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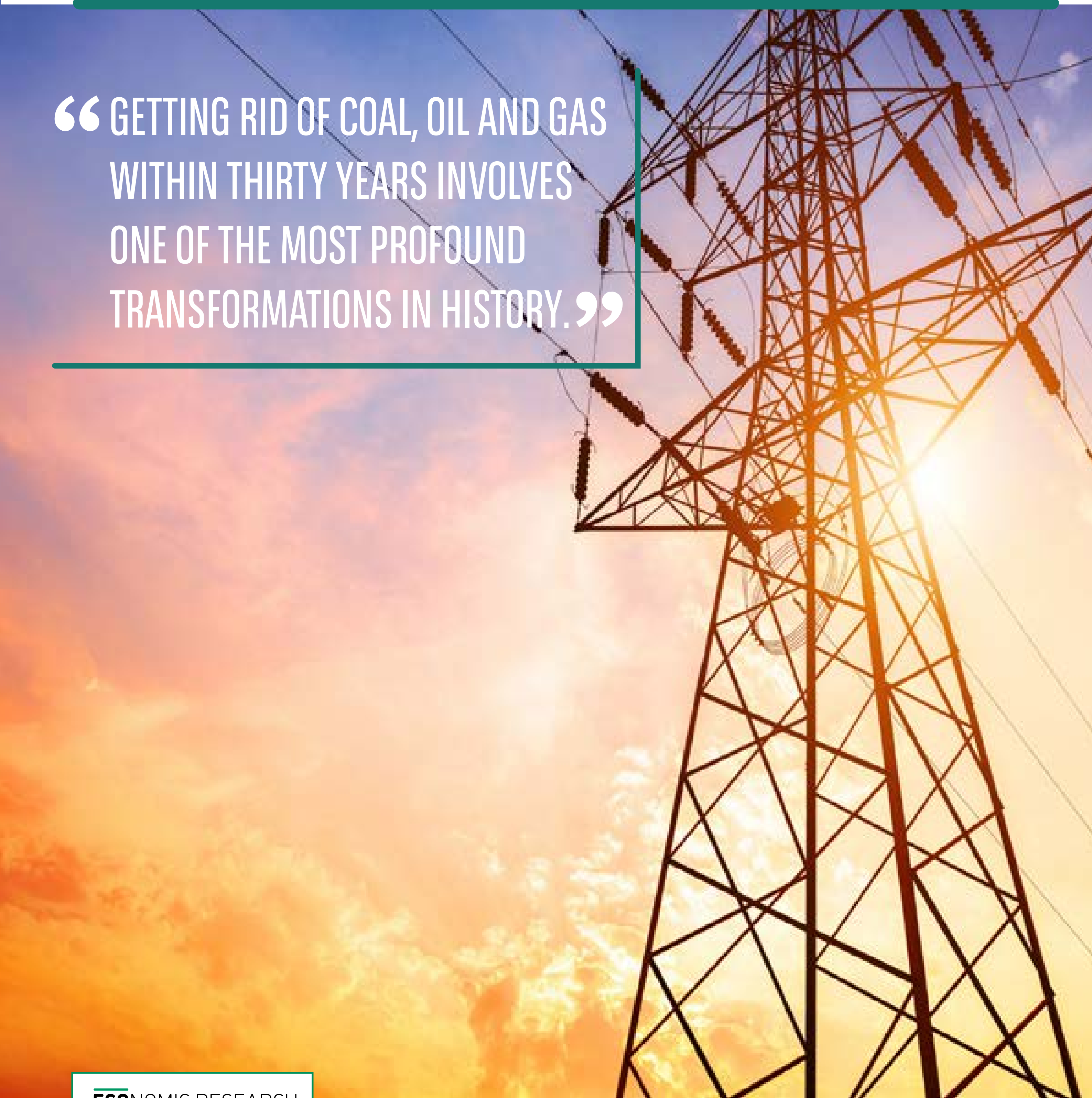
"GETTING RID OF COAL, OIL AND GAS WITHIN THIRTY YEARS INVOLVES ONE OF THE MOST PROFOUND TRANSFORMATIONS IN HISTORY."



ECONOMIC RESEARCH

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TABLE OF CONTENT

CLIMATE NEUTRALITY: THE RACE HAS BEGUN

Jean-Luc Proutat

Record temperatures in China and the United States, unprecedented forest fires in Canada, historic droughts in Spain and Morocco...: summer 2023, which looks to be the hottest ever recorded, confirms, as if it were still necessary, that climate change is here, that its effects are increasing, and that it is not sparing anyone. Its origin lies in a phenomenon that has been known for a long time, since it was first identified in 1824 by the French mathematician Joseph Fourier: the greenhouse effect, caused by human activities releasing a quantity of gas of the same name into the atmosphere.

This is a cumulative process which, unless we want to risk intolerable global warming, will have to stop. Today, there is no longer any scientific doubt as to the urgency of reducing greenhouse gas (GHG) emissions, in order to move towards climate neutrality, at best by 2050. This means almost completely getting rid of coal, oil and gas within thirty years, which, in a world shaped for two centuries by the Industrial Revolution, involves one of the most profound transformations in history.

CLIMATE NEUTRALITY: THE RACE HAS BEGUN

Record temperatures in China and the United States, unprecedented forest fires in Canada, historic droughts in Spain and Morocco, etc.: summer 2023, which looks to be the hottest ever recorded, confirms, as if it were still necessary, that climate change is here, that its effects are increasing, and that it is not sparing anyone. Its origin lies in a phenomenon that has been known for a long time, since it was first identified in 1824 by the French mathematician Joseph Fourier: the greenhouse effect, caused by human activities releasing a quantity of gas of the same name into the atmosphere. This is a cumulative process which, unless we want to risk intolerable global warming, will have to stop. Today, there is no longer any scientific doubt as to the urgency of reducing greenhouse gas (GHG) emissions, in order to move towards climate neutrality, at best by 2050. This means almost completely getting rid of coal, oil and gas within thirty years, which, in a world shaped for two centuries by the Industrial Revolution, involves one of the most profound transformations in history.

TWO HUNDRED YEARS OF HABIT

From Adam Smith to the present day, nations' wealth has been built on fossil fuels. Known since the Middle Ages, coal powered the steam engines which, from the end of the 18th century, made the Industrial Revolution possible. Two hundred years later, it continues to play an important role in the development of Asia's major economies, such as China and India. Oil and gas have become integral to our lifestyles, from replacing oil lamps to their use in transportation, agriculture, chemicals, textiles, and more. In 2022, all fossil fuels still accounted for 82% of the world's energy consumption, i.e. 137,236 terawatt hours[1].

If the world had failed to exploit the richness of the subsoil and remained propelled by animal strength, such power would have quite simply been inconceivable. At a conservative estimate, it would be equivalent to harnessing 100 billion horses, unequally distributed for that matter: An average of 200 workhorses for a family of four in the US, compared to half that in the European Union and fifteen to twenty times fewer in Africa[2]. As gross domestic product (GDP) is only ever but a conversion of energy, its curve has logically risen with the exploitation of fossil resources. Between 1820 and today, its real value (adjusted for inflation) has multiplied by 100 worldwide; humanity has seen its material conditions as well as its numbers turned upside down. At 8 billion people, it is eight times larger than at the beginning of the 19th century, but also infinitely better off, with a level of wealth (a real gross domestic product per capita) increased more than tenfold, and a life expectancy at birth more than doubled[3].

Having escaped from the Malthus' law for two centuries is no small feat for the 'industrial man'. However, there is another law that will never cease to apply, namely energy conservation. In a closed world, nothing is created or disappears, everything is transformed: no more than perpetual movement exists, fossil fuels do not make miracles. As the fruit of millions of years of decomposition of organic matter, their reserves cannot be replaced and are therefore destined to run out at some point. As for their by-products, greenhouse gases, we are reminded of the danger of their accumulation in the atmosphere each year with more insistence by climate change.

According to IPCC (Intergovernmental Panel on Climate Change) assessments, net GHG emissions from human production activities, land use and land development are between 55 and 60 billion tonnes of CO_2 equivalent (Gt CO_2 eq) per year[4]. Among them, carbon dioxide (CO_2) occupies a predominant place (64%), not that it is the most opaque to terrestrial infrared radiation (methane, nitrous oxide and even water vapour are much more so) but because its multi-century lifetime is particularly long. The carbon overload of the atmosphere, which is equivalent to no fewer than 4,400 Eiffel towers per day[5], is therefore largely irreversible. The air we breathe bears the traces of the first Liverpool-Manchester journey by steam train (1830), the tragic cruise of the Titanic (1912), the first transatlantic flight of Charles Lindbergh (1927), the Apollo 11 mission to the Moon (1969) and more generally all past or present acts requiring the combustion of fossil materials.

Referring to the pre-industrial era (by convention, the 1850–1900 period), the cumulative anthropogenic release of CO_2 amounts to 2,400 billion tonnes and results in an atmospheric concentration of 418 parts per million (ppm) in 2022, the highest for at least 2 million years. The associated rise in temperatures (the greenhouse effect) has reached 1.2°C on average on the surface of the world, while it has already exceeded 2°C in Europe, one of the most likely places to heat up today[6]. Once again, the phenomenon is irreversible, and one of the few certainties that the future allows is that it will increase.

GLOBAL WARMING:THE CONSEQUENCES SEEN BY THE IPCC

Although it is no longer called into question, the current episode of global warming is sometimes relativised on the grounds that it is not the first, and that the climate has varied from time to time. As the Earth does not have a regular orbit (it is influenced by the large planets of the solar system), the temperature on its surface changes according to the quantities of radiative energy that reach it and which determine, for example, the large quaternary cycles. Between the end of the last ice age (10,000–15,000 years ago) and today, the atmosphere has warmed by an average of around 6°C[7]. Palaeolithic France, which resembled the current Siberia, has evolved towards a temperate climate.

1 Sources: Our World in Data, Energy Institute Statistical Review of World Energy (2023). Here, a correction factor applies to account for energy losses (in the form of heat) resulting from the combustion of fossil fuels.
2 Calculation based on the mechanical power supplied by a workhorse, delivering 1,600 kilowatt hours per year for six hours of work per day.
3 Global GDP per capita in constant 2011 dollars and purchasing power parity (PPP) is valued at USD 15,200 in 2018, compared to USD 1,100 in 1820, and has therefore multiplied by nearly 14. Thanks to the decline in child mortality, the life expectancy at birth of the world population rose from just 30 years in 1820 to 72 years in 2018.
Sources: University of Groningen, Maddison Project Database, 2020; Riley J.C. (2005), Estimates of Regional and Global Life Expectancy, 1800-2001. Population and Development Review. Vol. 3; United Nations (2022), World Population Prospects.
4 This section is based on the respective contributions of IPCC Working Groups I, II and III to the IPCC's 6th climate report.
IPCC (2021), Climate Change 2021, the Physical Science Basis, Working Group I contribution to the Sixth Assessment Report, Summary for Policymakers, October.
IPCC (2022), Climate Change 2022, Impacts, Adaptation and Vulnerability, Working Group II contribution to the Sixth Assessment Report, Summary for Policymakers, October.
IPCC (2022), Climate Change 2022, Mitigation of Climate Change, Working Group III contribution to the Sixth Assessment Report, Summary for Policymakers, April.
5 The weight of the Eiffel tower is 10,000 tonnes, while global GHG emissions converted to carbon represent approximately 16 gigatonnes (60 Gt CO2 eq x 12/44), i.e. for one day: (16 x 10^9)/(10,000 x 365) ≈ 4,400 Eiffel towers.
6 One of the reasons given for this is the geographical location of the Old Continent, at the confluence of the sub-tropical and polar jet streams. See Rousi E. & All. (2022), Accelerated western European heatwave trends linked to more-persistent double jets over Eurasia, Nature Communication Review, July.
7 See for example Tierney J. & al. (2020), Glacial cooling and climate sensitivity revisited, Nature Review, August.

These new conditions, also present throughout Europe, have encouraged the emergence of agriculture (around 7,000 BCE) and the sedentarization of hunter-gatherer populations, who were previously required to roam immense territories as animals migrated. Long before the demographic explosion of the Industrial Revolution, humanity took the very first step in its expansion[8].

However, what is now being played out is something different. For the first time, the causes of climate change are no longer natural but anthropogenic, *i.e.* linked to human activities. The time scale is disrupted: at the rate observed over the past fifty years, the rise in temperatures is 30 to 50 times faster than all those that preceded it. Beyond its scale, it is the suddenness of the phenomenon that raises the question of the adaptability of species and which is worrying the scientific community.

Accelerated global warming leads to increased human mortality and morbidity, through hyperthermia, stress, and infectious diseases; intensification of droughts, forest fires, hurricanes, floods, and landslides, particularly in low-altitude coastal cities and regions as well as in mountainous areas where the cryosphere is weakened; biodiversity losses in terrestrial, river, and ocean ecosystems; the spread of food insecurity in relation to increased variability in agricultural yields, etc.

Since 2001, the IPCC has been using a "thermal scale" ranging from white-yellow (undetectable to measured risks) to red-purple (high to very high risks), which it breaks down into five major "reasons for concern" (RFC, box 1). Its judgement, as it becomes more refined, is that the consequences of global warming are more likely to worsen at lower thresholds of temperature rise than initially estimated. The sixth report of 2023 indicates, for example, that the critical zone for unique ecosystems (mountain glaciers, coral reefs, RFC1) and extreme weather events (RFC2) has already been reached, whereas the fifth report of 2014 put it at around a 1.5°C increase in global temperature.

The 2°C limit itself should prove less protective than expected in 2009, when it was first established at the fifteenth Conference of the Parties (COP 15) in Copenhagen. From this stage, and even more so beyond, the occurrence of large-scale singular events (RFC5) corresponding to climate "tipping points" can no longer be formally ruled out. These could include the break-up of all or part of the Greenland or West Antarctic ice sheets, or the collapse of the Atlantic Meridional Overturning Circulation (AMOC), identified by climate scientists as extreme risks by the end of this century.

However, envisaging the worst does not mean predicting it. In the IPCC scenarios, the worsening consequences of global warming are not inevitable, but depend above all on human action. In terms of adaptation, experts welcome the strengthening of risk prevention (weather alert systems, etc.) as well as that of infrastructure (dykes, dams, bank developments, etc.) which, in all likelihood, have already saved lives. But they note that progress remains incomplete and, often, far from the ambitions set by governments. In addition, investments in climate resilience are more likely to be in emergency situations than in a global long-term strategy; their geographical deployment is also very uneven. In low-income countries, the lack of financing remains the main obstacle, although it is not the only one (institutional, socio-cultural and geophysical aspects also play a role).

However, this is precisely where the most vulnerable populations live and where the effort to adapt seems both to be the most necessary and, potentially, the most beneficial. In Latin America, Africa and Asia-Pacific, it is not so much industrial or energy production that is responsible for the accumulation of CO_2 in the atmosphere as the change in land use: intensification of agricultural practices, soil artificialisation and deforestation[9]. In these regions of the world, even more so than elsewhere, adaptation to climate change must be combined with more sustainable management of land resources (reduction of monocultures, limitation of inputs, reforestation, diversification of

GLOBAL WARMING: THE IPCC'S FIVE MAJOR REASONS FOR CONCERN

The IPCC has grouped the risks associated with global warming into five major families or "Reasons For Concern" (RFC), based on their proximity and the accuracy of their assessment:

- Unique and threatened ecological and human systems (RFC1) that have restricted geographic ranges constrained by climate-related conditions (mountain glaciers, coral reefs) and/or which have a high rate of endemism (indigenous peoples of the Arctic or Amazon...).

- Extreme weather events (RFC2) such as heat waves, droughts, forest fires, hurricanes, torrential rain, floods or submersions, impacting people's property and health, their livelihoods and ecosystems.

- Distribution of impacts (RFC3) whereby certain regions of the world or categories of population would suffer more than others from the consequences of global warming, for geographical or socio-economic reasons (income levels and wealth, age, type of employment, etc.). In addition to the consequences in terms of public health (RCF2), the associated risks include the amplification of migratory phenomena as well as the rise in international or social conflict over the sharing of resources.

- Global aggregate impacts (RFC4) are those that can be summarised globally in a single measurement, such as financial or business losses (in dollars or GDP points), the number of lives affected, the decline in the numbers of animal or plant species, the percentage of those which face extinction, etc.

- Large-scale singular events (RFC5) relating to relatively large, sudden and sometimes irreversible changes in systems due to global warming, such as slowing ocean circulation (including the Gulf Stream) or the melting of the Greenland and West Antarctica ice caps.

BOX 1 SOURCE: IPCC

8 See for example Cohen D. (2015), The world is closed and desire is endless, Albin Michel.
9 IPCC (2022), Working Group III, ibid. p.14. In Latin America, South-East Asia and the Pacific and in Africa, land use, land-use change and forestry (LULUCF) account for around two-thirds of cumulative net CO_2 emissions since 1850.

species) and marine resources (development of aquaculture, establishment of protected areas). It also involves restoring natural areas (hedges, meadows, forests, wetlands) and integrating them into production methods such as agroforestry, intercropping plant cover, direct seeding, etc. Alongside the strengthening and securing of energy systems and the adaptation of urban policies (sustainable urban planning and water management, improved energy performance and reliability, etc.), the rehabilitation and enhancement of ecosystems are among the first lines of defence against global warming identified by the IPCC. Politically, the idea is gaining ground, as evidenced by the very first multilateral agreement on the preservation of biodiversity signed in 2022 in Montreal[10].

Nevertheless, regardless of the resilience plans envisaged, all have the same warning: their cost will increase and their efficiency will decrease with every tenth of an additional degree of overall temperature rise. Faced with climate change, adaptation and mitigation efforts are responding, which invariably leads to the problem of reducing greenhouse gas emissions and the means to achieve this.

THIRTY YEARS TO ACT

Staying on the current path is not an option. Admittedly, the ship has started to turn around: global net GHG emissions rose 0.5% per year on average between 2012 and 2022, four times slower than in the previous ten years, which were marked by the surge in activity in China and India. Not only the global economic slowdown following the 2008 financial crisis, but also the first real efforts to combat climate change, explain the trend shift. However, a simple extrapolation of this trend based on the policies implemented would still lead to global warming of 3.2°C by 2100 (the IPCC's median scenario), with a "high to very high" probability that all the risks mentioned above will materialise.

Therefore, there is a need to do better, or, in terms of emissions, much less. By focusing on one of the most persistent greenhouse gases in the atmosphere – namely CO_2 – the IPCC indicates that net global emissions should be reduced *"immediately, rapidly and continuously"*, if we hope to remain within the framework of the Paris Agreement defined in 2015. Compliance with the 1.5°C limit would mean halving them by 2035, for imperative climate neutrality (zero net emissions) around 2050. Remaining below 2°C is hardly any less demanding, as it leaves only twenty more years to achieve the same goal.

The capture and geological storage of CO_2 (CCS) may one day help the "ashes" of the Industrial Revolution return underground[11]. Moreover, the IPCC is relying on this to support its most favourable scenarios by the second half of this century. But with the current state of technology and knowledge, CCS offers only limited potential for net emission reduction, while "its difficult implementation and very high cost make it a risky solution that comes as a last resort in a cost-benefit analysis" (French Environment and Energy Management Agency, 2020[12]).

Therefore, will a radical downturn in CO_2 emissions require a shift to negative growth? After two hundred years of shared history, there is no doubt that GDP and carbon still have strong and complicated links to break down[13]. However, summarising the future as only an alternative between growth and the climate would lead to a impasse (Pisani-Ferry, 2023)[14]. Improvement of the material conditions of existence remains a powerful driver for most of human societies, as well as one of the guarantees of their cohesion. The decline in living standards (a fall in real GDP per head), when it occurs in a recession phase or, worse, economic depression, is not an organised collective choice, but a phenomenon that is suffered. A degrowth discourse implies unemployment; in advanced countries, where the question of the distribution of wealth, for example between working people and pensioners, is already a major issue, it is socially inflammatory; in developing countries, it is inaudible.

10 On 19 December 2022 in Montreal, the 15th Conference of the Parties (COP15) on Biological Diversity (chaired by China) led to the signing of a historical agreement between 190 countries, the first to define a multilateral framework of action for the protection of natural spaces. By 2030, COP15 plans to extend the protection of land (compared with 17% today) and sea (compared with 8% today) to 30%; the same target of 30% is assigned to the restoration of degraded ecosystems. In order to achieve this, a doubling of financial resources (from USD 100 billion to USD 200 billion per year) is planned, with advanced countries also committing to support the efforts of developing countries (up to USD 30 billion per year).

11 Expression borrowed from the philosopher and researcher Pierre Charbonnier and used in the France Stratégie report on the economic impact of climate action (see below). See Charbonnier P. (2020), Abundance and Freedom, Paris, La Découverte.

12 ADEME (2021),"Transition(s) 2050. Choose now. Take action for the climate", Report, November. See Charbonnier P. (2020), Abundance and Freedom, Paris, La Découverte.

13 Proutat J.L. (2023), "GDP and carbon, the pair remain united", BNP Paribas Economic Research,Chart of the Week, January.

14 Pisani-Ferry J., Mahfouz S. (2023), "The economic impacts of climate action", France Stratégie Report, May.

ON THE ROAD TO DECARBONISATION: THE CASE OF THE AUTOMOTIVE SECTOR IN FRANCE

In France, the transport sector is by far the leading emitter of greenhouse gases: 126 million tonnes of CO2 equivalent or 30% of the total in 2021, i.e. three times more than housing, for example. Contrary to what one might think, the biggest emitters are not heavy goods vehicles, and even less so aircraft (which account for around 10% of travel), but the approximately 38 million passenger cars that run on French roads and motorways. Hence the focus of public policies on an accelerated "greening" of the fleet. As part of the National Low Carbon Strategy (SNBC), a 2040 ban on sales of internal combustion cars is already enshrined in law; in reality, it should come into effect as early as 2035, the date set by the European Council. As a result, sales of electric vehicles are taking off. In a market that contracted in 2022, they rose by 25%, which is doubtless only the beginning. By 2035, provided that the supply of low-carbon electricity and the recharging infrastructure keep pace, the French electricity grid operator RTE expects the number of electric vehicles on the road to increase 25-fold, to almost 16 million units. By 2050, the conversion should be complete and the carbon footprint of people's mobility reduced by nearly 70% according to the "trend" scenario developed by ADEME. By combining the technological leap with sober behaviour (limiting demand for travel, particularly long-distance and by air, increasing load factors, etc.), the objective of climate neutrality (95% reduction in emissions) becomes achievable.

BOX 2

SOURCE: ADEME, FRANCE STRATÉGIE, BNP PARIBAS

In the "Shared Socioeconomic Pathways" (SSPs) linked to the IPCC's various projections of CO_2 emissions, a drop in real GDP per capita is not considered, unlike sobriety, which is a separate concept. This can be defined as the energy savings that, over and above those made possible by technical progress, result from changes in the behaviour of households and businesses. ADEME indicates that this may involve sobriety of use (limiting heating or air-conditioning, preferring walk or cycle for short distances, prioritising local or recycled items consumption, etc.), sobriety of size (for single-family vehicles, houses, etc.) or sobriety of cooperation (prioritising collective transport, carpooling, renting rather than buying equipment, etc.[15]).

Described as "non-negotiable" thirty years ago by the President of the United States[16], societies' way of life is now part of the equation that needs to be solved if we are to change the course of climate change. Adaptation, whether spontaneous or orchestrated by governments, is not, however, the main response: in the IPCC or ADEME scenarios, it supports rather than underpins the "net zero" hypothesis, which is based above all on the energy transition and the replacement of "brown" capital (based on fossil fuels) with "green" capital (based on renewable energies, see Box 2).

The best response to the degrowth theories is technological in nature: by decarbonising its energy mix through new and constantly more efficient means, the European Union is able, for example, to emit less without sacrificing its activity: since 1990, its carbon footprint per capita (which takes into account net imported CO_2 emissions) has fallen by 25%, while its real GDP per capita has increased by 54%[17].

The main objective of the "fit for 55" plan adopted by the European Council in 2022 is to increase the share of renewables from just over 20% of final energy consumption today to 40% or 45% in 2030. In some countries (France, the Netherlands, Finland, Sweden, etc.) the effort will be accompanied by a revival of the electronuclear sector, the aim (the only one compatible with climate neutrality) being to eliminate hydrocarbons from the energy mix by 2050. The US Inflation Reduction Act (IRA), while marking differences in strategy and agenda, places the United-States on a similar trajectory.

"GREEN" TECHNOLOGY REVOLUTION

"Green" technologies promise a great future, but they are not spared criticism. This is generally threefold: they are capital-intensive, which makes them cumbersome, natural resource-intensive (particularly in metals) and, ultimately, not so "green"; solar and wind power are not pilotable and will remain intermittent energies; they are expensive and require significant investment, which only rich countries seem able to afford. Let's take a look at each point.

Nothing is created, everything is transformed. To return to the law on energy conservation, green capital is obviously not created from nothing but, still often, from fossil fuels: this is the case for hydrogen, more than 90% of which is obtained by steam cracking hydrocarbons, but also for solar panels, electric batteries, and wind turbines, which require metals to be extracted and refined, with the use of gas, oil or coal still in the background. Paradoxically, it is by relying on the latter that China has risen to become the undisputed leader in "green" technologies, to the point of dominating the photovoltaic cell sector (70% of global supply) and lithium-ion batteries (75% of global supply).

Is pushing fossil fuels out through the door and back through the window really worth it in the end? The answer is "yes", as long as it results in a greenhouse gas saving. To assess this, we compare the carbon footprint of each technology, not at a given moment, but over a complete life cycle (manufacturing, transport, use, destruction-recycling). However, the verdict is clear: in order to produce energy, it is infinitely preferable to concentrate fossil fuels in capital, rather than burning them directly, and with a loss of heat. Whereas a conventional thermal power plant will emit between 900 and 450 grams of CO_2 equivalent per kilowatt hour (depending on whether it runs on coal or gas), a solar farm will only emit around 45 grams, a wind farm barely 15 grams, and a nuclear power plant even less (12 grams, according to the median IPCC assessments)[18].

There is no contest, except in terms of capital intensity: for like-for-like production, green technologies require more materials, particularly metals, than others, resulting in a lower weight-to-power ratio and greater use of space. But in this case, technical progress is such that limits deemed insurmountable are constantly being pushed back. As the main driver of the increase in global demand for minerals, the electric vehicle industry could soon be revolutionised (possibly within five to ten years) by "dry" or "solid-state" battery technology, which promise to be safer, cheaper and more efficient than the currently dominant lithium-ion[19] technology.

With the addition of perovskite to the silicon of which they are made, photovoltaic cells are close to reaching (if not already exceeding under certain conditions) the 30% efficiency mark, long considered an absolute theoretical ceiling. In a country like France, where there are plans to run high-speed trains using solar energy[20], the technological leap forward will encourage trade-offs: in the current situation, around 4,000 hectares (40 km^2) of land and roofs must be covered with panels to obtain the equivalent of the annual production of a 900-megawatt reactor. In ten years' time, this area could be halved[21]. Similarly, the projected footprint of wind turbines is likely to be revised downwards as yields improve. The French electricity grid operator RTE estimates that, without changing nuclear power capacity, it would be necessary to aim for some 30,000 land-based masts in, i.e. almost four times the current fleet, to achieve France's carbon neutrality by 2050 (RTE, 2021[22]). However, the power levels on which it is based (2.5 megawatts per wind turbine) have already been exceeded by the latest generation of equipment.

15 Ibid pp. 79-231.
16 George H.W Bush (1992), Speech at Rio de Janeiro Earth Summit, June.
17 Developments calculated over the 1990-2019 period. Sources: World Bank, World Development Indicators (for GDP per capita) and Our World in Data - The Carbon Project for carbon footprint data.
18 IPCC (2014), Technology-specific cost and performance parameters, Contribution of Working Group III to the Fifth Assessment Report, Annex III, June.
19 "Dry" or "solid-state" batteries do not contain any liquid electrolyte and therefore allow significant weight and space savings. They would also be safer, more efficient and cheaper to produce. On 4 July 2023, the Japanese manufacturer Toyota announced that it had reached a milestone in their development, making it possible to envisage a reduced charging time (10 minutes for 80% capacity) and a range in excess of 1,200 kilometres.See The Guardian (2023) "Toyota claims battery breakthrough in potential boost for electric cars", July.
20 On 6 July 2023, the CEO of the French National Railway Company (SNCF), Jean-Pierre Farandou, announced the creation of "SNCF Renewables" aimed at covering 15% of the company's electricity needs from solar panels.
See Farandou J.P. (2023), interview with Le Monde newspaper, 6 July.
21 With the following assumptions: average annual irradiation: 1,300 kWh/m2 in 2023, 1,350 kWh/m2 in 2033; average yield of a photovoltaic panel (combining different technologies): 12.5% in 2023, 25% in 2033.
22 RTE (2021) "Energy Futures 2050", October.

In the energy mixes of the future, sunlight and wind will have to supply most of the electricity production (up to 75% in the EU according to the EMBER research institute[23]), which means circumventing the obstacle of their intermittency. However, there are also significant advances in this field. Real-time flow measurement, the use of very high voltage direct current (HVDC), and new-generation transformers will enable much better integration of renewable energy sources into the grids, even when they are very far apart. The combination of wind turbines and batteries already provides a credible solution for electricity storage and real-time system balancing. In France, the "Ringo" experiment conducted by RTE, for example, already offers 10 megawatts of redistributable capacity.

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2022 will be remembered for the outbreak of the war in Ukraine, but perhaps also as a time when, for the first time in Europe, solar and wind power supplanted gas in electricity generation. Faced with the climate emergency, a technological revolution is taking place. Large-scale energy production that no longer relies on fossil fuels is becoming conceivable, the only question being for whom and when.

The fact is that most of the countries that have so far managed to reconcile growth and decarbonisation are starting from a high level of wealth (two-thirds belong to the top quartile of global GDP distribution per capita[24]). At the lower end of the income scale, falling emissions are the exception rather than the rule.

While "brown" energies are unrivalled in the early stages of economic development, it is because they are still accessible and affordable. The fact remains, however, that "green" alternatives are becoming increasingly credible, both technically and financially. In just fifteen years, the cost of onshore wind power has been cut by a factor of three, and the cost of photovoltaics by a factor of ten. At around 30 dollars per megawatt-hour for the former and 50 dollars per megawatt-hour for the latter[25], it makes the choice in favour of gas or coal less systematic, and not just in developed countries. Of the fifteen most powerful solar farms operating worldwide, four are in India and six in China. According to the International Energy Agency (IEA), China is still the country that is investing the most in its energy transition: USD 511 billion in 2022, almost double the amount in 2015 and more than all the other emerging countries combined[26].

The investments are there, but they will have to be multiplied, in China as elsewhere, if we hope to bring the emissions curve onto a "net zero" trajectory. Globally and by 2030–35, they are projected to reach USD 4,500 billion[27] annually, well over double the amount currently spent on tackling climate change. This is a major effort, to be carried out in a short period of time, and more necessary than ever.

Jean-Luc Proutat

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23 EMBER (2023) European Electricity Review, January.
24 Based on a panel of 126 countries, excluding the main hydrocarbon producers. See Proutat J.L. (2023) "CO2 emissions: who is setting the trend?", BNP Paribas Economic Research, Graph of the week, April.
25 Average overall cost calculated over a full life cycle, in 2021.
Source: International Renewable Energy Agency (2022), Renewable power generation costs in 2021.
26 IEA (2023), "Scaling up Private Finance for Clean Energy in Emerging and Developing Economies", June.
27 Investments in fossil alternatives (including nuclear) at constant 2019 prices.
See IEA (2021), "Net zero by 2050, a Roadmap for the Global Energy Sector", October.

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