The digital society:
A scenario for the energy transition by 2072

Nadia Maïzi,
director of the Centre de Mathématiques Appliquées, Mines ParisTech–Institut Mines-Télécom, PSL Research University;
Edi Assoumou,
junior researcher at the Centre de Mathématiques Appliquées de Mines ParisTech–Institut Mines-Télécom, PSL Research University;
& **Thomas Le Gallic,**
doctoral student at the Centre de Mathématiques Appliquées de Mines ParisTech–Institut Mines-Télécom, PSL Research University

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Abstract:
This prospective study on the energy transition examines the compatibility between a society where digital technology has been deployed and France's goal of "carbon neutrality" by 2072. If we are not careful, climate programs might be jeopardized due to the energy needed for information and communications technology. On the supply side, what digital techniques and devices are being designed to cope with climate change? On the demand side, what lifestyle trends will this technology trigger in a "digital society", and what impact will they have on energy consumption? Beyond the results of the scenario imagined herein, it is worthwhile examining a range of decision-making tools for laying out the pathways we would like to take.

The 2072 appointment

One warning from scientists about climate risks refers to a threshold marking the average temperature increase that it would be dangerous to exceed: 2°C had been mentioned in meetings organized under the United Nations Framework Convention on Climate Change until article 2 of the Paris Agreement advocated, for the first time, "*efforts to limit the temperature increase to 1.5°C above pre--industrial levels*".[1] This modification was made under pressure from countries already coping with the impact of global warming: the Alliance of Small Island States (AOSIS), Bangladesh and a few other lands whose very existence is at stake. Moreover, article 4 suggests a not very precise deadline for attaining carbon neutrality, namely: "*the second half of this century*". All of this led us to the idea of using a futurological approach to imagine what might happen by 2072 (MILLOT et al. 2017).[2]

The year 2072 is emblematic: it will mark a century since the Club of Rome's alarming report on the limits to growth (MEADOWS *et al*. 1972) and since the philosopher Cornélius Castoriadis's warning about the contrast between capitalism's mad pursuit of unlimited expansion and the physical limits to this expansion. Since current trends in development are not sustainable, there is no

[1] The Paris Agreement (United Nations) 2015 is available via
http://unfccc.int/paris_agreement/items/9485.php; and the United Nations Framework Convention on Climate Change (1992) can be downloaded at
https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf.
[2] This article has been translated from French by Noal Mellott (Omaha Beach, France).

doubt but that, by 2071, there will be more and worst instances of *"the accumulation of greenhouse gases, the irreversible loss of biodiversity, advancing deserts, pollution of various sorts, so many disturbing symptoms of degradation inherited from our past heedlessness"* (DUMESNIL 2002:109).

For this reason, it seems pertinent to try to see what might happen in the unknown future of the far-off date of 2072. We have adopted an approach to prospective studies that does not just extrapolate from what exists, since: *"If societies, like individuals, are frequently disappointed, the reason is that they are offered what they demand and not what they really want but without being able to express it adequately"* (BERGER 2007:39).

Hypothesizing that France will pursue the objective of carbon neutrality by 2072, we have tried to discern how a digitized society will help or hinder the reaching of this goal. This exercise has involved analyzing the supply and demand sides of this question.

Digital technology, a vector for a carbon-neutral digital society

Much of the enthusiasm aroused by digital technology (information and communications technology, henceforth ICT, as well as digital devices, computer equipment, applications and software) stems from its association with the idea of "green growth" — from expectations about how it will optimize products and the flow of energy. The deployment of "smart" devices is presented as a major contribution to "decarbonating" our energy system.

To be convinced, let us review the conditions for a transformation of the electricity industry. The amount of CO_2 emitted by generating electricity has been steadily rising since the invention of this sort of energy, which now produces more than 45% of CO_2 worldwide. This trend is sustained by the exploding demand for electricity, which results from the strong growth of emerging economies and the switch toward potentially carbon-free energy sources. It harbingers immense investments in both the production capacity for generating electricity and the current grids (in response to urban density and the dispersion of units for generating electricity from renewable sources).

Taking account of these structural aspects, the aim for the energy transition is to adapt the current electricity system; but the latter should retain its role as a supplier while rationalizing investments and limiting greenhouse gas emissions as much as possible. Among the many recommendations made for reaching this objective are: market instruments along with political commitments (the European Union Emission Trading Scheme, EU-ETS, taxes and subsidies, real-time pricing, legal texts, etc.); the promotion of low-carbon solutions (renewables, nuclear energy, the storage of CO_2) on the supply side; and the boost to energy efficiency and renewables on the demand side.

Digital technology is being asked to contribute to an integrated management of smart solutions designed for the grids and of intermittent renewables or controlling and monitoring how energy is used. These contributions, essential for optimizing the mix of centralized and decentralized grids, will have to take account of conditions specific to the electricity industry, namely: the requirement for maintaining an instantaneous equilibrium between supply and demand. This can be outlined as a choice between two options:

— Either invest in additional, permanent production and transmission capacities that, because of oversizing and the inertia of a global centralized system, will be capable of responding to sudden calls for power.

— Or else adopt a real-time, flexible, precise and decentralized management of existing capacities in order to locally satisfy demands for power thanks to storage systems and smart control devices implanted on the grid.

It is, therefore, worthwhile to assess the input from "smart" solutions for monitoring grids (DROUINEAU *et al*. 2014; ZHANG & REN 2005). This choice between, on the one hand, the excess capacity a centralized system (the energy contents of infrastructures, losses due to Joule's laws) and, on the other hand, the capacity of a decentralized system ("rush production", storage and monitoring) entails a life-cycle assessment of the reliability of the electricity supply.

In addition, the materiality of digital technology, in particular energy consumption, must be brought into the picture. When inquiring into supply-side issues, the conclusion about an environmentally friendly digital technology has, we are forced to concede, been drawn a little too fast.

The digital society's material nature: Energy consumption

The advent of digital technology opened the perspective of solutions that would reduce greenhouse gas emissions thanks to a more rational use of energy. The excess of optimism in the early days of this technology stemmed from the belief that the latter would be associated with a "structural dematerialization" (ROMM *et al*. 1999).

However a controversy soon broke out about the digital society's material nature, specifically about the impact of using digital technology on energy consumption (FAUCHEUX *et al*. 2001). These effects, now widely recognized, are measurable by the increase in electricity consumption. Everyone agrees that using the Internet and ICT has stimulated electricity consumption. Estimates of this technology's energy footprint have been calculated per component (DRAM, microprocessor), machine (PC, console…) and use (measured data centers and on the Internet).

In 2009, electricity consumption due to ICT was estimated to amount to approximately 13,5% of total electricity consumption in France, *i.e.*, between 55 and 60 TWh/year (BREUIL *et al*. 2009). As more powerful microprocessors were developed and the risks of congestion on the Internet diminished in line with Moore's law (WILLIAMS *et al*. 2002 & MATTHEWS 2001), consumption increased steeply: +10%/year. In the first decade of this new century, total losses due to the standby (monitoring) mode of household equipment represented between 5% and 15% of household energy consumption (BERKHOUT& HERTIN 2001). The share of personal computers in this percentage is continuously rising, and the generation of current in France is growing with the use of computers (COLLARD *et al.* 2005).

We must, therefore, increase the energy efficiency of the techniques used to "domesticate" energy and of digital devices, for example by improving RAM performance (DEMIGNY & FILIPE 2005). Before doing that however, it might be worthwhile quantifying energy issues. This exercise raises anew questions that have already been asked about the theoretical amount of energy needed to manipulate a byte of information, the basic unit in a digital operation. Theoretically, this value does not equal zero, since the bit-flip corresponds to a manipulation of information. Furthermore, according to the second law of thermodynamics, entropy cannot be reduced without using energy. The thought given to this fundamental, even philosophical, topic is to be related to calculations of the consolidated consumption of a gigaFLOPS (GERSHENFELD 1996).

The risk exists, therefore, that unreasonable uses of digital technology will be counterproductive in terms of energy. This risk must be kept in mind by anyone who is convinced of the leverage obtained by acting on the uses of digital technology (which are driving economic growth), and on the technology itself so as to fully integrate it in a universal energy network. This leverage, used for the purpose of optimization, might be the most efficient source of a socially acceptable sustainable growth.

The digital society’s life-style

An adequate integration of technology but partly repsonds to questions about how to develop the economy without deteriorating the environment in proportion. The points of view from the supply and demand sides must be reconciled. Society is sometimes reluctant about accepting technical innovations. For instance, demonstrations of prototypes have brought to light the gap separating a prototype from its deployment on an industrial scale. For example, volunteers became scarce and were reluctant to have smart electricity meters — considered to be intrusive — installed in their homes. Given the low financial returns or the difficulty of seeing the environmental implications of these connected devices, people had no motivation for changing their habits. Besides the supply of available technology, behavior patterns and life-styles are key factors for steering the right course — towards a carbon-free society.

Our research intends to evaluate whether the digital society’s life-style is compatible with the objective of carbon neutrality by 2072. Statistical tools can be used to probe the digital society as we imagine it, namely: more individualistic, technological and digital (LE GALLIC *et al*. 2016a & 2016b; LE GALLIC forthcoming). The following structural aspects of this coming society can be examined. Given the quest for personal development, more persons will be living alone; and the desire to have children will wane. The life expectancy will stretch out as more attention will be paid to health (and a larger share of budgets, devoted to it). The majority of households will be dwelling in large urban centers, especially downtown areas, where the leisure activities and services most in demand will be located. More will be done on line at home: shopping, work, social activities. Analyses, both economic (BRIENS 2015) and technological (MILLOT *et al*. 2017), of this digital society’s life-style have suggested that consumption and the need for services will explode.

Using 2010 as the baseline, the scenario for the digital society in 2072 concludes that:

— The total surface area occupied by primary residences will increase 34%, mainly because of people not living under the same roof; but this increase will be attenuated by the attraction exercised by big cities, where housing units are, on the average, much smaller than in rural or periurban areas.

— The demand for electricity will rise by 36%, a percentage higher than the population’s growth rate.

— A reduction in the mutualization of vehicles at the household level will be counterbalanced by the mobility of people living in densely populated urban centers, where fewer households have cars.

— The relation to technology will undergo a leveling effect on household equipment, but this leveling will be aligned on the best equipped households, thus multiplying by a factor varying from 1.8 to 2.3 the number of purchases of audiovisual equipment, computers and digital devices.

— The total distance of trips will fall by 11% as virtual mobility partly replaces physical mobility.

— The population will be more urban, better-off and, above all, more inclined to travel far. The demand for long trips will explode: +115% in distance and +77% in terms of the number of trips.

Under this scenario, the digital society’s total energy consumption will have increased +31% by 2072 compared with nowadays.

We must take account not only of technological advances or breakthroughs but also of this societal dimension. Using it as a lever will have an impact on life-styles. This means reshuffling the deck of cards: how will this digital society imagine its growth? It will probably have to forsake the individualistic, technocentric vision pursued till now.

The question of life-styles thus becomes, in our opinion, the key question for discussing the energy and digital transitions. A positive point: we have all the tools for probing social and environmental solutions with the help of prospective simulations and for eventually making designs *a priori* — and not just observations *a posteriori*. The aim is *"not to choose between foresight and forecasts, but to associate them. The one requires the other. It is necessary both to know the direction where we are headed and to be sure about where we are setting our feet for the next step"* (BERGER 2007).

References

BERKHOUT F. & HERTIN J. (2001), "Impacts of information and communication technologies on environmental sustainability: Speculations and evidence", report to the OECD, 25 May 2001.

BERGER G. "L'Avenir des sciences de l'homme" & "L'attitude prospective" texts from 1956 republished in Philippe Durance (ed.), *De la prospective. Textes fondamentaux de la prospective française (1955-1966) par Gaston Berger, Jacques de Bourbon-Busset et Pierre Massé* (Paris: L'Harmattan 2007).

BREUIL H., BURETTE D., FLURY-HERARD B., CUEUGNIET J., VIGNOLLES D. & BOISSON H., *TIC et développement durable* (Paris: La Documentation Française) March 2009.

BRIENS F., *La Décroissance au prisme de la modélisation prospective: Exploration macroéconomique d'une alternative paradigmatique*, doctoral dissertation, Mines ParisTech, 2015.

COLLARD F., FÈVE P. & PORTIER F., "Electricity consumption and ICT in the French service sector", *Energy Economics*, 27, pp. 541-550, 2005.

DEMIGNY D. & FILIPE A., "MRAM et architectures de calcul", paper presented at the École Thématique du CNRS, *Le spin dans les semi-conducteurs: physique et applications*, La Grande-Motte, France, October 2005.

DROUINEAU M., MAÏZI N. & MAZAURIC V., "Impacts of intermittent sources on the quality of power supply: The key role of reliability indicators", *Applied Energy*, 116, pp. 333-43, 2014.

DUMESNIL P., "Nouvelle économie, toile et soutenabilité", *Terminal*, 87, pp. 109-129, 2002.

FAUCHEUX S., HUE C. & PETIT O. "NTIC et environnement: enjeux, risques et opportunités", *Cahiers du C3ED*, 01-03, pp.1-29, October 2001. Available via https://www.researchgate.net/publication/239565933_NTIC_et_Environnement_Enjeux_Risques_et_Opportunites.

GERSHENFELD N., "Signal entropy and the thermodynamics of computation", *IBM Systems Journal*, 35, pp. 577-586, 1996.

LE GALLIC T., ASSOUMOU E. & MAÏZI N., "Investigating long-term lifestyles changes in France: A statistical and modeling approach", paper presented to the *22nd International Sustainable Development Research Society Conference*, Lisbon, 11-15 July 2016*a*.

LE GALLIC T., ASSOUMOU E. & MAÏZI N., "Future demand for energy services through a quantitative approach to lifestyles", paper presented at the *Eleventh Conference on Sustainable Development of Energy, Water and Environment Systems*, Lisbon, 4-9 September 2016*b*.

LE GALLIC T., *Exploration des évolutions des modes de vie dans les exercices de prospective énergie-climat: développement méthodologique en vue d'appréhender la réalité socioéconomique d'hypothèses de rupture*, doctoral dissertation, Mines ParisTech, forthcoming.

MATTHEWS, H.S., "The environmental implications of the growth of the information and communications technology sector", paper submitted to the Environment Directorate, OECD, Paris, 2001.

MEADOWS D.H., MEADOWS D.L., RANDERS J. & BEHRENS W., *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind* (London: Earth Island & New York: Universe Books, 1972).

MILLOT A., LE GALLIC T., DOUDARD R., ASSOUMOU E. & MAÏZI N., "Carbon neutrality challenges for France in 2072", *International Energy Workshop*, College Park, MD, 12-14 July 2017.

ROMM J., ROSENFELD A. & HERRMANN S., *The Internet Economy and Global Warming: A Scenario of the Impact of E-commerce on Energy and the Environment*, The Center for Energy and Climate Solutions (Global Environment and Technology Foundation), 79p., December 1999. Available at infohouse.p2ric.org/ref/04/03784/0378401.pdf.

WILLIAMS E., AYRES R. & HELLER M., "The 1.7 kilogram microchip: Energy and material use in the production of semiconductor devices", *Environmental Science & Technology*, 36(24), pp. 5504-5510, December 2002.

ZHANG Y. & REN Z., "Optimal reactive dispatch considering costs of adjusting the control devices", *IEEE Transactions on Power Systems*, 20(3), August 2005.