# 1

# The Necessary Transition of the 21st Century

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## 1.1. Introduction

The consumption of fossil fuels since the 18th century has undeniably enabled the development of industry, enhanced transport and increased the standard of living, particularly in the most industrialized countries, but it has also contributed to an increase in greenhouse gases in the atmosphere, provoking global warming in our planet. This phenomenon continues to worsen, so much so that if these gas emissions are not quickly and drastically reduced, global warming will impact the planet and our lifestyles even more, an issue that will become increasingly significant and difficult to live with. Though fossil fuels are the main source of $CO_2$ emissions, they are not the only one.

The first section of this chapter presents the connection between energy and societal issues. This will allow us to set the context, present the issues and bring out some initial aspects for reflection.

The second section presents some perspectives relating to climate change, from denial and inaction, to sustainable development, which includes technosciences and economics.

Finally, the last section brings out some scenarios that can be imagined for the next 30 years with the aim of limiting global warming. These scenarios offer many solutions that have varying levels of technological maturity and social acceptability. We will also identify a few conditions for these scenarios to be successful, as well as some obstacles to their deployment. A discussion will then be initiated which will continue throughout this book. The issue is so serious that our way of seeing the world (the planet, humanity and biodiversity) and our relationship to the world must

be transformed. The way we imagine the world has to be modified, and other sources of happiness other than those that have a negative impact on the world are to be promoted, by seeking or rediscovering sources of joy [GIO 20].

## 1.2. Connection of energy and social issues

### 1.2.1. *Living energy*

It is undeniable that energy has enabled a tremendous amount of development within human societies, particularly in terms of food, health, education, technology, mobility, etc.

The use of energy that comes from nature – such as fire for food and heating, wind for mobility through turbines or water to drive motors – has always brought about a considerable pace of evolution within the societies that it has impacted.

Humanity has also used animals as a driving force, such as horses, as well as humans. However, the hydraulic energy brought about by water mills, which appeared in Antiquity, caused a reduction in slavery. By milling up to 150 kg of wheat per hour, a single mill cut down the work of about 40 slaves [BAR 14]. However, a decisive leap was to be made by humanity when it started exploiting fossil fuels in combination with ever more sophisticated technologies. According to the historian Jean-François Mouhot, the emergence of steam was most likely a necessary condition for the abolition of slavery. This is because the exploitation of fossil fuels led to an energy transition that made slave labor appear more superfluous. This has led to machines all but replacing forced labor in modern societies [MOU 11]. Reflecting on our current conditions, supplying the equivalent of only 4 € of daily food to a slave who supplies 100 W for 10 h of work, which is exhausting for any human being, or 1 kWh every day at the price of 4 €/kWh, means that the kWh price is 27 times higher than the 2019 value of public electricity in France [CAS 20]. The average French citizen currently contains the energy potential equivalent to 500 humans!

### 1.2.2. *Fossil fuel, deforestation, cattle rearing and climate*

For hundreds of thousands of years, the concentration of carbon dioxide ($CO_2$) in the Earth's atmosphere remained stable due to a balanced carbon cycle: the $CO_2$ emitted was essentially equivalent to the $CO_2$ absorbed, which leads to carbon neutrality. People are increasingly practicing deforestation and fossil combustion, that is to say, when what is emitted exceeds what is being absorbed, and the concentration of $CO_2$ in the Earth's atmosphere is increasing [GRA 16].

The increase in the greenhouse effect makes the global surface temperature of the planet rise. However, due to human activity, the concentration of greenhouse gases has exploded since the pre-industrial period (1750–1800). The concentration of $CO_2$, which is the main greenhouse gas, has increased by more than 30% since the pre-industrial era. The combined effects of all greenhouse gases ($CO_2$, methane, ozone, etc.) that we are seeing today amount to an increase of more than 50% in $CO_2$ since this period [ROB 21].

Between 1860 and 2010, the Earth's average surface temperature increased by 0.6°C, and 1.2°C if we extend the period until 2022. Different future scenarios predict that by 2100, if current energy sectors and consumption habits are not modified, we can expect temperatures to increase by another 1.5 to 7°C. This considerable increase would be accompanied, more specifically, by a rise in sea level of 20 cm to 1 m. Though the evolution of the climate appears to be irreversible, it is however possible to slow down this evolution by significantly reducing greenhouse gas emissions.

Natural $CO_2$ sinks such as soil, trees and oceans would only be able to absorb a little less than half of the $CO_2$ produced by humans (produced in 2000). In order to stabilize the concentration of $CO_2$ at its current level, it would therefore be necessary to immediately reduce emissions of this gas by 50%–70%. Even though this immediate reduction is seemingly impossible, it is urgent to act, because we are faced with a cumulative problem. Considering that the lifetime of carbon dioxide in the atmosphere is around a century, it will take several generations to make $CO_2$ levels stabilize to an acceptable level. In 2018, the Intergovernmental Panel on Climate Change (IPCC) estimated that in order to limit global warming to 1.5°C in 2100, $CO_2$ emissions would have to decrease by 45% in 2030 compared to 2010, and by 91% in 2050 [INT 18].

$CO_2$ is produced when all fossil fuels are combusted: oil, gas and coal. $CO_2$ emissions are about twice as high for coal as for natural gas, those related to oil situated between the two [ROB 21].

Global warming, and more broadly human activities, have an impact on biodiversity. Rates of extinction of species are predicted to be 50–560 times higher than when compared with those of a stable biodiversity. Here, we are talking about the sixth extinction. In addition to this, 11% of greenhouse gas emissions are due to deforestation and change relating to land use, as we are seeing uses that store less carbon such as producing palm oil [GRA 16].

Livestock is also a major emitter of greenhouse gases, constituting around 9% of $CO_2$ emissions worldwide. These emissions can mainly be attributed to the production and transportation of food; a production use case that requires

agricultural land which as a consequence contributes to deforestation. The second source of emissions is the gastric fermentation of roaming animals. According to the IPCC, beef farming emits five times more $CO_2$ globally than pig or chicken farming.

Figure 1.1 highlights how $CO_2$ concentrations have increased (in parts per million, or ppm) in the atmosphere since 1700, with a dotted line which projects up to the year 2100, according to the worst-case scenario which has been provided by the IPCC scenario 8.5. This scenario implies business as usual, where a lack of intentional action to reduce $CO_2$ emissions leads to $CO_2$ concentrations above 700 ppm in 2100, compared to 400 ppm in 2014.

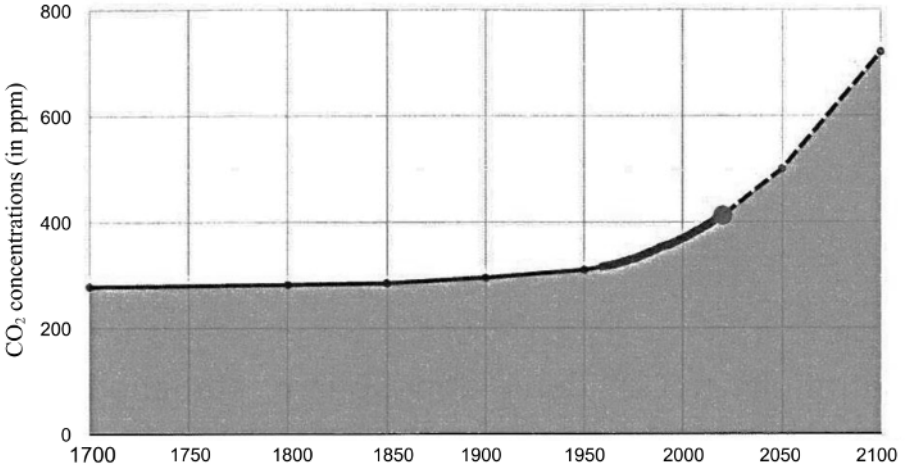


**Figure 1.1.** *Evolution of $CO_2$ concentrations (in parts per million, or ppm) in the atmosphere since 1700, with a dotted line to predict levels up to 2100 according to the worst-case scenario provided by the IPCC scenario 8.5*[1] *(based on NOAA/ASRL/ SIO/IPCC)*

Figure 1.2 illustrates how global $CO_2$ emissions evolve (in gigatons, or Gt) between 1960 and 2020 (shown in red), distinguishing those produced due to fossil fuels and industry (shown in gray), from those produced due to occupation soils (shown in green). It can be concluded that the emissions growth is essentially due to the consumption of fossil fuels and industrial activity. We can also note the effect of the 2009 economic crisis, which reduced industrial activity overall. In 2020, we can see that $CO_2$ emissions drop to 39.94 Gt compared to the 43.06 Gt emitted in 2019,

1 Available at: https://www.notre-planete.info/indicateurs/CO2-dioxyde-carbone-concentration.php.

that is, a drop of more than 8%. This is mainly due to the slowdown in economic activity induced by the Covid-19 pandemic.

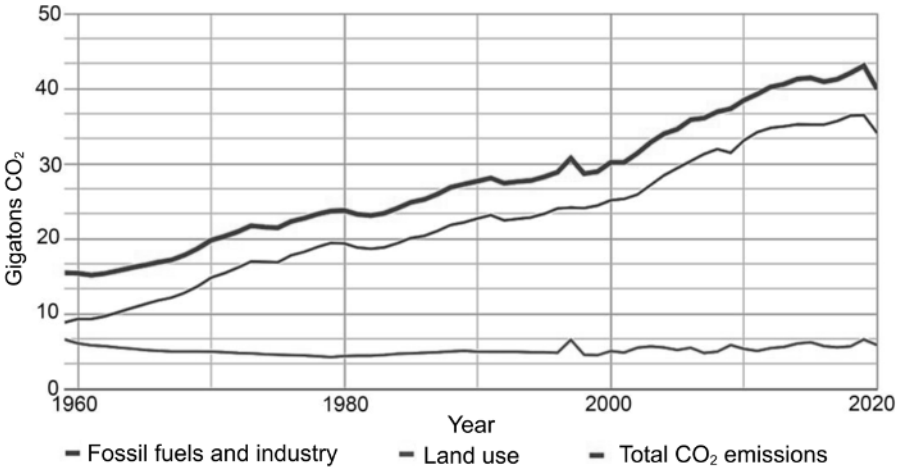


**Figure 1.2.** *Evolution of global $CO_2$ emissions (in gigatons, or Gt) between 1960 and 2020 (shown in red), those due to fossil fuels and industry (shown in grey) and those due to land use (shown in green)[2]. For a color version of this figure, see www.iste.co.uk/robyns/smartusers.zip*

### 1.2.3. *Renewable energies, or almost renewable energies*

Energy has always been present in the universe in two ways: nuclear energy contained in matter and kinetic energy created by the movements of stars and other particles moving in space.

The atoms that make up all matter possess enormous energy proportional to their mass. The sun and nuclear power plants harness this energy. Part of the heat in the center of the Earth results from nuclear reactions which allow for deep geothermal energy.

The sun gives off intense electromagnetic radiation which results from an enormous amount of nuclear fusion reactions. The Earth captures some of this radiation, allowing it to heat up. It enables photosynthesis, which makes plants grow, produces biomass and thus life. Fossil fuels come from transforming organic matter over millions of years. The sun also enables shallow geothermal energy, as

2 Available at: https://www.notre-planete.info/terre/climatologie_meteo/changement-climatique-GES.php.

well as the production of photovoltaic electricity and heat by means of heat exchangers, the evaporation of water which produces hydraulic energy, and it also heats up moving air masses, enabling wind power.

The gravitational pull of the Moon revolving around the Earth creates the tides, and the energy created from this process can be harvested by tidal power stations. Part of the wind comes from the Earth's rotation on itself [CAS 20].

In our times, renewable energies are those that can be continuously provided by nature. In this way, they come from solar radiation, the earth's core and the gravitational interactions of the Moon and the Sun with the oceans. A distinction can be made between different renewable energies – that is to say, wind, solar, hydro, geothermal and biomass origin [ROB 21].

Fossil fuels obviously do not fall into this category, because they are consumed in a much shorter time (less than 200 years) than what is required for them to be created (which is several million years).

Nuclear energy does not generate $CO_2$, with the exception of $CO_2$ emitted during the construction and deconstruction of power plants and when enriching uranium that is consumed in power plants. Uranium reserves are approximately 90 years long, based on "reasonably assured resources" which are added to "additional recoverable resources", at less than $130/kg, at a cost of between $80 and $260/kg of natural uranium and conventional fission which exploits the 235 isotope. This type of energy, which is therefore not a renewable source, will continue to be developed in a certain number of countries including France, subject to a satisfactory processing and management of waste, the development of a new generation of safer reactors, as well as, in the long term, the development of nuclear fusion. The latter concept will only be properly explored well beyond the year 2050 [ROB 21].

It is important to note that hydrogen is not a renewable energy source, because even though it is the most abundant atom in the universe, it does not exist in an $H_2$ form that can be directly used on Earth. It must be extracted from methane, which is fossil energy, or water by electrolysis, which consumes electrical energy. However, when used as energy, hydrogen does not emit $CO_2$ if it is produced from renewable or nuclear energy, other than that generated during the production of these technologies.

Figure 1.3 provides information about the estimated amount of greenhouse gases, essentially $CO_2$, per ton of oil equivalent (1 toe = 11.6 MWh) of final energy, that is, useful energy, for various energy sources.

Table 1.1 shows the quantities of $CO_2$ that are emitted into the atmosphere by different sources that are used to produce electricity. These emissions quantified in g/electric kWh were obtained via an analysis of the life cycle (LCA) of the sector which combines the construction of the installation, the extraction and transportation of fuel, the production of electrical energy, the treatment and storage of waste and the deconstruction of the installation.

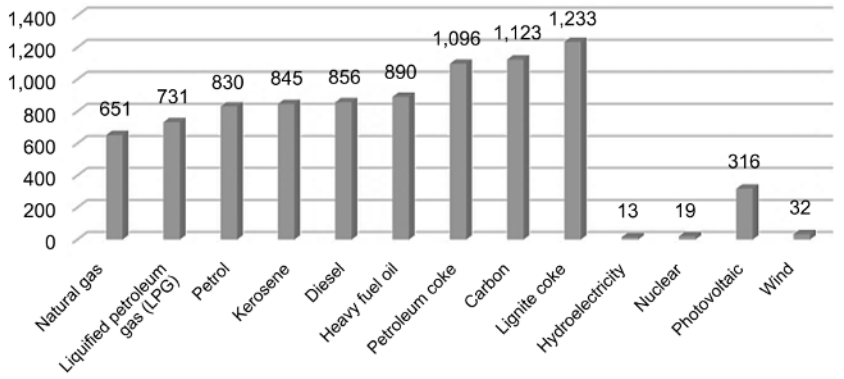


**Figure 1.3.** *Estimated greenhouse gas amount, mainly $CO_2$, per ton of oil equivalent (toe) of final energy for diverse energy sources [JAN 20a]*[3]

Transportation between the place where components are manufactured and where the power plants are installed has a significant impact in the case of wind power, and especially photovoltaics. High amounts can be obtained in the case of photovoltaics if battery storage is associated with the plant. This means one must take the LCA of the battery into account when evaluating the overall LCA of the photovoltaic energy source.

The value of wood energy emissions given in the table is extreme. If the forest from where the wood comes is managed sustainably, by replanting as much wood as is extracted, emissions induced by the use of wood energy are low, generated only by the cutting and transportation of wood.

Finally, Table 1.1 shows that an adequate and sustainable implementation of renewable energies allows for the production of low-carbon electricity. Apart from renewable energies, only nuclear energy has low carbon emissions. However, this type of energy also raises the question of radioactive waste and carries risk. In the future, the use of coal, which remains abundant on the planet, could still be

3 Available at: https://jancovici.com/changement-climatique/economie/quest-ce-que-lequation-de-kaya.

implemented through the recovery and storage of $CO_2$ emissions, a technology which is currently in development, but which is costly, and leaves the issue of secure storage of $CO_2$ open.

| Electricity production source | $CO_2$ emission in g/kWh |
|---|---|
| Carbon | 800 to 1,050 depending on the technologies |
| Petrol | 985 |
| Gas combined cycle | 430 |
| Nuclear | 6 |
| Hydraulic | 4 to 70 depending on the type of unit |
| Wood biomass | 200 to 1,500 without replanting (deforestation) |
| Wind | 3 to 22 depending on the place of manufacture |
| Photovoltaic | 5 to 150 depending on the place of manufacture and the type of cell |

**Table 1.1.** *Amount of $CO_2$ emitted in the atmosphere by different sources which enable the production of electricity, in g/kWh, determined from an LCA*[4]

### 1.2.4. *Energy and economy*

Humanity has developed significantly because of energy, which is a development that has progressively accelerated for about 200 years with the exploitation of fossil fuels, which still correspond to 80% of energy currently consumed. This is an extremely short time scale compared to the millions of years that it took for *Homo sapiens* to appear and the 4.5 billion years that constitute the age of planet Earth. An abundance of energy has allowed mankind to work less for food, housing, treatment, etc., allowing for reflection, developing culture and creating new knowledge and new technologies. A significant correlation exists between higher energy consumption and longer life expectancy. A correlation also exists between energy consumption and the United Nations Human Development Index, which takes into account life expectancy, level of education and per capita income, and the Human Capital Index of the World Bank, which considers a child's chances of survival until age 18, the duration and achievements of their school education and their health [CAS 20].

In economics, the gross domestic product (GDP) is widely used to measure economic growth and therefore human activity (though this is not necessarily a

4 Available at: https://jancovici.com/changement-climatique/quel-monde-ideal/existe-t-il-des-energies-sans-co2 and https://bilans-ges.ademe.fr/documentation/UPLOAD_DOC_FR/index.htm?renouvelable.htm and EDF.

reflection of human happiness!). Economic activity requires a lot of energy to extract raw materials, transport them, transform them, provide services, etc. World GDP truly began to increase in the middle of the 19th century in connection with coal consumption, and the evolution of GDP has since been exponential. Figure 1.4 compares consumption of primary energy (energy consumed before transformation) with GDP on a global scale. It shows that the greater the GDP of a country, the higher the level of primary energy consumption, and vice versa. The relationship is more or less linear, as the line shows. There is therefore a very strong correlation between wealth creation (measured by GDP) and primary energy consumption.

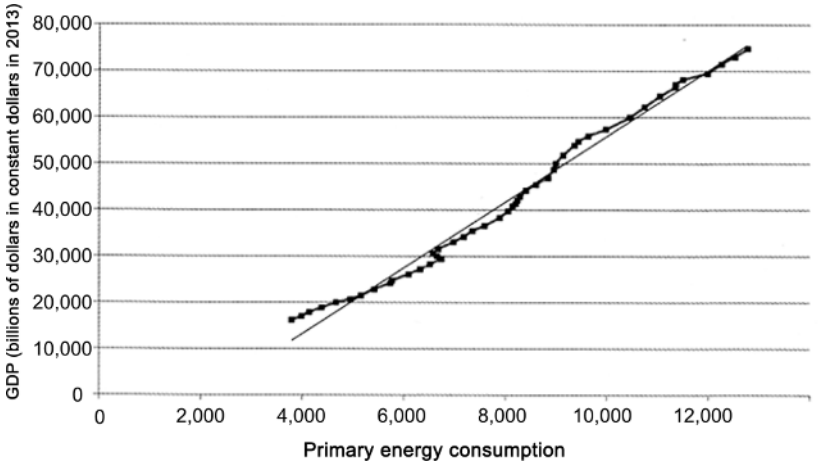


**Figure 1.4.** *Global GDP evolution in constant dollars (in 2013) in relation to primary energy consumption in Mtep [GIR 14]*[5]

In 1993, the Japanese economist Yoichi Kaya proposed an equation that highlights the links between $CO_2$ emissions, demography, GDP and energy [CAS 20, JAN 20a]:

$$CO_2 = Population \times \frac{GDP}{Population} \times \frac{Energy}{GDP} \times \frac{CO_2}{Energy}. \qquad [1.1]$$

The first term represents the world population, which came to 6.9 billion people in 2010, almost 8 billion people in 2020 and which could reach 9.8 billion in 2050 according to the United Nations (UN). The delta between 2010 and 2050, $\Delta P_{10-50}$, is therefore 1.42.

5 Available at: https://climatetenergie.wordpress.com/2018/02/20/energie-croissance-economique-et-energie.

The second term represents wealth per person, in other words purchasing power. Of course, the majority of the population would like this term to increase! Between 2010 and 2018, it increased by 1.61%. Following this same pace, the increase, $\Delta GDP_{10–50}$, will be 1.9% in 2050.

The third term illustrates the energy intensity of GDP, shown in Figure 1.5. Its evolution over time reflects the energy efficiency of our systems and processes, such as our habitats, electricity production, industries, transport.

Fortunately, if primary energy consumption grows at the same time as GDP does, it grows less rapidly. Between 2010 and 2018, the energy to GDP ratio decreased by 1.26% per year. By extrapolating this observation, we can obtain a delta, $\Delta E_{En\_10–50}$ of 0.6 between 2010 and 2050.

Finally, the fourth term represents greenhouse gas emissions, mainly $CO_2$, that are emitted by the primary energies consumed. It will be at its weakest when exploiting renewable energies or nuclear energy. This ratio only decreased slightly (by 0.45%), between 2010 and 2018. This is because while the use of renewable energies has increased, the use of coal has also increased in certain regions of the world in order to meet growing demand faster than renewable energy sources. By extrapolating the variation between 2010 and 2018 up to 2050, we obtain for this ratio a delta, $\Delta E_{CO2\_10–50}$ of 0.84.

By multiplying the estimates for the four terms on the right of the equation, we obtain the following result:

$$CO_2\ (2050) = \Delta P_{10\text{-}50} \times \Delta GDP_{10\text{-}50} \times \Delta E_{En\_10\text{-}50} \times \Delta E_{CO2\_10\text{-}50} = 1.42 \times 1.9 \times 0.6 \times 0.84 = 1.36.$$

This means that $CO_2$ emissions would increase by 36% by 2050. However, the IPCC recommends that $CO_2$ emissions decrease by 91% in 2050 compared to 2010 to limit global warming to 1.5°C in 2100 [INT 18].

Starting from the hypothesis that the first two terms cannot be reduced, since economic decline is not favorable among the societal majority, the last two terms of the equation should be drastically reduced as follows (the values of 0.183 are assumptions allowing the target of 0.09 to be reached for the evolution of $CO_2$ emissions):

$$CO_2\ (2050) = 1.42 \times 1.9 \times 0.183 \times 0.183 = 0.09.$$

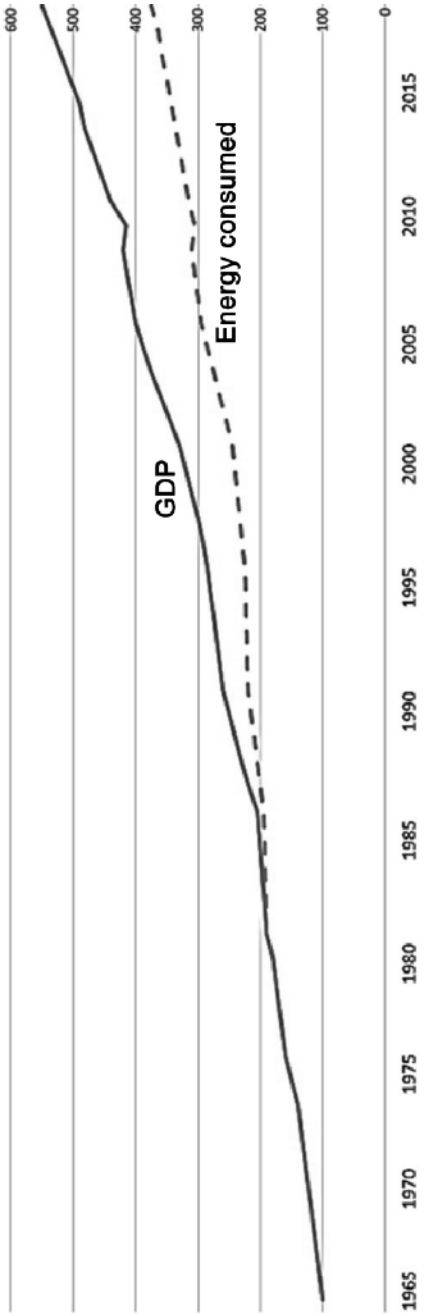


**Figure 1.5.** *Evolution over time of world GDP in constant dollars in 2010 and primary energy consumed in the world, with base 100 in 1965 [CAS 20]*

We should considerably increase the efficiency of our energy systems (gain even more than 40% efficiency) and almost exclusively use energy sources that do not generate greenhouse gases (reduce the use of carbon-generating energy sources by 65%). A decrease in the second term would mean consuming energy in a sober manner by modifying our lifestyles, even at the risk of limiting our comfort, without reducing the efficiency of our health systems. Even if an evolution toward more sober choices and behaviors is desirable, a drastic reduction of this term seems difficult to imagine, considering that nearly a billion human beings do not yet have access to electricity. However, limiting the main sources of energy that are currently exploited, as well decreasing the raw materials available on planet Earth, will one day inevitably lead to limited growth of the first two terms of the equation. These reflections do not account for the effects of a pandemic which would automatically decrease these first two terms (the Covid-19 pandemic in 2020 reduced GDP of France by around 8% and global GDP by around 5%)…

Many people are announcing serious economic and social crises induced by climate change, and yet solutions exist that will make it possible, if not to avoid these crises, to reduce their effects.

### 1.2.5. *Energy and meaning*

"I believe in an afterlife, simply because energy cannot die; it circulates, transforms and never stops". These were the words of Albert Einstein. Einstein showed that matter can be transformed into energy (atomic energy) and vice versa (as at the very beginning of the life of the universe) using the famous formula $E = mc^2$ (m being the mass and c the speed of light). Matter is in fact only a gigantic concentration of energy in an insignificant volume. There is also a link between energy and information. Information is contained in the genetic code, and this requires a lot of energy in order to create living forms. Information is needed to shape energy, followed by matter. Information is carried by energy, for example via radio waves. Information then becomes abundant and the energy required to process it becomes significant, as we will see later in this book.

Energy is therefore essential for human life. However, the combustion of fossil fuels not only contributes to a huge increase in greenhouse gases and therefore to global warming, but also generates pollution directly, which is a source of death. Coal-fired power plants cause nearly 23,000 premature deaths every year in Europe (Poland 5,380; Germany 4,350; Britain 2,860; France 390, etc.) [WWF 16]. Note that 670,000 people died in 2012 from burning coal in China. The cost of atmospheric mortality is estimated in China at 10% of GDP [GRA 16]. The number of premature deaths due to global pollution in France is estimated at 50,000 per year. This means that pollution kills more people today than tobacco [BAR 20].

The dangers of nuclear energy are better known to the general public, because they are more sensational and more publicized. The Chernobyl and Fukushima accidents are emblematic examples of this. But, according to the World Health Organization, fossil fuels account for several hundred Chernobyl deaths each year [CAS 20].

Figures 1.6–1.8 illustrate the number of illnesses and deaths induced by electricity production alone in Europe [MAR 07]. Figure 1.6 shows the number of fatalities per accident per 100 TWh of electricity produced. Figure 1.7 represents the number of deaths due to pollution per 100 TWh of electricity produced. In addition, Figure 1.8 highlights the number of serious illnesses. It should be noted that electrical energy consumed annually in Europe in 2018 was around 3,330 TWh. Annual electricity consumption per capita in Europe is high, at 5,448 kWh in 2016, 75% higher than the world average consumption [WIK 20a]. Among the energy sources taken into account in Figures 1.6–1.8, nuclear energy appears to be the least dangerous. However, renewable hydraulic, wind and photovoltaic energies have not been taken into account. According to Rabl and Spadaro [RAB 01], wind energy is the least lethal energy, followed by nuclear energy. Hydraulics do not generate direct pollution, but accidents caused by the rupture of large dams have already caused deaths, such as the rupture of the Banqiao dam in 1975 in China, which is said to have caused more than 100,000 deaths [CAS 20].

These illustrations of the mortal dangers presented by implementing and using energy sources raise the question of the value attributed to them, independent of their economic value. Indeed, we seem to attach less importance to risks that seem more diffuse, but more intense in terms of mortality, than to risks that are more impressive, but lower in intensity. Risks that are diffuse and random in nature seem more acceptable. This finding will no doubt lead some countries to pursue the development of nuclear energy, even in a moderate sense, as well as to a drastic reduction of this type of source in other countries. We also cannot lose sight of the treatment and storage of highly reactive waste over long periods of time, which can raise ethical questions, since it is a question of leaving waste management to future generations. In addition to this, global warming tends to increase the temperature of cold sources (rivers, seas, air) which are necessary for nuclear power plants to function properly. This means risking a loss of productivity in order to ensure their safety.

The value of energy also comes from its accessibility to all, insofar as we can see how it enables a standard of living with decent levels of health and education. As a reminder, nearly a billion people do not yet have access to electricity. In addition, 14% of the French population finds themselves in fuel poverty, that is to say, they have difficulty paying their electricity and heating bills, which can reduce their access to these energy sources. We must therefore ensure that the essential energy

transition does not overlook these populations, rather that it allows everyone a minimum level of access to different sources of energy, by implementing modes of energy solidarity and, where appropriate, local solutions and regulation of the forms of competition that would be unfavorable to this transition. According to Nicolas Hulot, the economic and ecological transition must allow countries and populations to strike an economic balance, to erase injustices and to forge links that will produce peace and solidarity [GRA 16].

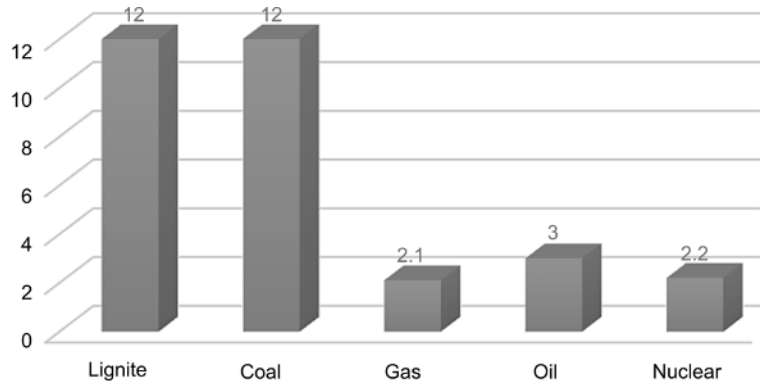


**Figure 1.6.** *Number of accidental deaths for 100 TWh of electricity produced [MAR 07]*

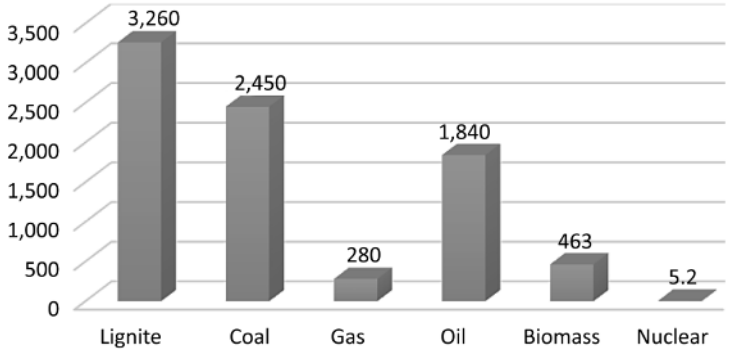


**Figure 1.7.** *Number of deaths caused by pollution for 100 TWh of electricity produced [MAR 07]*

Beyond energy poverty, the energy and societal transition must be inclusive by involving all populations: poor, rich and well off. However, beyond the financial question, we must allow everyone to access knowledge about climate and societal

challenges, to access and appropriate technologies that can help the transition, to be able to take the necessary steps in order to understand the world differently and to change one's relationship to the world in order to preserve it. This is for the good of everyone, but especially of future generations.

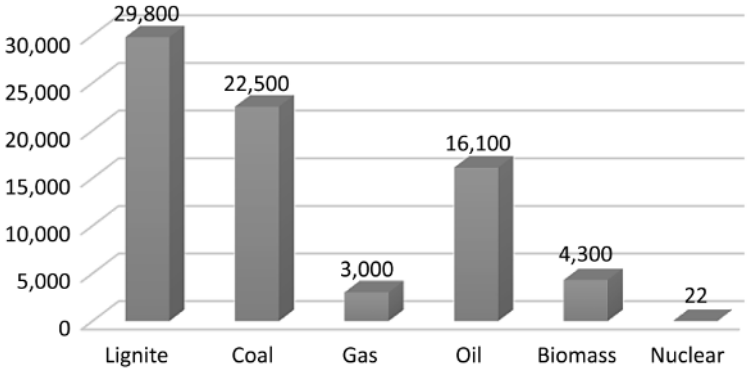


**Figure 1.8.** *Number of serious illnesses due to pollution for 100 TWh of electricity produced [MAR 07]*

## 1.3. Opinions surrounding climate change

### 1.3.1. *Denial and inaction*

The climate emergency appears increasingly in the news. The climate changes already felt by everyone will have impacts in many senses – environmental, societal, health, economic, etc. And yet, a level of denial continues to persist at times among leaders of major world powers, which is all the more worrying. This is an attitude that can lead to withdrawal when faced with the scale of the phenomenon. This withdrawal into oneself cannot however be sustainable as the economy becomes increasingly globalized, as no country will be spared the effects of global warming.

The economist Nicholas Stern, former chief economist at the World Bank, has pondered the cost of climate change: "If left unaddressed, the overall costs and risks of climate change will be equivalent to the loss of at least minus 5% of global GDP every year, now and forever. If a wider range of risks and consequences are taken into account, damage estimates could amount to 20% of GDP or more. On the other hand, the costs related to action, namely the reduction of greenhouse gas emissions to avoid the worst consequences of climate change, can be limited to 1% of global GDP each year" [GRA 16].

In 2013, the World Bank alerted the world to the cost of natural disasters, which are set to increase with climate change. It estimated that natural disasters have killed 2.5 million people and cost 3,800 billion dollars between 1980 and 2012, mainly in emerging countries, which have seen their GDP weakened by climate change [GRA 16].

### 1.3.2. *Faith in technosciences*

A second view is based on total faith in technosciences. Science and technology will save us, and tomorrow we will find new sources of energy and new technologies.

One could postulate that the scarcity of fossil fuels will force us to do just this. In this way, we can count on a shortage to limit climate drift. However, in order to limit the increase in temperature to 2°C in 2100, it is essential that we do not emit more than a thousand gigatons of $CO_2$ by the end of the century. Of this thousand gigatons, fossil fuels are affected by 300 gigatons of carbon. But knowing that the latter emit a little more than 30 gigatons per year, at this rate, the carbon budget will be largely exceeded before 2050, especially since the known reserves of fossil fuels allow for it [GRA 16].

Technology is largely at the origin of the climate problem, and it will certainly be part of the solution, but not alone. According to Pierre Giorgini: “What we are experiencing is more than a crisis, we are experiencing a dazzling transition from an old world to a new world. This transition is economic, financial, social, environmental and geopolitical. It is global and is part of a transformation of the world whose nature no one is able to accurately predict. So it’s a transition to something else. The strength of this transition is probably unprecedented in terms of both its acceleration and its magnitude. This apparent magnitude comes in particular from the combination of a new techno-scientific revolution, with the shift to a new paradigm relating to modes of cooperation between man and machines, combined in turn with the transition to the creative economy. We are in fact talking about a systemic upheaval” [GIO 14, GIO 16b].

Technology will be part of the solution, but how should one assess this part so that these technologies are effectively aimed at reducing the climate impact of human activities? Pierre Giorgini and Thierry Magnin [GIO 21a] propose an ethical approach to guide research and development actions by:

– promoting and participating in technological development when it aims to repair ecosystems, address ecological damage, the fight against pollution and global warming;

– favoring technologies when they repair the social fabric, contribute to reducing the digital divide when they aim to connect the human race around issues of safeguarding and the promotion of mankind in the protection of the freedom of conscience.

In this context, we must recognize the preferential option for vulnerable populations, and natural and social ecosystems that are in danger, as a universal value of law and conscience. Wherever we are engaged locally, for any development or technological innovation, regionally, nationally or internationally, in business or any civic activity, we must support, act and claim the option that favors the poor and the most vulnerable people, as a source of radical innovation that benefits all of humanity.

### 1.3.3. *Saving through economy*

Dominant thinking is liberal in nature: the market will be efficient, and invisible forces will come about when the time is right to integrate climate issues with financial parameters. Across a large part of the economic and financial world, investors would be perfectly informed. If stock market prices or insurance premiums do not reflect the risks linked to climate change, it is because these do not really exist. When risks materialize, investors will take them into account and financial flows will be oriented in such a way that we are able to deal with the new climate situation. There is no need to regulate financial authorities to direct flows toward the financing of the transition, as this will be done naturally in due time. However, the financial crisis of 2008 proved that perfect information held by the actors of the financial world is a myth [GRA 16]. The same is true for the pandemic crisis of 2020–2021…

Moreover, the costs of renewable energies decrease over time, and it can be assumed that they will inevitably become cheaper than fossil energies. The same will no doubt be true for various technologies that emit low carbon, or even allow carbon to be captured before it is emitted into the atmosphere. One could then believe that future generations will inherit solutions that are more economical than those that exist today, and which will therefore be able to be implemented more easily. Placing the responsibility on those who come after us is however audacious and ethically questionable... .

### 1.3.4. *The reason for sustainable development*

In 1986, the concept of sustainable development was defined as follows: “meeting the needs of the present without jeopardizing the ability of future generations to meet their own needs”.

This concept involves exploiting renewable energy resources, which are the only guarantors of a sustainable environment, while minimizing the environmental impacts associated with their conversion and the manufacture of their converters. Fossil fuels emerge as a finite and economically limited resource, inducing emissions that affect the environment and contribute to climate change. A sustainable energy system must integrate renewable energy sources and/or conversion chains using low-emission renewable fuels, which are accessible at acceptable costs. Despite the fact that the creation of new energy infrastructures takes several decades, a growing number of large companies are involved in the development and commercialization of these new technologies.

Sustainable development requires managing a balance between economic development, social equity and environmental protection in all regions of the planet. This concept cannot therefore come to pass without the real political will of a growing number of countries [ROB 21].

Pierre Giorgini expresses this concept in the form of an ethical rule, going further by emphasizing the need to restore original ecosystems: “You will not entrust your children with the task of solving problems that you have created voluntarily, which are vital for your offspring and for which you are not sure of the current or future existence of a realistic solution. On the other hand, the advances generated by scientific discovery and/or technical development will aim to strengthen the common good and will promote the restoration of the original ecosystems if they provide balance and harmony, wherever possible” [GIO 18].

The United Nations (UN) has set 17 Sustainable Development Goals to save the world, shown in Figure 1.9. These Sustainable Development Goals provide the roadmap for achieving a better and more sustainable future for all. They respond to the global challenges we face, including those related to poverty, inequality, climate, environmental degradation, prosperity, peace and justice. The goals are interconnected and, in order to leave no one behind, it is important to achieve each of them, and each of their targets, by 2030. These 17 goals are broken down into 169 sub-goals for which the contribution of each actor (company, community, association, university, etc., but also the individual) can be evaluated through indicators.

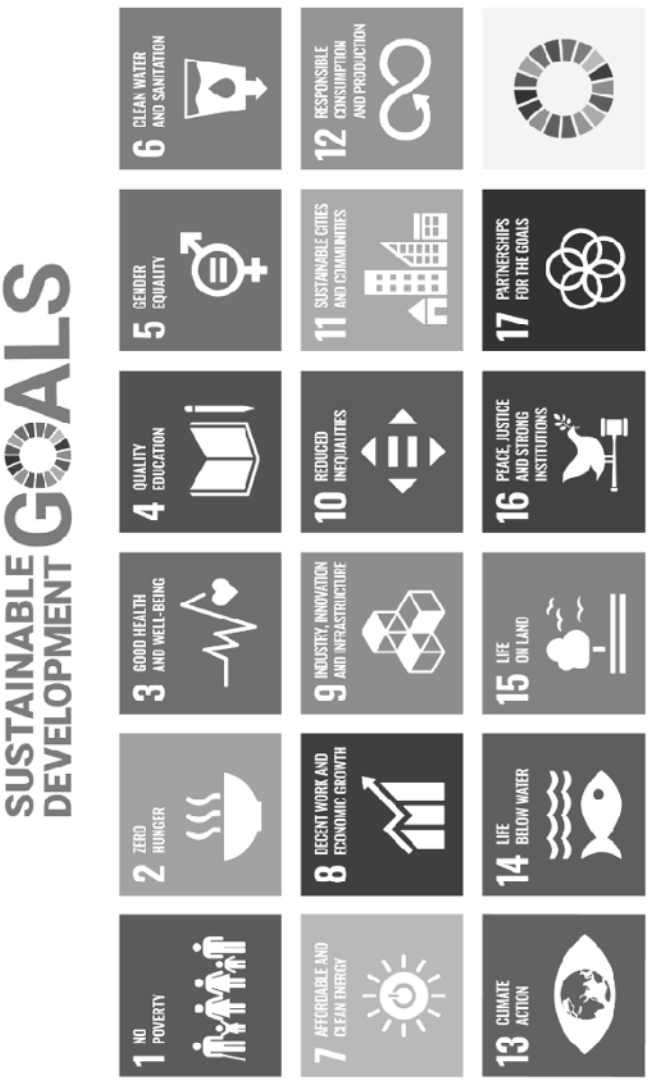


**Figure 1.9.** *The 17 sustainable development objectives from the UN*

## 1.4. Scenarios and possible solutions

### 1.4.1. *Scenarios, so many stories of a desirable future?*

In order to limit the increase in temperature in 2100 to 2°C, we should aim for carbon neutrality by 2050. Carbon neutrality does not only mean that we no longer emit carbon at all, but that the carbon being emitted is either offset by the development of carbon sinks (forests), or it 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, governance and territories, but also of our lifestyles. In France, in 2021, three organizations proposed scenarios: NégaWatt, Ademe (French agency for environment and energy management) and RTE (manager of the electricity transmission network). The NégaWatt and Ademe scenarios present proposals that can be widely shared on a global scale. The scenarios proposed by RTE are strongly inspired by the current energy mix in France, which relates to a study of an electricity grid powered by 100% renewable energy, the conclusions of which can be extended to many countries around the world.

Greenpeace [GRE 13], the World Commission on the Economy and Climate [NEC 15], and the American economist Jeremy Rifkin [RIF 12] offer scenarios with an international vision.

The main aspect of these scenarios is sobriety, which is strongly linked to our lifestyles, an increase in the energy efficiency of our systems (housing, transport, industries, etc.) and an increased use of renewable energies. However, the weights of these axes differ according to scenario concerned.

These scenarios form the basis of many possible narratives for the next 30 years. It is desirable that at least one of them materializes in order to achieve carbon neutrality in 2050, but are they desirable in themselves? A big unknown relates to the acceptability of these scenarios by populations, in particular those calling for sobriety. These scenarios generally implicate a social change, an evolution of behavior, even a break in everyone's vision of the world and in their relationship to it. It is therefore a significant challenge to make these scenarios desirable…

In the rest of this section, the trending scenarios are presented, though they are by no means exhaustive. All these scenarios can be explored further via the websites of the organizations that offer them. These scenarios and others are beginning to be questioned on certain particularly important aspects, such as the role of digital

technology, the importance of returning to the local, the involvement of all actors and the development of demonstrators.

### 1.4.2. *Renewable energies and sobriety*

The NégaWatt scenario aims for carbon neutrality in France by 2050 and the reduction of greenhouse gas emissions by 55% on a European scale by 2030 compared to 2019. Figure 1.10 illustrates the evolution of carbon emissions in France until 2050 by considering a trend evolution (shown in red) which assumes that few intentional reduction actions are implemented, compared to the situation in 2020, and the evolution that aims to achieve carbon neutrality in 2050 (shown in blue).

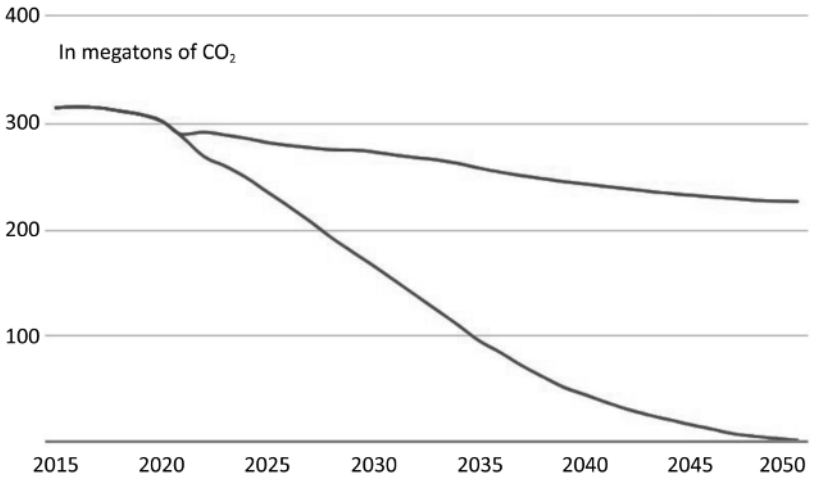


**Figure 1.10.** *Evolution of carbon emissions in France until 2050 considering a trending evolution (shown in red) and the objective carbon neutrality (shown in blue) [NÉG 21]. For a color version of this figure, see www.iste.co.uk/robyns/smartusers.zip*

The objective of reducing carbon emissions presupposes a sobriety of demand, by dividing into two the final energy consumption in France by 2050 (production of electricity, mobility, heating of buildings, industries). But according to NégaWatt: "The transformation of our energy system which is necessary cannot be achieved by simply replacing fossil fuels with carbon-free energy sources. Limiting environmental and social impacts and reducing the pressure on raw materials requires a profound transformation of the way we consume and produce energy and material goods. These perspectives call for strong societal transitions, both individually and collectively" [NÉG 21].

Sobriety is therefore one of the three major areas to be developed. According to NégaWatt, it will be necessary to prioritize the most useful uses, to restrict the most complicated and to eliminate the most harmful. Sobriety has several dimensions, partly conceptualized by the NégaWatt association [VIL 18, WIK 20b], in the spirit of democratization and sharing:

– dimensional sobriety: by favoring equipment that is adapted to the need, when choosing a purchase or an investment (e.g. opting for a smaller surface area for your living accommodation, using a vehicle adapted to the load and number of passengers);

– cooperative sobriety: by pooling uses, whether it concerns spaces, goods, etc. (e.g. carpooling, car sharing, co-location, loan of equipment between neighbors);

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

– organizational sobriety: by structuring activities differently in space and time (e.g. promotion of telework, regional planning, provision of public transport);

– material sobriety: by reducing the consumption of material goods and products (e.g. reducing the rate of equipment, limitation of packaging). These same goods indirectly require energy to be designed, assembled, transported, etc. In this sense, we are thinking about indirect energy, or embodied energy.

The second axis is to increase the energy efficiency of our systems, that is, to reduce the quantity of energy necessary to satisfy the same need. This translates into better insulation of buildings, which accounted for 45% of overall energy in France in 2016 [ROB 19], through improved efficiency of electrical appliances and transport systems, etc.

Figure 1.11 illustrates the evolution of energy uses in France up to 2050 in the NégaWatt scenario. The gains obtained in energy efficiency when it comes to consumption and production constitute a significant part of the reduction in primary energy used up to 2050, that is, 38.2%, and energy sobriety contributes to 13.8% of the reduction in this energy.

The third axis assumes that energy production in all sectors (heat, electricity, transport) would be based 100% on renewable energies.

Figure 1.12 shows the evolution of $CO_2$ emissions by activity sector in France by 2050 according to the NégaWatt scenario. The most drastic reductions concern the energy sectors, manufacturing industries, transport and residential, tertiary, institutional and commercial buildings.

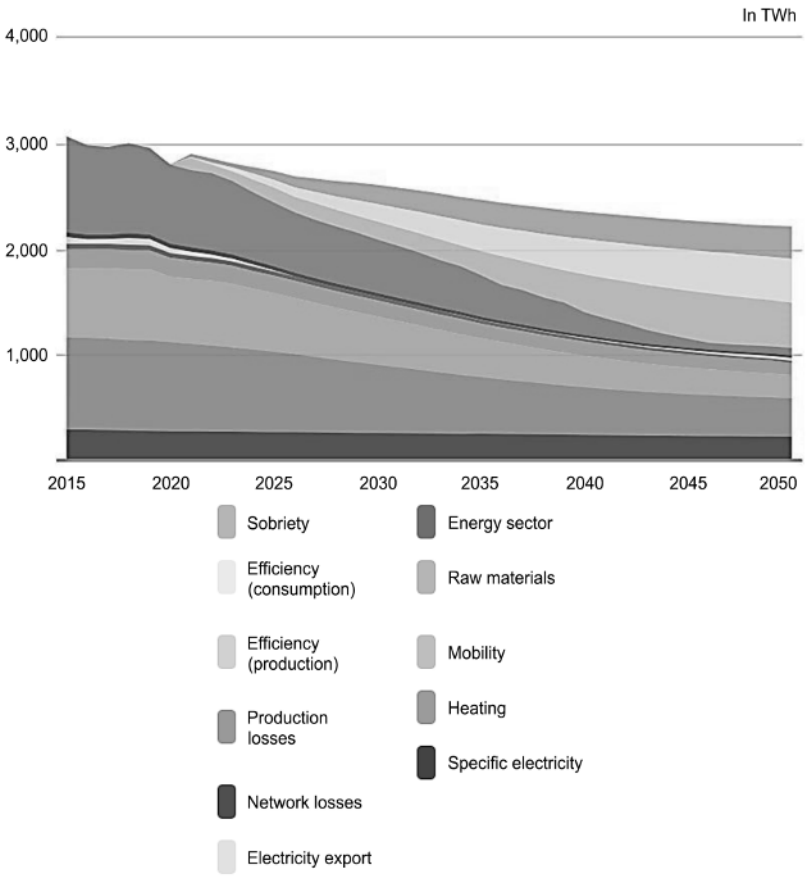


**Figure 1.11.** *Evolution of energy uses up to 2050 in France in the NégaWatt scenario [NÉG 21]. For a color version of this figure, see www.iste.co.uk/robyns/smartusers.zip*

The first scenario proposed by Ademe (S1), entitled "frugal generation", relies heavily on sobriety and energy efficiency [ADE 21]. This scenario is based on a search for meaning which leads to a sense frugality that has been agreed to (but also partly constrained by a legislative body), a preference for local products and nature which is protected. It advocates for society to divide the consumption of meat by three, to sharply reduce the mobility rate by making people take half the number of their journeys by foot or bike, and to renovate 80% of housing stock in low-energy buildings. Alongside this, it favors governance that prioritizes local decision-making, the creation of new economic indicators (based on income disparities, quality of life, etc.), the development of production processes which meet needs as

much as possible and the promotion of a circular economy (a high rate of material recycling).

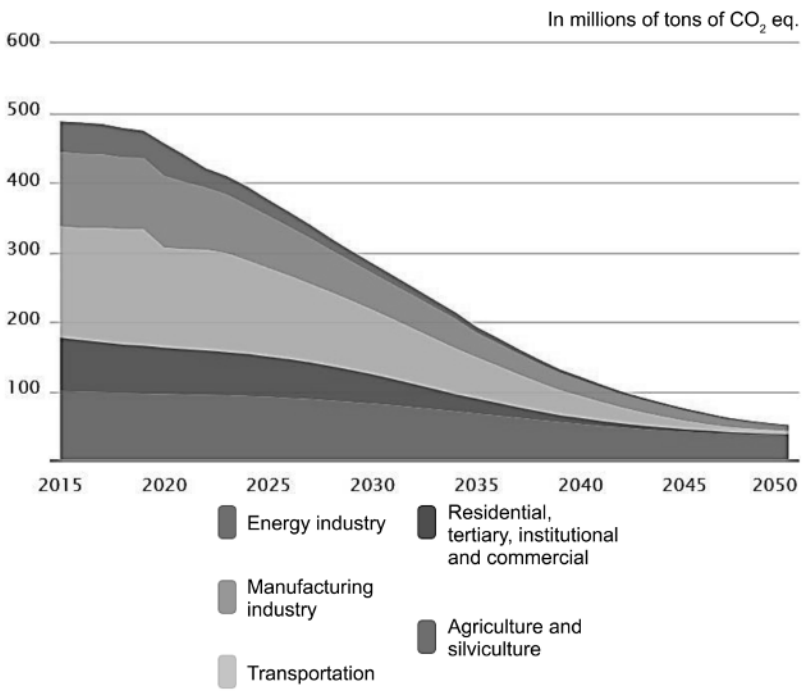


**Figure 1.12.** *Evolution of energy uses up to 2050 in France in the NégaWatt scenario [NÉG 21]. For a color version of this figure, see www.iste.co.uk/robyns/smartusers.zip*

Greenpeace also proposes scenarios based on sobriety and 100% renewable energy [GRE 13].

To keep up with the rate of growth envisaged for renewable energies and energy efficiency, it would be satisfactory to invest in the large sums required, provided there is support from the political bodies.

The question of sobriety is more delicate, because in addition to changing our lifestyles, it could be associated with economic decline, which would not be welcome globally. It is important to note that UN Sustainable Development Goal 8 (Figure 1.9) targets economic growth, and not decline. Another aspect to consider is reviewing the founding criteria on which our economy is based (such as GDP) in order to introduce new criteria such as quality of life.

Surveys carried out by Ademe show that in 2020, 58% of the French population were convinced that it would be necessary to change their way of life. According to 52% of French people, we must get out of the "myth of infinite growth" and completely review our economic model [ADE 20].

How might we make this evolution desirable? How might we find a new social consensus and modify collective imaginations to move from narrative to action? All of this without producing an increase in inequalities between the richest and the less well-off? A decline in fossil fuels and the necessary protection of biodiversity will force people to consume less and differently. In any case, lifestyle changes will be necessary, and "acceptable sobriety" remains to be seen [FRA 15].

### 1.4.3. *From 100% renewable energies to a mix of solutions*

In 2021, the French electricity transmission system operator published its six energy progression scenarios for France up to the year 2050 [RTE 21]. The scenarios center around electricity, but an essential aspect of all the scenarios is the story of possible futures. Since global energy consumption must decrease, electricity consumption will increase as fossil fuels are replaced in several sectors: transport, including electric vehicles, industry, hydrogen production from renewable sources, etc. This increase would sit at 35% in the year 2050 compared to 2020.

However, the report insists on a reduction of global energy consumption because of both an increase in the energy efficiency of energy systems, and to the concept of energy sobriety, which for some constitutes the first response to the environmental crisis, while others reject the principle in the name of individual freedom and to maintain a subjective form of "comfort" [RTE 21]. This decline is estimated to be around 40% in the year 2050 compared to 2020, but new European objectives aim to accelerate this decline to 55% by 2030.

A scenario based on 100% renewable solutions for the sole production of electricity has been proposed by Ademe [ADE 18] as well as by RTE [RTE 21]. Given the fluctuating nature of several renewable energy sources – wind, photovoltaic, small hydraulics and marine energies [ROB 21] – it will be necessary to considerably develop how electrical energy is stored [ROB 15, ROB 17, ROB 19] and enhance the flexibility of loads, that is to say, to modulate electricity consumption over time, in particular by adapting to the variability of renewable sources, but also by investing in electricity networks adaptations. RTE imagines different variants of this scenario depending on the amount of development of onshore and offshore wind power and photovoltaics. One scenario predicts that one in two houses in France would be equipped with photovoltaic panels for partial self-consumption [ROB 19].

However, RTE also foresees scenarios whereby part of the electricity in France would still be generated by nuclear power sources, by extending existing power plants and building new ones. According to RTE, these scenarios would be less costly in terms of investment than a 100% renewable scenario. However, the uncertainties around the extension of certain power stations and the delays inevitable when constructing new power stations may lead to a situation in which the desired objectives are reached by 2060 and not by 2050. In this case, in order to achieve the objectives put forward for 2050 despite everything, the economic implications of the different scenarios would be similar.

In some cases, scenarios that are based on mixed energy solutions with renewable and nuclear energy sources offer the chance for some $CO_2$ to be captured which is emitted by the fossil fuels that are still in use, even though in steep decline, by certain industrial processes. These scenarios are, for example, proposed by Ademe [ADE 21] and the IPCC [INT 18].

Although still expensive, $CO_2$ capture and storage (CCS) will have to form part of the combination of solutions. The electricity sector is the largest emitter of $CO_2$ in the world, but it can get rid of CCS by altering production methods, in favor of renewable and nuclear energies, as is the case in France. This is not the case for countries that continue to exploit shale gas (like the United States) or coal (like China). But for industries such as steel or cement, the use of carbon-free energies only makes it possible to cut around half of the emissions generated by the industrial process; in these cases, CCS will often be the optimal solution. Processes to capture $CO_2$ are complex but well known and mastered by several industrial sectors. $CO_2$ is stored in saline aquifers situated around 1,000 m underground or under the surface of the sea. This is a technique mastered by the oil sector, in particular the chemicals industry. Such storage facilities already exist in Norway. Their difficulty lies in the large-scale deployment of this capture and storage technique, which is costly.

Alain Grandjean [GRA 16] advocates for the scenario published by the World Commission on the Economy and the Climate, also called NCE for New Climate Economy [NEC 15]. This scenario suggests favoring compact cities. The comparison of the cities of Atlanta in the United States and Barcelona in Spain illustrates this proposition. These two cities have comparable standards of living and populations with approximately 5.3 million inhabitants. Atlanta covers 4,300 $km^2$ while Barcelona occupies 162 $km^2$. In Atlanta, public transport and individual transport emit 7.2 tons of $CO_2$ per inhabitant per year, but Barcelona emits 10 times less. In Ademe's S2 scenario, entitled "territorial cooperation", we see the idea of favoring medium-sized towns over large agglomerations. These cities are becoming denser in a controlled manner and are becoming "quarter-hour cities" where almost everything is nearby, allowing for the development of soft mobility and public transport [ADE 21].

The NCE report also highlights the need for reforestation. About a quarter of the world's agricultural land is degraded, and climate change threatens water supplies. Net deforestation (meaning the balance between deforestation and reforestation) is responsible for approximately 11% of greenhouse gases. Reforestation is necessary to create carbon sinks, which are essential to gain time in the fight against global warming. Finally, as in all the other scenarios, it is proposed that all energy carriers are decarbonized. According to this report, decarbonizing the economy does not cost more than maintaining the status quo.

### 1.4.4. *The Third Industrial Revolution*

The first industrial revolution was that of coal in the 19th century, the second that of oil in the 20th century and the third that of digital technologies in the 21st century. The Third Industrial Revolution has been characterized by economist Jeremy Rifkin [RIF 12]: it is based on renewable energies, energy-producing buildings, energy storage in buildings, energy exchanges via a smart grid and electric vehicles. He is optimistic because he thinks that because of these solutions, society will be able to continue to consume energy without resorting to sobriety, possibly experiencing a drop in energy consumption for equivalent service where possible.

Rifkin stresses that the Internet of energy, materialized by mainly smart grids, which are associated with the Internet of Things (objects communicating with each other via sensors), will play a strategic role in what is to come. He speaks of an Internet of transport that can optimize the loading of trucks to avoid empty transport. He then speaks of Internet convergence. The Hauts-de-France region was largely inspired by his story. The region adapted it to their specific context so that they could launch their own industrial revolution which was aimed at transforming their economy while reducing their carbon footprint. This approach will be presented in Chapter 2 alongside some initial feedback.

Pierre Giorgini goes further by bringing the highly connected or interconnected human into the picture: "This internet convergence applies to all levels of our human activity. This dazzling transition therefore brutally modifies the place of mankind in organized systems, calling on them to bear more universal conscience in each of their actions within interconnected communities. Mankind is no longer just a source of data and information servers, they are both a source and a recipient of it. The very notion of an 'organized society' is misplaced. The exercise of subjectivity and the imagination may be disturbing for some and may also raise the question of the future of the subject" [GIO 14, GIO 16b].

### 1.4.5. *Smart due to digital technology*

Like the First Industrial Revolution profoundly changed society in the 19th century, the digital transformation we witnessed at the beginning of the 21st century is still in its infancy, but we already know that it will revolutionize our world. In fact, technological progress makes it possible to envisage a world where almost all the objects that surround us will interact not only with us humans, but also with each other. It is the Internet of Everything (IoE or Internet at all): gigantic computer networks where several billion human beings and tens of billions of real or virtual objects exchange massive amounts of data.

Big Data will allow artificial intelligence (AI) algorithms to assist users and actors within buildings, energy networks and cities in order to make them more economical and more sustainable, and to make them smart buildings, smart grids and smart cities.

But we will have to be vigilant because digital technology and AI are energy intensive. AI requires machines with rare materials for batteries, electrical power for operations and lots of energy to cool and manage hardware. However, solutions are emerging which allow one to recover the heat released by data centers and use it for other purposes. It will also be a question of thinking about the genuinely useful pieces of data, how frequently they are acquired and the operations that need to be carried out wisely.

In 2018, digital technology was the source of 3.7% of global greenhouse gas emissions, and 4.2% of global primary energy consumption: 44% of this footprint occurs due to the manufacture of terminals, computer centers and networks, and 56% to their use [SÉN 20].

Currently, the digital sector emits as much carbon as the air transportation sector. In 2019, the digital sector represented 2% of France's carbon emissions. Growth of up to 6.7% in 2040 is predicted if nothing is done to reduce the carbon impact of the digital sector [SÉN 20].

It should be noted that "the Internet of energy" holds special status within the IoE because of the challenge it represents in terms of the sustainability of the planet (regarding the management of random renewable energies, the control of consumption profiles, the increase in the energy efficiency of buildings, transport systems, etc.). This is a strategic issue that impacts the effective functioning of the economy and of security systems. Additionally, from a legal point of view, we must consider the binding regulations surrounding the right to produce one's energy, to use public energy networks, to meter energy and to share it. Indeed, new approaches are beginning to develop in order to make it possible to produce and consume

energy locally, called individual and collective self-consumption in France, and more generally local renewable energy communities.

Ademe's S3 scenario entitled "green technologies" is based on optimizing performance in all sectors without radically changing behavior, because of digital technology which helps to create a more optimized and connected society. This scenario predicts that by 2050, data centers will consume 10 times more energy than in 2020. This energy will however be carbon free, and the $CO_2$ still emitted would be captured and stored [ADE 21].

Ademe's fourth and final scenario (S4) entitled "remedial bet" relies even more on digital technology and technology to maintain our lifestyles based on consuming goods and energy. It depends on society's ability to manage and repair social and ecological systems which are damaged by global warming. This approach is based, among other things, on the capture and storage of the $CO_2$ that is generated, but which is also already present in the atmosphere, because of technologies that are not yet technically and economically mature on a large scale. It also predicts an increase in the importance of digital technology, the omnipresence of the Internet of Things and AI, and data centers which will consume 15 times more energy in 2050 than in 2020 [ADE 21]. This is a trending scenario, similar to the current trend we can see in our society, which entails the significant risk of not achieving the necessary carbon neutrality by 2050. But is this a desirable narrative?

### 1.4.6. *From global to local*

Globalization has made many companies relocate, meaning that many countries have become dependent on only a select few states. This dependence had already emerged in the 1970s when it came to the supply of oil, a fossil fuel whose extraction is highly concentrated in the Middle East, a region that is relatively politically unstable. This is why some countries, including France at the forefront, have developed nuclear energy in order to reduce dependence. However, in recent times, a new dependence has emerged vis-à-vis countries in the Far East, including China and India, which begins to pose questions, even serious problems, for certain rare materials that are necessary for the manufacture of magnets which are used to construct electric generators for wind turbines. Examples of this are the manufacture of batteries, or of photovoltaic panels that make long journeys which generate carbon, or even for the supply of sanitary products, which is unacceptable in times of a global pandemic...

A movement is therefore emerging to bring essential productions from a global to a national scale. However, a trend is also emerging which favors even shorter circuits at the regional, urban or even district level. The development of local

renewable energy communities and collective self-consumption goes in this direction. The same is true for short circuits for agricultural products, by eating locally, or even by sourcing from new urban farms that can produce food in any season. It is also a question of promoting a circular economy at the scale of a territory both in terms of recycling goods and reducing the distance of journeys, thereby reducing the carbon footprint.

In terms of everyday life and the relationship of the individual to economic and democratic activity, Pierre Giorgini believes, following the thinking of Jeremy Rifkin, "that technosciences that are emerging today will make a large decentralization possible, along with relocation on a domestic scale of energy resources, and the creation on a local scale of an energy mix, through inter-object cooperation within cooperative mesh networks known as smart grids".

In such a model, scarcity will no longer be at the center of the energy economy because energy will have become predominantly renewable or even renewed for solar, wind and bioenergy [GIO 16a]. He speaks of "glocality" to underline these links, or even the mesh that is to be recreated between the local and the global.

### 1.4.7. *All actors*

Smart grids will truly deploy their potential for innovation when promoting interactions between the various players in the electrical system (producer, consumer, storage company, network manager), themselves becoming "electrically" smarter players. These actors have very different consumption and/or production profiles, and extremely variable economic and societal objectives and/or constraints. New sets of actors can therefore appear, making it possible to target new economic models, but also to respond to energy and climate issues by promoting the development of renewable energies. One challenge tied to this evolution is that all the actors become winners, without leaving the actors who are experiencing fuel poverty to one side [ROB 19].

According to Erik Orsenna: "The time has come for consumers to take revenge on producers. The most striking example is that of energy. The old mode of production was in the hands of monopolies. No other source was available. The market was opened wide to many new players" [ORS 18].

Buildings are becoming smarter, as well as producing energy because of the deployment of numerous sensors and automations aimed at increasing energy efficiency and user comfort. This notion of comfort is very subjective and varies according to the users. Users are invited to become actors in their building, both to adjust their comfort levels, but also to contribute to the objective of energy

efficiency. This is because technology cannot be used in an optimal way by everyone in the world, and also because it consumes energy itself. Ideally, smart buildings should be inhabited by smart users...

Thus, to succeed in the energy transition, everyone should become an actor working in their own interest, but also according to a logic of cooperation, thus making it possible to achieve objectives and overall gains which are greater than the sum of individual gains, acknowledging that the levels of rationality among individuals is very variable [ROB 19]. Pierre Giorgini speaks of cooperative mesh networks which allow one to generate a new form of creativity and new potentialities [GIO 14].

But, does everyone want to become an actor, consumer-actor (or *prosumer*)? In Giorgini and Vaillant [GIO 16b], Malik Bozzo-Rey, philosopher and ethicist, ponders the meaning of this term: "What does it mean for a consumer to behave like an actor? Are we not creating a huge illusion so as to ensure, precisely, that the consumer continues to perform only one action which is always the same? In other words, they do not stop consuming, which is after all the great anxiety of the capitalist system in which we live. How can we act so that people continue to consume and prevent the system from declining? Are we not creating a completely fictitious conception of the individual? A new species of fictitious individuals who would serve as a receptacle for a whole load of injunctions and recommendations, with varying degrees of descriptiveness and normative speech, without showing what the genuine pillars of the conception that we are building really are".

Becoming an actor concerns not only individuals, but also companies. Do they all share the desire for change beyond discourse, or *greenwashing*? Obstacles to the energy transition are still numerous, many legal changes are still necessary, and the preservation of the interest of certain companies still contributes to fueling these obstacles, rather than seeking to change economic models. Fortunately, young people who are the first to be impacted by the success of the energy transition are more and more careful to work in companies that operate and evolve in line with their values relating to their desires to change their habits in order to make the planet more sustainable. The willingness of politicians to create a framework that is conducive to the transition will also be decisive.

On the desire for individuals to cooperate, which appears to be a condition for the success of the energy and societal transition in *La Transition fulgurante* by Pierre Giorgini [GIO 14], the economists Ben Lakhdar, Le Lec and Vaillant call into question the presuppositions of the author surrounding the fact that human beings are inclined to spontaneously adopt cooperative behaviors, and that we live in a

world in which information is accurate, with each person supposed to know all of their own possible choices and those of others (theorized in tools such as game theory and blockchain technology [DUR 20, DUR 21, ROB forthcoming, STE 20, STE 21]). Researchers in experimental economics do indeed observe a spontaneous tendency toward cooperation, but this, without a supporting force, tends to decline very quickly. Individuals do not seem to be so much opportunistic or selfish as motivated by reciprocity: the presence of one or more uncooperative individuals is generally enough to demotivate others. The opportunism of some people, which feeds on information asymmetries, affects the behavior of the members of an entire group, and can even destroy this group.

It is not a question of being pessimistic, but of questioning the criteria and conditions essential for the success of the energy and societal transition. Obviously, the technoscientific approach alone is not sufficient to ensure we achieve success. It will be necessary to consider interdisciplinary approaches that integrate engineering sciences, human and social sciences, sociology, economics, ethics, law, etc.

### 1.4.8. *Small steps to start*

Although slowing down global warming requires strong actions to be implemented very quickly, the importance of the issue should lead everyone to question their ability to act. And yet, it seems as though everyone is implicated in some way and thus can contribute to reducing our carbon footprint by starting with small steps.

Many small individual gestures allow everyone to contribute to reducing greenhouse gas emissions, and therefore to slowing down global warming through travel and the means of transportation used, food, the use and recycling of various appliances, waste, etc. [BAR 20]. It is the beginning of a type of sobriety.

Let us cite a few examples. Transportation is the sector of human activity that produces the most greenhouse gases. It generates around 25%–30% of $CO_2$ emissions in developed countries, levels which are constantly increasing. Eight percent of greenhouse gas emissions are due to tourism, transport, food, accommodation and traveler purchases. The rise in the standard of living in emerging countries encourages continued growth in world tourism, the impact of which will be only negative on greenhouse gas emissions [WIK 20c].

The bin of an average French person stores more than 400 kg of waste per year and per inhabitant. This corresponds to approximately 200 kg carbon equivalent emitted per person per year [JAN 20b]. Reducing waste and sorting it with a view to

recovering it are small gestures that are beginning to occur in everyday life. It is important to note that nature does not generate waste, since everything decomposes and recycles naturally; waste is specifically produced by humans.

It has already been pointed out that livestock farming is a major emitter of greenhouse gases. Eating less meat will therefore help reduce carbon emissions, without having to become a vegetarian.

Many initiatives are emerging among young people and in particular secondary school and university students, for example, to encourage the recycling of used appliances and contribute to developing a local circular economy. Citizen initiatives are also being developed, through setting up repair workshops for used appliances, encouraging carpooling and developing renewable energy sources.

In France, in 2019, carbon emissions of each inhabitant were on average 10 tons of $CO_2$ per year. Figure 1.13 shows the breakdown of emission sources, with petrol and diesel cars, meat consumption and fossil fuels being the three largest emission sources. To achieve carbon neutrality in 2050, the average emission level should be reduced to around 2 tons of $CO_2$ per year.

### 1.4.9. *The need for demonstrators and transdisciplinary approaches*

Implementing the energy and societal transition will entail real-scale experimentation with numerous technological and economic solutions, local societal organizations, etc., running through a series of trials, errors and adjustments. This involves validating the viability of technologies, their efficiency and their impact on the environment, social acceptance, which should not be taken for granted, finding new economic models, designing new legal frameworks, etc. It is also about convincing people in order to limit resistance to change. It is a question of setting examples, of being exemplary…

Science and technology are generally developed in laboratories where the conditions for testing are controlled. This usually follows the development of prototypes for innovations. The complexity and speed of the transition encourage earlier and more systematic testing of emerging solutions in real conditions, in which not everything is under control, particularly when it comes to climatic conditions and human behavior. For example, the technologies will have to be tested, but also ideally designed, in the case of smart buildings, with the users of a building occupying that building as usual.

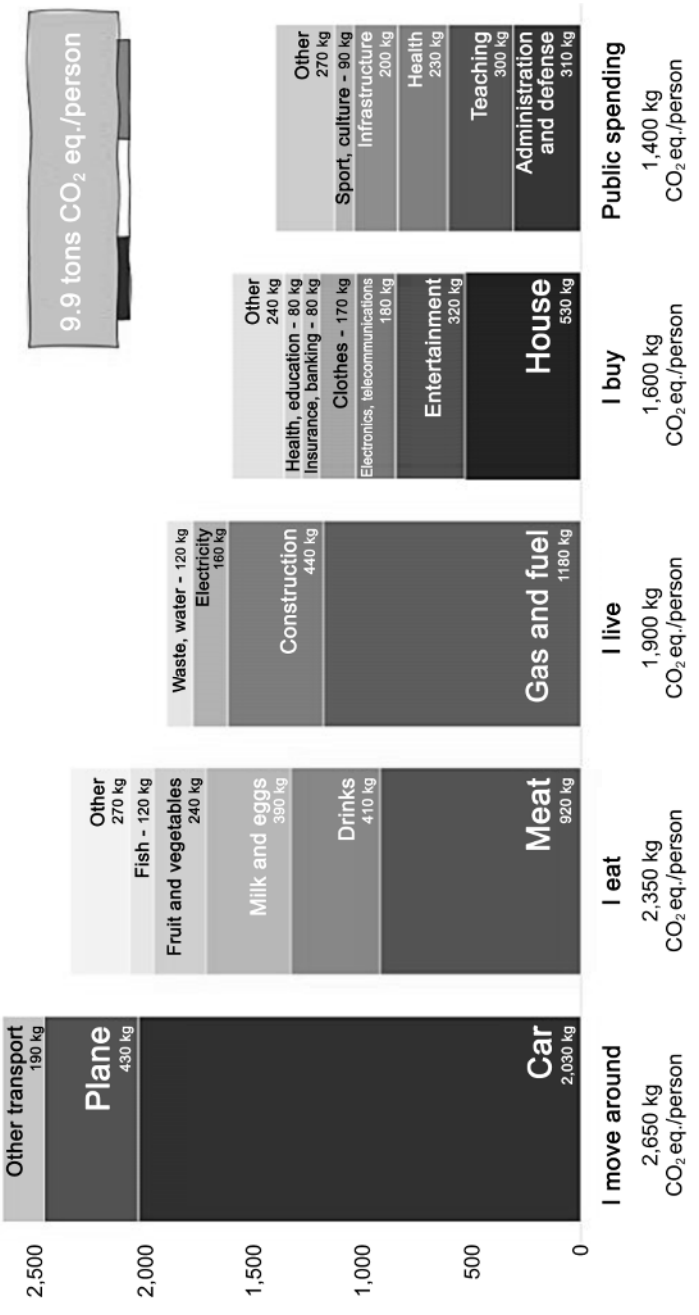


**Figure 1.13.** *Carbon footprint in France in 2019, evaluated by MyCO2 (https://www.myco2.fr/fr/empreinte-carbone-francaise-moyenne-comment-est-elle-calculee/). For a color version of this figure, see www.iste.co.uk/robyns/smartusers.zip*

A confrontation with the reality on the ground, with what is really happening, requires facing up to many disciplines, both in terms of technologies, electrical, communications for smart grids for example, but also in terms of sociological disciplines in order to assess the acceptability and involvement of economic actors, because new viable models are to be found which are legal, ethical, etc. Interdisciplinarity, even transdisciplinarity, will be necessary for the success of the transition.

The legislator must specify a framework allowing for, or even encouraging, the deployment of demonstrators, wardening off “playgrounds” with “sandboxes”, allowing teams the right to experiment for several years.