, we take stock of the issues and initiatives in this area and give concrete examples of innovations underway, particularly at the CEA.

Issue editors:
Olivier Appert and **Richard Lavergne**