
From Transition Challenges to Smart Grids and Smart Buildings

1.1. Introduction

The consumption of fossil fuels (coal, oil, gas) since the 18th century has undeniably enabled the development of industry, transport and improved living standards, particularly for those living in the more industrialized countries; however, it has also contributed to the increase of greenhouse gases in the atmosphere, responsible for the warming of our planet's climate. This phenomenon is continuing, and if these gas emissions are not rapidly and drastically reduced, global warming will have an enormous impact on the planet and our lifestyles, which will become increasingly consistent and difficult to live with. Fossil fuels are the main source of CO₂ emissions but are not the only culprits.

In [ROB 23], connections between energy and societal issues were highlighted. Section 1.2 of this chapter summarizes the climate challenges. Section 1.3 presents four typical scenarios devised by ADEME to achieve carbon neutrality by 2050. These narratives suggest several possible solutions that are technologically more or less mature, and socially more or less acceptable, sought after or desirable, which are discussed in the remainder of this chapter.

Sufficiency appears to be a major area for development, but it is not the stuff of dreams. Section 1.4 identifies different types of sobrieties, introduces the concepts of smart sharing and wise sharing and discusses the link between human sufficiency and nature's prosperity and the potential drivers and motivators of sufficiency such as meaning, values, spirituality, etc.

The ecological transition raises numerous ethical questions of both a private (individual) and public (institutional) nature, which present a major challenge for

our democracies today: to combine ethics and politics in a way that respects individuals and protects their interests, as well as those of future generations. After summarizing some of these ethical issues, the question of governance to ensure the energy and societal transition in view of its urgent nature is discussed in section 1.5, highlighting the need to reinvent our democracies. The difficulty for politicians to take account of the urgency of climate change and to act to reduce our societies' impact on the climate is a source of eco-anxiety, particularly among the younger generations.

Research must make an essential contribution to the success of the energy and societal transition. To do this, it needs to move out of the laboratory and into the real world, which is interdisciplinary, by testing innovations on a real scale and in real operating conditions, via demonstrations. Section 1.6 develops this necessary shift in the world of research towards trans-disciplinary research in the engineering sciences, the humanities and the social sciences and underlines the importance of systematically assessing the societal and environmental impact of research results. The UN's Sustainable Development Goals (SDGs) are benchmarks for assessing this societal and environmental impact, as are ADEME's four 2050 scenarios. The results presented in this book are based on research work that is generally interdisciplinary, often carried out in partnership with companies or local authorities and in many cases tested by means of demonstrations. They will be positioned in relation to the UN's SDGs and ADEME's scenarios.

Section 1.7 introduces the importance of the energy issue in terms of the transition, with energy consumption needing to be reduced and renewable energies to be increased, and introducing the notion of the smart grid. New modes of local self-production and self-consumption of energy represent a revolution adapted to the development of intermittent renewable energies (such as photovoltaics and wind power). Sharing this energy in collective self-consumption or within local energy communities raises new technological, economic, sociological and ethical questions: can this sharing be smart sharing or wise sharing? The nature of the digital dimension associated with the smart dimension, as well as a few other ethical and sociological concerns, are raised.

Section 1.8 introduces the concept of the smart building, after outlining some 2050 prospects for the building sector and positioning these prospects in relation to ADEME's 2050 scenario. The low-tech approach is also introduced, as it is of particular interest in the digital buildings of the future.

Section 1.9 intersects the concepts of the smart building and smart grid, showing that both will be actively interrelated in the future, with buildings becoming active

nodes (producer, consumer, storage, flexible, integrating electric mobility) of future smart grids.

Section 1.10 summarizes the case studies and methodological contributions of each chapter in the book.

Section 1.11 draws attention to some of the issues raised by artificial intelligence (AI).

1.2. Climatic challenges

For hundreds of thousands of years, the concentration of carbon dioxide (CO₂) in the Earth's atmosphere has remained stable due to a balanced carbon cycle: CO₂ emitted was practically equivalent to CO₂ absorbed, which corresponds to carbon neutrality. However, since human activity has increasingly involved deforestation and fossil fuel combustion, what is emitted exceeds what is absorbed, and CO₂ concentration in the Earth's atmosphere is increasing, leading to a rise in the global temperature [GRA 16].

Due to human activity, the concentration of greenhouse gases has exploded since the pre-industrial period (1750–1800). The concentration of CO₂, the main greenhouse gas, has increased by more than 30% since the pre-industrial era. The combined effects of all greenhouse gases (CO₂, methane, nitrous oxide, carbon monoxide, ozone, etc.) are now equivalent to an increase of over 50% in CO₂ since that period [ROB 21, ROB 23].

Between 1860 and 2010, the average temperature of the Earth's surface rose by 0.6°C, and by 1°C if we extend the period to 2018 [INT 18] and 1.2°C in 2023¹. Various prospective scenarios predict that by 2100, this temperature will have risen by between 1.5 and 7°C if current energy sources and consumption habits are not modified (an estimated increase of 4°C in France and 7°C in the Arctic). This considerable increase would be accompanied by a rise in sea levels of between 20 cm and 1 m, depending on the area of the planet concerned. While climate change appears irreversible, it is possible to slow it down by significantly reducing greenhouse gas emissions, which requires strong and urgent action.

Natural CO₂ sinks such as soils, trees and oceans are only capable of absorbing just under half of the CO₂ produced by human activity (in 2000). In order to stabilize CO₂ concentration at its current level, we would therefore need to immediately

¹ See: <https://wmo.int/fr/news/media-centre/lomm-confirme-que-2023-bat-le-record-mondial-de-temperatures>.

reduce emissions of this gas by 50–70%. While such a drastic reduction is impossible, action is urgently needed, as we are faced with a cumulative problem. Indeed, given that the lifetime of carbon dioxide in the atmosphere is of the order of a century, it will in any case take several generations for CO₂ concentrations to stabilize at an acceptable level. In 2018, the Intergovernmental Panel on Climate Change (IPCC)² estimated that in order to limit global warming to between 1.5 °C and 2 °C by 2100, CO₂ emissions must fall by 45% by 2030 compared with 2010 and by 91% by 2050 [INT 18].

CO₂ is produced by the combustion of all fossil fuels: oil, gas and coal. CO₂ emissions from coal are around twice as high as those from natural gas, with those from oil in between [ROB 21, ROB 23].

Global warming and, more broadly, human activities are having an impact on biodiversity. The rate of species extinction is estimated to be 50 to 560 times higher than the extinction rate for stable biodiversity; this is known as the sixth extinction. Moreover, 11% of our greenhouse gas emissions are due to deforestation and land-use change, with uses that store less carbon, such as palm oil [GRA 16].

Livestock farming is also a major emitter of greenhouse gases, accounting for around 9% of global CO₂ emissions. The primary source of these emissions is the production and transport of food, which requires agricultural land and contributes to deforestation. The second source of emissions is ruminant gastric fermentation. According to the IPCC, beef farming emits five times more CO₂ worldwide than pig or chicken farming.

Figure 1.1 shows the evolution of annual mean global surface temperature, observed and simulated by the IPCC over the period 1850–2020. The black line represents the observed temperature. The brown line represents the temperature evolution simulated by the IPCC model, taking into account human and natural factors. The green line represents the evolution of this temperature considering only natural factors such as solar and volcano activity. The bold-colored lines show the model averages, and the colored shading shows the probable limits of the simulation

2 The IPCC was set up in 1988 and published its first report in 1990. Two years later, the United Nations Framework Convention on Climate Change was adopted, with the aim of stabilizing greenhouse gas emissions. The COPs, or Conference of the Parties, are the annual meetings of the members of this Convention. In 1990, under the Kyoto Protocol, industrialized countries agreed to reduce their emissions by 5% between 2008 and 2012 (compared with 1990 levels). However, these agreements were scarcely respected. It was not until 2015, with the Paris Agreements, that the parties made a strong commitment. They call for the rise in average global temperature to be kept below 2°C compared with pre-industrial levels or ideally 1.5°C. Only a tiny proportion of signatories are meeting these commitments.

range. This figure clearly shows the decisive influence of human activities. Over the same period, the increase in atmospheric CO₂ has risen from 280 ppm (or parts per million) in 1850 to 400 ppm in 2020, following a curve similar to that of observed mean temperature ([ROB 23] and Figure 1.1).

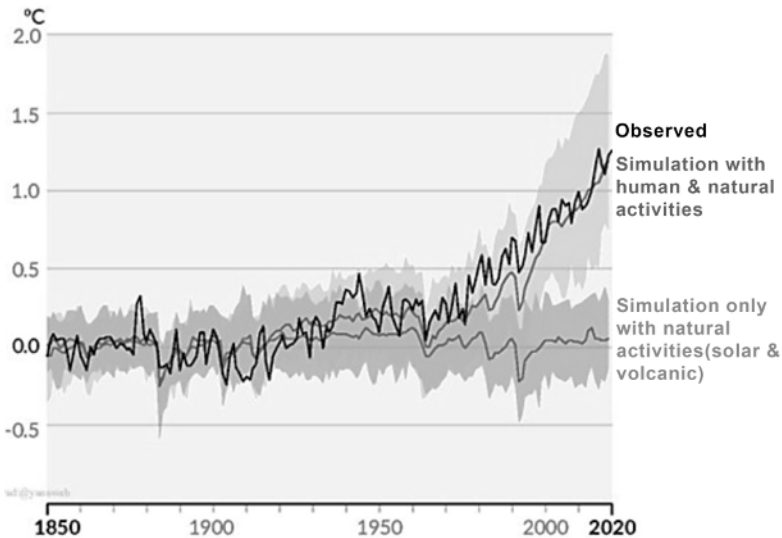


Figure 1.1. Change in average annual global surface temperature observed (in black) and simulated by the IPCC³ over the period 1850 to 2020, with simulation taking human activities into account (in brown) or not (in green). For a color version of this figure, see www.iste.co.uk/robyns/smartgrids.zip

1.3. Four inspiring social and climate scenarios

In order to limit the temperature rise by 2100 to 2°C, we need to aim for carbon neutrality by 2050. Carbon neutrality does not simply mean that we no longer emit carbon at all, but that the carbon still emitted is either offset by the development of carbon sinks (forests) or that this carbon is captured and stored so that it is not released into the atmosphere.

With the aim of achieving carbon neutrality by 2050, various organizations are proposing scenarios based on the evolution of technologies, the economy,

³ IPCC Report 2021: Summary for Decision-makers. See: <https://resumegiec.wordpress.com/2021/08/11/ipcc-report-summary-for-decision-makers/>.

governance and territories, as well as our lifestyles. In France, three organizations have proposed scenarios for 2021: négaWatt, ADEME and RTE. The negaWatt [NEG 21, ROB 23] and ADEME [ADE 21] scenarios present proposals that can be widely shared worldwide.

Greenpeace [GRE 13], the World Commission on the Economy and Climate [THE 15] and the American economist Jeremy Rifkin [RIF 12] propose scenarios with an international vision. The main thrusts of these scenarios are that sufficiency should strongly influence our lifestyles (particularly those geared towards mass consumption), that energy efficiency in our systems (housing, transport, industry, etc.) should be increased, and that renewable energies should be used more extensively. However, the weight of these axes differs from scenario to scenario.

These scenarios form the basis of so many possible narratives for our next 30 years; it is realistic for one or other of them to materialize in order to achieve carbon neutrality by 2050, but are they desirable? One big unknown is the acceptability and appropriation of these scenarios by the population, particularly those calling for sufficiency. These scenarios generally presuppose a social mutation, a change in behavior or even a rupture in everyone's vision of the world and their relationship with it. The challenge is therefore to make these scenarios desirable.

In the remainder of this section, we introduce and discuss ADEME's four transition scenarios for 2050, to serve as a reference point for the methodological and experimental proposals and the various developments presented in the rest of this book.

Figure 1.2 summarizes ADEME's S1 and S2 transition 2050 scenarios, while Figure 1.3 summarizes ADEME's S3 and S4 scenarios [ADE 21].

Let us start with the fourth S4 scenario, entitled "Restoration Betting"⁴, as it is the closest to current lifestyle trends. The lifestyles of the early 21st century are preserved, but the proliferation of goods consumes a lot of energy and materials, with potentially strong impacts on the environment. Society places its trust in the ability to manage, and even repair, social and ecological systems with more material and financial resources to maintain a habitable world. This exclusive reliance on technologies is a gamble, given that some of them are not yet mature. This gamble is based on, among other things, the capture and storage of CO₂ already present in the atmosphere, thanks to technologies that are not yet technically and economically mature on a large scale. This scenario also predicts an increase in the importance of

4 Proposed translation for: *Pari réparateur*.

digital technology, the ubiquity of the Internet of Things (IoT)⁵ and AI [ROB 23], and data centers consuming 15 times more energy in 2050 than in 2020 [ADE 21].

This S4 scenario is a business-as-usual scenario, close to the current trend in our society, with a high risk of not achieving the necessary carbon neutrality by 2050, while leading to depletion of materials and other resources before 2050. Although this scenario relies heavily on innovation, research and development, it does not appear realistic from the point of view of the 2050 target and even less desirable. Indeed, we might well ask whether focusing on adaptation and repair might not entail ratifying the continued economic development of activities that generate greenhouse gases. François Gemenne then speaks:

of “maladaptation”, that is to say a “process of adaptation which results directly in an increase in vulnerability to climate variability and change and/or in an alteration of current capacities and opportunities and ‘futures of adaptation’”. This is the case when these projects increase greenhouse gas emissions, increase pressure on the most vulnerable, cost too much (compared with more effective policies), or commit countries to technological paths on which they will become dependent. Today, we have a problem with the concept of growth: we have always associated it with the idea of having more, doing more, and so growth is necessarily inseparable, for the moment, from greenhouse gas emissions. The big challenge will be the idea of associating growth with the idea of doing better, not more [VIO 20].

The third scenario, S3, entitled “Green Technologies”, is based on technological development to meet environmental challenges, rather than on behavioral changes towards greater sufficiency. Metropolises are growing. Technologies and digital technology, which enable energy efficiency and the optimization of material resources, concern all sectors. The best technologies are widely deployed and widely accessible to solvent populations.

This scenario predicts that data centers will consume ten times more energy in 2050 than in 2020. However, the energy would be decarbonized, and the CO₂ still emitted would be captured and stored [ADE 21]. Numerous innovations, R&D projects and demonstrations [ROB 23] are being developed in line with this scenario. While this scenario seems realistic for reaching the 2050 target, we will need to assess the carbon impact of the technologies we develop with ever greater precision, in order to minimize it, while integrating the socio-technical, economic and ethical dimensions.

⁵ The Internet of Things concerns objects (appliances, buildings, etc.) connected to the Internet, enabling communication between them and digital algorithms.

In this scenario, the transformation of jobs towards more specialized ones is very likely, with the risk of accentuating inequalities if “green technologies” are difficult to appropriate and not necessarily affordable. This scenario, which is essentially aimed at solvent individuals, therefore runs the risk of increasing social inequalities, and as such is undesirable.

ADEME’s second scenario is entitled “Territorial Cooperation”⁶. Society is being transformed by shared governance and territorial cooperation. Non-governmental organizations, public institutions, the private sector and civil society are finding pragmatic ways of cooperating to maintain social cohesion. To achieve carbon neutrality, society is betting on a gradual but steady evolution of the economic system towards a sustainable path combining sufficiency, efficiency and renewable energy. Consumption of goods is becoming measured and responsible, and sharing is becoming widespread [ADE 21]. Meat consumption is halved, and housing renovation is favored over new construction and adapted to the number of occupants. Land is no longer artificially developed, and nature is preserved and even protected. Personal mobility is reduced by 17%, while encouraging the development of medium-sized towns.

This scenario relies on the sharing economy (or economy of functionality), the circular economy, second-hand approaches and therefore second lives for appliances, clothing, etc. To ensure that everyone is aware of their environmental impact, the carbon footprint of each and every one of us should be measured on a regular basis. This scenario seems both realistic and desirable for reaching the 2050 target. One major obstacle will be the highly developed individualism of Western societies.

The first scenario, entitled “Frugal Generation”⁷, relies on major alterations to the ways in which we travel, heat, eat, buy and use equipment. It makes it possible to achieve carbon neutrality without involving carbon capture and storage technologies, which are unproven and uncertain on a large scale. New consumer expectations and, above all, new consumption practices are rapidly taking shape. The growth in energy demand, which is depleting resources and damaging the environment, is being interrupted by behavioral, organizational and technological innovations. The transition is mainly driven by frugality through constraint (increasing user costs, restrictive regulations, etc.) and sufficiency [ADE 21].

6 Proposed translation for: *Coopérations territoriales*.

7 Proposed translation for: *Génération frugale*.

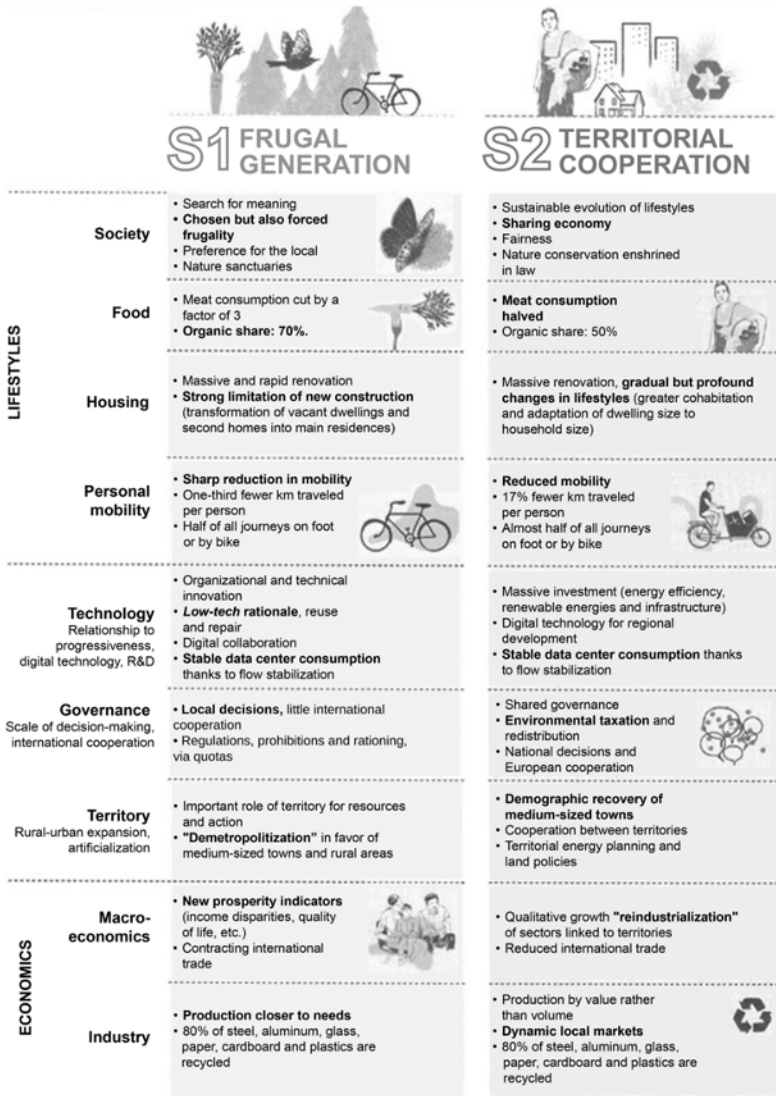


Figure 1.2. Summary of ADEME's S1 and S2 transition 2050 scenarios [ADE 21]⁸

⁸ See: <https://transitions2050.ADEME.fr/>.

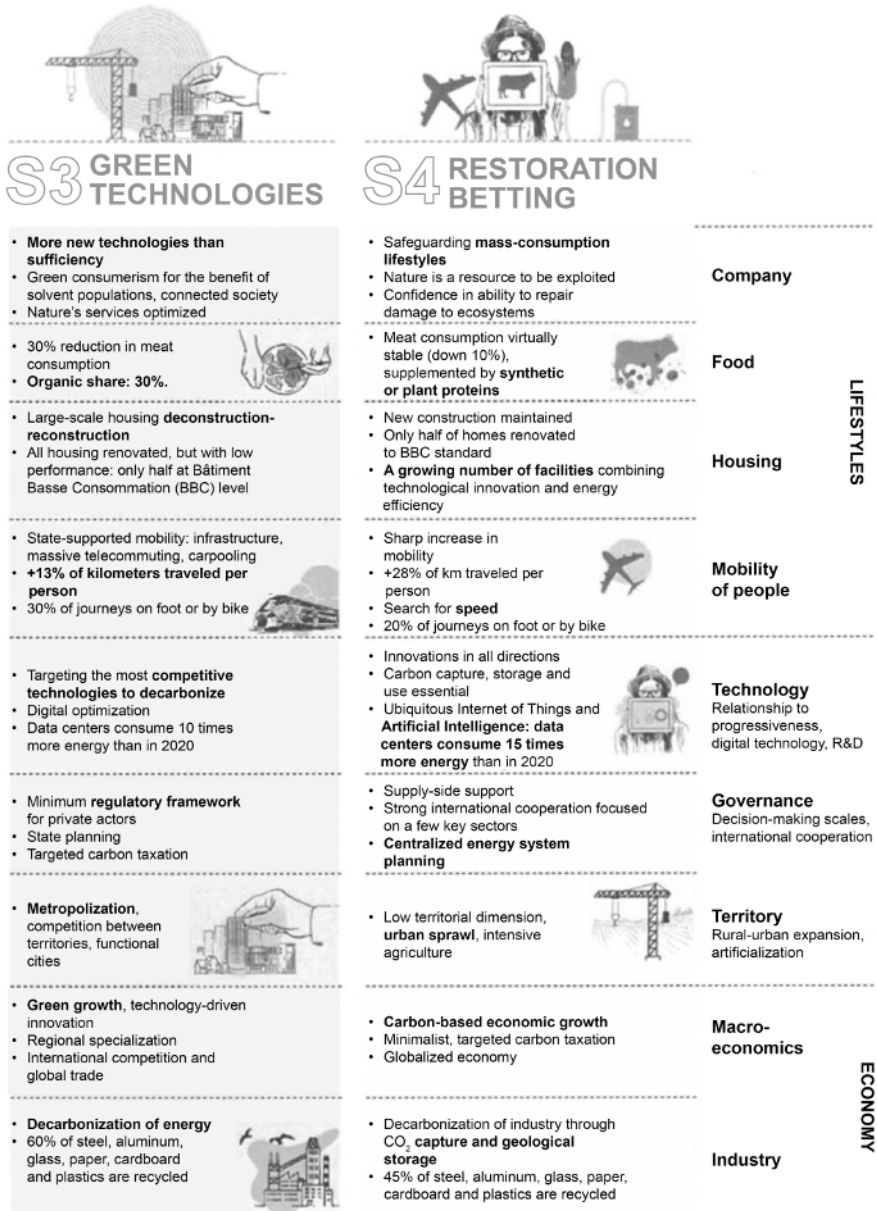


Figure 1.3. Summary of ADEME's transition 2050 S3 and S4 scenarios [ADE 21]⁹

9 See: <https://transitions2050.ADEME.fr/>.

This scenario is based on a search for meaning, leading to a consensual frugality (but also partly constrained by legislation), a preference for local products and a sanctuary for nature. It advocates a threefold reduction in meat consumption; a sharp reduction in mobility, stipulating that half of all journeys be made on foot or cycle; and the renovation of 80% of the building stock to be converted into low-energy buildings. Governance favors local decision-making, and the introduction of new economic indicators (based on income disparities, quality of life, etc.), the development of low-tech production (with a low carbon footprint) as close as possible to needs and a circular economy (with a high material recycling rate). To achieve these objectives and make this scenario realistic, we sense the need for strong governance, a reinvention of democracy (a strong democracy with a mandate to change lifestyles?) and the existence of a truly ecological political force that believes in its legitimacy. To make this scenario desirable and sought after, we need to show the link between human sufficiency and the prosperity of the planet and its biodiversity and the link between sufficiency and a quest for meaning and spirituality. A major obstacle to this scenario is the greed that has become the moral and economic model of the 20th century, but which is also inherent to human nature [BHO 19]. These issues will be discussed later in this chapter and touched upon throughout this book.

Jeremy Rifkin, who was the promoter of the Third Industrial Revolution [RIF 12], which was implemented in particular in the Hauts-de-France region [ROB 23], gives his vision of the future, updated for the world of today:

The change in consciousness is real, it is resilience versus efficiency. Be more sufficient? Okay, we can make an effort, consume less, etc. But that is still staying within the same framework. It means staying within the same framework, in a more cramped environment. That is not enough. We need to move to a completely new system of economic governance, from growth to fulfillment, from financial capital to ecological capital, from productivity to recycling, from GDP to quality-of-life indices, from hyper-consumption to cyclical economics, from vertically integrated scales to a lateral economy, from giant conglomerates to networks of connected SMEs, from intellectual property to open sources, from geopolitics to biomanagement or biopolitics [RIF 22, authors' translation].

In [ADE 21], ADEME compares the different scenarios applied to France, according to a number of criteria. By way of illustration, Figure 1.4 compares the energy consumption of the four scenarios in 2050 with that of France in 2015, specifying the share of renewable energies (REs). In scenario S1, energy consumption in 2050 is 44.6% of that in 2015, while in scenario S4 it is still 77.6%.

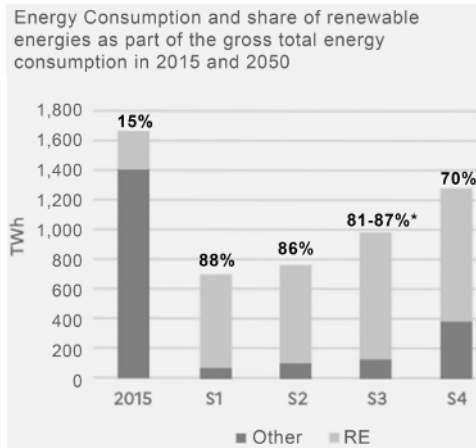


Figure 1.4. Comparison of the energy consumption of the four scenarios in 2050 with that of France in 2015, specifying the share of renewable energy (*values dependent on industrial policy choices to develop floating wind farms or nuclear power) [ADE 21]. For a color version of this figure, see www.iste.co.uk/robyns/smartgrids.zip

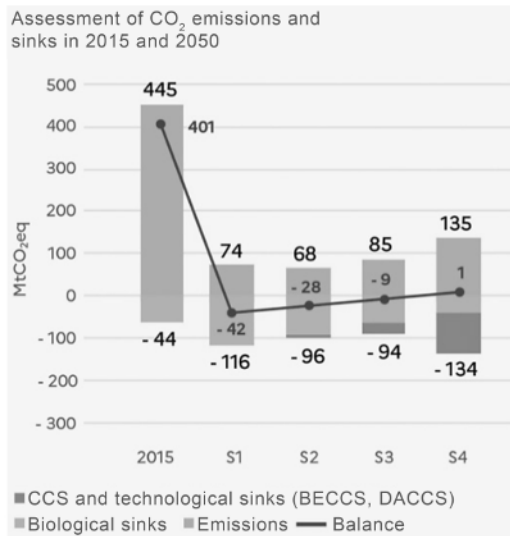


Figure 1.5. Carbon emissions and sinks for the four scenarios in 2050, compared with the 2015 assessment for France [ADE 21]. For a color version of this figure, see www.iste.co.uk/robyns/smartgrids.zip

Figure 1.5 shows the emissions and carbon sinks for the four scenarios for France in 2050, compared with the 2015 figures. Natural carbon sinks are shown in green, and the carbon that would be recovered by technological solutions is shown in gray. The importance of technological CO₂ capture in 2050 in scenario S4, which frankly is a bold bet on the future, makes this scenario less credible than scenarios S1, S2 and S3.

1.4. Sufficiency or prosperity

1.4.1. *Personal, shared and organizational sufficiency*

Sufficiency is therefore one of the major areas to be developed. It takes on several dimensions, partly conceptualized by the négaWatt Association¹⁰ [VIL 18, WIK 20a, ROB 23], in a spirit of equity and sharing:

- dimensional sufficiency: choosing equipment that is adapted to needs, when making purchases or investments (e.g. preferring a small surface area for your home, using a vehicle that is adapted to the load and number of passengers, etc.);

- cooperative sufficiency: pooling uses, whether of space, goods, etc. (e.g. carpooling, car-sharing, sharing, lending equipment to neighbors, etc.);

- sufficiency of use: reasonably managing the use of appliances and goods (e.g. eco-driving, precautions to limit breakage and premature wear of goods, heating regulation, etc.);

- organizational sufficiency: structuring activities differently in terms of space and time (e.g. promoting telecommuting, regional planning, provision of public transport, etc.);

- material sufficiency: reducing the consumption of material goods and products (e.g. reducing the level of equipment, limiting packaging, etc.). These same goods indirectly require energy to design, assemble, transport, etc. This is known as indirect energy or gray energy.

Sufficiency can therefore be a personal commitment, shared and collaborative, but it also concerns organizations (companies, administrations, local authorities, associations, etc.). It is the commitment to sufficiency at all these levels that will contribute to achieving the 2050 objective of the energy and societal transition. While organizational sufficiency can be imposed, at least in part by the management

¹⁰ French non-governmental think tank for energy experts. Recommends solutions on energy demand and supply in the context of France's energy transition.

of these organizations or by the legislator, personal and shared sufficiency requires a strong commitment on the part of each individual.

1.4.2. From smart sharing to wise sharing

For businesses, and also for healthcare organizations and other sectors, Navi Radjou [RAD 19, RAD 21] proposes a business-to-business (B2B) sharing economy, which complements the peer-to-peer sharing economy (consumer-to-consumer sharing (C2C), strongly developed since the 2008 economic crisis) whose champions are now known to all: Uber, Airbnb, BlaBlacar, etc. For Radjou, the B2B sharing economy has potential benefits for social inclusion, the environment and health, particularly if we can move from smart sharing to wise sharing. This sharing can involve waste that can become raw materials for other companies, buildings and other equipment; joint purchasing; skills via human resources; customers; or even intellectual property.

But why would a company want to commit to B2B sharing? Companies need to be clear about their motivation and make clear their commitment to this path. Radjou's analysis highlights the following fact:

If most companies answer the “why?” question with “we just want to save money or make more money”, we shall see the rise of smart sharing, whose limited objective is simply to make the current capitalist economic model, with all its flaws, even more efficient. However, if most companies answer “we want to have a positive social and ecological impact”, then they can enable wise sharing, whose lofty goal is to radically reinvent entire industries and accelerate the transition to a frugal economy in the post-Covid-19 world [RAD 21, authors' translation].

Radjou summarizes his analysis graphically, shown below in Figure 1.6.

One potential benefit of wise sharing for companies is to contribute more rapidly to the 17 SDGs to save the world, outlined by the United Nations (UN) and shown in Figure 1.7. These Sustainable Development Goals set out the path to a better, more sustainable future for all. They address global challenges such as poverty, inequality, climate change, environmental degradation, prosperity, peace and justice. These 17 objectives are broken down into 169 sub-objectives, to which the contribution of each actor (company, community, association, university, etc., as well as individuals) can be assessed by means of indicators.

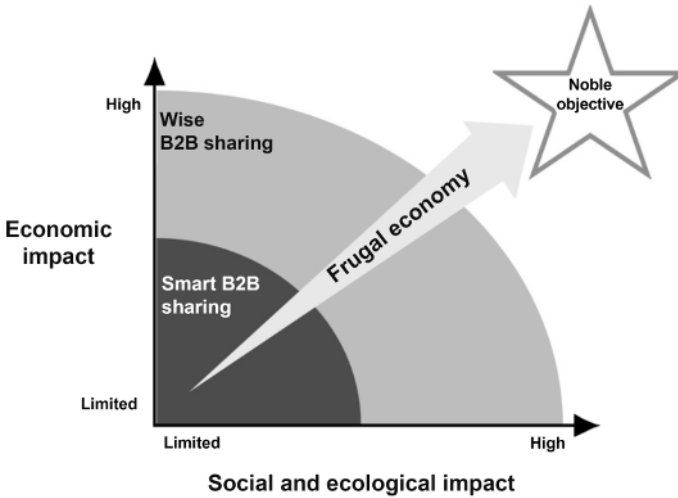


Figure 1.6. *Economic, societal and ecological impacts of smart sharing and wise sharing between companies (B2B) [ARD 21]. For a color version of this figure, see www.iste.co.uk/robyns/smartgrids.zip*

Radjou points out, however, that:

Given the climate emergency, companies must go far beyond the concept of “sustainability” and rapidly adopt the principles of regeneration, a set of science-based practices that aim to reverse global warming, for example by sequestering carbon in products and processes. Whereas a sustainable business just aims to reduce its carbon footprint and waste (negative impact), a regenerative business consciously aims to expand its positive socio-ecological footprint – i.e. “doing more good” – by boosting the health and vitality of people, places (communities) and the planet [RAD 21].

Food companies, for example, can help reduce world hunger by sharing their intellectual property with others (in the same way that Open Science is developing within academic research by making scientific publications accessible to all). Medical care can be improved by sharing care equipment and pooling purchases (including medicaments), thus improving health and well-being worldwide.



Figure 1.7. *The 17 UN Sustainable Development Goals (SDGs)*

Radjou also cites a thought-provoking example of carpooling in France:

70% of French people drive to work and spend an average of €6,049 a year on car maintenance. 70% of these home-to-work journeys are made alone. Private cars contribute to almost 16% of France’s greenhouse gas emissions. Public transport is not practical for all workers, given that 40% of French people live in areas poorly serviced by public transport. Inspired by the great success of BlaBlaCar, which facilitates carpooling between individuals, startups Klaxit and Karos have built carpooling networks dedicated to companies, offering their employees a sustainable, comfortable, user-friendly, and economical mobility solution. Klaxit and Karos alone facilitate more than three million home-to-work carpools a day. Karos estimates that, thanks to its carpooling services, its business users save an average of two full tanks of gas per month and 26 minutes per trip [RAD 21, authors’ translation].

1.4.3. From sufficiency to prosperity

Sufficiency, however, is not the dream of the majority of the population, even though over the centuries, philosophers, hermits, monks, clerics, movements seeking simplicity or even a break with the dominant world, etc., have extolled its virtues or lived it. However, the greed advocated as a core value in the West throughout the 20th century is at odds with sufficiency. In his book *Le Bug Humain* [BHO 19], Sébastien Bohler argues that:

In reality, the brain is a largely defective organ, bent on destruction and domination, pursuing only its own interests and unable to see beyond a few decades. We are swept along in a headlong rush of overconsumption, overproduction, overexploitation, overeating, over-indebtedness, and overheating, because part of our brain is automatically pushing us to it, without us currently having the means to curb it [BHO 19, authors' translation].

This controversial thesis needs to be qualified, however, by considering the influence of other biological mechanisms, the weight of socialization, education, norms, etc., and all the new contributions of the human and social sciences [WIK 22].

According to economist Gaël Giraud:

[I] do not believe that over-consumption is deeply rooted in the human soul. Material abundance as such is not part of the Enlightenment project. Contemporary consumption is a matter of impulse, but desire is not impulse: the Lacanians will be happy to remind you of this. Billions are spent every year on marketing and communication to keep these artificial needs alive, this deadly idea that life is one big supermarket, and that happiness lies in the devouring impulse. This conditioning will evaporate in a few years as soon as we ban advertising for polluting goods and services, starting with SUVs. Grenoble has banned all advertising in public places. What a liberation for our brains! Imaginations can change very quickly [VIO 20, authors' translation].

Sociologists and philosophers Bruno Latour and Nikolaj Schultz [LAT 22] encourage the development of an ecological class based on the following analysis:

Energies are easily mobilized when it comes to increasing production. Yet increased production, development and progress are aberrations associated with the destruction of the Earth's habitability. However, our mental structures, our moral systems, our organization, our administration, our laws, all our "equipment" is designed to manage increased production (authors' translation).

The ecological class must therefore work towards a:

decisive change of tack [...] giving priority to maintaining the habitability conditions of the planet and not to developing production. [...] As the long history of the Earth shows, it's living things that have

enabled the continuity of terrestrial life [...] To produce means to assemble and combine resources; it does not mean to engender, that is, to carefully induce the continuity of beings that the world's habitability depends on. Instead of the strange metaphor of development, it would be more helpful, if we want to capture this reversal, to talk about envelopment: all the issues of production are surrounded, wrapped up in the practices of engendering they depend on. We're used to seeing "growth" as the sole means of getting out of trouble, forgetting about the destruction it causes, whereas prosperity has always depended on engendering practices. It's not a matter of degrowing but finally prospering [LAT 22].

Prosperity, then, rather than sufficiency, in the knowledge that the prosperity of nature is generally conducive to the prosperity of human beings. But how can we reverse this worldview and return to the principles of growth and development of living things to be protected and imitated (biomimicry) and concern ourselves not only with the world in which we live, but also with the world from which we live [BOU 22, LAT 22]?

Let us try to interpret these different considerations by means of the synthetic diagram in Figure 1.8¹¹. Human sufficiency contributes to the prosperity of a nature that is no longer systematically enslaved by humankind to satisfy its growing needs. As nature regains its freedom, it becomes abundant; observing it, contemplating it, meditating within it on our link with it, living a spiritual experience that connects us to humanity past, present and future, to nature, to the cosmos and beyond become sources of inspiration for a more sufficient life that goes to the essentials. Encouraging existential and civic commitments, including concern for otherness, the most vulnerable and the most disadvantaged, opens up intelligence in all its various forms.

Obviously, greed distances us from nature and is not conducive to its prosperity. Nevertheless, awareness of the benefits of a more sufficient life must be rooted in a world order experienced by each individual. This order can be religious, secular or cosmological. Ideally, it will link what we observe, contemplate, meditate on or experience spiritually, inscribing it in a narrative that feeds our imagination and positively affects our emotional world. This will enable us to stop living in cognitive dissonance, i.e. according to psychologists, in tension between our thoughts, beliefs and emotions, in the hope of leaving our grandchildren a pleasant planet to live in, and our attitudes, which are still largely consumerist and predatory towards nature.

¹¹ Benoît Robyns thanks Anne-Laure Boursier, a doctoral student in philosophy at the ETHICS Unit of the Université Catholique de Lille, for her inspiring exchanges on this subject.

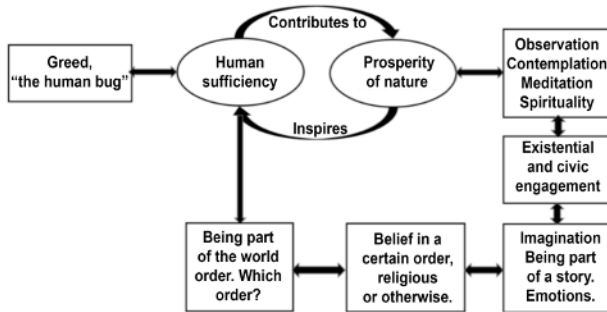


Figure 1.8. *The link between human sufficiency and nature's prosperity, what strengthens this link and what detracts from it*

1.4.4. Spirituality and ecological transition

In his encyclical *Laudato si* [POP 15], Pope Francis urges us to listen to the clamor of the Earth and the clamor of the poor! To become aware of a common origin, a mutual belonging and a future shared by all.

This awareness will be greatly helped by a spiritual experience that everyone can have, like the one described by André Comte-Sponville in his essay *L'esprit de l'athéisme*:

We were walking [...]. The starry sky above me, immense, unfathomable, luminous, and nothing in me but this sky, of which I was a part, nothing in me but this silence, this light like a happy vibration, like a joy without subject, without object [...]. Nothing in me but the dark night, the dazzling presence of everything [...] [COM 06, authors' translation].

Or as Spinoza wrote in *Ethics*: “We feel and experience that we are eternal” [SPI 11, authors' translation].

Well, there you have it: I had felt and experienced it, indeed, and it was like a revelation to me, but without God. It was the most beautiful moment I've ever experienced, the most joyful, the most serene, and the most obviously spiritual. [...]. Intellectually, I see no proof of anything: but I can't pretend it didn't happen either [COM 06, authors' translation].

Philosopher Glenn Albrecht speaks of the “Earth Emotions”:

What does a surfer feel when he catches a beautiful wave? How do we feel when we walk into a forest? When we walk beside the ocean? For much of our history, we have not needed to name these psychic states, to describe what moves and affects us when we come into contact with the Earth. However, as a result of deforestation, land artificialization, global warming and the sixth mass extinction, we are losing these emotions, along with landscapes, species, sounds and the fine-tuning of the senses that brought them to life within us. At the same time, we are increasingly mediatizing our relationship with nature: held back by our telephones, obsessed by our screens, we find it harder and harder to literally feel the beauty of our environment. We live entrenched in technological bubbles, monopolized by the pulses of work and consumption [VIO 20, authors’ translation].

Thierry Magnin analyzes the following fact:

Faced with the great challenges of ecological transition, for example, human beings realize that without an inner drive, shared with others, no real change is possible. Lifestyles cannot be transformed without transformation of the heart, without “conversion” in the etymological sense of turning around. Does not the return of spirituality in our Western societies correspond to a lack that may have dried up man’s heart and enclosed him in a dehumanizing materialism? [MAG 22, authors’ translation].

According to André Comte-Sponville, “the spiritual [...] is that which appeals to man’s interiority, makes him reject the inhuman, invites him to fulfill himself in a search for transcendence and to give meaning to his actions, puts him in touch with others and leads him to give, exchange and receive” [COM 06, author’s translation].

In an essay, Thierry Magnin analyzes the spiritual dimension of the human being, linking its body-psyche-spirit dimensions [MAG 21] from non-religious and religious angles. He stresses the difference and complementarity of psychological and spiritual experiences. Medical experience highlights four dimensions of an individual’s spiritual life:

- meaning (that which guides life, what gives a profound reason for living);
- values (what characterizes what is good and true for a person);

- transcendence (relationship to the ultimate, elements that transcend a person, in relation to that which a person names his or her existential relationship);
- identity (singular coherence of the person, uniqueness of the subject, whether at the level of his or her thoughts, emotions or relationships) [MON 10].

More recently, the life sciences have highlighted the relationship between the biological, the psychic and the spiritual. Biology shows that the environment influences the evolution of living organisms, right down to the expression of their genes (epigenetics). Epigenetics shows that certain genes are inhibited, while others are strongly expressed, depending not only on the biological environment, but also on the behavior of living beings themselves. In the case of humans, for example, it has been shown that nutrition, exercise, stress management, pleasure and social networks can all influence epigenetic mechanisms, demonstrating that the biological and psychic realms are in a permanent reciprocal relationship. Epigenetics opens up new horizons, suggesting that what humans pass on to their descendants could be the fruit, in part, of their behavior [MAG 17, MAG 21, MAG 22]!

Thierry Magnin notes that in so-called “mindfulness” meditation (presently very popular), we initially focus on the level of the mind (the mental, in terms of the psyche), favoring a possible opening to the universal and to the spirit (and therefore potentially to awareness of nature and its prosperity, and of our interdependence with other humans and with nature) [MAG 21].

Teilhard de Chardin, a forerunner of the “everything is connected” concept, emphasized the collective aspect of human interaction, of creative union at the level of humanity, under the influence of the Omega point of convergence in the universe, the source of the “amorization”¹² that irrigates all creation (the Noosphere nourished by Love, by Spirit). Love is thus the summit of the spiritual life. A love that personalizes within a linked humanity: a link between two humans “from center to center”, says Teilhard, a link between humans and the cosmos, all of which enables a dynamic of Socialization and Personalization [DEC 76, MAG 21]. For Teilhard, Personalization is that internal deepening of consciousness upon itself that characterizes the particular destiny of the element (individual) that has become fully self through reflection. Teilhard extends this notion to the collective future, to the evolutionary equilibrium of the Noosphere [DEC 55].

¹² “Amorization” refers to the act of being primed, strengthened or invigorated by divine love. “The priming of the Universe [...] The Universe “amorising” and personalizing itself in the very dynamism of its evolution [...]: provided sufficient attention is paid to its extraordinary and significant power of “pan-amorization”” (Pierre Teilhard de Chardin, *Le Christique*, 1955) (French Wiktionary definition, authors’ translation).

For Luc Ferry, the question of meaning and that of the sacred – why it would not be foolish to consider sacrifice – are inseparable [FER 96]. The sacred can be religious, it can be our children, grandchildren and great-grandchildren, it can be nature, etc. Ferry highlights a secular spirituality in *La révolution de l'amour* [FER 10], which does not deny a secular transcendence (in immanence, which assumes that there is something that comes from outside, of which we are the discoverers and not the creators), and which can be a source of powerful commitment in the ecological transition.

Spirituality is therefore a human dimension linking humankind's perception of themselves to their relationship with the world, and with transcendence – that which is greater than us and passes through us – whether religious (the attribute of God, “the transcendent” par excellence) or secular (that which is beyond what we commonly admit being humanly capable of thinking). It is an experience that appears to be a powerful motor for committing to the ecological transition by transforming our habits and lifestyles over the long term. This spiritual dimension broadens our horizons, encouraging sufficiency and frugality, gaining freedom, and finding peace by uniting body, mind and spirit, divided between the gravity of the planetary situation and the absence of decisive changes in our behavior. Drawing on transcendence provides us with external resources and powerful energy, whereas human beings, however militant they may be, who draw solely on their internal energy, run the risk of burning out more quickly.

1.5. Ethical and political issues

1.5.1. *Ethical issues in the ecological transition*

In [ROB 23], Malik Bozzo-Rey summarizes some of the ethical issues raised by the energy and societal transition. To sum up, climate issues and the necessary transition raise immense challenges such as:

- the confrontation between the interests of people living now and those who will live in the future (with the difficulty of acting in the interests of people we will never know, such as our great-great-grandchildren);
- the prospect of a less prosperous future and/or one with living conditions different from today's, forcing us to reassess what we mean by a “good life” or a “fulfilled life” (or a “more sufficient life”);
- if the basic needs of the majority of the world's population cannot be met in the future, then we will have to face tragic situations where the choice between life and death will no longer be simply hypothetical.

Bozzo-Rey stresses the need to rethink and question three presuppositions that have structured modern ethical thinking:

- the interests of present generations coincide with those of future generations;
- future people will be better off than we are;
- favorable living conditions will continue indefinitely.

He concludes that in order to identify the best ways of influencing behavior and lifestyles, the energy and societal transition requires the unification of private (individual) and public (institutional) ethics, something which presents a major challenge for our democracies today: to combine ethics and politics in a way that respects individuals and protects their interests, as well as those of future generations [ROB 23].

In *The Imperative of Responsibility*, Hans Jonas stresses that “we are responsible for the future, all the more so insofar as we know neither certain consequences (of our technological choices, our lifestyles), nor their probabilities of occurrence (of the harmful effects induced by our choices), yet these may have an “infinite” destructive power (or at any rate be sufficiently great to compromise human survival on a large scale)”. More than 40 years ago, Hans Jonas was already advocating the Responsibility Principle, which reads as follows: “Act in such a way that the effects of your action are compatible with the permanence of authentically human life on Earth” [JON 77, authors’ translation].

In his encyclical *Laudato si* [POP 15], supplemented by the encyclical *Fratelli tutti* [POP 20] on fraternity and social friendship, Pope Francis insists that “it is not enough to balance, in the medium term, the protection of nature with financial gain, or the preservation of the environment with progress [...] it is a matter of redefining our notion of progress [...] A technological and economic development which does not leave in its wake a better world and an integrally higher quality of life cannot be considered progress” (LS 194).

1.5.2. Questions of governance or the need to reinvent democracies

ADEME’s various scenarios are based on technological developments and changes in individual behavior, as well as on modes of governance that may differ considerably from one scenario to the next. Scenario S1, “Frugal Generation”, assumes a strong state presence, but which kind of state? Scenario S2, “Territorial Cooperation”, assumes a decentralization of power to local authorities that cooperate with each other. Scenario S3 “Green technology” assumes a regulatory state. Scenario S4 “Restoration Betting”, on the contrary, is part and parcel of today’s globalization, a globalization that has been undermined by the Covid-19 crisis and

the geopolitical situation brought about by the war in Ukraine (to name but one example). Nevertheless, ultimately, does not the ecological emergency call for new planning “from the top down”? According to Patrick Jolivet of ADEME:

To achieve carbon neutrality by 2050, we need to effectively implement structuring choices now. However, planning does not exclude participation. Just as participation does not induce paralysis. Didn't the 150 members of the Citizens' Climate Convention¹³ manage to come to an agreement on a measure as divisive as limiting freeway speeds, even though it was spontaneously rejected by a large majority of French people? This means that with a well-informed process of collective deliberation, we can make choices that go beyond our immediate interests, in the name of a democratically defined common good [ADE 22].

In 1972, the *Meadows Report* by Dennis Meadows, Donella Meadows and Jørgen Randers, entitled *The Limits to Growth*, was published, setting out for the first time the dramatic consequences of exponential growth in a finite world: resource depletion, oil crisis, serial shortages, etc. In an interview with Usbek and Rica in April 2022 [MAY 22], Jørgen Randers deplores the fact that this prescient report has concretely affected barely 5% of Westerners, while bringing about some changes in the daily lives of ordinary people, voters and workers. According to Randers' analysis:

We cannot grow our population, our use of natural resources, our CO₂ emissions, or our land use forever. Our global footprint must be reduced. On the other hand, we are in no way saying that economic activities should stop. GDP is measured in dollars, not in tons of CO₂ emissions: theoretically, GDP can grow as long as these two curves remain decoupled [although, in [ROB 23], Chapter 1, a link between GDP and CO₂ emissions is highlighted via the economist Kaya's equation]. The problem is that this distinction very quickly disappeared in favor of a longsuffering discussion on “sustainable development” [...] contrasted with degrowth [note that the UN SDGs presented in Figure 1.7 do not assume economic degrowth] [MAY 22, author's translation].

Although Randers agrees with the IPCC that fossil fuels should be phased out, enabling a rapid reduction of 70–80% in CO₂ emissions, he notes that humanity can

13 The Citizens' Climate Convention, an unprecedented democratic experiment in France, was designed to give citizens a say in accelerating the fight against climate change. It was held in 2019–2020. See: <https://www.conventioncitoyennepourleclimat.fr/>.

continue to increase greenhouse gas emissions until at least 2050, without depleting natural and food resources. In this case, he predicts that “a global collapse is not the most likely outcome – at least not in the next fifty years. What is more likely is that we will not be able to bring down the curve of greenhouse gas emissions fast enough. We will probably exceed +2.5°C, which will lead to social and localized collapses” [MAY 22, authors’ translation].

By “collapses”, Randers considers that:

Inequality levels will continue to rise, as will unemployment rates. People will become increasingly dissatisfied with the unpredictability of weather events and the inaction of their governments. Public services will be outdated. Politicians will no longer have a clear majority for their decisions to be sufficiently consensual. This will create very strong social tensions [...]. There will be a fall in the level of well-being, but GDP will continue to rise – because it represents the total value of wealth produced, even if it is unbalanced [MAY 22, authors’ translation].

To limit the consequences of these potential collapses, the question of governance arises. According to researcher and political scientist François Gemenne, it is quite simply “impossible to convince a majority of people to vote for a program compatible with the Paris Agreement”¹⁴ (authors’ translation), at least in unindustrialized countries. Randers points out:

The weakness and limitations of our democratic systems since the 1990s [...]. The short-term interests that parasitize our institutions are very powerful. Similarly, at the individual level, no ordinary worker will willingly agree to pay the additional taxes needed to implement policies adapted to the challenges of the future. The energy transition, for example, implies the closure of all jobs linked to the fossil fuel industries and the opening up of new jobs in renewable energies. The problem is that, in the meantime, many jobs are disappearing. That is why, in my view, these policies can only be led by strong states, able to provide the necessary financial compensation to the employees concerned. Private companies will never be able to take on this task alone, as their interest will always remain short-term profit [MAY 22, authors’ translation].

14 The Paris Climate Agreement is an international treaty on global warming adopted in 2015. It covers climate change mitigation, adaptation and financing. The agreement was negotiated by 196 parties at the 2015 Paris climate change conference in France (Wikipedia).

However, is it a strong democratic state or a strong authoritarian state?

Randers continues:

In the West, it seems that neoliberalism has been pushed to the limit. We have now reached a point where it is impossible not to reintroduce a strong state to provide for the needs of the population. The difficulty is that, from a political point of view, the divisions into two or three blocs – as in the United States with the Republican bloc and the Democratic bloc, or as in France with the far-right bloc, the centrist bloc and the leftist bloc – are likely to deepen in the coming decades. To overcome this difficulty, I have been advocating for some years now the creation of a small assembly in each country, entirely dedicated to the long term. It would be made up of around fifteen people elected for life, rather like the American Supreme Court. It would have veto power over all public decisions impacting on greenhouse gas emissions. The only other alternative is the Chinese model: a central party that enlists the most educated. They become the masters of all decisions because they are considered to have the most experience. Conversely, it is a far less democratic system. It would take us back several centuries [MAY 22, authors' translation].

Nevertheless, as economist Gaël Giraud points out:

At the heart of the fossil fuel world, private banks are the main obstacle to ecological reconstruction. Many of their assets are linked to oil, coal, or gas. This is hardly surprising: their balance sheets reflect past economic activities, which have been massively dependent on sub-surface energy sources. If tomorrow, by some extraordinary occurrence, these investments were to lose all value and become stranded assets, most banks would have to declare bankruptcy. This was recognized in 2015 by the head of the Bank of England, in a speech that became famous under the title *Tragedy of the Horizons* [CAR 15]. These institutions have all the more reason to slow the greening of the economy as British Petroleum has already begun to devalue its assets [VIO 20, authors' translation].

Giraud points out that “despite this, in 2018, an Oxfam report showed that for every €10 invested by French banks, seven still go to fossil fuels, and two to so-called renewable energies [POI 18] [...]. The banks are back at it again, talking about “sustainable finance” and “green bonds” to boost their image. Unfortunately, for the moment, this is nothing but greenwashing [EKE 19]. Collectively, we need to decide on their future. Should we nationalize them and create a bad bank, as we did

in 2008, to rid them of stranded fossil assets? If so, who will foot the bill?" [VIO 20, authors' translation]. In the end, public authorities have a decisive role to play, one that will certainly require a great deal of courage!

Radjou also stresses the importance of governance to accelerate B2B sharing between companies and organizations and to move from smart sharing to wise sharing. Public authorities must be urged to accelerate the movement, and governments must set up a new regulatory framework and introduce tax incentives. Some regulatory constraints need to be eased in critical areas such as legal liability, taxation, intellectual property protection and workers' rights [ARD 21].

However, despite the urgency of climate change, the weakness of ecological political parties in most countries is questionable. According to Latour and Schultz's analysis:

On the contrary, ecology seems to propose a step backwards, questioning the idea of progress and wanting to limit our freedoms. It therefore generates negative emotions. To mobilize people, we need to find ways to get them excited about ecology. However, the ecological class has not yet sufficiently engaged in the cultural battle, and it sorely lacks an aesthetic capable of fueling political passions [LAT 22, authors' translation].

A priori, sufficiency does not inspire dreams, it is not really a spontaneous practice, and lifestyle changes are not encouraged by a natural resistance to change. Latour and Schultz ask "how to bring about the emergence of an 'ecological class, conscious and proud of itself', which would contribute to giving ecology a central political place, as has been the case in the past for liberalism, socialism or neo-liberalism" [LAT 22, authors' translation]. In 76 propositions, they present an action plan designed to make ecology the new political paradigm.

In section 1.4.3, we have already introduced the notions of "engendering" and "prosperity", concepts that Latour and Schultz develop to provide a new vision, a new positive narrative for ecology. The authors propose using the concept of "prosperity" to designate wealth that does not imply increased production, which destroys ecosystems or material accumulation. In fact, they call for an effort to express ecological issues in enthusiastic terms, whereas today ecology is often perceived as punitive. Indeed, to prosper is a word with a positive connotation that can be interpreted, in line with its etymology, as conveying hope: to prosper is to enjoy healthy air, clean water, quality food and to be surrounded by natural ecosystems that are not degraded and that are aesthetically pleasing and that also prosper. It is also the possibility of being free from the frenzy of consumerism, while

still having enough material goods, without destitution or excessive clutter. The idea of prosperity conveys a utopian vision of ecology. Taking care of the world in this way allows us to “maintain the conditions of habitability”. Prosperity is the consequence. Indeed, “prosperity has always depended on begetting practices. It is not a question of decreasing, but of finally prospering” [BOU 22, LAT 22, authors’ translation]. It is about re-enchanting the imaginary world around ecology and allowing nature to prosper once again, to the delight of humanity and the planet’s biodiversity!

Finally, let us make mention of François Gemenne’s very pragmatic vision:

Of course, it is very difficult to anticipate the effects of global warming: we can reduce uncertainties, but we shall never achieve perfect model transparency. That is why we need to work on developing the resilience of populations and territories. Among the “vulnerability” factors that need to be taken into account are the configuration of space (how dangerous is submergence), the sensitivity of the environment (the degradation of sand dunes, for example), the cohesion of society (social redistribution, the feeling of solidarity), the diversity of economic and food-producing activities, the political and institutional organization and the living conditions of the population (income). [...] These models take us away from the purely economic model: the poorest are not necessarily the most vulnerable, even if economic resources play an important role. What is more, this approach frees us from the dichotomy, which I believe to be futile, between ecology and capitalism. Rather than waiting for the big night or a utopian upheaval in our behavior, it is preferable to redirect investments towards technologies and services that emit less carbon. It is not capitalism we should be aiming for, but short-termism: for the moment, the expected rate of return on capital is directing investment towards the “fossil fuel” economy. Adaptation saves us from long-term costs, which is inevitably less attractive, but states can regulate finance and markets [VIO 20, authors’ translation].

The European Union (EU) has presented the Green Deal for 2019. This is a set of measures designed to start the EU on the path of ecological transition, with the goal of achieving climate neutrality by 2050. It promotes the transformation of the EU into a fair and prosperous society with a modern and competitive economy. The Green Pact has been defined by Commission President Ursula von der Leyen as the EU’s “new growth strategy” to reduce greenhouse gas emissions “while creating jobs and improving our quality of life”¹⁵. The EU’s target of reducing greenhouse

15 See: www.consilium.europa.eu/fr/policies/green-deal/.

gas emissions by 55% between 1990 and 2030 (Fit for 55) was revised at the end of 2022 to achieve a more ambitious reduction of 57%.

1.5.3. *Eco-anxiety*

Parts of the population, mainly young people, feel abandoned by those in power who are deemed unaware of the climate emergency; in particular, by politicians who are often powerless in a democratic system yet to be reinvented, as explained in section 1.4.2, or caught up in power games.

The concept of “eco-anxiousness” has been around since the late 1990s. The “eco-anxious” develops anxiety in the face of predicted ecological disasters: climate disruption, loss of biodiversity, pollution, deforestation, etc. This anticipatory anxiety is not a pathology, but a healthy natural reaction to awareness of the short- and long-term impacts of climate change, which are already observable today. A study published in *The Lancet* [MAR 21], based on a survey of 10,000 young people aged between 16 and 25 carried out in 10 different countries, reveals that, for 74% of the young French people questioned, the future is frightening, and that for 77% of them, we have failed to take care of the planet. Many young people stressed that their anxiety was linked to political decisions perceived as ineffective and compared to a form of betrayal on the part of the generations that preceded them [FOU 21, OGO 22].

Not all classes of the population are affected in the same way, as illustrated by Figure 1.9 showing greenhouse gas emissions by income group in France in 2021. Average greenhouse gas emissions are 8.5 tonnes per French person per year in 2021. However, this average conceals a wide disparity: French people with the lowest incomes emit far less greenhouse gases.

“Eco-anxiety” is to be distinguished from solastalgia. For Glenn Albrecht, “solastalgia is the pain or illness caused by the loss or lack of comfort and sense of isolation associated with the current state of one’s home and territory” [ALB 05, authors’ translation]. In this case, it is not a question of anticipation, but of living in a deteriorating habitat and environment, of feeling homesick.

These new concepts point to a malaise linked to the environment, highlighting a cognitive dissonance between our obsolete categories and practices, and the forms of human life to be invented to make the planet habitable in the future.

It should be noted that this phenomenon of “eco-anxiety” is part of a fundamental framework in which we already have difficulty integrating our vulnerability and finitude [GRE 22], vulnerability and finitude further exacerbated

by the rapidity of climate change and its consequences. Thierry Magnin points out that:

The feeling of being misunderstood, even despised by the powers that be, is transformed into a demand for personal freedom against a backdrop of injustice, discrimination, and uncertainty about the future. In a world plagued by the Covid-19 pandemic, psychological insecurity is superimposed on social and economic insecurity, fueled by new fears linked to global concerns about the effects of global warming, terrorism, growing immigration and uncontrollable geopolitics. And many are wondering what might happen to them in these uncertain times. The hardships of life are all the more keenly felt [MAG 22, authors' translation].

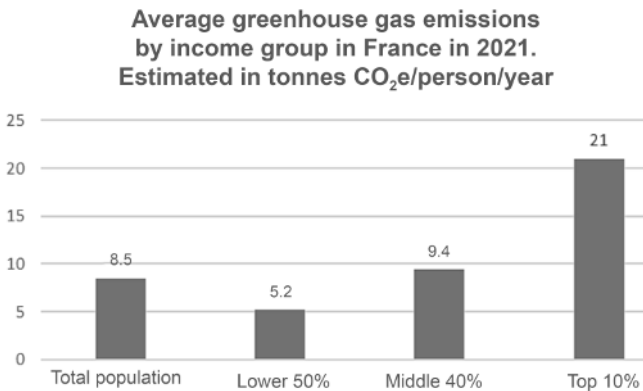


Figure 1.9. Greenhouse gas emissions by income group in France in 2021 [OGO 22] (Source: Lucas Chancel)

Against this backdrop and given that our societies are finding it difficult to make the ecological transition, we need to learn to live with our eco-anxiety. Individually, as physician Alice Desbiolles [DES 20] explains, solutions do exist. “Reconjugating our lives to the present” by not constantly anticipating the future, “avoiding hyper-responsibility and hyper-guilt”, “learning to let go without giving up”, “getting rid of anxiety-provoking observations *to move towards solutions and courses of action*” are just some of the possible keys. Being part of a collective is also an excellent remedy [OSO 22, authors' translation].

1.6. Bifurcating research

Implementing the energy and societal transition will require full-scale experimentation with a wide range of technological, economic and local societal solutions, while accepting trial, error and adjustment. The aim is to validate the viability of technologies, their effectiveness and impact on the environment, their acceptance and social appropriation, which are by no means automatic, to find new economic models and to design new legal frameworks. It is also a question of convincing, to limit resistance to change. It is about being examples, being exemplary [ROB 23].

Science and technology are generally developed in laboratories under controlled test conditions¹⁶. This generally leads to the development of prototypes for innovations. The complexity and rapidity of the transition make it necessary to test emerging solutions more systematically under real-life conditions, where not everything is under control, particularly climatic conditions and human behaviors. For example, smart building technologies not only need to be tested, but also ideally designed, with the users of a building under normal operation.

Confronting the realities of the field with what is happening requires us to engage with a wide range of disciplines, not just electrical and communication technologies (for smart grids, for example), but also sociological ones (to assess the acceptability and involvement of stakeholders), economic ones (to find viable new models), legal ones, ethical ones, etc. Interdisciplinarity, and even transdisciplinarity, will be essential to the success of the transition.

The legislator needs to define a framework that allows, and even encourages, the deployment of demonstrations, by delimiting “playgrounds” with “sandboxes”, by allowing for the right to experiment over several years.

To make sure that energy and societal transition is a success, we need to get the various scientific and humanities disciplines to work together, in order to develop the interdisciplinary approaches between the humanities, social sciences and engineering sciences that are essential to a successful transition that belongs to everyone. Each field of science has developed its own methods and language, which are shared by an often-restricted community. This makes dialogue between the sciences difficult. Researchers need to simplify their discourse to make it more accessible to non-experts in their discipline. Exchanges between disciplines on vocabulary and methods are essential to identify more precisely the possibilities for dialogue. Interdisciplinary research, which crosses disciplines, and transdisciplinary

¹⁶ The growing use of AI, however, may call this presupposition into question. This topic is discussed in section 1.11.

research, which makes equal use of the expertise of at least two disciplines, must be encouraged and recognized by the authorities who guide and evaluate research, because this effort to cross disciplines is an adventure that takes time to be productive; and up to now, evaluations of research activities have been essentially mono-disciplinary. Time is needed to build trust and respect for different disciplines on an ethical basis.

Some innovative and promising technologies have not been as successful as expected, because potential users have not accepted them or appropriated them. These technologies were developed primarily with a technical logic in mind, without considering the interests and acceptability of users from the outset. Examples include Google Glass, a pair of augmented-reality glasses that can film people without their knowledge, and France's smart electricity meter (Linky), which, based on a fine-grained measurement of a home's consumption, would provide insight into the habits of its inhabitants. It cannot be decreed that this or that technological solution will be good for the planet without integrating the sociological, psychological, ethical, economic and legal dimensions as far upstream as possible in their design, in addition to assessing the impact or even the gains, for the environment. In other words, we need to develop interdisciplinary approaches and support the changes brought about by transition.

Interdisciplinary research with a desire to develop full-scale, manned demonstrations can fuel "action research", which can be defined as research in which there is a deliberate action to transform reality, research with a dual objective: to transform reality and to produce knowledge concerning these transformations [WIK 20b].

In an article published in *Le Monde*, "Science et Médecine", David Larousserie notes that "more and more researchers are deciding to modify their way of working, even to change their subject of study, to branch off, to get out of inertia in the face of global warming, to maintain coherence between their values and their practices or quite simply to "make humanity possible tomorrow", as Jean-Michel Hupé, one of these "bifurcators", simply sums it up" [LAR 22, authors' translation]. At the end of 2020, this CNRS researcher left his neuroscience laboratory in Toulouse for another team in the human and social sciences. Gone will be the study of synesthesia and vision, replaced by work in political ecology. "I was increasingly uncomfortable with the idea that nothing was happening, while climatologists were making clear observations about the climate situation", he recalls (authors' translation). By the end of 2018, he had set up Atécopol¹⁷ in Toulouse, a collective made up of around 160 members designed to "share knowledge and make it operative in the face of ecological devastation".

17 An amalgamation of "Atelier d'écologie politique": Political Ecology Workshop.

The year 2019 saw the creation of “Labos 1point5” [LAB 22], which is committed to carrying out greenhouse gas assessments and helping labs make the transition. In [HUM 21], scientists recount their intimate encounters with the Anthropocene.

While it is important to assess the environmental impact of research (laboratories, publications, conferences, travel, etc.), it is becoming necessary to assess the societal impact of the results of a research activity. This assessment can be based on the UN’s Millennium Development Goals (Figure 1.7) and its 169 sub-goals. It is no longer just a question of scientific evaluation based on the impact of scientific publications in specialized journals, but of assessing whether the results and innovations of the theme are accessible, appropriable and have concrete spin-offs for society (i.e. a wide audience) through popularization actions (conferences, publications, mass media, social networks, etc.), training, dissemination of technical or software applications or services or new economic models (circular economies), etc. Open science, which makes scientific publications freely available on the Internet, is a step in the direction of accelerating the transition, but these publications are generally not understandable and appropriate for a wide audience.

By way of example, Figure 1.10 illustrates the sub-objectives of the UN’s SDGs, research themes that Junia¹⁸ builds on and contributes towards, following a pre-analysis of the outputs of these themes.

The results presented in this book come from research work that is generally interdisciplinary, often carried out in partnership with companies or local authorities and in many cases tested by means of demonstrations. They will thus be positioned in relation to the UN’s SDGs and ADEME’s scenarios.

1.7. Smarter energy networks

1.7.1. From 100% renewable energy to a combination of solutions

Energy is a fundamental issue for a successful energy and social transition. We need to stop consuming fossil fuels, and to do so, we need to consume renewable energy, either directly in thermal form or in electrical form. As the latter is a very practical energy vector for many uses, electrical energy consumption will tend to increase, even though, overall, energy consumption will have to decrease; for the planet, the best energy is the one we do not consume!

In 2021, the French electricity transmission system operator published its six energy evolution scenarios for France up to 2050 [RTE 21]. The focus is on

18 The Junia Engineering Graduate School in Lille, France.

electricity, but this is a key aspect of all the scenarios that set out our possible futures, because while overall energy consumption is set to fall, electricity consumption will increase as it replaces fossil fuels in many sectors: transport, including electric vehicles, industry, hydrogen production from renewable sources, etc. This increase would be 35% in 2050 compared with 2020.



Figure 1.10. Sub-objectives of the UN’s SDGs, research themes that Junia builds on and contributes towards (Source: Muriel Billamboz and Franck Chauvin)

However, the report insists on the need to reduce overall energy consumption by increasing the energy efficiency of our energy systems and through energy sufficiency, which some see as the first response to the environmental crisis, while

others reject the principle in the name of individual freedoms and the maintenance of a subjective form of “comfort” [RTE 21]. This reduction is estimated at around 40% by 2050 compared to 2020, but new European targets aim to accelerate this reduction to 55% by 2030. The various ADEME scenarios forecast reductions of between 22.4% and 55.4%, depending on the type of scenario (Figure 1.4).

A scenario based on 100% renewable solutions, for electricity generation only, has been proposed by ADEME [ADE 18] and RTE [RTE 21]. Given the fluctuating nature of many renewable sources – wind, photovoltaic, small-scale hydro and marine energies [ROB 21] – it will be essential to develop electrical energy storage [ROB 15, ROB 16, ROB 19] and load flexibility, i.e. to modulate electricity consumption over time, in particular by adapting to the variability of renewable sources, and also to investigate and adapt electricity networks. RTE imagines different variants of this scenario, depending on the level of development of onshore and offshore wind power, as well as photovoltaics. One scenario predicts that one out of every two houses in France will be equipped with photovoltaic panels for partial self-consumption [ROB 19].

However, RTE also foresees scenarios in which part of France’s electricity would still be generated by nuclear power, by extending existing plants and building new ones. According to RTE, these scenarios would be less costly in terms of investment than a 100% renewable scenario, except that uncertainties over the extension of certain power plants and delays in the construction of new plants will probably lead to these scenarios reaching their objectives in 2060 rather than 2050. In this case, to achieve the 2050 targets, in spite of everything, the economic balances of the different scenarios would be similar.

Scenarios based on combined energy solutions, with renewable and nuclear energies, include in some cases the capture of CO₂ emitted by fossil fuels that are still in use, even though they are declining significantly, and by certain industrial processes [ROB 23]. These scenarios are proposed, for example, by ADEME [ADE 21] and the IPCC [INT 18].

However, by 2022, the financial assessments of these scenarios had to be revised, due to the impact of the recovery from the Covid-19 crisis, the war in Ukraine, and the shutdown of many French nuclear reactors for maintenance, as well as corrosion problems in these reactors (32 out of 56 by mid-2022 and another 15 or so shut down by the end of 2022). In its July 19, 2022 edition, the French newspaper *Les Echos* ran the headline “Wind Power: Surprise \$8 billion gain for the State”¹⁹ [WAJ 22]. This expected gain for 2022 and 2023 is explained by the supplement remuneration system. Under this system, the state supplements operators’

19 Proposed translation for: *Éolien : un gain surprise de 8 milliards pour l’État.*

remuneration when the market price is lower than the tariff granted to renewable energy projects (EUR 80 to 120 per MWh). Conversely, when the market price is higher than the agreed feed-in tariff for renewable electricity, operators pay back the excess to the state (by mid-2022, MWh was fluctuating between EUR 300 and 500 or even more). This compares with EUR 30 to 50 per MWh in January 2020. Forecasters predict that this cost could reach EUR 1,000/MWh by early 2023.

The same applies to photovoltaic solar power, which is tending towards financial equilibrium. These renewable energies are clearly becoming competitive, all the more so given that we can expect electricity costs to continue to rise (but hopefully to levels below EUR 1,000/MWh) and gas costs to rise (by a factor of 10 between early and mid-2022).

According to Jeremy Rifkin:

Solar and wind power are the cheapest and most competitive energies, and they also consume the least water. In the United States, 41% of freshwater reserves are used to cool nuclear power plants. There are 12,000 nuclear and thermoelectric power plants worldwide. In their place, renewable energies would save 95% of the world's freshwater. Why continue with nuclear and fossil fuels when solar or wind power are so much cheaper and less predatory on natural resources? [RIF 22, authors' translation].

1.7.2. Towards the decentralization of electricity grids

The historical organization of an electricity grid is based on centralized management of the transmission network, to which traditional nuclear, thermal and hydro generation units are connected. At the time, the distribution network only served consumers, and only carried power flows from the higher voltage levels, from the interconnection points with the transmission network, to the lower voltage points. At the distribution level, however, control is limited, and system services (voltage and frequency control) are therefore provided at the transmission network level by the generating units connected to it [ROB 15, ROB 19, ROB 21].

The development of decentralized generation, generally low-power, unplanned and not centrally controlled, is changing the picture considerably; it is often connected to the distribution grid and dispersed over a territory, unlike conventional high-power generation, which is concentrated in a limited number of well-identified sites. Today, the impact of the integration of this generation – mainly wind and photovoltaic, and also run-of-river hydro and marine resources [ROB 21] – is becoming increasingly significant and is creating new constraints. The variable and

forecast error-prone nature of these renewable sources obviously greatly complicates grid management.

The liberalization of the electricity market, which has been underway in the European Union since the beginning of the 21st century, has led to the separate management of electricity generation, which is subject to competition, from the management of transmission and distribution networks, as the latter's infrastructure cannot be multiplied. In France, the CRE²⁰ [COM 19] is responsible for ensuring that the competition mechanisms that are being put in place are respected, while regulating this competition to ensure that it is not unfavorable to consumers and does not jeopardize an infrastructure that is vital to the country's economy and security. This liberalization calls for new approaches to managing the power system, and new market mechanisms that take into account the characteristics of the new decentralized sources. Starting from the premise that electricity grids cannot be rebuilt, three types of evolution will be necessary:

– at source level: by using the functionalities offered by power electronics to develop new control and supervision strategies to participate in system services, notably by associating energy storage, and by developing multisource systems (integrating intermittent renewable generation, predictable conventional sources and storage) with integrated and optimized energy management [ROB 15];

– at grid level: by deploying smart grids, developing new grid architectures such as microgrids to increase the efficiency, security and availability of electricity grids and increasing energy storage capacities, whether centralized or dispersed throughout these networks [ROB 15, ROB 19];

– at consumer level: in industrial processes, tertiary and residential buildings, electric and plug-in hybrid vehicles, as well as guided transport systems (trains, metros, streetcars) [ROB 17, ROB 19], in order to modulate energy demand according to demand, available renewable production and electricity grid constraints.

Actions between these different system components require a certain degree of coordination, which raises the question of the degree of decentralization that is desirable or acceptable, and the need for a system of communication between these components. These issues are not purely technological, but integrate economic and sociological aspects and will require new developments in the legal framework, energy consumption patterns and the link between production and consumption, in turn raising ethical questions.

20 Commission de régulation de l'électricité: an independent body that regulates the French electricity and gas markets. It is a member of the European Union organisation ACER and the all-European CEER.

1.7.3. Smart grids, self-generation and self-consumption

This calls for the implementation and use of new communication technologies, combined with advanced management tools. System and network intelligence has two facets. The first corresponds to the intensified deployment on transport and distribution networks of a telecommunication network, devices and equipment enabling a higher degree of telecontrol and automation of network operation. The second involves advanced management of generation (centralized and decentralized) and load, resulting in the development of new products and services by producers and suppliers for network operators to increase the degrees of freedom in network control, and for end consumers, who could benefit from service offerings and pricing systems enabling them to adopt ambitious behaviors with regard to the control of instantaneous electricity demand and the integration of renewable energies [ROB 19].

Smart grids will really unfold their innovative potential by fostering interactions between the various actors in the electricity system (producer, consumer, storage operator, network manager), themselves becoming “electrically” smarter actors. These actors have very different consumption and/or production profiles and very different economic and societal objectives and/or constraints. New sets of actors may therefore emerge, enabling us to target new business models, but also to meet energy and climate challenges, by promoting the development of renewable energies. One of the challenges of this evolution is to ensure that all actors win, not forgetting those in fuel poverty [ROB 19].

According to Erik Orsena:

The time has come for consumers to take revenge on pro-producers. The most striking example is energy. The ancient mode of production was in the hands of monopolies. No other source was available. The market opened wide to many new actors [ORS 18].

The development of renewable energy sources therefore encourages local production close to the loads to be supplied and therefore local consumption. This is particularly true for energies where the primary source varies independently of demand, where there is no natural storage (e.g. in the form of water or fuel) and where production forecasts are subject to error, as in the case of wind power and photovoltaics. In this context, we define self-generation and self-consumption of renewable energy, based on Figure 1.11, as follows [ROB 19]:

– Self-generation is the share of total consumption provided by local renewable energies, on one day for example; i.e. area C/area B (generally calculated over one year).

– Self-consumption is the share of renewable production consumed in real time, on a given day for example; i.e. area C/area A (generally calculated over a year).

On the basis of Figure 1.11, we can also specify definitions for zero- or positive-energy buildings by extending the reasoning over one year:

– A building is zero-energy if surface area B is equivalent to surface area A over one year.

– A building is energy-positive if surface area B is less than surface area A over one year.

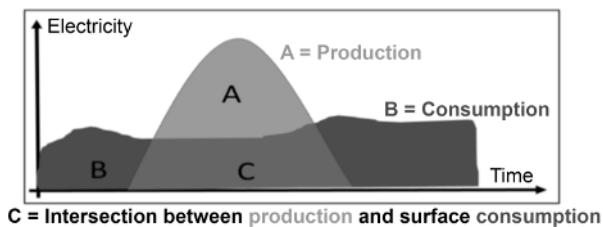


Figure 1.11. Self-generation and self-consumption over a 24 hour day. For a color version of this figure, see www.iste.co.uk/robysns/smartgrids.zip

A local network will only be able to operate autonomously, or be islanded from the main electricity grid, if production A is at all times, in the absence of energy storage devices, equal to or greater than consumption C.

Self-generation and self-consumption of energy will encourage the development of renewable energy communities encouraged by the European Union and a return to short circuits and local production [ROB 23]. It should be noted that self-production and self-consumption tend to make users more aware of the origin of the energy they consume, thus encouraging them to seek greater efficiency in their consumption, control it better and be more sufficient.

1.7.4. An increasingly miraculous electricity fairy – yes but?

The development of self-consumed locally generated energy raises fundamental ethical questions, since energy, particularly electrical energy, has become indispensable in industrialized societies to ensure our lifestyles in terms of comfort, health, safety, education, etc. Indeed, self-consumption calls into question today's highly centralized electricity grids in terms of production and management; in fact,

it constitutes an energy revolution that could be compared for collective self-consumption, in an extreme situation, i.e. if the public distribution grid operator no longer played the role of trusted third party, to the “uberization” (exchange of services between private individuals without going through large established companies thanks to Internet applications) of urban car transport services or short-stay accommodation. Except that the availability of electricity has become crucial to the functioning of our societies, which have become highly dependent on it²¹, and that self-consumption could call into question the French principles of energy solidarity and equal access to energy (in terms of cost). These last points raise new ethical questions, particularly in view of the risk of increasing energy insecurity or even the emergence of energy communitarianism.

Is it not conceivable that self-consumption could enrich consumers who are already in a favorable position, such as well-off households who are able to install solar panels on the roofs of their homes? These considerations echo smart sharing and wise sharing (see section 1.4.2).

Self-consumption also aims to develop the production of “new” renewable energy sources (mainly solar, and also wind and small hydro), which are by their very nature variable and weather-dependent (with significant diurnal and seasonal effects). Ongoing climate change means that there is added uncertainty as to how these new technological approaches will behave in the future.

These considerations should lead us to bear in mind an ethical rule proposed in [GIO 18]:

You will not entrust your children with the task of solving problems that you have voluntarily created, that are vital for your descendants and for which you are not certain of the existence of a realistic solution, now or in the future. On the other hand, the advances generated by scientific discovery and or technical development under consideration will aim to strengthen the common good and promote the restoration of the original ecosystems, if they provide balance and harmony, wherever possible [GIO 18, authors’ translation].

21 One novel masterfully illustrates the rapid collapse of our societies in the event of a widespread and sustained power cut. It is *Black-out* by Austrian author Marc Elsberg (Penguin Books, 2016). A novel can undoubtedly do more to open up imaginations than a scientific work.

The aim is not to limit research on the development of smart grids and self-consumption, but to ensure that this research is regularly challenged by the ethical issues highlighted above (even though the risks appear to be of a lesser magnitude and of a different nature than those induced by the development of nuclear energy). This will require interdisciplinary approaches to these issues, combining science and technology with sociology, economics, ethics and even legal issues. Lawmakers will play an important role in providing an “ethical counterweight” [GIO 18] to new methods of energy production and consumption.

These new modes of production and consumption, combined with better control of consumption with a view to reducing it and making it flexible, to adapt as much as possible to the times of availability of renewable energies, but also to contribute to reducing the constraints to which electricity grids are subject in this new decentralized context, will make increasing use of communication and data management resources. These abundant data, or big data, will enable AI (see also section 1.11) algorithms to assist users and actors in buildings, energy networks and cities to make them more economical and sustainable, to turn them into smart buildings, smart grids and smart cities²².

However, we need to be careful since digital technology and AI are energy hungry. AI requires machines with rare materials for batteries, electrical power for operations and lots of energy to cool and air-condition hardware. Solutions are emerging, however, to recover the heat released by data centers and use it for other purposes. We also need to think about what data are *really* useful, how often they need to be acquired and what operations need to be carried out wisely [ROB 23] or even whether we need to implement low-tech solutions (approaches to the design and evolution of products, services, processes or systems that aim to maximize their social utility while controlling their environmental impact [ADE 22]).

In 2018, the digital sector accounted for 3.7% of global greenhouse gas emissions, and 4.2% of global primary energy consumption; 44% of this footprint was due to the manufacture of terminals, data centers and networks and 56% to their use [FRE 20]. Currently, the digital sector emits as much carbon as the air transport sector. In 2019, the digital sector accounted for 2% of France’s carbon emissions. Growth of up to 6.7% in 2040 is predicted if nothing is done to reduce the carbon

22 Once again, a novel illustrates very well the potential excesses of the all-digital world through the global network that is the Internet, combined with ever more powerful AI (thanks to Deep Learning), which some imagine or dream could make machines conscious, or even become a planetary brain, drawing parallels with Teilhard de Chardin’s Noosphere. The book in question is *Immortal* by Portuguese author J.R. Dos Santos (Hervé Chopin, 2020, for the French edition). Enough to open up the imagination!

impact of digital technology [FRE 20]. ADEME's S3 scenario predicts that data centers will consume 10 times more energy in 2050 than in 2020, while the S4 scenario predicts a 15-fold increase (Figure 1.3 and [ADE 21]).

In their book *La servitude électrique* [DUB 21], sociologists Gérard Dubey and Alain Gras draw our attention to the invisible or hidden sides of the electricity fairy and the risk of enslavement to digital technology:

Contemporary digital society is indeed the product of an electrical history in which polluting generators and waste are relegated to the background. The machines of our e-world seem to be borne by the enchantment of a fairy to whom the algorithm owes its social existence. The image of green transition is an old story [DUB 21, authors' translation].

These authors note that “even though coal's share of the energy generation is declining in wealthy countries, including the United States, on a global scale, coal is once again the leading energy source, accounting for almost 40% of the total due to demand for electricity” [DUB 21, authors' translation]. In fact, growth in electricity demand is outstripping the development of renewable energies, so the trend is to meet this demand by exploiting energy that is still abundant and available just about everywhere (particularly in Asia, led by China and India, and in Africa). This is illustrated by Figure 1.12, which shows emissions from fossil fuels (and cement used by the construction sector) from 1990 to 2022; after a decline in 2020 due to Covid-19, the rise continues and is particularly high for coal, the biggest CO₂ emitter. As Dubey and Gras put it:

Make no mistake, [...] a large part of the relative sufficiency of the rich is due to globalization and the outsourcing of their energy consumption. The world's various workshops work for the West and deliver their goods with energy that is counted as a debit. Here we have another layer exposing the conditions for the existence of the electrical phenomenon, but in the second degree [DUB 21, authors' translation].

Figure 1.13 illustrates the evolution of greenhouse gas emissions according to the economic situation of countries: emerging, developed, less advanced. Only in developed countries will emissions fall significantly. Total emissions for 2022 are estimated to have risen to 40.6 gigatons of CO₂, compared with around 23 gigatons of CO₂ in 1990.

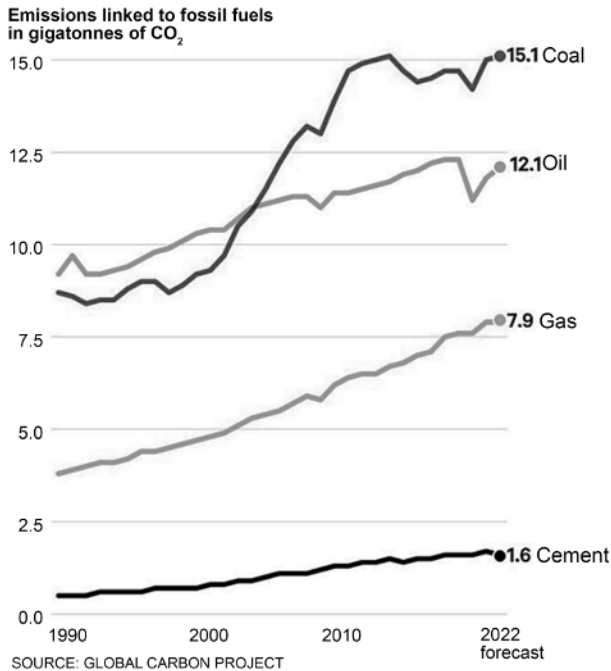


Figure 1.12. Emissions linked to fossil fuels (and cement used for construction) from 1990 to 2022 [JAC 22]

In 2020 and 2021, the Covid-19 crisis clearly highlighted the shortcomings of globalization for many countries, particularly in the West, making them overly dependent on a small number of (mainly Asian) countries manufacturing drugs and medical devices (both of which require energy and therefore generate CO₂). In 2022, the war in Ukraine highlighted the overdependence of European countries on Russia for energy (especially gas and oil). This energy crisis is encouraging some countries to make greater use of coal (e.g. Germany, Poland); even France has re-commissioned a coal-fired power station, despite its substantial but aging nuclear fleet and significant renewable energy potential. These successive crises highlight the need to return to a more local production of goods and energy, thus favoring short circuits that reduce carbon emissions. For a country like France, the only locally available energy sources are renewables (uranium for nuclear power plants is non-renewable and imported).

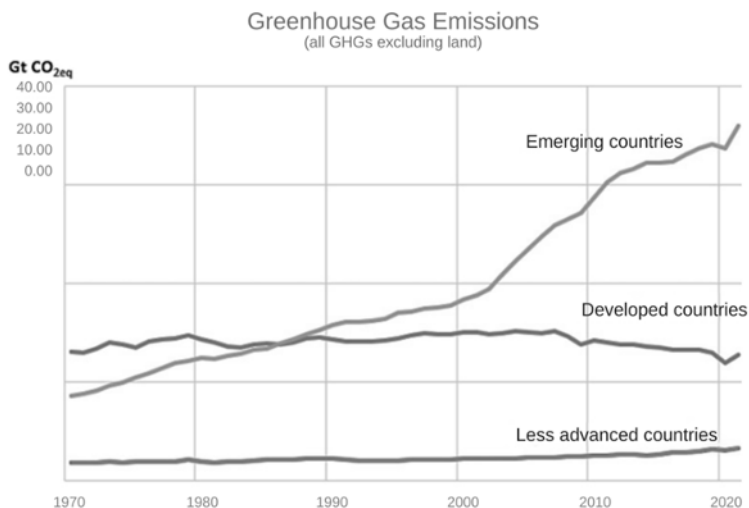


Figure 1.13. Trends in greenhouse gas emissions according to the economic situation of countries: emerging, developed, less advanced. A significant decline in emissions is only effective for developed countries [PER 22]

According to Dubey and Gras:

The intermittency of renewable energies, which we hope today to be able to tame by perfecting existing techniques and systems, is in fact an invitation to change times and social organization. It is a far more conflict-ridden and revolutionary process than the euphemisms of “energy transition“ and “digital transition” suggest. Not just because powerful positions and interests are at stake, which those who benefit from them have no intention of abandoning. But because the irregularity, variability and unpredictability of renewable energies remain irreducible to the temporal regime of digital capitalism and its mode of apprehending reality. To welcome intermittence, then, is to welcome disorder in all its creative and subversive implications, by dispelling the confused fear it inspires [DUB 21, authors’ translation].

The development of renewable energies is clearly in line with ADEME’s S3 “Green Technologies” scenario. Self-consumption, particularly collective and in local energy communities, is in line with scenario S2 “Territorial Cooperation”, and if we move from smart energy sharing to wise energy sharing, these modes of local energy production and consumption are in line with scenario S1 “Frugal Generation”. In this way, they contribute to UN Sustainable Development Goal 7,

“Clean and affordable energy” (Figure 1.7). This SDG emphasizes energy efficiency, takes into account the need to reduce fuel poverty and focuses on developing regions with little or no access to electricity (Africa, Asia, etc.). Nearly a billion people in the world still have no access to electricity, a figure that is slowly declining (in addition to the 1.6 billion who had no access to drinking water at the start of the 21st century, and the 2.5 billion who had no access to proper sanitation).

In addition to the need to reduce fuel poverty, we need to remain vigilant to the fact that the development of digital technology associated with the “smartization” of our environment can marginalize part of the population. According to INSEE²³, 20% of French people will have difficulty using the Internet in 2019.

According to Dubey and Gras:

This “illectronism” or digital divide refers not only to the under-equipment of some and the lack of computer literacy of others, but to a major anthropological fact: some people just can’t adapt to the norms of a touchless world. Although increasingly marginalized, this “deviant” fringe of the population puts its finger on what is incommensurable about digital technology, and at the same time raises a crucial anthropological question that should, in any case, be of interest to all those concerned about the future of our societies. Undoubtedly impressed by the prevailing techno-legalistic fatalism, few dare to tackle the issue. And yet, as we all know, it is always at the frontiers and margins that the important things happen [DUB 21, authors’ translation].

We must realize that not all users will be smart users.

1.8. Smarter buildings in a desirable habitat

1.8.1. Buildings and living spaces

The buildings in which we live, work and shop, as well as those used for leisure and sport, are the main CO₂ emitters. In France, in 2016, residential and tertiary buildings accounted for 45% of total final energy consumption. The French PACTE law, passed in 2019, aims to reduce building consumption by 40% by 2030 and 60% by 2050. In 2019, these residential and tertiary sectors accounted for just over 20% of greenhouse gas emissions, with a downward trend thanks to energy efficiency and

23 Institut national de la statistique et des études économiques: the National Statistics Bureau of France.

renovation efforts [GAS 22]. The technologies used to construct and operate these buildings play an important role in the scale of these carbon emissions, but the ways in which they are lived in and used also contribute to these emissions. These buildings are equipped with devices that enable them to better understand and control energy. They can become energy producers and store energy, thanks to the new materials used to construct these buildings, and also increasingly thanks to new energy and digital technologies, while ensuring the comfort of their occupants. They are becoming smart buildings.

And yet technology alone is not enough to optimize a building's operation and reduce its carbon footprint. Building users also play an important role, with activities and comfort needs varying from one individual to the next, to the point where we might well ask whether, for smart buildings to achieve their low-carbon footprint objective, should they not be used and inhabited by smart users who are adapted or integrated into the building's intelligence? In Chapter 5 of [ROB 23], sociologist Hervé Barry develops a socio-technical analysis of buildings becoming smart, based on feedback from two smart building demonstrations at the Université Catholique de Lille.

1.8.2. Building trends in 2050

The different ADEME scenarios, presented in Figures 1.2 and 1.3, assume a reduction in energy consumption and greenhouse gas emissions in the building sector. Compared to 2015, when energy consumption in buildings in France stood at 725 TWh of total energy, scenario S1 assumes a decline of almost 50% in energy consumption, while scenario S4 assumes a decline of only 16%. The decline in GHG emissions induced by direct energy consumption (Scope 1 and 2, Figure 2.1 in [ROB 23]) is even more drastic: in scenario S1, the decline is 96% compared to 2015 emissions (85 MtCO₂eq), while in scenario S4, the decline is 80% [GAS 22].

The ADEME scenarios show other trends, such as the surface area of dwellings per person, which evolves from 49 m²/person in 2050 to 48 m²/person in S1 and 54 m²/person in S4. The temperature set point of air conditioners also rises from 22°C in 2015 to 26°C in 2050 in S1; however, it remains unchanged in S4 [GAB 22].

In [GAS 22], several scenarios for the evolution of buildings up to 2050 are presented, based on the four ADEME scenarios. These scenarios are based on the availability of resources (materials, labor, finance, etc.), the speed at which actors (companies, owners, users, and also the legislator) evolve, and the form this evolution will take. If the actors evolve little and/or if certain resources experience shortages, the scenarios that emerge, entitled "Difficult to do everything" and "Shortage", do not herald a very desirable future. On the other hand, if the actors

evolve strongly, two more positive scenarios emerge, entitled “Building as a service” and “Rebalancing”. The “Building as a service” scenario is marked by the rapid adaptation of building and real estate actors to the challenges of the ecological transition and demographic growth, and more specifically to two key issues: avoiding urban sprawl and renovating the building stock. The relationship between buildings and property undergoes profound change. In the city, buildings increasingly become services made available to their occupants by institutional actors. This allows for greater flexibility in space management, aided by digital solutions [GAS 22]. This scenario is in line with ADEME’s S3 “Green Technologies” scenario (Figure 1.3). The “Rebalancing” scenario is marked by a territorial rebalancing in favor of peri-urban areas, medium-sized towns and rural areas. Preserving the environment and anticipating systemic crises are becoming high priorities for society. We are witnessing the emergence of dynamics based on greater frugality, the use of local resources and reinvestment in housing and local services [GAS 22]. This scenario is in line with ADEME’s S1 and S2 scenarios “Frugal Generation” and “Territorial Cooperation” (Figure 1.2). It focuses on renovation rather than construction, which can reduce GHG emissions by 30% compared to the most planet-friendly new buildings, and on a far-reaching change in lifestyles towards frugality, particularly in the use of everyday and digital equipment.

1.8.3. Smart buildings

Buildings will therefore have to considerably improve their energy performance. They will also play a fundamental role in the development of smart energy grids, energy microgrids, eco-neighborhoods and smart cities. Figure 1.14 illustrates the different characteristics of a smart building, which integrates local energy production and storage, controllable loads whose consumption can be modulated (lighting, heating, electric vehicles, etc.); this building can be connected to the electrical distribution network and to external sources or operate in isolation, i.e. not connected to the electrical distribution network [ROB 19, ROB 23].

An intelligent building integrates a range of technical equipment interfacing between:

- all or part of the weather conditions (heat, light, air quality, wind);
- all or part of the energy-consuming equipment that accompanies use of the building (heating, air conditioning, ventilation, lighting, electric vehicles), local energy production and storage;
- all or part of the spaces and times of use for the building, whether for residential or business use.

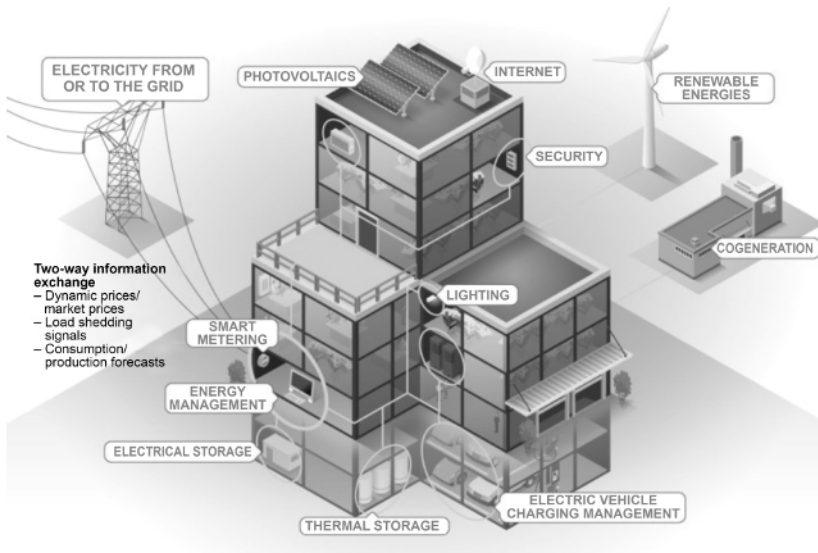


Figure 1.14. Smart building connected to a smart grid²⁴

A building's level of intelligence is not standard. It varies according to the range of services provided by the technical equipment. Several dimensions are involved in the graduation of this intelligence, developed with the dual aim (ideally) of maximizing energy efficiency and maximizing comfort of use. There are four such dimensions [ROB 19, ROB 23]:

– *Automation*: according to a typical scheme, in response to a measurement or time setting, a technical tool (e.g. a sensor) triggers an adjustment action (more or less heat, more or less light, more or less ventilation). For example, brightness sensors can control the switching on of lights or the activation of blinds according to sunshine and time. The use of such automated systems in the home is usually referred to as home automation. Actions can be triggered by a strict dialogue between devices, with or without human intervention.

– *Centralization*: all or part of the device is controlled by a single system, such as a thermostat for home heating. There are, however, frequent exceptions to this centralization rule, such as thermostatic valves on radiators.

– *Regulation*: this generic term covers all actions, technical or otherwise, automatic or otherwise, designed to adjust energy demand and/or user comfort levels

²⁴ See: <http://www.objetconnecte.com/batiments-intelligents-marche-iot/>.

according to their needs. For example, a window that can be opened is a regulation device in its own right. In the same way, regulations, information on consumption or awareness-raising through eco-gestures are all ways of regulating (or modifying, to put it another way) the socio-technical conditions of energy use.

– *Information*: consumption needs to be tracked as closely as possible, i.e. over the year, month, week, day, time, equipment, etc. The challenge is to establish the link between technical devices, consumer appliances, usage periods and actual consumption. This information is not enough to know consumption practices, but simply the times and sometimes the intensity of use (e.g. with an oven set more or less hot).

Smart buildings are becoming increasingly digital and are therefore processing a growing amount of data. According to the ADEME scenarios (see Figures 1.2 and 1.3), the rate of growth in the volume of data processed in small data centers varies greatly from one scenario to the next. Considering the extremes, for S1, there is an increase of 50%/year between 2020 and 2023, then a decrease of -10%/year between 2024 and 2032, followed by a rate of 0% until 2050. In scenario S4, this rate increases perpetually by 50%/year between 2020 and 2025, by 60%/year between 2026 and 2028, and then by 25%/year until 2050 [GAB 22].

The low-tech approach makes a lot of sense in the building sector, even though it is still not very widespread. Low-tech obviously concerns energy renovation, with a set of simple techniques and know-how that take into account what is already there, mobilize local, accessible and renewable resources in materials and energy and call on transferable know-how for low-cost implementation, maintenance and use, accessible to all. Some key aspects of a low-tech approach include: definition of needs, user involvement, short circuits, reuse, etc., with constant questioning of energy, carbon, resources and biodiversity, while dealing with program, operating and financing constraints; in short, it is techno-discernment [ADE 22b].

Low-tech approaches are at the heart of ADEME's S1 and S2 scenarios (Figure 1.2), while a high-tech smart building approach is more in line with scenario S3 (Figure 1.3). Smart buildings can also be approached from a more socio-technical angle, which is not incompatible with scenario S2 or even ADEME's scenario S1 (this subject is extensively covered in Chapter 5 of [ROB 23]).

The evolution of buildings will have to integrate into their environments, which are part of the habitat in which we live; the aim is to preserve and even contribute to the development of biodiversity, and more generally to bring nature back into the city [ROB 23]. With this in mind, buildings undergoing renovation or construction must respond to the UN Sustainable Development Goal 11 "Sustainable cities and communities" by becoming part of sustainable urbanization, with a reduced or,

better still, positive environmental impact and contributing to the resilience of territories in the face of climate change.

1.9. Smart buildings as nodes of smart grids

As nodes in a smart energy network, smart buildings will become increasingly active participants in the energy ecosystem, going beyond simple service to the smart grid to become an integral part of it. This means developing a true smart building vision, considering buildings as a network (buildings of different kinds, energy-coherent blocks, neighborhoods, etc.), strongly integrating all the technological dimensions and interests of users, operators and owners and positioning them as intelligent actors in energy networks, integrating all the potential of digital platforms.

Demand for electricity continues to grow worldwide. Traditional approaches to meeting this demand would require significant resources for additional generation.

Making the electricity grid “smarter” through information technology can offset some of the growth in demand by more finely optimizing grid management, but this is only half the solution. The other half of the solution must be to make buildings smarter, and to better integrate them into an extended electricity grid. Smart buildings, with their intelligent interaction in networks of buildings, islands of buildings, districts, etc., will enable the implementation of innovative control technologies to save energy, reduce energy costs and reduce the constraints induced on electrical networks by the development of intermittent renewable energies and electric mobility by modulating consumption/production as seen from these networks (by bringing flexibility to the networks). They integrate the needs of users and residents, ensuring their comfort and involvement.

When properly connected to the electricity grid, a smart building or building island can be configured as a virtual back-up station or virtual power plant (behaving like a conventional power plant [ROB 15, ROB 21]) for electricity grid regulation and balance.

Each building block is potentially a node in the electrical grid and can be likened to a microgrid providing multiple services to its owners and occupants and to the energy networks [ROB 19, ROB 23]. An increasing number of these microgrids will integrate energy production and storage services. The operators of these “micro-companies”, both owners and businesses, will be able to optimize services and energy consumption at each node in conjunction with energy network managers and potential energy and service aggregators [MEM 17].

Figure 1.15 illustrates the smart buildings as nodes of smart grids concept by combining the smart grid (SG) vision, i.e. the multiple benefits for the power grid in this case, and the smart building (SB) vision, integrating the benefits for buildings and building clusters in terms of reduced CO₂ emissions, and also quality of life for users, financial savings and even business. This concept will be a key component of future smart cities. Nodes are characterized by transformer substations and/or meters that can communicate.

An aggregator will probably be needed to aggregate interactions with energy networks [ROB 19].

At present, few tertiary, commercial and residential buildings have the infrastructure to participate in such a transformation. However, the deployment of smart meters will help to accelerate this transformation. Several aspects of this smart buildings as nodes of smart grids concept are discussed in Chapters 4–8.

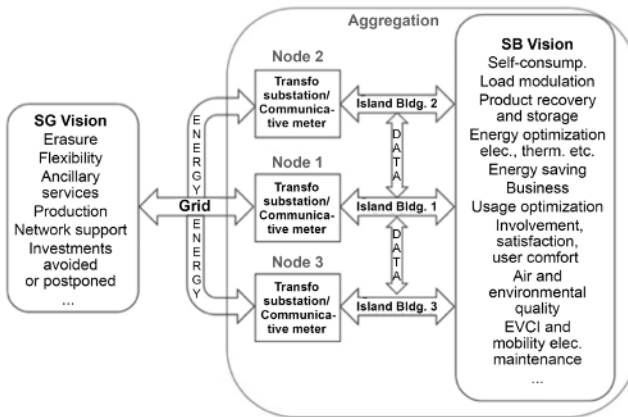


Figure 1.15. Smart buildings as nodes of smart grids (electric vehicle charging infrastructure (EVCI,))

Once again, this approach can respond to ADEME’s S3 “Green Technologies” scenario with a highly technological vision. However, if we integrate smart sharing or wise sharing visions, the smart buildings as nodes of smart grids approach can respond to the S2 “Territorial Cooperation” or S1 “Frugal Generation” scenarios. In terms of contributions to the UN’s SDGs, the aim is to develop an integrative approach to SDGs 7 and 11.

1.10. Methodological contributions

Chapter – Theme	Objectives	Methods, tools and disciplines used to build an energy management strategy
2. The “smart” imaginary	<p>To show that so-called smart techniques are based on an imaginary growing distance between technical systems and their users</p> <p>This raises the question of how to bring together technology and the user? The rest of the book aims to provide some answers to this question</p>	Sociology and anthropology
3. Production and consumption forecasting	Forecast local photovoltaic production and building consumption to enable self-consumption of local production and flexibility for the public distribution grid and reduce CO ₂ emissions	<p>Neural networks</p> <p>Satellite data</p> <p>Camera data (from a camera)</p>
4. Taking into account actors in energy management strategies	Identification of stakeholder profiles with a view to building an energy management system	<p>Sociology</p> <p>Microeconomics</p>
5. Energy supervision of a local residential smart grid integrating stakeholder involvement	<p>Smooth out the district’s electrical load drawn from the distribution grid</p> <p>Increase consumer satisfaction by considering costs and renewable energy consumption</p> <p>Respect acceptance by each actor</p>	<p>Game theory</p> <p>Dynamic programming</p> <p>Fuzzy logic</p>
6. Auto-Consumption within a local renewable energy community of tertiary buildings	<p>Encourage self-consumption of local photovoltaic production by taking into account actor profiles</p> <p>Assessing the environmental impact of blockchain</p>	<p>Digital twin</p> <p>Game theory</p> <p>ADMM algorithm</p> <p>Blockchain technology</p>
7. Potential of smart buildings	<p>Smart building services</p> <p>Temperature control taking user comfort into account</p> <p>Indoor air quality</p> <p>Environmental impact</p>	<p>Digital twin thanks to BIM</p> <p>Multiple linear regression models</p> <p>Genetic algorithm</p>
8. Demonstration smart grids and buildings	<p>Demonstration of energy flexibility</p> <p>Acceptability of flexibility solutions</p>	<p>Digital twin</p> <p>Full-scale demonstration</p> <p>Sociology</p>

Table 1.1. *The different contexts considered, the objectives pursued, the tools and disciplines, as well as the methods used to build supervision systems*

In the remainder of this book, various contributions of smart grids and smart buildings to energy and societal transition are developed and applied to real-world case studies. Several methodologies are developed and implemented, based on interdisciplinary approaches between the engineering sciences, the humanities and the social sciences. These methodologies call on artificial intelligence tools such as neural networks, fuzzy logic and genetic algorithms, game theory, optimization algorithms such as alternating direction method of multipliers (AMM) typically used to minimize the sum of two functions dependent on different variables coupled by a constraint, blockchain technology, etc., while integrating sociological and economic considerations. The performance of the solutions developed is tested by means of numerical simulations on models (or digital twins), case studies and demonstrations at real scale and in real operating conditions. Table 1.1 summarizes the different contexts considered and the objectives, tools and disciplines implemented, as well as the methods used to build energy, electrical or thermal supervision systems.

1.11. The question of artificial intelligence

Various AI techniques are used throughout this book. These tools are highly effective when it comes to dealing with complex systems that are difficult to model precisely or that require a great deal of computing time to simulate. AI is thus very useful for making forecasts, modeling a system, supervising a system, etc. AI seeks to copy a number of living mechanisms (reasoning, neuronal functioning of the brain, genetics, social behaviors, etc.) that have proved their worth in the deployment and functioning of life. In addition to this attempt to copy the living, AI makes use of a lot of data, and if there are a lot of data, we talk of Big Data. A priori, the more data there are, the better the AI's performance. A distinction is made between weak AI, whose operating stages are mastered and whose results can be physically interpreted – even though the AI does not use a model, the model may exist – and strong AI, such as Deep Learning, for which no model exists.

Pierre Giogini and Thierry Magnin warn of the dangers of strong AI [GIO 21]. Thierry Magnin summarizes the problem as follows:

The problem comes when you do not have the basic mathematical equations, you do not know the phenomena, and you use AI and massive data processing by “deep learning” to predict possible evolutions [of a system]. By going digital without knowing the mathematical equations of the phenomena under study, the search for correlations will take precedence over the search for causes. Prediction changes status, as it is not based on statistics linked to physical phenomena. This is a promising approach, provided we can

conduct “critical experiments” based on the “possible futures” provided by AI. However, this is not always possible. This represents a major break for scientists accustomed to subjecting their hypotheses and theories to the sieve of critical experimentation. This does not call into question digital tools as such, but it does alert us to the framework in which they are used. The transition from “data-assisted science” to “data-driven science” is thus problematic in terms of “scientific truth” in the sense of the usual experimental sciences. The hypothesis of man losing his grip is no longer a fiction. It is already here, be it in a form that is still latent [MAG 22, authors’ translation].

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