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REPORT

NOVEMBER 2023

THE ECONOMIC IMPLICATIONS OF CLIMATE ACTION

Jean Pisani-Ferry
and Selma Mahfouz

A Report to the French Prime Minister

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FRANCE STRATÉGIE

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FOREWORD
TO THE ENGLISH VERSION

Achieving greenhouse gas (GHG) emissions-reduction targets is central to climate-action policies. These policies, which will play a key role in many areas of public policy, will only be sustainable if proper consideration is given to their full economic and social implications. It is therefore vitally important to have solid tools for analysing and simulating the impacts of these policies on the economy. This report presents such tools and details the simulations they support.

This is the English version of the report published in May 2023 under the title *Les incidences économiques de l'action pour le climat*. It was accompanied by 11 thematic reports, all available in French on France Stratégie's website.

The report built on an interim report published in November 2022 and entitled *L'action climatique : un enjeu macroéconomique*, also available in French on France Stratégie's website.

This English version has not been updated. It has been edited for language precision and the removal of a few ambiguities in the original version.

PREFACE

Achieving greenhouse gas (GHG) emissions-reduction targets is central to climate-action policies. These policies, which will play a key role in many areas of public policy, will only be sustainable if proper consideration is given to their full economic and social implications. It is therefore vitally important to have solid tools for analysing and simulating the impacts of these policies on the economy. This report presents such tools and details the simulations they support.

This report is the result of a major collective endeavour. Jean Pisani-Ferry published a key paper in the summer of 2021, where he highlighted the scale of the macroeconomic shock that climate-action policies could cause.[1] France Stratégie subsequently decided to bring together the main institutional players involved in producing and using analytical tools that could answer the questions raised in the paper. They all accepted France Stratégie's invitation to take part in the exercise. In September 2022, the Prime Minister sent an engagement letter to Mr Pisani-Ferry, setting out her expectations of the project as well as a work schedule. She entrusted the task of coordinating the project to France Stratégie, establishing a strong foundation and well-defined objectives. Mr Pisani-Ferry and Selma Mahfouz, the general rapporteur, led a body of work that culminated in the production of 11 thematic reports plus a summary report with supporting simulations. We would like to extend our warmest thanks to the many contributors who made possible, within a very tight time frame, a project that – to our knowledge – is without equivalent.

For France Stratégie, this project represents a major step towards building a reference corpus for analysing decarbonisation policies and estimating their effects. This corpus includes the definition of the value of climate action (or the shadow price of carbon), which has served as a benchmark for public investment (Alain Quinet, 2019); the chapter on climate change in *The Major Future Economic Challenges*, a report by the international commission chaired by Olivier Blanchard and Jean Tirole (2021); and all the

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[1] Pisani-Ferry J. (2021), "Climate policy is macroeconomic policy, and the implications will be significant", Peterson Institute for International Economics, *Policy Brief*, No. 21-20, August.

publications by the commission chaired by Patrick Criqui on carbon abatement costs in key emitting sectors.[1]

We are therefore continuing to execute on our mission of informing government policy- and decision-making by drawing on the broadest possible pool of expertise and bringing the full conclusions of this work to public attention.

Gilles de Margerie
Commissioner General of France Stratégie

[1] Quinet A. (2019), *La valeur de l'action pour le climat*, France Stratégie, February; Blanchard O. and Tirole J. (2021), *The Major Future Economic Challenges*, France Stratégie, June; for Patrick Criqui, see the work of the commission on abatement costs on the France Stratégie website.

FOREWORD

In the engagement letter she sent me on 12 September 2022, the Prime Minister asked me to focus on developing a clearer understanding of the macroeconomic impacts of the climate transition, with a view to "better-informed decision-making".[1]

The aim of this exercise may seem unusual. Since the issue of climate change came to the fore in the early 1990s, a great deal of work has been dedicated to its economic impact. The Intergovernmental Panel on Climate Change (IPCC), multilateral organisations, governments, specialised modelling teams and the academic community have tackled the subject head-on, producing a number of high-quality studies.

Yet for too long, climate change was approached from a long-term perspective. It was a top priority, but only an issue for the day after tomorrow. Macroeconomists, who are generally not climate specialists, could ignore climate change in their practical discussions about growth, employment, inflation or public finances. So they duly ignored it – as did most of those tasked with making economic decisions for the years to come.

Awareness of the immediate economic implications of the climate transition is still very recent. Three events have precipitated a change in perspective. The first was the Paris Agreement, signed in late 2015, which set out a framework and an ambition. The second came in 2019 with the European Union (EU) agreement on achieving carbon neutrality by 2050, and on reducing GHG emissions by 55% by 2030 compared with the 1990 baseline. This abrupt step-change saw macroeconomists sit up and take notice of climate issues. The third event was the enactment of the Inflation Reduction Act (IRA) in the summer of 2022, which brought the issues of competitiveness and attractiveness sharply to the fore, as the United States adopted a different climate strategy from the EU.

Change has also come only recently in France. Initially, after the 2017 election, the government made carbon taxation a priority, before having to back down in view of the uproar caused by this approach. Later, a series of concrete decisions were taken based on recommendations from the Citizens' Climate Convention. But there was no guarantee

[1] See Appendix 1 for the engagement letter.

that the sum of these decisions would actually allow the target to be achieved. It was only after the 2022 election that a method – ecological planning – was chosen and that work on setting up the corresponding instruments began. The creation of the General Secretariat for Ecological Planning (SGPE) reflected a desire for consistency between targets and measures, which should be established in the forthcoming Energy-Climate Programming Law.

The work behind this report was conducted in this changed context. Once the working group got under way at France Stratégie, I immediately came to understand the level of commitment shown by government bodies, economic institutes and the academic community. It was on this basis that the interim report[1] was prepared last November, and that this summary report and the 11 thematic reports[2] on which it is based were produced. These outputs were developed with the participation of around 100 experts, with whom we shared the questions, the methodological issues and the results. The recommendations in this report were also discussed with these experts, although they bear no responsibility for these recommendations. I would like to thank them all, and to express my gratitude to the government bodies and institutions that were involved in this exercise.

The work was also carried out in close conjunction with the SGPE, and is aligned with ongoing efforts by the Ministry for the Ecological Transition to prepare the new version of France's National Low-Carbon Strategy (SNBC 3) and the Energy-Climate Programming Bill. Although the assessments and recommendations in this report are the sole responsibility of its authors, we worked together with these other bodies in a spirit of full information-sharing and mutual trust.

One of the aims of this exercise was to identify the strengths and weaknesses of the modelling tools used to assess the macroeconomic impact of mitigation measures. Thanks to the input from the teams at the French Environment and Energy Management Agency (ADEME) and the International Centre for Research on Environment and Development (CIRED) – and to the support of the French Economic Observatory (OFCE), the French Treasury (DG Trésor) and the Department of the Commissioner-General for Sustainable Development (CGDD) – we were able to "lift the lid" and progress together in understanding the economic mechanisms at play. Although the process has been long and demanding, I am convinced that it has been useful and that it will lead to future progress.

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[1] Pisani-Ferry J. and Mahfouz S. (2022), "L'action climatique : un enjeu macroéconomique", *La Note d'analyse*, No. 114, France Stratégie, November.

[2] The 11 thematic reports are available (in French) on the France Stratégie website. They cover the following themes: Well-being, Competitiveness, Loss and Damage and Adaptation, Indicators and Data, Distributive Issues, Inflation, Capital Markets, Labour Markets, Modelling, Productivity, and Sufficiency. The list of authors can be found in Appendix 2.

I owe special thanks to the people at France Stratégie who supported this exercise, and especially to its Commissioner General, Gilles de Margerie, who took the risk of asking me to take on this task without knowing whether I would be able to complete it in the required time frame.

Finally, Selma Mahfouz is named as a co-author of this report – and of *L'action climatique : un enjeu macroéconomique*, an interim report published in November 2022 – in recognition of the prominent role she played at every stage in its preparation.

This report is much more far-reaching in scope than the interim report: it deals, for example, with issues of international collective action, competitiveness, inflation, effort-sharing and public finances, which were only mentioned briefly in the interim report. The report is divided into two sections: the first deals with the transition from an international perspective and over the long term, while the second, which is less conceptual and more concrete, looks ahead to 2030 and focuses on the situation in France, as determined by the European context.

Jean Pisani-Ferry

Acknowledgements

Our warmest thanks go to all the organisations that contributed to this report: the French Environment and Energy Management Agency (ADEME), the Banque de France, Bruegel, the Center for Prospective Studies and International Information (CEPII), the Department of the Commissioner-General for Sustainable Development (CGDD), the International Centre for Research on Environment and Development (CIRED), the Directorate for Research, Studies and Statistics (DARES), the Budget Directorate, the Directorate General for Energy and Climate, the Directorate General for Enterprise, the French Treasury (DG Trésor), France Stratégie, the Institute for Climate Economics (I4CE), the French National Institute of Statistics and Economic Studies (INSEE), the French Economic Observatory (OFCE), the French electric transmission system operator (RTE), and the General Secretariat for Ecological Planning (SGPE).

Special thanks go to Cédric Audenis, Louis Boillot, Léa Boudet, Isabelle Cabanne, Nicolas Carnot, Antoine Deruennes, Gaël Callonec, Benoît Campagne, Alma Monserand and Xavier Ragot, as well as to all the coordinators of the thematic working groups: Didier Blanchet, Nicolas Carnot, Stéphane Dees, Anne Epaulard, Lionel Fontagné, Pierre-Louis Girard, Carole Hentzgen, Vincent Marcus, Michaël Orand, Aude Pommeret, Nicolas Riedinger, Xavier Timbeau and Jérôme Trinh. We would also like to thank the project team: Anne Epaulard, Maxime Gérardin, Miquel Oliu-Barton, Aude Pommeret, Nicolas Riedinger, Alice Robinet, Romain Schweizer, Athiana Tettaravou and Mathilde Viennot.

Particular thanks go to Boris Le Hir, who spearheaded this project through its initial phase, and to Benoît Cœuré, Damien Demailly, Thierry Pech, Luiz Pereira da Silva and Clara Pisani-Ferry for their careful proofreading.

Special thanks go to Olivier de Broca and Gladys Caré from the editorial team for their unfailing support in the preparation of this report, as well as the eleven thematic reports. Finally, we would like to thank Martin Hemmings for the English version of the report.

CONTENTS

EXECUTIVE SUMMARY

This report was commissioned by French Prime Minister Élisabeth Borne. It aims to develop a clearer understanding of the macroeconomic impacts of the climate transition, with a view to "better-informed decision-making".

The report was prepared with input from around 100 experts from government bodies, economic institutes and the academic community. The work was carried out in the new institutional environment resulting from the creation of the General Secretariat for Ecological Planning (SGPE), and as the revised National Low-Carbon Strategy (SNBC 3) was being prepared. Issues raised in the November 2022 interim report[1] were explored in greater depth, and new questions were addressed. Eleven thematic reports, prepared as part of this exercise and under the sole responsibility of their authors, are published at the same time as this summary report.[2] The analyses and recommendations that follow draw on these contributions.[3]

The key messages are as follows:

1. Climate neutrality is achievable, but it will require a transformation on a scale comparable to an industrial revolution. Yet unlike past industrial revolutions, this transformation will be global, it will be faster, and it will be primarily driven by public policies rather than technological innovations and markets.

2. This transformation will be based on three economic mechanisms:
    a. The redirection of technological progress towards green technologies
    b. Sufficiency (i.e. reducing energy consumption over and above what would result from energy-efficiency gains)

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[1] Pisani-Ferry J. and Mahfouz S. (2022), "L'action climatique : un enjeu macroéconomique", *La Note d'analyse*, No. 114, France Stratégie, November.

[2] The 11 thematic reports are available (in French) on the France Stratégie website. They cover the following themes: Well-being, Competitiveness, Loss and Damage and Adaptation, Indicators and Data, Distributive Issues, Inflation, Capital Markets, Labour Markets, Modelling, Productivity, and Sufficiency. See Appendix 2.

[3] However, the conclusions and recommendations contained in this report are the sole responsibility of its authors.

   c. The substitution of capital for fossil fuels

3. There is no permanent trade-off between growth and climate. In the long term, redirecting technological progress could even lead to rates of green growth that are higher than past – or potential future – rates of fossil fuel-centred growth. The falling cost of renewables suggests that this new type of growth is a possibility.

4. In order to achieve our emissions-reduction targets by 2030, and thus reach climate neutrality by 2050, we need to achieve in 10 years what has barely been achieved in 30. This sudden acceleration implies that all sectors will have to contribute. To avoid slippages, the targets set for 2030 and 2050 should be supplemented by binding carbon budgets, at both the European and national levels.

5. In the coming years, emissions reductions will rely mainly on substituting capital for fossil fuels. Sufficiency will contribute to reducing emissions, but only by around 15%, or 20% at most. Sufficiency does not necessarily lead to lower growth. It can also be a source of well-being.

6. Decarbonisation will require significant additional investment in the next decade (more than 2 percentage points of GDP in 2030, or €70 billion, in comparison to a scenario without climate action). Despite recent progress, we are not yet on the path to climate neutrality.

7. Financing these investments will likely entail an economic and social cost between now and 2030, since they do not increase the growth potential. Of course, the extra investment will have a positive effect on growth by stimulating demand. But the transition away from fossil fuels will likely result in a temporary slowdown in productivity, estimated at one quarter of a percentage point per year. This is due to the redirecting of investment towards reducing reliance on fossil fuels rather than towards expanding production capacity or increasing its efficiency. It will also bring labour reallocations.

8. More broadly, the transition will affect well-being in ways that are inadequately measured by conventional indicators such as GDP. Regulations are no less painful than carbon pricing in this regard.

9. Understanding the effects of the climate transition requires the combination of different levels of analysis: technical, microeconomic (within relevant sub-sectors) and in some cases spatial, as well as macroeconomic (to understand overall trends) and international (given competitiveness and coordination issues). The tools used to assess the economic implications of climate action in all these dimensions require further improvement.

10. The climate transition is inherently a source of inequality. Even for a middle-class household, it costs the equivalent of around one year's income to renovate a house and change the heating system, or to replace a conventional vehicle with an electric one. Even if the investment is cost-effective, thanks to the energy savings it delivers, it may not be affordable without government support. To be accepted politically and socially, the economic cost of the climate transition must be distributed fairly.

11. Households and businesses will require substantial support from the public purse. Considering new expenditures and the temporary decline in revenue due to slower economic growth, the risk to public debt is approximately 10 percentage points of GDP in 2030, 15 percentage points in 2035 and 25 percentage points in 2040, assuming that the decline in energy-related revenue is offset in order to maintain a constant aggregate tax and social security contribution rate.

12. Delaying mitigation efforts to keep a lid on public debt would be counter-productive. Absent technology breakthroughs, such a delay would only increase the cost to public finances and require even greater effort in subsequent years in order to achieve our climate targets. Public debt is not the main instrument for financing the climate transition. However, excessively restricting its use could further complicate the task for policy-makers.

13. Beyond the necessary reallocation of expenditures (including of fossil fuel-related budgetary and tax expenditures), and in addition to public debt, a temporary increase in aggregate tax and social security contributions will likely be required in order to finance the climate transition. This could take the form of a one-off levy on the financial assets of the most affluent households. The magnitude of this one-off levy would depend on the anticipated public finance cost of the climate transition.

14. The climate transition poses a risk of inflationary pressure over the next decade. Amid uncertainty over how inflation is measured, central banks will need to clarify their policy approach and spell out how they intend to respond to the price pressures induced by the transition. At the very least, they will need to take a cautious approach to monetary policy, and will likely need to temporarily raise their inflation targets.

15. The U.S. Inflation Reduction Act (IRA) shows that, although climate ambitions may be converging, the same is not necessarily true of climate policies and strategies, which will likely remain divergent for some time to come.

16. The EU faces competitiveness problems on several fronts, with high energy prices, an imperfect Carbon Border Adjustment Mechanism (CBAM) that limits carbon leakage but does not fundamentally address competitiveness concerns, and a challenge to the bloc’s industrial strategy in the shape of the IRA. The EU cannot remain competitive while being all at once a champion of the climate, a champion of multilateralism and a champion of fiscal virtue.

17. The division of labour between EU and domestic policies must be revisited. Currently, the EU sets the objectives but leaves a large part of the corresponding political and financial costs to Member States, while relying on soft coordination whose effectiveness is uncertain. The EU cannot afford to put forward a grand climate strategy while remaining vague about its actual implementation. It needs to define and implement a new climate governance framework that matches its ambition.

18. The best approach to navigating the transition is to strike the right balance between subsidies, regulation and carbon pricing. The EU and France currently have a better blend of these three instruments than the United States and China. Despite the political and social challenges, it is important not to give up on price signals, which enable decentralised decision-making.

PART ONE

THE URGENT NEED FOR MAJOR ACTION

CHAPTER 1

IN THE LONG TERM, THE ECONOMIC COST OF GLOBAL CLIMATE INACTION FAR EXCEEDS THE COST OF ACTION

1. Getting the cost-benefit analysis right

There is almost universal agreement as to the fact that Earth's atmosphere and surface are warming – and to the causes of this trend. Thirty-five years on from the creation of the IPCC,[1] it would take an incredible act of blindness to fail to recognise that climate change is happening, that it is – and will increasingly become – severely damaging, that there is a causal link between the build-up of greenhouse gases (GHGs) in the atmosphere and rising temperatures, and that there is an urgent need for global collective action. These statements of fact were reaffirmed in the clearest possible terms in the summary of the IPCC's sixth report, issued in March 2023.[2] And some 80% of people from both developed and emerging countries now believe them to be true.[3]

At the same time, it would also be incredibly flippant to claim that this urgent and imperative action will have no economic cost by 2030. The aim of this report is to formulate a realistic assessment of the economic implications of large-scale action that is commensurate with the problem we face today and that will enable us to achieve climate neutrality by 2050.

How we assess these costs depends on the benchmark against which we measure them. Should this benchmark be a hypothetical trajectory with no climate disruption and no efforts to stem global warming, or should it be based on realistic assessment of future economic loss and damage? What time horizon should we consider, and how is this future loss and damage to be assessed? Should we only consider climate mitigation efforts, or should we

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[1] The Intergovernmental Panel on Climate Change (IPCC) was established in 1988.

[2] See IPCC (2023), "Climate Change 2023: Synthesis Report: Summary for Policymakers", March.

[3] See Dechezleprêtre A. et al. (2022), "Fighting Climate Change: International Attitudes Toward Climate Policies", *NBER Working Paper*, No. 30265, National Bureau of Economic Research, July.

also build adaptation efforts into our thinking? How should we approach the issues of loss and damage distribution, and preventive action? And lastly, should we look at the issue from a French, European or global perspective? Since each of these questions sheds light on a different aspect of the problem, they each require a detailed response.

2. At the global level, a clear incentive to take urgent action

From a global perspective, it is pertinent to consider the costs and benefits of mitigation efforts versus a baseline scenario where collective action remains unambitious, resulting in uncontained global warming in the coming decades. This would lead to increasingly significant loss and damage, and force countries to take more substantial, individual adaptation measures.[1]

The latest IPCC report (2023) places a strong emphasis on the urgent need for collective action to contain global GHG emissions within, or as close as possible to, the permissible carbon budget for global warming of around 1.5°C. The likelihood of significant and potentially irreversible loss and damage increases sharply beyond this threshold, and even more so if temperatures rise by more than 2°C.

This loss and damage would also be very unevenly distributed, with developing countries and vulnerable populations experiencing a disproportionately high impact. More than three billion people live in areas particularly exposed to climate change.

Box 1: Cost of loss and damage, and climate adaptation

The impact of climate change on human and natural systems is already being felt and will increase over the coming decades. As detailed in the *Dommages et adaptation* (Loss and Damage and Adaptation) thematic report,[2] assessing the related loss and damage is a complex task: while the qualitative analysis of the associated risks is now well advanced, their quantification still needs to be refined. This implies reducing a number of uncertainties, starting with those related to the forecasting of future climate hazards.

However, this physical projection is not enough, since we also need to determine which systems are exposed and what their vulnerabilities are. The combined effect

[1] There are, of course, many ways to define such a scenario, particularly since total inaction is now an unrealistic prospect. The International Energy Agency (IEA) considers as its baseline scenario the implementation of stated policies (the so-called “STEPS scenario”).

[2] See France Stratégie and OFCE (2023), *Les incidences économiques de l’action pour le climat. Dommages et adaptation*, thematic report coordinated by Xavier Timbeau, May.

of climate stresses is pushing human and natural systems off their historical trajectories. These systems react to stresses and changes, and these reactions lead to cascading effects. The inherent uncertainties are many and various, and in some cases irreducible, ranging from emissions trajectories to climate and economic modelling.

By 2030, regardless of the envisaged scenario, the effects of climate change in France will likely remain modest. Excluding impacts on productivity, on human life, and on carbon emissions constraints in the event of CO_2 being released by natural carbon sinks, the total loss and damage would not exceed €5 billion per year. The monetary cost of the impact on human life (based on the statistical value of the latter) could be more significant over that same period (approx. €20 billion per year), but preventive measures should make it possible to bring this cost down. Were emissions to be released from natural carbon sinks, it would take a very substantial effort – at a potentially very high cost – to reconstitute these sinks or to reduce anthropogenic emissions.

Regarding adaptation, the Institute for Climate Economics (I4CE) has compiled a list of quantified, ready-to-be-deployed, "no-regret" measures, involving an additional expenditure of at least €2.3 billion per year.[1] However, these measures are merely the first steps in a more comprehensive strategy requiring trade-offs. For example, these could involve assets located in coastal and other at-risk areas, or imply changes to agricultural and tourism models. The estimate will need to be refined as needs become better articulated and as these trade-offs are addressed.

However, our analysis should not be limited to these still very tentative figures.

- First, a coherent, decentralised inventory based on uniform methodologies needs to be established. It should include the reactions of stakeholders and natural systems, and should anticipate the potentially irreversible structural shifts that climate change may well bring about. Rather than an assessment, the aim is to build shared and coherent adaptation scenarios that can serve as a basis for decision-making.
- Second, we need to look beyond 2030. Loss and damage will increase as the average national temperature rises, and could well be amplified by the build-up of stresses and by inadequate responses. Climate change will only continue beyond 2030. The focus must therefore be on "no-regrets" adaptation measures, i.e. those that are not likely to be rendered obsolete by climate change after 2030.[2]

[1] I4CE (2022), "Ensuring sufficient means to adapt to climate change consequences in France: What are the costs?", June, 66 pages.

[2] This criterion is typically not met by installing snow cannons at lower-altitude ski resorts as an adaptation measure.

The purely economic implications of such a scenario are tough to assess and even tougher to quantify. The 2006 Stern Review concluded, based on a series of assumptions, that the economic cost of climate inaction would be at least equivalent to a permanent 5% fall in global consumption.[1] Subsequent studies have placed the economic cost of climate change to global economic activity even higher, suggesting a loss of GDP of between 7% and 23% by 2100.[2] Yet once again, these assessments are often both rough and questionable. And beyond the economic impact of global warming, they ignore the cost of human loss and damage in terms of mortality and public health. On top of this, they also overlook the risks of catastrophic events.

Yet even if we consider the scale of future loss and damage from a strictly economic point of view – ignoring, in this instance, climate-related issues of intergenerational ethics and distributive justice – there can be no doubt as to the need to act, and to do so urgently.

3. A baseline scenario with neither action nor loss and damage remains relevant at the national level

France, which currently accounts for less than 1% of global GHG emissions, faces the incontrovertible fact that domestic climate mitigation efforts will have only a minor impact on global emissions and global warming, both of which depend primarily on the actions of all other countries. For national policy-makers, it therefore makes sense to measure the economic and social cost of climate action against a scenario where the absence of such action would have no direct effect on global warming, which is itself determined solely by the actions of other countries.[3] In order to isolate the effects of mitigation policies, and to distinguish them from the effects of global warming, it is also legitimate to assume that, in the baseline scenario with no domestic action, global warming, and loss and damage, are limited.

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[1] See Stern N. (2006), *The Economics of Climate Change*, Cambridge, Cambridge University Press.

[2] See Burke M. B., Hsiang S. M. and Miguel E. (2015), "Global non-linear effect of temperature on economic production", *Nature*, No. 15725, November; Kalkuhl M. and Wenz L. (2020), "The impact of climate conditions on economic production. Evidence from a global panel of regions", *Journal of Environmental Economics and Management*, Vol. 103, September; and Network for Greening the Financial System (NGFS) (2022), "NGFS Scenarios for central banks and supervisors", September. However, these studies, which are based on econometrics, have been disputed.

[3] On a similar note, the Trump administration required the U.S. Environmental Protection Agency (EPA) to revise its calculation of the social cost of carbon by focusing solely on the effects of climate policies on the United States.

This does not mean that countries should only take climate mitigation actions if they can expect a direct economic benefit measured in this way.[1] This kind of thinking would be tantamount to behaving like a free rider, and would run counter to the need for collective action as detailed out above. It would also ignore the growing call among citizens for their country to act in an environmentally responsible way – in accordance with Kant’s moral philosophy – and to shoulder its full share of the responsibility for collective climate action. This is the very approach taken by the EU’s Green Deal, which is discussed further in Chapter 3.

Yet this means that, as unrealistic as a no-action, no-loss-and-damage, business-as-usual scenario may be, it is this very kind of scenario that shapes the reasoning of many households and businesses today. In order to accurately assess the economic impact of domestic mitigation policies, it is useful to consider a scenario with no domestic action and no associated additional loss and damage – in other words, to separate the economic assessment of the cost of unavoidable loss and damage from the assessment of the cost of emissions-reduction measures.

[1] Domestic climate action also has indirect benefits, particularly in terms of air quality and health.

CHAPTER 2

THE PARIS AGREEMENT REMAINS THE BEST AVAILABLE FRAMEWORK FOR COLLECTIVE ACTION

1. The nature of the problem

GHG emissions – and, therefore, climate action – are pure externalities. Since every additional tonne of GHG emissions affects the climate in the same way regardless of where it occurs, only continent-sized countries such as China and the United States can expect to benefit directly from their own efforts, and only to a very limited extent: 33% for China and 13% for the United States in 2021.

This specific feature implies that climate coalitions are intrinsically unstable. As William Nordhaus (2015) pointed out, it is in every country's interest to encourage the creation of such coalitions in order to magnify the impact of their own actions. But, at the same time, it is also in every country's interest to drop out as soon as such coalitions become large enough that they can reap the benefits as free riders.[1]

The benefits of international climate action are also very unevenly distributed, both spatially and temporally. Some countries or regions can expect to gain from a worsening climate because global warming will free up land for agriculture or open up shipping routes, while others, like Bangladesh and other coastal regions, are threatened by rising sea levels. Generally speaking, the lower the preference for the present – and, therefore, the lower the discount rate – the greater the benefits.

[1] Nordhaus W. (2015), "Climate clubs: Overcoming free-riding in international climate policy", *American Economic Review*, Vol. 105, No. 4, p. 1339–1370.

2. The long-running quest for a collective response

The United Nations Conference on Environment and Development – known as the "Earth Summit" – was held in Rio de Janeiro, Brazil, in 1992. This UN conference, which took place less than a year after the collapse of the USSR, marked the starting point of efforts to contain climate change. It recognised the reality of human interference with the climate system and established the United Nations Framework Convention on Climate Change (UNFCCC) which, for the past three decades, has been the backbone of multilateral efforts to mitigate global warming. The *Rio Declaration on Environment and Development*, adopted at the conference, set out a series of 27 principles (known as the "Rio Principles"). It aimed to strike a fair balance between the "sovereign right" for every State to exploit their own resources, and their "responsibility" not to cause damage to the environment of other States (Principle 2). This quest for balance also lies behind the notion of "common but differentiated responsibilities" in preventing global environmental damage (Principle 7).

However, efforts to operationalise the Rio Principles have failed on two occasions. The first came with the Kyoto Protocol, adopted in 1997, when advanced economies signed up to a binding international agreement to tackle free-rider behaviour. However, this coalition was too narrow, as it did not include China or India. The second failed attempt occurred at the 2009 Copenhagen conference: the international community tried to replicate the Kyoto Protocol on larger scale, but emerging economies were reluctant to sign up to an agreement that, in their view, would hamper their development.

The 2015 Paris Agreement resolved this stalemate. After trying but failing to negotiate and implement binding targets for each country, the international community agreed to set a common goal of holding the global temperature increase to well below 2°C, along with a series of non-binding unilateral commitments on GHG emissions.[1] In doing so, the international community acknowledged that national sovereignty could not be bypassed, that commitments to reduce emissions could not be limited to advanced economies, and that any agreements should reflect the diversity of the parties involved.

The Paris Agreement proved to be a turning point, as the focus of talks shifted from internationally negotiated national commitments, to unilateral but coordinated commitments. At its core, the agreement established a "pledge-and-review" method combining a common target, an obligation for transparency, a peer-review framework, and a structured process for comparing intentions with concrete actions. As the *Compétitivité* (Competitiveness) thematic report[2] emphasises, this agreement gradually came to serve

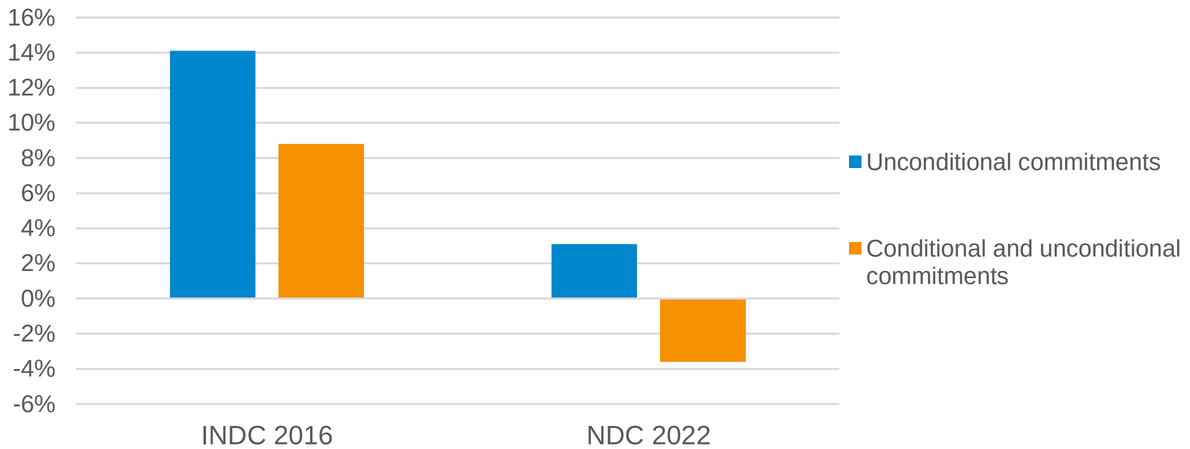
[1] Now known as Nationally Determined Contributions (NDCs).

[2] See France Stratégie and Banque de France (2023), *Les incidences économiques de l'action pour le climat. Compétitivité*, thematic report coordinated by Lionel Fontagné, May.

as a framework for supplementary and mutually reinforcing regional, sectoral and financial commitments. Today, this framework is viewed as more than a mere reporting mechanism: it is seen as a critical tool in the fight against global warming.

Taken together, current national and local commitments – including those of businesses and investors – will fall short of the Paris Agreement goal of holding the average global temperature increase to well below 2°C, with a target of 1.5°C. However, the process initiated by the Agreement has several key strengths. It has almost global participation, a mechanism for monitoring the implementation of national commitments, and a multilateral process for reviewing commitments every five years based on the results achieved. The framework is supplemented by sectoral agreements, and civil society is involved in the process through citizens' organisations and sub-national authorities (regional and municipal councils) that hold governments to account and act as an echo chamber on a global scale. The progress made since the 2015 Paris conference has clearly fallen short of what is necessary and, as the International Energy Agency (IEA) has pointed out, the credibility of national commitments remains highly questionable.[1] However, the trend in national commitments between 2016 and 2022 shows that the process initiated by the Paris Agreement has at least led to an increase in ambitions (see Figure 1).

Figure 1: Impact of the 2015 Paris Agreement on national climate ambitions (projected total emissions in 2030, compared with 2019 levels)



How to read this chart: In 2016, projected total emissions for 2030 on the basis of States' commitments were between 14.1% (unconditional commitments) and 8.8% (all commitments, including conditional commitments) above 2016 levels. In 2022, these differences were 3.1% above and 3.6% below 2016 levels respectively.

Source: UNFCCC (2022), based on a census of 166 Nationally Determined Contributions (NDCs) communicated by the parties to the Paris Agreement, or based on their Intended Nationally Determined Contributions (INDCs) (the equivalent to NDCs in 2016).

[1] See Pisani-Ferry J. and Mahfouz S. (2022), "L'action climatique : un enjeu macroéconomique", *La Note d'analyse*, No. 114, France Stratégie, November.

Reversals remain a possibility. Looking at the bigger picture, the question arises as to whether the world's major powers can reconcile the two opposing positions of rivalry and cooperation. President Biden's National Security Advisor, Jake Sullivan, clearly stated that "we've come to a point where we can and simply have to tackle both on an equal plane: geopolitical competition and shared transnational challenges", adding that "we are building a strategy fit for purpose for both competition we cannot ignore and global cooperation without which we cannot succeed".[1] But whether China and the United States can follow through on this dual strategy remains to be seen.

Commitments made as part of the Conference of the Parties (COP) process have now generated sufficient momentum for a significant proportion of major global firms to invest in building a carbon-free economy. This is the real success of the 2015 Paris Agreement: while it does not promise a low-carbon future with a high degree of certainty, it was very much a turning point, paving the way, and at least partially guiding technological progress, towards a greener economy. The Biden administration's endorsement of the carbon-neutral targets is a good illustration of this, despite all the challenges it poses.

Despite ongoing suspicions as to private-sector statements of intent, there is plenty of evidence pointing to a genuine shift in at least some parts of the capitalist system. Detailed financial data confirms a significant and increasing penalty in the stock-market valuations of fossil-fuel-linked companies, with this particularly affecting large corporations, transition-relevant sectors, and European companies (by contrast with U.S. companies).[2]

Similar valuation gaps, albeit lesser in magnitude, also appeared on the corporate debt markets following the signature of the Paris Agreement, whereas such gaps were negligible beforehand. It is therefore legitimate to conclude that the Agreement made a major difference to the importance ascribed by the markets to the climate performance of listed companies and, by extension, has influenced the behaviour of companies themselves.[3]

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[1] See Sullivan J. (2022), "Remarks by National Security Advisor Jake Sullivan on the Biden-Harris Administration's National Security Strategy", The White House, 12 October.

[2] See Bolton P., Halem Z. and Kacperczyk M. (2022), "The financial cost of carbon", SSRN, April.

[3] See Bolton P. and Kacperczyk M. (2021), "Global pricing of carbon-transition risk", *Journal of Finance*. It is interesting to note that this response to the Paris Agreement is driven primarily by Asian companies.

3. Climate policies will likely remain divergent for some time

It has long been thought that the main problem with the Paris Agreement was that it left room for divergent emissions-reduction *ambitions*. With no consensus emerging on the practical expression of the notion of "common but differentiated responsibility", the COP process was unable to prevent free-rider behaviour. This is why Nordhaus suggested creating a climate club with members bound by a minimum effort requirement.[1] But the 2022 U.S. Inflation Reduction Act, which marked a clear departure from the EU's strategy, underscored another pressing problem: a divergence in the *means* deployed to achieve carbon neutrality.

The United States' essentially incentive-based strategy, combining subsidies and protective measures, is symptomatic of a deeper issue: the parties to the 2015 Paris Agreement are not bound to adopt similar policies in pursuit of the same goal. Climate change has reopened a long-standing debate on the extent to which economies should enjoy autonomy in selecting their policy aims and instruments, within a framework compatible with economic multilateralism. This debate, which was supposed to be resolved after China joined the World Trade Organization (WTO), was only superficially closed. Climate change, among other issues, is forcing the world to reopen this debate.

As the *Compétitivité* (Competitiveness) thematic report[2] shows, carbon intensity per unit of added value currently varies significantly across sectors: it is as high as 50% in the mining industry, and stands at around 20–30% in several heavy-industry sectors. In Europe, these sectors currently benefit from free quotas. However, the rising carbon price within the European Union Emissions Trading System (EU ETS) and the planned end of free allocations imply that divergent climate policies will have serious implications for competitiveness. None of the instruments that can be used to reduce the impact of these divergences on competitiveness can neutralise the effects of disparities between countries in the choice of instruments. Nor can they completely eliminate carbon leakage. We will come back to this topic in Chapter 12.

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[1] See Nordhaus W. (2015), "Climate clubs…", op. cit. Nordhaus proposed using customs duties as an incentive to participate in the climate-action efforts.

[2] France Stratégie (2023), *Les incidences économiques de l'action pour le climat. Compétitivité*, op. cit.

CHAPTER 3

THE EUROPEAN UNION HAS PUT ITSELF AT THE FOREFRONT OF CLIMATE ACTION

1. Two possible strategies

Based on its GHG emissions, the EU is neither a small country nor a major power. The bloc is responsible for 7.5% of global territorial emissions, and 10% of global emissions if emissions embedded in imports are included. If we factor in the United Kingdom, whose climate policy is broadly similar to the EU's, as well as countries involved in the EU accession process, and the non-EU countries in the European Economic Area, the EU accounts for 10% of global territorial emissions.[1] The bloc therefore has limited power to influence global emissions, especially given that, irrespective of climate policies, the EU's share of global emissions will fall rapidly as a result of anticipated differences in growth.

On the other hand, the EU is a major trading power. As Wolff (2023) notes, the WTO's top three members are China, the EU-27 and the United States, whose trade volumes are roughly similar: $6,000 billion, $5,100 billion (excluding intra-EU trade) and $4,700 billion respectively.[2] Wolff adds that, of these, "only the EU currently has the values, the economic interest, and the potential to lead in reforming the multilateral trading system".

This is almost certainly why, in 2019, the EU committed to the Green Deal. At that time, there were two possible strategies:

- A "follower" strategy consisting of minimising the economic impact of the climate transition by staggering it over time, by adopting tried-and-tested technologies and by prioritising research in sectors already solidly established in Europe. This strategy, which would have lacked ambition, could have led to the failure of the Paris Agreement.

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[1] Source: Our World in Data/Global Carbon Project.

[2] Wolff A. Wm. (2023), "The world trading system needs a more assertive European Union", Peterson Institute for International Economics, 15 March.

- A "leadership" strategy geared towards building a climate-neutral economy, with a view to setting standards for the future and reaping the technological and economic benefits. The EU ultimately chose this strategy after having demonstrated its standard-setting power in a number of other fields, ranging from industrial standards to banking regulations and the processing of personal data.

European Commission President Ursula von der Leyen unveiled the Green Deal in December 2019, describing it as "Europe's man on the moon moment".[1] The goal was to reconcile the economy with protection of the planet, to redefine the growth model, and to put Europe at the forefront of shaping the future of industry. Just over three years later, most of this vision has been translated into quantified targets for 2050 and 2030, and set out in a series of legislative provisions that have been adopted or are going through the adoption process. Most notably, the EU has officially adopted the goal of achieving carbon neutrality by 2050 and has set a target of reducing its emissions by at least 55% by 2030 compared with 1990 levels.

Despite reservations and regrets among some Member States, especially relating to the ban on the sale of new cars with internal combustion engines from 2035, the plan is extremely far-reaching and its adoption would have seemed improbable just three years ago. Achieving the 2030 target implies more than tripling the pace of emissions reductions compared with 1990–2019. This will require a major step-change in effort, even taking account of the anticipated slowdown in growth.[2]

2. Changes have been accelerated by the energy crisis

Even before the conflict in Ukraine, this strategy seemed risky from an industrial perspective because the EU could not rely on its expertise in sustainable and green technologies, except in certain areas like wind turbines. The sudden rise in gas prices, coupled with the suspension of deliveries from Russia in mid-2022, abruptly dashed hopes of a gradual transition, which envisaged an initial 10- to 15-year phase during which gas would replace more carbon-intensive fossil fuels (oil, coal and lignite). This approach had the dual advantage of keeping the cost of energy low and allowing time to test the feasibility of an energy system that combined renewables, nuclear power and hydrogen energy storage.

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[1] Euractiv (2019), "EU Commission unveils European Green Deal: The key points", 11 December.

[2] See Figure 1 in Pisani-Ferry J. and Mahfouz S. (2022), "L'action climatique : un enjeu macroéconomique", op. cit.

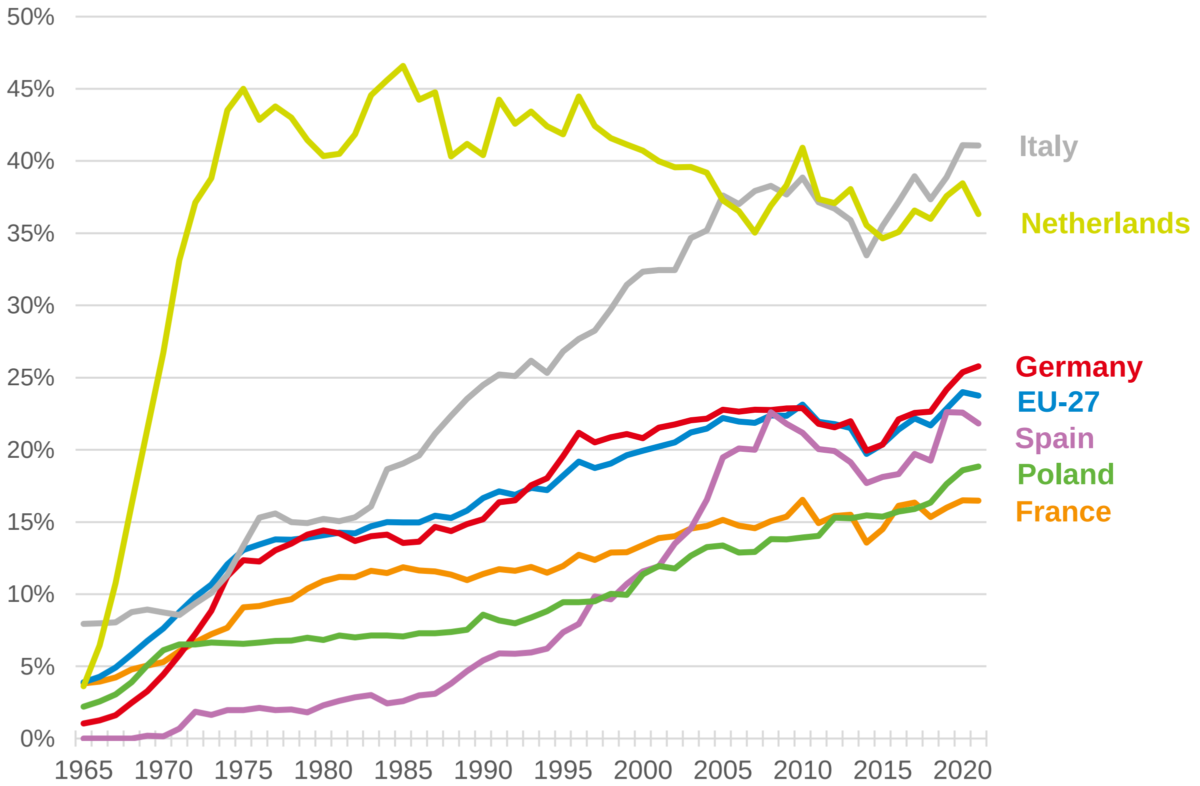
The cutting-off of supplies from Russia affected the production system in two ways. The first, immediate effect was to make energy-intensive products less competitive:

– This cut-off sent gas prices soaring on European wholesale markets, which had an impact on the price paid by industrial buyers.

– It led to an increase in industrial electricity prices, to varying extents across countries.

The second effect was to accelerate decarbonisation efforts by pushing the EU to skip the use of gas a transition fuel. Until 2021, the share of primary energy from gas was growing both across the EU in a whole and in the largest Member States (see Figure 2). Since gas is less carbon-intensive than other fossil fuels (especially coal), it was considered a viable candidate for the transition to a completely carbon-free economy.

Figure 2: Share of primary energy from gas, EU-27 and largest Member States



How to read this chart: In 2021, gas accounted for 16.5% of France's primary energy supply.

Source: Our World in Data

The sudden cut-off of deliveries from Russia forced the EU to look for alternative suppliers. But, more important still, it accelerated the bloc's transition away from fossil fuels. The REPowerEU plan unveiled by the European Commission in May 2022 aimed to diversify sources of supply and reduce energy demand, as well as to increase the share of renewables in primary energy supply, raising the target for 2030 from 40% to 45%. Despite widespread expectations of an increase, emissions actually fell by 2.5% in 2022, due in part to a mild winter, but also to an acceleration in the roll-out of renewables.[1] Another contributing factor was the fall in the demand elasticity of fossil fuels from consumers (see Box 2).

Box 2: Early lessons from the energy crisis

According to the IEA, the 2022 European energy crisis, which was linked to the conflict in Ukraine and exacerbated by problems with French nuclear plants and low water levels, caused gas and electricity consumption in the EU to fall by 13% and 3% respectively compared with 2021 levels. The European economy nevertheless proved to be more resilient than expected, even though some energy-intensive sectors were severely affected. Euro-area GDP grew by 3.5% in 2022, a rate slightly lower than estimated before the outbreak of the conflict.[2]

Although it is still too early to draw comprehensive conclusions from the crisis, and despite mild temperatures in 2022 absorbing part of the energy-supply shock, this supports the idea that there is scope for significant substitution, including in the short term, between gas and electricity on the one hand, and other factors of production on the other, across the economy as a whole.[3]

An analysis by the IEA[4] indicates that half of the 25% drop in industrial gas consumption in Europe can be attributed to the use of other energy sources, as well as to efficiency gains and energy sufficiency efforts. The other half is linked to cuts in certain types of production, although these are relatively clustered around a few highly gas-intensive sectors, with the fertiliser industry alone accounting for almost half (and, therefore, almost a quarter of the total drop in industrial gas consumption).

[1] See IAE (2023), *CO_2 Emissions in 2022*, report, March.

[2] The International Monetary Fund's (IMF) economic outlook, revised in January 2022, predicted euro-area GDP growth of 3.9% for 2022.

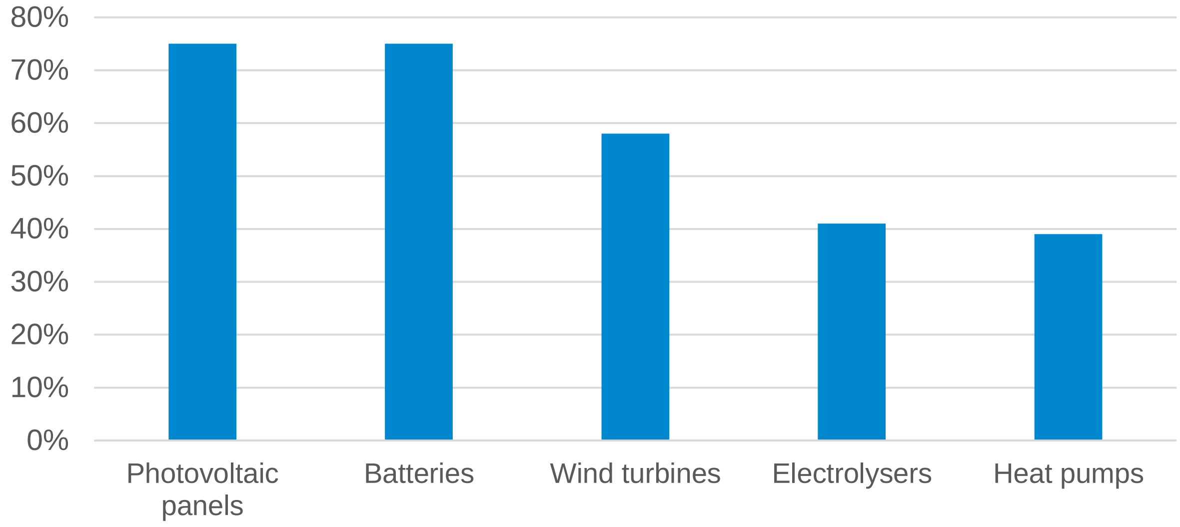
[3] The extent of this substitutability was one of the key issues in the spring 2022 debate on the impact of the conflict on German GDP. See Bachmann R. et al. (2022), "What if? The Economic Effects for Germany of a Stop of Energy Imports from Russia", *EconPol Policy Report*, No. 36, Ifo Institute, March.

[4] IEA (2022), "Europe's energy crisis: What factors drove the record fall in natural gas demand in 2022?", March.

3. Europe is lagging behind in green industries

In the EU, there is however a worrying lag in the production of equipment for the climate transition. The IEA's global overview of green technologies reveals China's undisputed dominance in the production of solar panels and batteries (see Figure 3), as well as its dominant position in wind power (which also reflects strong domestic demand). Its dominance is further entrenched if projects announced for entry into operation by 2030 are included, since 80–90% of them involve China.[1]

Figure 3: China's share of global manufacturing output for various items of equipment, 2021



How to read this chart: In 2021, 75% of global solar panel output was manufactured in China.

Source: IAE (2023), "Geographic concentration by supply chain segment, 2021", in Energy Technology Perspectives 2023*, January*

It is deeply worrying that the EU is lagging behind in technologies where experience and scale effects are crucial, since the transition is likely to weaken a number of established strongholds of European industry – internal-combustion-engine vehicles, the aerospace industry and carbon-intensive intermediate goods – as demand for these products is set to decline while the transition progresses. The risk of de-industrialisation would then be substantial if the EU's share in the production of "green" goods remained unchanged. Consequently, the transformation must go hand in hand with an increase in the production of at least some of these goods in the EU.

[1] With the exception of electrolysers (for hydrogen production), where China's share is only around 25%.

The EU is well aware of this. To support the transformation of the bloc's economy, the European Commission recently announced an ambitious industrial plan (the Green Deal Industrial Plan, February 2023) to supplement the Green Deal. The plan includes an industrial policy strategy (the Net Zero Industry Act, March 2023), legislation on critical raw materials (the Critical Raw Materials Act, March 2023) and a proposal to reform the electricity market.

The EU's key ambition is to ensure that, across a range of sufficiently mature green technologies that are essential to decarbonisation – and in which Europe currently depends on outside supplies, especially from China – around 40% of these technologies deployed on the internal market each year come from EU-based manufacturers.

To this end, the European Commission has put forward a series of regulatory initiatives (harmonisation of standards, regulatory sandboxes), as well as measures covering State aid controls (targeted and temporary loosening of the rules to encourage the transition) and access to European funding (specific transfers from the Recovery and Resilience Facility, EIB loans and investments, InvestEU guarantees, and the Innovation Fund). The Commission has been mandated to put forward proposals for the creation of a European Sovereignty Fund by the summer of 2023. It is also focusing on the skills gap and how to fill it.

Is this 40% target realistic? There is no simple answer. China currently dominates global output of solar PV technologies and batteries, as shown in Figure 3. The EU has genuine potential to catch up to China in battery manufacturing, but the same cannot be said with anything like as much certainty in solar PV. In wind power, the bloc remains at the forefront of innovation and can turn this advantage into an industrial asset if it solves its production capacity problem. When it comes to heat pumps, the EU is also a leader in innovation, but its industry is fragmented and its external trade deficit has increased significantly. On hydrogen production through electrolysis, the EU is technologically vulnerable and the deployment of industrial-scale solutions is hampered by the high price of electricity. The target of 40% self-sufficiency is clearly achievable in some sectors, but is out of reach in others.[1]

[1] This paragraph is based on the European Commission report *Progress on competitiveness of clean energy technologies*, COM(2022) 643 final, November 2022.

CHAPTER 4

A TRANSFORMATION ON A SCALE COMPARABLE TO AN INDUSTRIAL REVOLUTION, BUT FASTER AND DRIVEN BY PUBLIC CHOICES

1. Energy-system changes lead to industrial revolutions

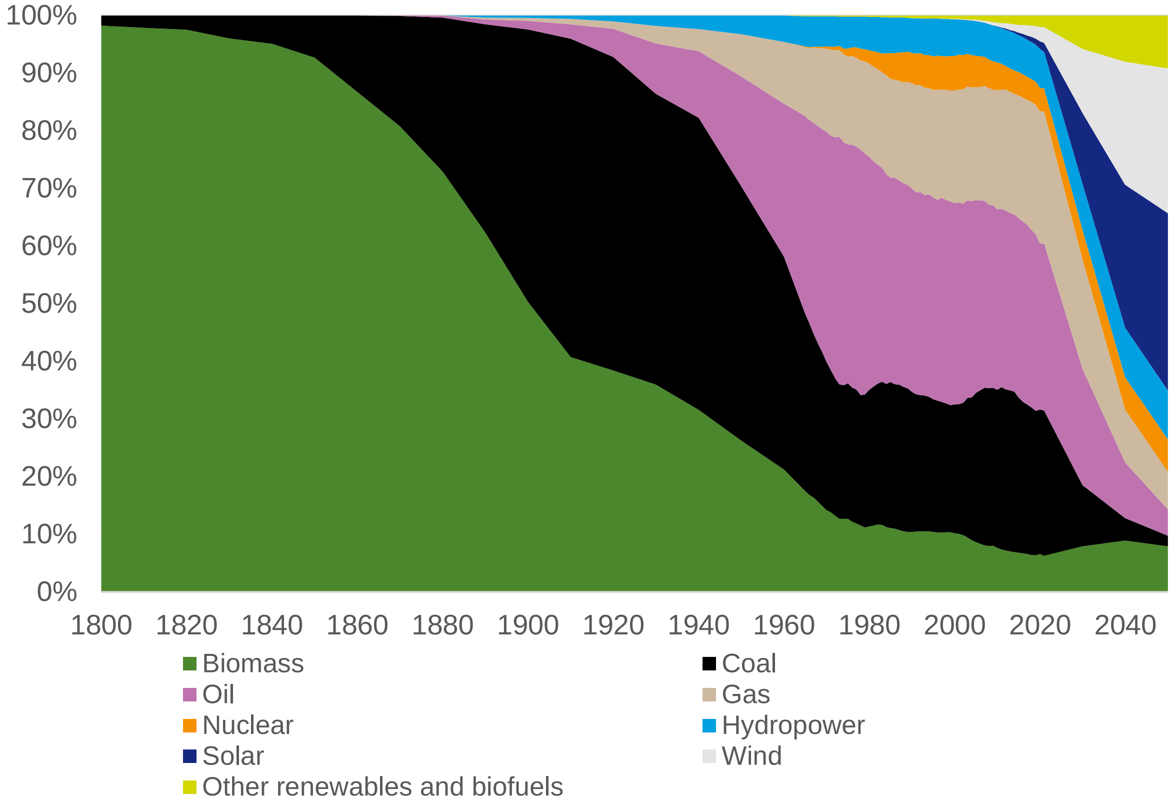
The first industrial revolution is inextricably linked with the advent of coal. Although coal was still marginal at the beginning of the 19th century (but already dominant in the UK), it conquered the world in less than six decades. Accounting for 5% of the global primary energy market in 1840 and 10% in 1855, its share had reached 50% by 1900, a mere 45 years later.[1] The golden age of coal was short-lived, however, as it was soon supplanted by hydrocarbons, which are strongly associated with the second industrial revolution: the revolution that saw the emergence of cars and aeroplanes. Hydrocarbons represented 5% of the global primary energy market in 1915, passed the 10% mark in the 1920s, and exceeded 50% by the 1970s. These two fossil fuels therefore came to dominate the global market at roughly the same pace (see Figure 4).

Renewables – including the oldest, such as hydropower – now account for 13.5% of the world's primary energy supply. This represents a significant increase since the 2000s.[2] According to the IEA (2022), under the net-zero scenario, they are expected to exceed 30% of total primary energy supply by 2030. Even under a scenario where fossil fuels remain a part of the energy mix, renewables should be predominant by the middle of the century.

[1] Smil V. (2017), *Energy and Civilization: A History*, Cambridge, The MIT Press, p. 395.

[2] Source: Our World in Data, based on the BP database. Renewables include hydropower, a long-established form of energy whose installed capacity was still twice that of wind and solar power in 2020.

Figure 4: Share of different energies in global energy supply, 1800–2021



Note: The conversion factors between energy vectors needed to connect historical data and projections are taken from the reference source below (Vaclav Smil). The low-carbon transition is more abrupt than past transitions not just because it is faster, but also because low-carbon energy sources – especially wind and solar PV – must replace, not be added to, fossil fuels.

How to read this chart: In 2021, traditional biomass accounted for 6.3% of the world's energy supply.

Source: World energy supply data for 1800–2021 reconstructed by Vaclav Smil (Energy Transitions: Global and National Perspectives, 2016), plus the IEA's "Net Zero Emissions by 2050" scenario

This transition will also bring about a profound transformation of the economic system, with far-reaching consequences such as large-scale electrification, decarbonisation of industry, a revolution in mobility, and wholesale lifestyle changes. But there are three differences that will set this industrial revolution apart from those of the past. This first is its pace, which will far outstrip historical trends observed for coal and hydrocarbons. The second is its scope, since virtually every country will take part in it, even if not at exactly the same pace. The third – and most important – difference is that this revolution is, and will remain, driven by public policy rather than by technological innovations and market forces.

2. Three key mechanisms

This transformation will be based on three main economic mechanisms: the substitution of capital for fossil fuels, changes in lifestyles and consumption patterns (sufficiency), and the redirection of technical progress towards resource frugality.[1]

The first mechanism, which relies mainly on supply-side changes, reflects both the need to invest to transition away from fossil fuels, and the fact that low-carbon production is generally more capital-intensive. This mechanism is a very powerful force. Its importance in terms of electricity production is reflected in the technical and economic characteristics of renewables and nuclear power compared to fossil fuels (see Figure 2 in the November 2022 interim report). But it is equally relevant in other areas beyond electricity production: the same type of reasoning applies to building renovation (an energy-neutral building is more expensive to build than a less efficient one), to private transport (with the replacement of internal combustion engine vehicles with electric ones, which are currently more expensive to buy but have a lower cost of use) and to public transport (construction of infrastructure, especially railways). From a macroeconomic point of view, these transformations will generally lead to an increase in the capital-output ratio. However, this increase will be greatest in countries other than France, where nuclear power accounts for a significant share of total electricity production.

While this first mechanism will have a transformative impact on output, the second mechanism – sufficiency – will directly affect demand. Lifestyles and consumption patterns will need to change in order to help bring down emissions. Households and businesses will also have to adapt their practices in order to reduce their total energy consumption.

The key question, therefore, is what will drive these changes. On the face of it, part of the reduction in energy consumption will come from gains in energy efficiency. But efficiency gains require investment, even small in size, and are therefore more a matter of substituting capital for fossil fuels or of technological progress. Part of the reduction in energy demand will also come from changes – spontaneous or induced by public policy – in the structure of final consumption.

In economic terms, sufficiency can be defined as a reduction in household and business energy consumption that does not result from improvements in energy efficiency, but instead from changes, voluntary or otherwise, in energy demand and consumption patterns. This raises three questions. The first is whether sufficiency is necessary, or whether it is enough to rely on energy-efficiency gains and low-carbon energy production.

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[1] These points were developed in the interim report: Pisani-Ferry J. and Mahfouz S. (2022), “L’action climatique : un enjeu macroéconomique”, op. cit. The paragraphs that follow summarise and supplement the analysis given in that report.

The second concerns the levers which will induce these changes in behaviour. And the third, which we will address in the next chapter, concerns the economic effects of sufficiency on total consumption, on growth and, beyond that, on well-being.

The answer to the first question is quite straightforward. Achieving energy-efficiency gains and transitioning to low-carbon energy production are vital steps. But they will not be enough to achieve our emissions-reduction targets. In some areas, such as air travel, the transition to low-carbon fuels is unlikely to happen by 2050, and the industry's current commitment to carbon neutrality[1] relies in part on offsetting mechanisms, which will play a major role in the years to come. In others, such as cattle farming, there is simply no immediate supply-side solution. On top of this, energy-efficiency gains are likely to be accompanied by rebound effects that will mitigate the direct impact of emissions reductions. Parallel action on the demand side is therefore essential.

The second question is more difficult to answer. Lifestyle patterns from bygone eras teach us the importance of collective norms in structuring household consumption. Our lifestyles have become increasingly energy-intensive with the passage of time. Suburbanisation has led us to become dependent on private cars, with many households now having no option but to own multiple vehicles. The trend for people to live further away from shops, public services, leisure facilities and urban amenities has consolidated a lifestyle that has led to significant inertia in household consumption. It would be unrealistic to consider sufficiency while ignoring this systemic dimension. As Pierre Veltz writes, "it is difficult to demand individual sufficiency in a society that is organised around abundance and waste".[2]

Change will undoubtedly come from a combination of price signals and shifts in collective norms. The gradual extension of the EU ETS to buildings and transport, which will increase the price of fossil fuels for these uses, will only be accepted if it goes hand in hand with the emergence and progressive spread of new collective norms.

It is easy to analyse changes in consumption patterns from a strict microeconomic perspective if they result from taxation of carbon-intensive consumption or from regulation. But this is not generally how the term sufficiency is understood. Rather, it refers to the idea that lower consumption of carbon-intensive energies could result from people making better-informed individual choices, such as via carbon labelling of products and services, or voluntarily considering the external effects of carbon-intensive consumption.

In a simple model based on individual consumer rationality, it is difficult to represent unconstrained sufficiency, which refers to the idea of moderation and a reduction in over-

[1] International Air Transport Association (IATA) (2021), "Net-Zero Carbon Emissions by 2050", Press Release, No. 66.

[2] See Veltz P. (2022), *Bifurcations*, La Tour-d'Aigues, Éditions de l'aube.

consumption. Either sufficiency is a response to a constraint, and reduces the consumer's individual utility, or it is voluntary, and follows from the assumption that the consumer is mistaken and misjudges the direct utility of their consumption, which then contradicts the traditional rationality hypothesis. To put it more concretely: wasting less food, cycling instead of driving, or reducing red meat consumption would undoubtedly have individual co-benefits. Why, then, do consumers not make these choices more often? Why do we need to consider public policy initiatives?

In recent years, social psychologists and behavioural economists have developed tools for better understanding behavioural biases and, where necessary, correcting them.[1] In this vein, List et al. (2022)[2] recently proposed a simple model of consumer choice that takes into account both behavioural biases leading to individual choices that are sub-optimal regarding the utility of the individuals themselves, and the effects of classical externalities (i.e. the consideration of the external costs or benefits of individual behaviour on others, such as GHG emissions in the livestock sector). With this in mind, public policies can either act on the behavioural bias or force consumers to consider the externality, such as through taxation. This model makes it possible both to precisely define the notion of sufficiency and to determine whether a public policy that is designed to promote it is preferable to carbon pricing.

The third and final lever of transformation involves redirecting technological progress. Traditional thinking dictates that this progress is redirected either towards total factor productivity (capital and labour in the simplest case, and potentially extended to other factors of production), or towards labour productivity alone. Yet the climate transition calls for a rethink of this model, with priority given to reducing fossil-fuel consumption.

Of course, this kind of approach only makes sense in a climate of endogenous growth, where relative prices and public policies determine the focus of innovation efforts. It is not unreasonable to consider that so-called "green" technologies are *potentially* at least as productive as fossil-fuel-based ones. But the build-up of knowledge and patents in fossil-fuel-based industries over the past century and more has led to a situation of path dependency in their favour. The rapid fall in the cost of renewables (see Figure 5) is clear evidence of this path dependency.

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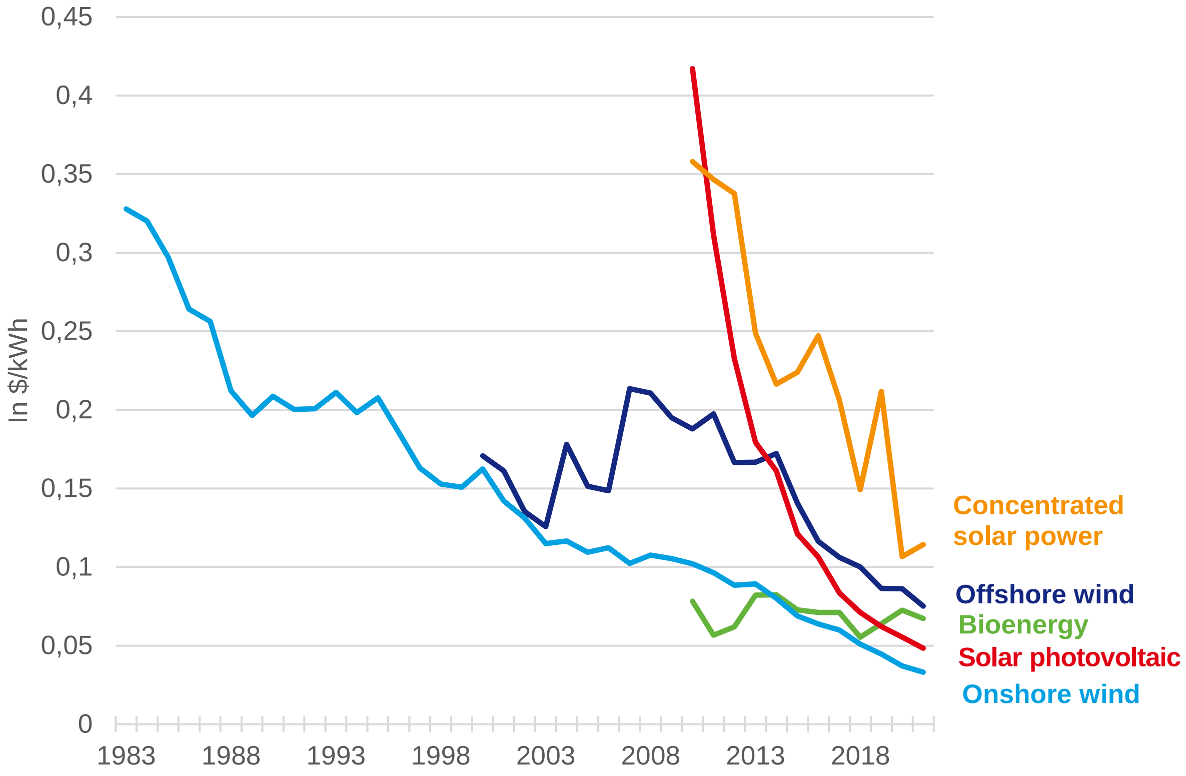
[1] Thaler and Sunstein (2008) have promoted public-policy strategies known as "nudges", which aim at altering the "choice architecture" underlying individual decisions, such as by changing the default option to take advantage of people's tendency to passively comply with it. To count as a nudge, an intervention must be "easy and cheap to avoid. Nudges are not mandates." These strategies have been successfully implemented, particularly in public health. See Thaler R. and Sunstein C. (2008), *Nudge: Improving Decisions about Health, Wealth, and Happiness*, New Haven, Yale University Press.

[2] List J. A., Rodemeier M., Roy S. and Sun G. (2023), "Judging nudging: Understanding the welfare effects of nudges versus taxes", April.

Figure 5: Total cost of different technologies (excluding back-up and system costs)



How to read this chart: In 2021, the total cost of concentrated solar power was $0.11/kWh.

Source: Our World in Data

Nowadays, we can consider that this redirection has already taken place for solar PV and wind power, and that all that remains is to harness the effects of experience and scale.[1] Full decarbonisation, on the other hand, will imply significant progress between now and 2050 in areas such as hydrogen production, carbon capture and electricity storage. The IEA estimates that, by 2050, one-third of currently projected reductions in global emissions will come from technologies that have not yet progressed beyond the demonstration stage.[2]

[1] For France, this assumes that the local acceptability issues that have hampered the deployment of renewables will eventually be resolved.

[2] See IEA (2020), *Clean Energy Innovation*, report, July.

3. The relative role of these three mechanisms depends on the time horizon and the geographical scope

Although the transition will necessarily involve all three of these mechanisms, their relative importance will vary according to geographical scope and time horizon.

Globally, by 2050, the IPCC (2022) estimates potential emissions reductions relative to a baseline scenario of 29% through sufficiency and 17% through efficiency in energy use, with half (53%) of this reduction supposedly resulting not from demand-side policies and measures but from the composition of supply.[1] In the EU, lifestyle changes such as teleworking, reducing travel, making dietary changes, reducing food waste and recycling could, on their own, lead to a 16% reduction in cumulative emissions between 2011 and 2050 relative to the baseline scenario.[2]

France, meanwhile, has a wide range of possible futures, depending on whether or not significant changes in social norms – such as reducing the number of homes and surface area per capita, travelling less, and eating less meat – are factored into the equation. In any event, the most ambitious scenarios point to a reduction in final energy demand of around 15% by 2050 relative to current levels.[3]

Between now and 2030, the main driver will almost certainly be the substitution of capital for fossil fuels (including, therefore, energy-efficiency gains), although sufficiency will likely contribute to somewhere between 12% and 17% of emissions reductions in this period. On the other hand, most of the technologies that are expected to be implemented by 2030 are already available. Further efficiency gains are likely, but this will be due more to scale factors than to radical innovation.

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[1] See France Stratégie (2023), *Les incidences économiques de l'action pour le climat. Sobriété*, thematic report coordinated by Aude Pommeret, May; and IPCC (2022), *Climate Change 2022: Mitigation of Climate Change*, Chapter 5: *Demand, services and social aspects of mitigation.*

[2] See Van de Ven D.J., Gonzalez-Eguino M. and I. Arto (2018), "The potential of behavioural change for climate change mitigation: a case study for the European Union", *Mitigation and Adaptation Strategies for Global Change*, Vol. 23, pp. 853–886.

[3] See the négaWatt, ADEME and RTE scenarios detailed in the *Sobriété* (Sufficiency) thematic report.

CHAPTER 5

CLIMATE TRANSITION AND ECONOMIC GROWTH: A MATTER OF TIME HORIZON

1. Climate sustainability and economic growth: a distorted debate

The central question for 2050 is whether achieving climate neutrality and improving well-being are compatible aims. This exact question was raised during the Gilets jaunes (Yellow Vests) protests against fossil-fuel tax rises. It is the very reason why the Biden administration has opted for a subsidy-focused strategy. And it is the reason why developing countries have long approached climate change with caution.

To answer this question, it is not enough simply to demonstrate that the economic cost of climate inaction far surpasses the cost of action. We also need to convince the public that there is no binary choice between the future of the planet and their own well-being, or even, in the long term, between protecting the climate and maintaining living standards.

Since the Club of Rome published its report *The Limits to Growth* in the early 1970s, this debate has unfortunately all too often been framed in terms of a choice between growth and degrowth. This Malthusian approach underpins the entire report and is captured in its conclusion, which reads as follows: "If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years."[1] More recently, the work of Tim Jackson (2009) has fuelled a movement that sees no way out other than degrowth.[2]

From a philosophical or sociological standpoint, it is useful to think in these terms, since decades of economic expansion have shaped our perceptions and expectations. We have

[1] Club of Rome (1972), *The Limits to Growth*, New York, Universe Books.

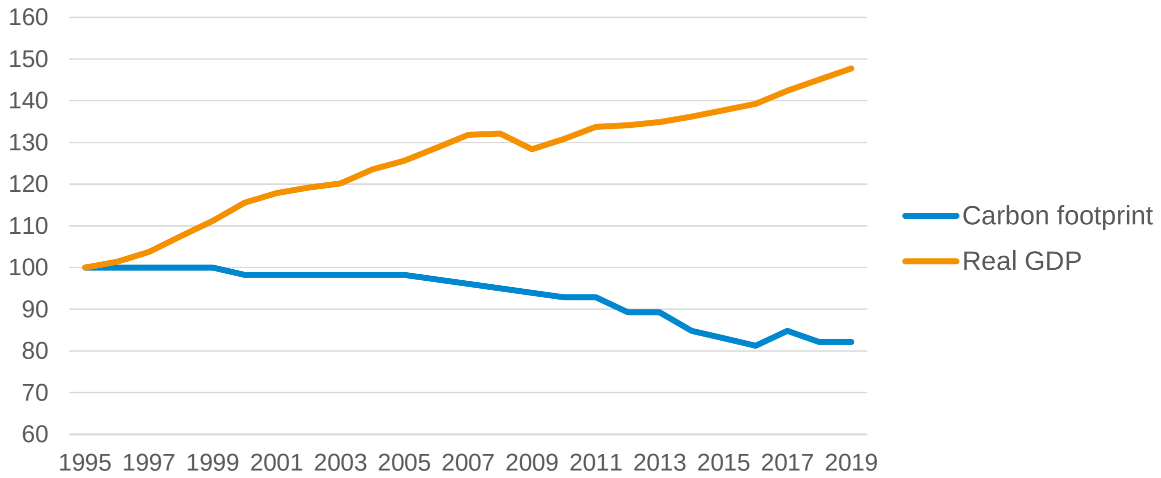
[2] Jackson T. (2009), *Prosperity without Growth*, Routledge.

long believed that affluence and freedom go hand in hand, as epitomised in Franklin D. Roosevelt's famous phrase "freedom from want". But we have failed to see the conditional nature of this relationship. As Pierre Charbonnier reminds us, "it is the ashes of industrial freedom that are accumulating over our heads".[1] It is therefore essential that we now re-examine the very foundations of our conceptions of freedom, progress and well-being.

From an economic standpoint, however, the call for degrowth is a red herring because, for advanced countries at least, reality shows that it is entirely possible to decouple growth from GHG emissions (see Figure 6). Pursuing degrowth is also socially disastrous, since it amounts to asking those struggling to make ends meet to tighten their belts by another notch or two in the name of higher goals.[2] And above all, it is a blind alley: if the aim is indeed to reduce net emissions to zero, achieving this through degrowth alone would mean wiping out most of the real income gains of recent centuries. No one imagines that this is possible, or even desirable.

The need to preserve the climate does not, in and of itself, force us to give up on growth. It does, however, oblige us to find ways of achieving a new kind of growth – one that recognises that the planet's resources are finite and, therefore, that takes account of the environmental externalities of individual and collective choices.

Figure 6: Real GDP and GHG emissions, France, 1995–2019 (base 100 = 1995)



How to read this chart: France's GDP grew by close to 50% between 1995 and 2019, while its carbon footprint shrunk by close to 20% over the same period.

Source: Ministry for the Ecological Transition and INSEE

[1] Charbonnier P. (2020), *Abondance et Liberté*, Paris, La Découverte.

[2] We will return to the subject of fairness and the climate transition in Chapter 9.

2. Carbon neutrality and economic growth: what can we expect?

Climate neutrality will not be achieved through degrowth. Sufficiency efforts will, of course, make a contribution. But climate neutrality will largely be attained through the substitution of capital for fossil fuels, and through the redirection of technological progress towards green technologies. These mechanisms may temporarily slow growth (we will return to this point later). But there is no strong reason to believe that they will permanently alter the course of economic development.

Let us look first at the substitution of capital for fossil fuels. Essentially, this mechanism can be analysed using a Solow exogenous growth model, where the pace of technological progress is independent of the capital intensity of production.

In this model, there are three sources of growth in output per worker (*Y/L*):

- The rate of exogenous technological progress (γ)
- The capital intensity of production (*K/Y*)
- The fossil-fuel intensity of production (*F/Y*)

Increasing the capital stock (*K*) in order to reduce the use of fossil fuels (*F*) affects the level of Y but not its steady-state growth rate, which is determined by γ. Once the new productive mix has been established, the only source of growth in output per worker is exogenous technological progress. The *level* of potential output may be affected, but there is no reason why the *growth rate* of the economy should be permanently reduced.

Of course, this approach is overly simplistic and, therefore, incomplete. Under the modern theory of endogenous growth, which follows a Schumpeterian logic, the emphasis is on innovation and, more specifically, on investment in innovation, which is considered to be risk-taking. Within this framework, the redirection of technological progress towards reducing fossil-fuel use may lead to a temporary slowdown in the pace of growth. Weaning ourselves off fossil fuels entails devaluing all or part of the stock of intangible capital (patents and know-how) built up over decades, and reinvesting in the development of green technologies.[1]

There is, however, nothing to suggest that green technologies are structurally less productive than fossil-fuel-based ones. Quite the opposite, in fact: the good news to emerge from recent decades is that green innovation in power generation, heating and

[1] See France Stratégie (2023), *Les incidences économiques de l'action pour le climat. Productivité*, thematic report coordinated by Anne Epaulard, May.

transport has already led to technologies that are, or soon will be, as efficient as their fossil-fuel-intensive predecessors.

Twenty years ago, it was not a given that a decarbonised economy would be as efficient as, or more efficient than, a carbon-intensive one. Progress has certainly not been uniform: think, for example, of air travel or agriculture. But progress has been broad and far-reaching enough to hold out the promise of a new growth model. The big question for the viability of this growth model is the availability of resources, especially critical materials. We will come back to this topic in Chapter 11.

As for sufficiency, it is difficult to assess its macroeconomic impact at first glance. Reduced consumption of carbon-intensive products is likely to weigh on growth if it is accompanied by higher rates of savings. But this will likely not be the case if, instead, consumption shifts towards other goods and services. In turn, it all depends on whether the production of these goods and services itself entails an increase or a slowdown in productivity gains. We cannot reason in general terms.

3. Climate transition and well-being

We know that national accounting metrics such as GDP are ill-suited for measuring social progress, particularly at a time when environmental sustainability is an increasingly pressing concern.[1] Moreover, such metrics are not designed for this purpose. Contrary to common perceptions, this issue is taken very seriously by economists, who do not regard GDP as the be all and end all, or as a target that should be maximised at all costs. Instead, economists have long used a different concept for measuring progress – one that takes into account the damage caused by growth: well-being.

In order to quantitatively assess the extent to which climate neutrality can be accompanied by an improvement in well-being, we would need to assign a value to the non-monetary benefits induced by the transition. This is a natural approach. Yet the approach adopted in the 2009 Stiglitz-Sen-Fitoussi Commission report[2] and subsequent research has tended to focus on supplementing conventional national accounting methods rather than exploring genuine alternatives. Developing an objective measure of well-being, or an alternative indicator to GDP, would imply assigning a value to damage to the environment, to the

[1] Conventional economic indicators do, however, make an important contribution to our understanding of the impact of the climate transition on household well-being. This is particularly true for investment-consumption trade-offs and inequalities between household categories. See the *Bien-être* (Well-being) thematic report coordinated by Didier Blanchet.

[2] Stiglitz J. E., Sen A. and Fitoussi J.-P. (2009), *Report by the Commission on the Measurement of Economic Performance and Social Progress: Executive Summary*.

climate and to future living conditions, including life expectancy. This presupposes that these different dimensions could be reduced to a common monetary metric – something for which we do not, and probably never will, have an indisputable pricing system.

Nevertheless, national accountants have begun to develop indicators that supplement GDP. In particular, they are working on a way to measure the net domestic product of environmental damage caused by GHG emissions (which, of course, supposes that a value can be assigned to these emissions).[1]

As discussed in detail in the *Bien-être* (Well-being) thematic report, there are also valid reasons to believe that the climate transition induces direct non-monetary co-benefits, which are distinct from the elimination of the negative externality. In particular, these include the health benefits of reducing local pollution, eating a healthier diet, walking and cycling, and so on. In this case, a monetary measure of well-being that ignored these co-benefits would provide a biased indicator of the effects of the climate transition.

Box 3: Climate transition and well-being: methodological issues

Conventional indicators of living standards, such as GDP and household disposable income, should account for a significant proportion of the effects of the climate transition on economic well-being, whether they result from technological progress or government intervention (i.e. subsidies, taxes and certain types of regulation). This will hold true at the point at which these effects become apparent in nominal household incomes, or in the structure and general level of prices.

However, these indicators capture the effects of regulatory constraints on well-being only partially, if at all, when such constraints are applied directly to households rather than to businesses. They also fail to capture the depreciation of fossil-fuel-linked assets held directly by households. To find these effects, we need to look at household assets instead of incomes – and quantifying them is not entirely straightforward. It is also important to consider the impact of the climate transition on the volume-price split of in-kind public services, and on the shift between market production and household production (which is not accounted for).

Moreover, these indicators do not take into account two factors that are likely to facilitate the transition. First, certain non-monetary co-benefits of the transition (gains in terms of health, leisure and quality of life) can mitigate its economic costs – although the list of co-benefits to be included here requires careful reflection, since other non-monetary aspects can increase these costs. Second, consumers

[1] See the *Indicateurs et données* (Indicators and Data) thematic report coordinated by Nicolas Carnot and Nicolas Riedinger, as well as the INSEE blog post on “augmenting” national accounts.

who attach increasingly less importance to fossil-fuel-intensive products will be less affected by restrictions on their use than if their preferences remain unchanged – a fact that is imperfectly captured by conventional indicators.

In order to better capture these co-benefits and changes in preferences, we can use expanded income-based or subjective well-being indicators, which give a more holistic view of the net impact of the transition on well-being.

Equivalent or expanded income-based indicators assign monetary values to non-monetary dimensions of well-being, reflecting the importance attributed to them by agents. This avoids the need to use multi-criteria dashboards, which implies implicit aggregation and is therefore not especially transparent.

Subjective well-being, meanwhile, offers a way of capturing the effects of quality-of-life factors that cannot be quantified in monetary terms. Sufficiency, for instance, can have a positive impact on well-being if it leads people away from over-consumption – a practice that causes as much frustration as it does genuine well-being. To take another example, greening the economy will have a positive effect on well-being if it reduces climate-change anxiety, a phenomenon that has been empirically verified, especially among young people.[1] In any event, for positive effects to emerge, people need to develop an awareness of environmental issues. And, on a more general note, it is not the state of the climate at a given moment *per se* that influences current well-being, but rather the future outlook.

It is important to bear in mind that the main gains expected from the climate transition will benefit future rather than current generations, and will be felt largely in those countries threatened by climate change. These gains will need to be compared with the costs incurred during the transitional phase. Evaluating these gains is part of a wider issue, namely the assessment of sustainability indicators at the global rather than the national level.

As we mentioned earlier, it is also likely that a shift in consumer behaviour towards sobriety can happen without any deterioration in consumer utility, provided that energy-intensive behaviour is more the result of inertia or habit than a genuine optimisation of utility under budget constraints.

The *Bien-être* (Well-being) thematic report also opens up a third and final avenue: the gradual shift towards greener preferences. Although this avenue poses methodological problems and is tricky in principle, since it goes against the usual assumption of preference stability, it is nevertheless worth exploring. Its potential value becomes even clearer over

[1] Clayton S. and Karazsia B.T. (2022), "Development and validation of a measure of climate change anxiety", *Journal of Environmental Psychology*, Vol. 69, pp. 1014–1034.

a long-term time horizon, and when we consider the disruptive impact of climate change on our daily lives. After all, it would be short-sighted to suggest that our preferences are unlikely to change between now and 2050.

Box 4: Statistics and the climate transition

Macroeconomic monitoring and evaluation of the climate transition raise specific statistical issues and call for appropriate investment from official statistics providers.

The first of these issues concerns the measurement of GHG emissions, where an equal focus should be placed on two related concepts:

- Inventory, which accounts for emissions produced on French territory
- Footprint, which aims at measuring all emissions linked to France's domestic final demand, regardless of whether the goods or services are produced in France or imported

High priority should be given to ongoing work to improve carbon footprint estimates and to widen the scope for cross-referencing emissions and footprint statistics with other economic data.

Beyond these expected short-term improvements, the second issue concerns the use of private carbon accounting for statistical purposes. The carbon footprint assessments currently produced by major companies are still somewhat inconsistent and difficult to aggregate. The ongoing discussions on the IFRS S2 Climate-related Disclosures standard mark a first step towards reducing this disparity. But we are unlikely to have a solid foundation for carbon accounting and economic analysis until we reach the point where accounting data that can be aggregated (carbon footprint associated with invoices) is collected more systematically.

The third issue relates to the value and quality of sub-annual emissions statistics. Are these statistics intended to provide genuinely informative content? If so, what content are they supposed to provide? Or, conversely, are they merely a way of reporting to the public at the same frequency as the usual cyclical indicators?

The fourth issue concerns the way in which emissions are broken down and assigned to individual households. Current methods require improvement, since they rely on over-simplified assumptions such as the proportionality of emissions from a product to expenditure on that product.

The fifth issue relates to economic scenarios involving different levels and distributions of mitigation efforts. This issue calls for a new approach to the measurement of certain variables, starting with investment. Beyond merely classifying investments as "green" or "fossil-fuel-intensive", it is necessary to characterise their performance in terms of GHG emissions, and to connect physical and monetary data in order to infer unit costs. France's official statistical service already publishes a great deal of relevant data in this respect, but the categories are evolving, which has led organisations such as I4CE to produce data that could have been part of official statistics.

The sixth issue, which concerns how prices are measured, requires particular attention. For example, it costs more for a household to buy an electric vehicle than a conventional one, but standard price indices fail to capture this extra cost because the electric car is considered a new, higher-quality product. The challenge here is to quantify the effects at play (also taking into account the fact that electric cars are cheaper to run).

The seventh and final issue relates to composite indicators of macroeconomic performance that factor in the constraint of climate sustainability. Such indicators can be developed by adjusting conventional national accounting metrics for the costs associated with GHGs. The adjusted net savings (ANS) indicator provides an indication as to sustainability, while adjusted net domestic product (ANDP) corrects GDP, a composite measure of economic performance, to account for the limits imposed by climate sustainability. Such indicators, which INSEE is currently considering, provide meaningful information that can alter the message conveyed by conventional metrics. However, they are still experimental in nature, and raise the tricky question of how to assign a value to GHG emissions.

PART TWO

UNPRECEDENTED CHALLENGES IN THE DECADE AHEAD

CHAPTER 6

ACHIEVING IN 10 YEARS WHAT HAS BARELY BEEN ACHIEVED IN 30

1. Bringing down emissions at a rapid pace

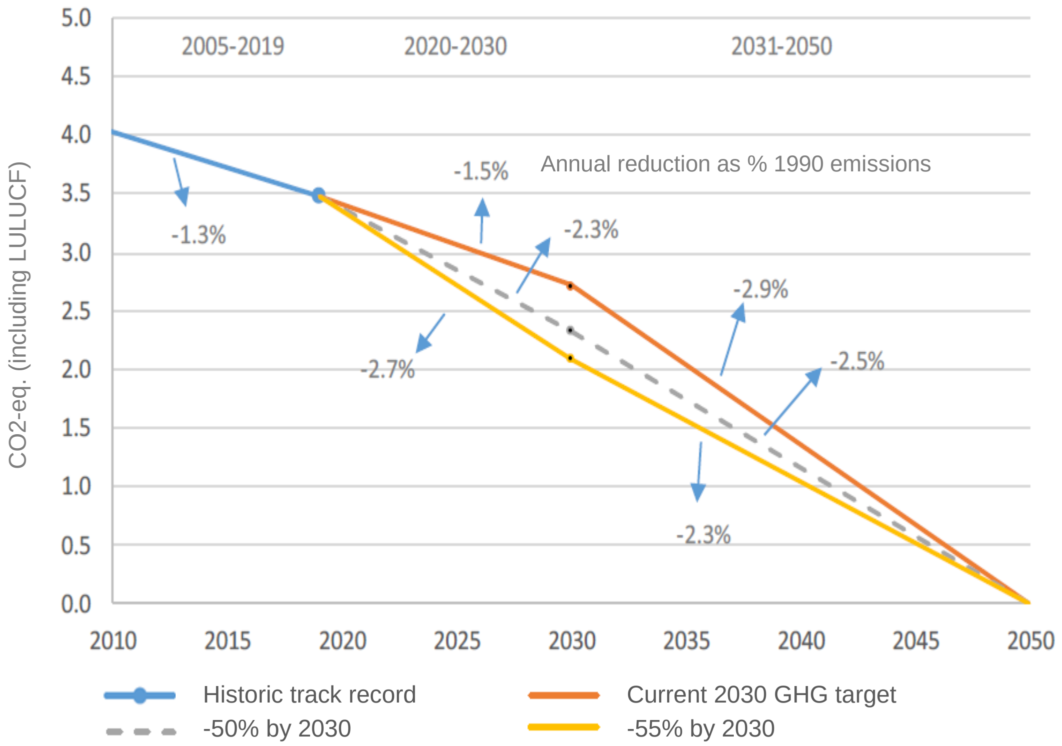
The European Climate Law set EU-wide greenhouse gas emission targets for 2030.[1] In order to meet these ambitious targets, emissions will need to be reduced at more than twice the rate observed in 2010–2020 (see Figure 7 below). This collective effort is then broken down by Member State for sectors not covered by the EU ETS, primarily according to their level of development and, secondarily, to their average abatement costs.[2]

Under the EU's "Fit for 55" package (see Box 5 below), it is up to each Member State to set its own sectoral targets and to mobilise the corresponding instruments, in addition to the measures taken at European level. States therefore retain partial control over the interim targets: they can, for example, choose between electrification and sufficiency, or between vehicle fleet modernisation and energy retrofitting of buildings. They can also choose how quickly they wish to reduce their emissions, provided the 2030 target is met.

[1] The law was adopted on 24 June 2021.

[2] See the Effort Sharing Regulation, which covers approximately 60% of EU emissions (sectors covered by the EU ETS are not included, since they fall under a separate, common mechanism). Emissions-reduction targets for 2030 (relative to 2005 levels) range from 10% for Bulgaria to 50% for Germany.

Figure 7: EU GHG emissions-reduction pathways under the "Fit for 55" package



How to read this chart: In order to achieve the target of reducing GHG emissions by 55% by 2030 relative to 1990 levels, the EU needs to reduce its emissions by 2.7% per year, compared to 1.3% per year between 2005 and 2019.

Source: European Commission (2020), Stepping up Europe's 2030 Climate Ambition. Investing in a Climate-Neutral Future for the Benefit of our People, Impact Assessment, *September, p. 9*

Box 5: The "Fit for 55" package

On 14 July 2021, the European Commission proposed a package of 13 legally binding measures (5 directives and 8 regulations) entitled "Fit for 55", with the aim of reducing GHG emissions by 55% by 2030 relative to 1990 levels. As they currently stand, the texts that have been adopted or are going through the adoption process include the following main provisions:

- Strengthening the provisions of the current EU ETS (which covers the energy sector, energy-intensive industries and commercial aviation) by reducing the cap more rapidly, phasing out free allowances (including for aviation) and topping up the modernisation and innovation funds, as well as gradually extending the scope of the system to include maritime transport between 2024 and 2026 (adopted in April 2023)

- Creating a Carbon Border Adjustment Mechanism (CBAM) as a way to compensate for the elimination of free allowances under the EU ETS, with a gradual ramp-up between 2026 and 2034 (adopted in April 2023)
- Creating a new emissions trading system for the building and road transport sectors, to be implemented starting in 2027 or 2028; under this new system, the carbon price will initially be capped at €45 per tonne (adopted in April 2023)
- Creating a Social Climate Fund (SCF) in connection with this new emissions trading system, as a way to mitigate the social and distributive impacts within and between countries; the SCF will be financed by the revenues from this new trading system, up to €65 billion between 2026 and 2032, possibly supplemented by national contributions (adopted in April 2023)
- Strengthening the 2030 targets (from a 29% reduction to a 40% reduction relative to 2005 levels) for effort-sharing in sectors covered neither by EU ETS 1 nor by the Land Use, Land-Use Change and Forestry (LULUCF) Regulation (adopted in March 2023)
- Strengthening the net carbon removals target for the LULUCF sector (i.e. the carbon sink) to at least 310 million tonnes of CO_2 equivalent ($MtCO_2e$) per year by 2030 (34 $MtCO_2e$ for France) (adopted in 2023)
- Raising the target for the share of renewable energy in the EU's energy consumption to at least 42.5% by 2030 (compared with 32% in the previous directive) (in progress, provisional agreement in March 2023)
- Revising the Energy Efficiency Directive to raise the target for reducing final energy consumption across the EU from 32.5% to 38% by 2030 (in progress, provisional agreement in March 2023)
- Revising legislation to accelerate the roll-out of electric charging stations and alternative fuelling points for cars, aircraft and ships (in progress, provisional agreement in March 2023)
- Banning the sale of new CO_2-emitting cars and vans from 2035 (with intermediate emissions-reduction targets) (adopted in March 2023)
- Revising the Energy Taxation Directive to bring it in line with the EU's environment, energy and climate policy (under discussion, Commission proposal not adopted in December 2022)
- Introducing a requirement for the fuels made available at EU airports to include a minimum share of "sustainable aviation fuels" from 2025 (in progress, provisional agreement in April 2023)

- Setting a maximum GHG intensity threshold for fuels used in maritime transport, which will be progressively lowered in order to achieve a 75% reduction by 2050 (in progress, provisional agreement in March 2023)
- Introducing a requirement for all new buildings to be carbon-neutral by 2030, along with energy performance standards for existing buildings (in progress, Council agreement in October 2022)

In France, the forthcoming National Low-Carbon Strategy (SNBC 3), which is currently being finalised, will determine effort-sharing between sectors and set out the range of associated public policy instruments. It will also determine the mix of drivers for decarbonising power generation. These are genuine public policy choices, which are promoting lively debate and will ultimately be formalised in the Energy-Climate Programming Bill (LPEC), to be voted upon by parliament (see Box 6).

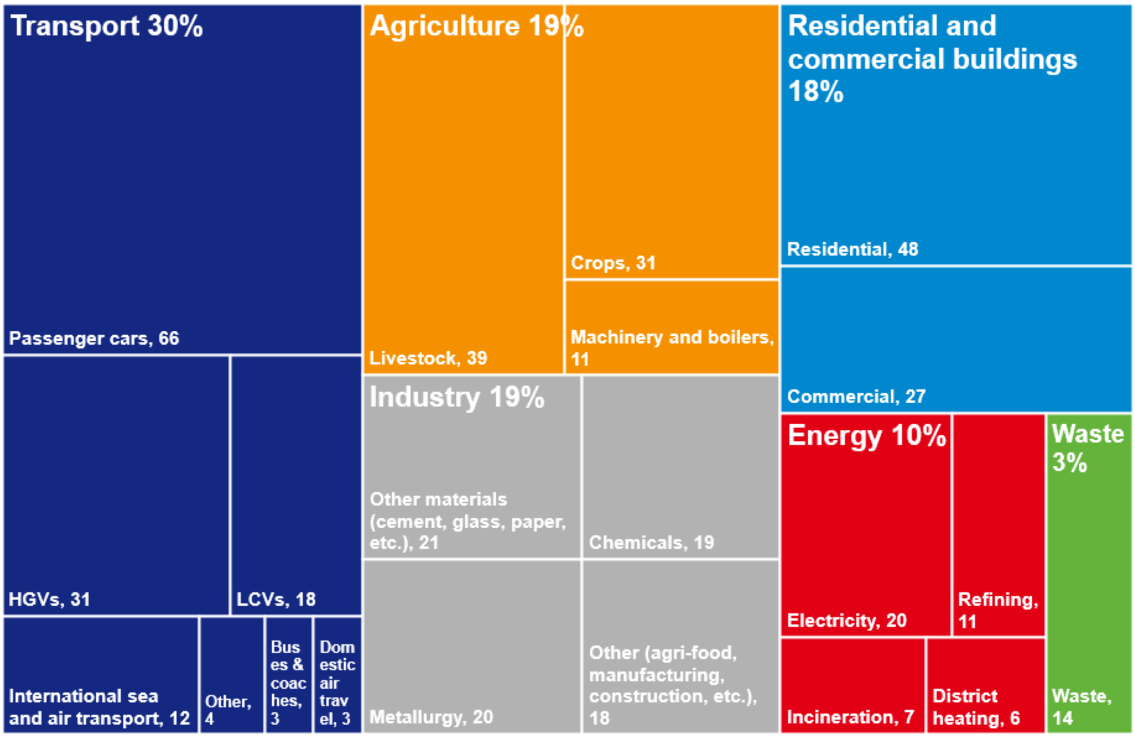
Box 6: Key French laws and regulations

- Energy-Climate Act (2019): set the goal of climate neutrality by 2050 and introduced the LPEC
- Climate and Resilience Act (2021): wrote into law the proposals of the Citizens' Climate Convention
- Energy-Climate Programming Bill (LPEC): scheduled for summer 2023
- National Low-Carbon Strategy (SNBC): introduced in 2015, currently being revised (SNBC 3)
- Multi-Year Energy Programme (PPE)

2. Every sector will need to play its part

In 2021, France's national GHG emissions amounted to 418 $MtCO_2e$.[1] Transport accounted for 30% of this total, with agriculture, construction and industry representing just under 20% each (see Figure 8). By contrast, the breakdown was significantly different in 2001, when transport accounted for 26% of GHG emissions, industry for 23% and agriculture for 17% (see Figure 9). In accordance with UNFCCC guidelines, these territorial emissions do not include GHG emissions in countries where the goods imported into France were produced. Instead, these emissions are included in France's carbon footprint (see the *Indicateurs et données* (Indicators and Data) thematic report).

Figure 8: France's GHG emissions in 2021 (in $MtCO_2e$)



How to read this chart: In 2021, agriculture accounted for 19% of French GHG emissions, with livestock farming alone representing 39 $MtCO_2e$ of emissions in that year.

Source: Based on CITEPA-Secten, monthly barometer, excluding LULUCF but including international transport

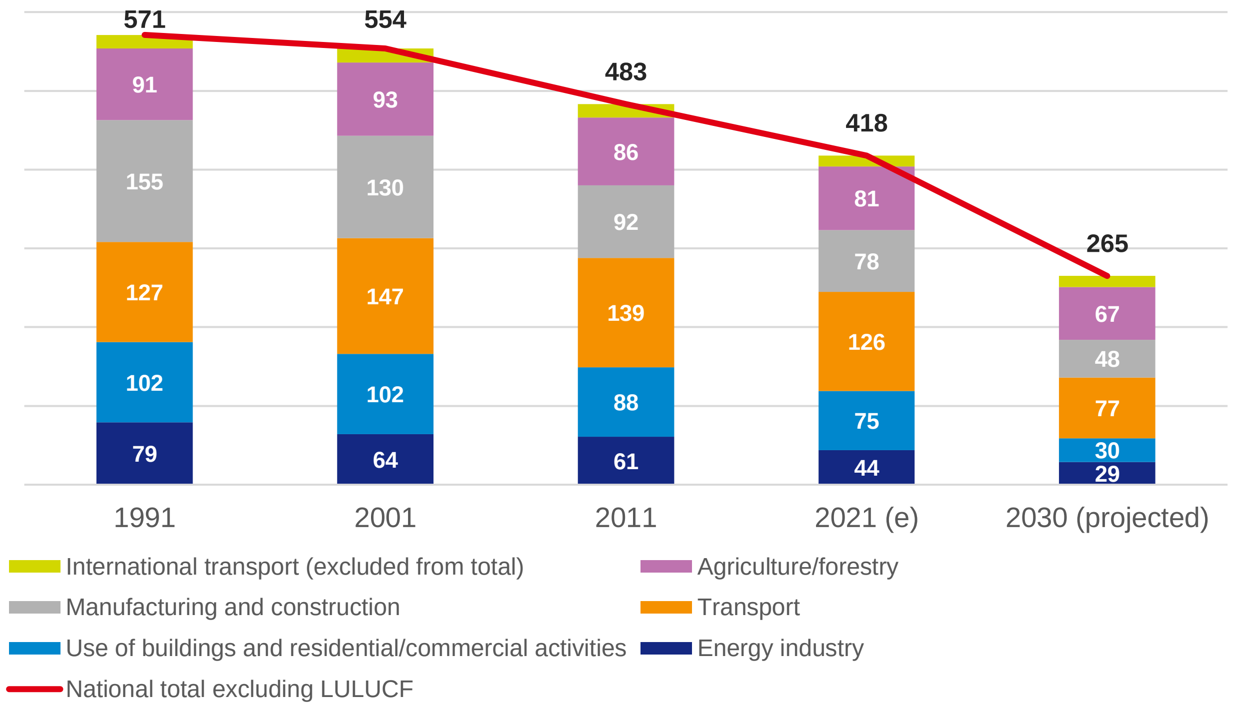
[1] Source: CITEPA (2022), *Inventaire des émissions de polluants atmosphériques et de gaz à effet de serre en France – Format Secten*, June; provisional estimate for 2021 of emissions excluding LULUCF (see Box 7) (404 $MtCO_2e$ including LULUCF); emissions are expressed in tonnes of CO_2 equivalent but include GHG emissions other than CO_2; national emissions do not include emissions from international maritime and air transport (12 $MtCO_2$ in 2021), or emissions not linked to human activity (3.5 $MtCO_2$ in 2021). The scope covers mainland France and French overseas territories within the EU. For 2022, the pre-estimate based on CITEPA's monthly barometer is 408 $MtCO_2e$.

The 2030 target in the SNBC 3 will likely be in the region of 270 $MtCO_2e$, representing a reduction of 150 $MtCO_2e$ between 2021 and 2030.[1] This is roughly equivalent to the decline in territorial emissions observed over the previous three decades. In other words, the ambition for 2030 is to achieve in 10 years what we have previously done in 30, but without relying on the offshoring of carbon-intensive sectors – and doing so at a time when France is reindustrialising.

This represents a reduction rate of roughly 5% (or 16 $MtCO_2e$) per year, which is nearly three times faster than the rate observed since 2010.

In some sectors, the acceleration will need to be even greater. In the transport sector, for example, emissions need to be reduced by around 50 $MtCO_2e$ by 2030, whereas the reduction observed in the last decade, largely due to the COVID-19 crisis, merely offset the rise in emissions recorded since 1990 (see Figure 9).

Figure 9: France's GHG emissions, 1991–2030 (in $MtCO_2e$)



How to read this chart: In 2021, transport sector emissions stood at 126 $MtCO_2e$, versus 147 $MtCO_2e$ in 2001.

Source: CITEPA (2022), Format Secten, op. cit., and authors' calculations

[1] At the time of writing, the choices relating to SNBC 3 have not been finalised. We are therefore working from assumptions that are consistent with the work in progress, but which are the sole responsibility of the authors of this report.

In order to better appreciate the economic implications of the climate transition, it is necessary to examine the concrete measures considered for each sector in detail. Doing so will ensure that the reality of the transition and the changes it implies are fully considered from an economic point of view. In contrast, one of the limitations of existing assessments is their lack of detail about the measures implemented. This may be due to insufficient granularity, particularly in the case of international assessments. But it could also be attributed to doubts over which levers to use, or to the challenge inherent in making difficult choices.[1]

The key measures proposed to achieve the 2030 targets are presented in the remainder of this chapter and listed in Table 2 at the end of Chapter 7. On a general note, the gradual integration of transport and buildings into the EU ETS 2 system is likely to have the effect of accentuating the price signal, if is not fully offset by a reduction in fuel taxes.

The *transport* sector (excluding international transport) represents over 30% of emissions, with passenger cars and heavy goods vehicles (HGVs) accounting for three-quarters of emissions within this sector. For a 2030 target of 87 $MtCO_2e$ (i.e. a reduction of around 50 $MtCO_2e$ compared with 2019 levels), emissions reductions could be distributed as follows: 25 $MtCO_2e$ for passenger cars, 12 $MtCO_2e$ for HGVs, and 7 $MtCO_2e$ for light commercial vehicles (LCVs).[2]

The main levers for reducing emissions from these three vehicle categories are as follows: (i) electrifying the fleet, (ii) switching to other modes of transport and (iii) reducing mobility or freight transport.

By 2030, the primary driver for reducing emissions should be the electrification of the passenger car fleet, accounting for 11 $MtCO_2e$, or 44% of the total (see Figure 10). This means reaching a point where electric vehicles account for 15% of the total fleet (versus 1.2% today), which would imply electric vehicles representing 66% of new vehicle registrations (versus 12% today). Electrifying the LCV fleet could also reduce emissions from this category by 3 $MtCO_2e$.

[1] One example is the use of shadow prices to model behaviour changes. While this technique allows us to represent the effects of norms or bans, it assumes that the behaviour changes targeted by the norm will indeed occur but does not question the mechanisms (and possible blockages) associated with their implementation.

[2] The COVID-19 crisis caused a temporary reduction in transport-related emissions in 2020–2021. For this sector, the most appropriate baseline year is therefore 2019. Moreover, given the spontaneous upward trend in transport emissions, the necessary measures should in fact reduce emissions by 30 $MtCO_2e$ for passenger cars, 18 $MtCO_2e$ for HGVs and 9 $MtCO_2e$ for LCVs (based on the optimistic assumption that mobility demand, expressed in km per capita, remains stable).

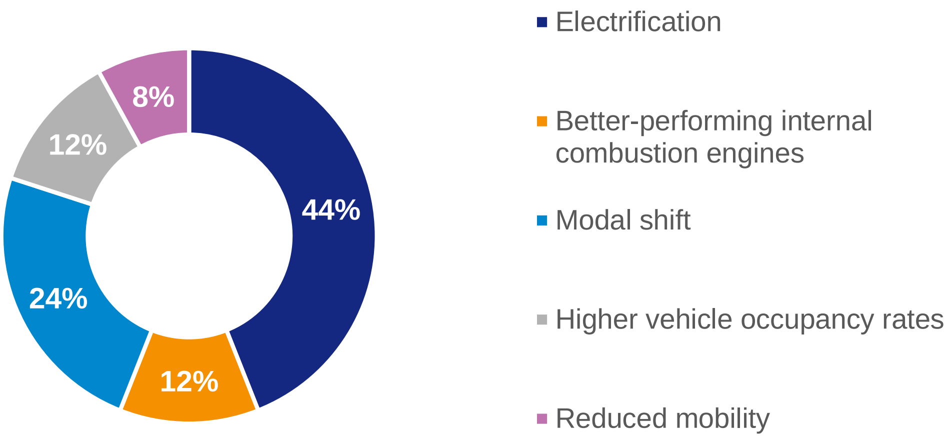
The main measures for achieving this increase in the number of electric vehicles are as follows:

- European regulations on emissions from new vehicles (requirements for manufacturers to reduce these emissions by various deadlines, ban on the sale of cars with internal combustion engines in 2035)
- Decarbonisation obligations for company fleets (Mobility Reform Act)
- The targeting of purchase subsidies (car scrapping bonus and emissions-based bonus-penalty scheme) towards electric vehicles with a smaller construction footprint
- The roll-out of more charging infrastructure

The second driver is the reduction of car use, which can be achieved by switching to other modes of transport (reduction of 6 $MtCO_2e$) and by increasing vehicle occupancy rates (reduction of 3 $MtCO_2e$). But these two levers presuppose a change in practices in order to counter the upward trend in passenger car traffic (around 0.75% per year between 2012 and 2019). In this respect, commuting by bicycle or by public transport, and taking the train for holiday and weekend travel, should be encouraged. These changes in behaviour obviously require the development of appropriate infrastructure (bike lanes and bike parking facilities) and improved public transport services.

The third driver involves reducing overall mobility, which clearly ties in with the concept of sufficiency. This measure would account for a reduction of 2 $MtCO_2e$. For passenger cars, this could be achieved if more people worked from home or chose to take holidays locally, or if towns and cities were reorganised to avoid the need for people to take certain journeys.

Figure 10: Contributions to reducing emissions from passenger cars, 2019–2030



How to read this chart: Reducing overall mobility between 2019 and 2030 could account for 8% of the total reduction in emissions from passenger cars.

Source: Authors' calculations

For HGVs, the gradual electrification of the fleet[1] will also help to reduce emissions by 2030: having electric HGVs represent 35% of sales and 7% of the total fleet by 2035 would enable a reduction of 2 $MtCO_2e$. But the most significant reductions will come from other levers such as the development of more energy-efficient internal combustion engines (reduction of 4 $MtCO_2e$). Similarly, modal shift to rail and river freight could reduce emissions from HGVs by 4 $MtCO_2e$. A reduction in transport demand, meanwhile, may come from the development of local distribution channels, a decline in new construction and the shift towards more sustainable logistics practices.

Emissions from *industry* amounted to 78 $MtCO_2e$ in 2021. This sector has made the biggest contribution to emissions reductions since 1990, with an average decline of 1.5% per year, partly due to deindustrialisation. By 2030, emissions from this sector would need to fall by an additional 30 $MtCO_2e$, or 4.3% per year. This represents a considerable effort, especially at a time when France is committed to reindustrialisation.

Since 2005, industry has been covered the EU ETS, with a current carbon price of €100 per tCO_2e and the gradual phase-out of free allowances (50% reduction in 2030, abolition in 2034) in those sectors that fall under the EU's CBAM (i.e. cement, steel, aluminium, fertilisers and electricity). This is the first lever for decarbonising the sector.

Beyond this, the measures distinguish between high-emitting sites and other, smaller sites:

- The 50 highest-emitting industrial sites account for 50% of the sector's emissions. As part of the 2030 and 2050 decarbonisation road maps for each of these sites,[2] the France Relance and France 2030 plans finance calls for decarbonisation projects to the tune of €5.6 billion and €1.2 billion respectively.[3]
- Decarbonisation measures for other, smaller industrial sites include ongoing calls for decarbonisation projects, the ramp-up of energy saving certificates to €27 per kWh by 2050, and the Heat Fund, the budget for which will reach €1 billion by 2027.[4]

Reducing emissions is not the only challenge facing industry. The sector also has a role to play in facilitating the deployment of the disruptive technologies needed for the transition, covering both hydrogen (H_2) and carbon capture and storage (CCS). Industry must also

[1] Beyond 2030, other energy vectors (such as hydrogen) could be used for long-distance transport.

[2] And the road maps of the strategy committees for the highest-emitting sectors (chemicals, cement, metallurgy and agri-food).

[3] Directorate General for Enterprise (DGE) (2023), "L'action de l'État en faveur de la décarbonation de l'industrie", *Les Thémas de la DGE*, No. 8, March.

[4] Energy saving certificates require energy suppliers to carry out or finance energy-saving measures that reduce final energy consumption. The Heat Fund, managed by ADEME, provides financial support for the production of heat from renewable energy sources.

help secure the supply of critical components for the transition, such as lithium, as well as transform the nature of its production (e.g. electric vehicles rather than those with internal combustion engines).

In 2021, direct emissions linked to the use of *buildings* amounted to 75 $MtCO_2$: 48 $MtCO_2$ for the residential sector and 27 $MtCO_2$ for the commercial buildings sector. A possible target for 2030 could be 30 $MtCO_2e$, i.e. a reduction of 45 $MtCO_2e$, or 6.7% per year – three times higher than the rate observed over the past decade.

The inclusion of building- and transport-related emissions in the EU ETS (see Box 5) will contribute to achieving the 2030 target for buildings. Other measures include:

- The phasing out of oil-based heating systems, which were responsible for emissions of 13 $MtCO_2e$ in the residential sector and 9 $MtCO_2e$ in the commercial buildings sector in 2021, with a ban on the installation of new oil-fired boilers from 2022 and the early replacement of existing boilers by 2030
- A reduction in the use of gas-fired heating (which currently accounts for emissions of 27 $MtCO_2e$ in the residential sector and 14 $MtCO_2e$ in the commercial buildings sector), with a gradual phase-out of new gas-fired boilers
- An overhaul of renovation subsidies
- Extensive energy retrofitting of the most inefficient buildings (which account for emissions of around 12 $MtCO_2e$), with the aim of completing work on three-quarters of these buildings by 2030
- The implementation of the "tertiary decree",[1] along with enforcement mechanisms and sanctions
- An ambitious plan to retrofit public buildings in line with the Energy Efficiency Directive
- Sufficiency energy-saving measures (i.e. lowering temperatures)

Meeting the emissions-reduction targets for the transport and industrial sectors (and achieving the "zero net artificialisation" target by 2050) will also require a slowdown in the pace of new construction. Demographic factors should facilitate this shift, which also presupposes a reduction in the number of vacant dwellings and second homes. However, in the absence of any clearly defined measures, the effects of the transition will be assessed here without assuming any significant change in the pace of new construction (see Chapter 7, section 2).

[1] Decree 2019-771 of 23 July 2019, also known as the Tertiary Eco-Energy Scheme (DEET), which requires all commercial buildings larger than 1,000 m^2 to reduce their final energy consumption by 40% by 2030 and by 60% by 2050.

In 2021, the *energy production* sector accounted for emissions of 44 $MtCO_2e$, or 10% of the total. Close to half of these emissions (20 $MtCO_2e$) came from power generation, followed by refining processes (11 $MtCO_2e$), incineration (7 $MtCO_2e$) and district heating (6 $MtCO_2e$). The sector has been the second-biggest contributor, after industry, to emissions reductions since 1990, with a total fall in emissions of 34 $MtCO_2e$, or 1.4% per year. This reduction has been made possible by increasing the share of renewables in the energy mix, which now stands at 19.3%, even though the target of 23% in gross final energy consumption, set by the EU's RED and RED II directives, had not been met.

The target for 2030 could be a reduction of 15–20 $MtCO_2e$ (4–5% per year). Achieving this target will require a 22% reduction in final energy consumption, an increase in the share of electricity and biomass in all sectors, and a steep rise in the share of renewables in energy production (heat and electricity). At this point, no new nuclear power plants will be operational.

Agriculture is the second-biggest emitter of GHGs, with emissions amounting to 81 $MtCO_2e$ in 2021, or 19% of the total – a level close to emissions from industry and buildings. The emissions-reduction target for agriculture could be in the region of 13–15 $MtCO_2e$ by 2030. In this sector, the transition must factor in the use of biomass for different purposes (carbon sinks, bioenergy, food sovereignty): carbon sinks will absorb 14 $MtCO_2e$ in 2021, which is less than in 1990 and three times less than in 2005 (see Box 7).

Box 7: The collapse of the forest carbon sink

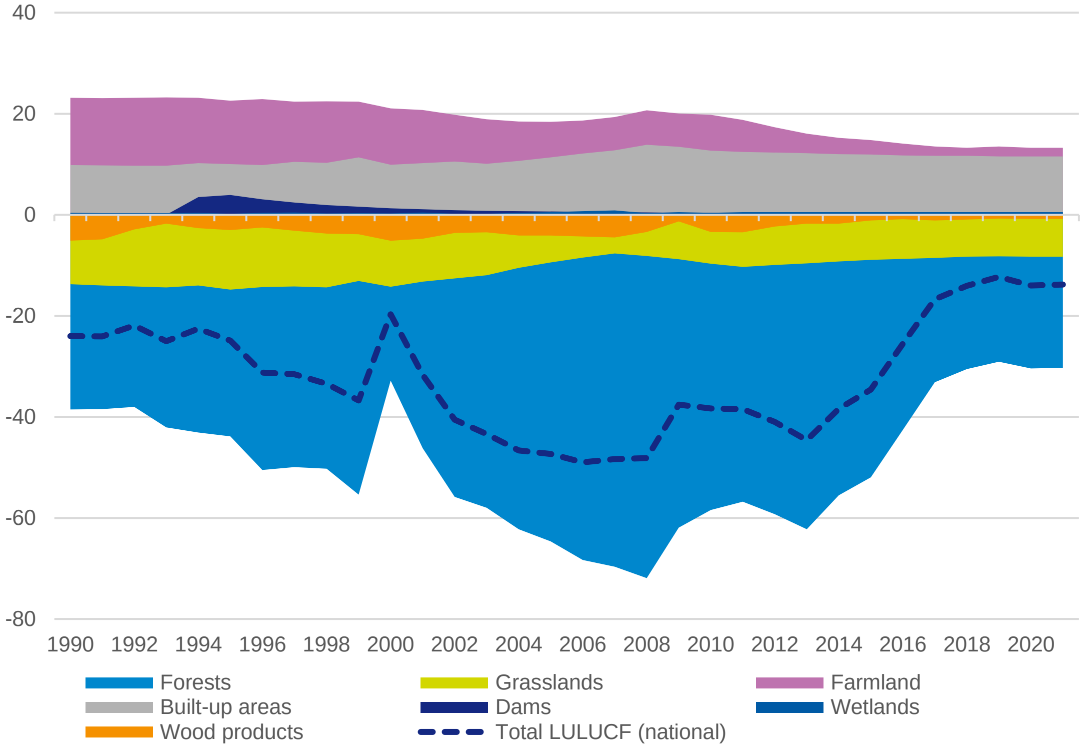
Net territorial emissions are defined as gross emissions from all sectors minus "negative emissions" removed from the atmosphere by carbon sinks. The majority of these negative emissions are accounted for by CO_2 absorbed by forests. In technical terms, this sector is defined as Land Use, Land-Use Change and Forestry (LULUCF). Negative emissions from the sector increased significantly between 1990 and 2005 (from -24 to -47 $MtCO_2e$), almost entirely due to an increase in forest sink storage linked to the conversion of farmland back to woodland. This figure then fell from around -45 $MtCO_2e$ in the mid-2000s to -35 $MtCO_2e$ in 2015. The decline then accelerated sharply: by 2021, it was down to -14 $MtCO_2e$, mainly due to the collapse of the forest carbon sink.

Recent trends can be explained in particular by the decline in tree growth and the rise in tree mortality – due to the increased frequency and intensity of droughts, forest fires and, since 2015, diseases (dieback) – as well as by the rise in harvesting (CITEPA, 2022).

Stand resilience and forest adaptation to climate change are key variables in limiting the extra effort required across the rest of the economy. In particular, the loss of natural storage efficiency will require further reductions in final emissions, which will prove all the more difficult to achieve as sectors become decarbonised.

By way of illustration, if the 21 $MtCO_2e$ decline in LULUCF-related negative emissions between 2015 and 2021 were to be offset by forest renewal alone (ignoring the many other forestry-related levers that could be mobilised), the required additional investment costs could be around €20 billion by 2030.[1] This estimate does not take into account forest mortality and the adaptation of tree species to climate change. Nor does it accurately model the variety of different soil types that will need to be renewed.

Figure 11: LULUCF emissions in 1990 and 2021, in $MtCO_2e$



* 2021 emissions are a provisional estimate. *Source: CITEPA 2022, Secten scope.*

Note: The sharp variations in 1999 and 2009 are due to storm damage.

How to read this chart: In 2008, forests absorbed around 60 $MtCO_2e$, versus 30 $MtCO_2e$ in 2020.

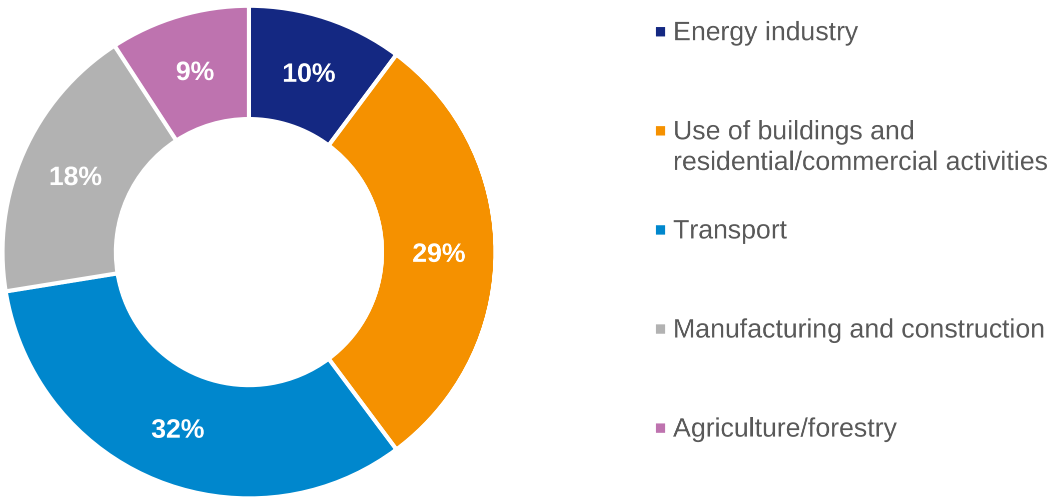
Source: French Treasury

[1] Based on a soil storage factor of 0.8 tCO_2 per hectare per year for conversion from crops to woodland with a transition period of 20 years, and considering identical storage potential in above-ground biomass: see French National Institute for Agricultural Research (INRA) (2020), *Stocker du carbone dans les sols français, Rapport scientifique*, December, p. 105, based on a meta-analysis by Poeplau C. and Don A. (2015), "Carbon sequestration in agricultural soils via cultivation of cover crops. A meta-analysis", *Agriculture Ecosystems & Environment*, Vol. 200, pp. 33–41.

The three drivers for reducing emissions in agriculture are as follows: (i) reducing methane emissions from livestock farming, (ii) reducing nitrous oxide emissions from field crops, and (iii) reducing CO_2 emissions from farm machinery and boilers. The main levers, which are detailed in Table 2 at the end of Chapter 7, rely heavily on changes in behaviour and production practices (dietary changes, organic crops).[1]

In broad terms, this sector-by-sector breakdown underscores the fact that the 2030 target is highly ambitious, and that achieving it will require an immediate break with past trends – in other words, nothing short of a revolution in consumption patterns and production methods.

Figure 12: Breakdown of emissions reductions by sector, 2021–2030 (in $MtCO_2e$)



How to read this chart: The transport sector could account for 32% of the total reduction in emissions between 2019 and 2030.

Source: CITEPA (2022), Format Secten, op. cit., and authors' calculations

[1] In addition to these key sectors, there is also the waste sector (14 $MtCO_2e$) and international transport (12 $MtCO_2e$, excluded from the total).

3. By 2030, emissions reductions will primarily come from the substitution of capital for fossil fuels

It is worthwhile examining the required effort through the lens of the key mechanisms discussed in Chapter 4, namely sufficiency, the substitution of capital for fossil fuels, and the redirection of technological progress. It is difficult to isolate the share of the effort that will be linked to the redirection of technological progress between now and 2030. Much investment within this time frame will focus on existing technologies, which are partly the result of past redirection efforts. But new innovations will only bear fruit in the longer term: the technologies that will be developed between 2023 and 2030 will, by and large, become part of the technology portfolio of the 2030s and 2040s.

It is possible, however, to determine the breakdown of effort between the substitution of capital for fossil fuels, and sufficiency. The latter, in it its strict sense, will concern the transport, residential and agricultural sectors. By 2030, taking into account the levers identified in each sector as described above, we can expect a reduction from sufficiency of between 16 and 23 $MtCO_2e$ out of a total of 138 $MtCO_2e$, i.e. somewhere between 12% and 17% of the total reduction (see Table 2 at the end of Chapter 7). In other words, most of the effort will come from the substitution of capital for fossil fuels.

The substitution of capital for fossil fuels implies investment. This is what we will cover in the next chapter.

CHAPTER 7

A MAJOR INVESTMENT NEED

1. By 2030, additional investment could exceed 2 percentage points of GDP per year

Before we continue, let us briefly recap:

– In order to achieve the 2030 target, we will need to reduce emissions by around 150 $MtCO_2e$ in 10 years, i.e. by 35%

– Some 85% of this effort will come from the substitution of capital for fossil fuels

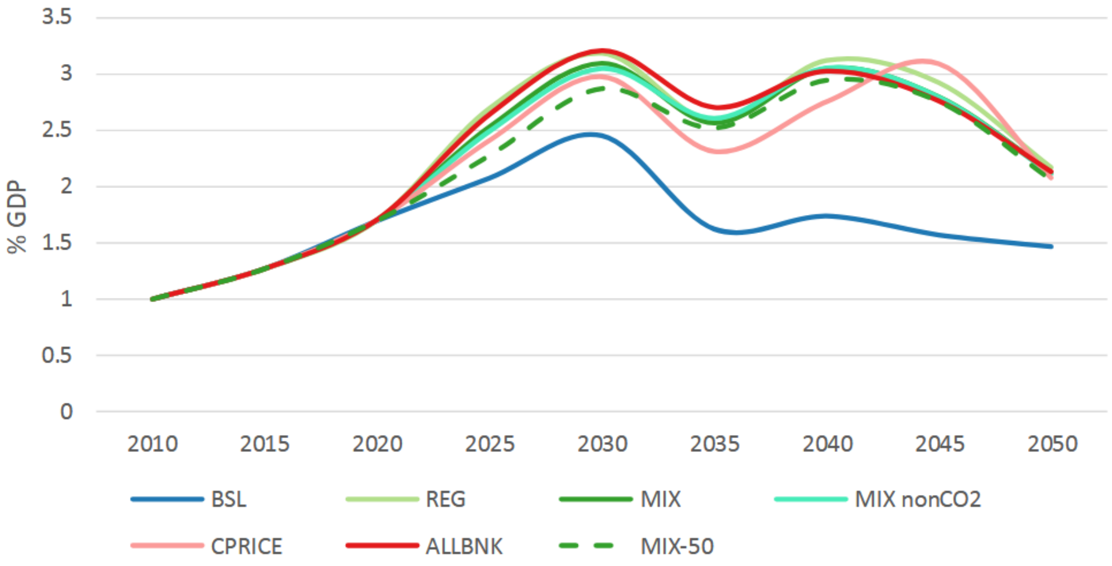
The first question is how much investment this will require. Various estimates of the investment needed to progress towards climate neutrality by 2050 have been made for France, the European Union, the United Kingdom and other countries.[1] They all converge on a figure of roughly 2 percentage points of GDP of additional investment by 2030.[2]

As an example, Figure 13 below shows the level of investment under different transition scenarios considered in the impact assessment for the “Fit for 55” package prepared by the European Commission. In the baseline scenario (BSL), under which emissions would be reduced by just 40% in 2030, investment (excluding transport) increases by around 1 percentage point of GDP between 2020 and 2030. Under the 55% reduction scenarios – which use regulations (REG), carbon pricing (CPRICE) or a mix of the two (MIX) – investment increases by between 0.5 and close to 1 percentage point of GDP by 2030 (see Figure 13).

[1] Here, investment encompasses purchases of durable goods (vehicles, boilers, etc.) by households, which are included in household consumption in national accounts.

[2] Pisani-Ferry J. (2022), “The missing macroeconomics of climate action”, in Tagliapietra S., Wolff G. B. and Zachmann G. (eds), *Greening Europe’s post-Covid-19 Recovery*, Brussels, Bruegel, Bruegel Blueprint series, No. 32, February, pp. 63–87, table 2, p. 71.

Figure 13: Investment in energy systems
(based on EU emissions-reduction scenarios)



Note: Including building renovation but excluding transport.

How to read this chart: In the baseline scenario (BSL), investment in energy systems will reach 1.5% of European GDP in 2050.

Source: European Commission (2020), Stepping up Europe's 2030 Climate Ambition…*, op. cit., fig. 11, p. 70*

Differences between estimates can be attributed to several factors: what is being measured (gross or net investment in fossil-fuel reduction, direct or indirect, for the whole economy or a restricted field), the benchmark against which the additional effort is measured and, of course, the nature of the transition policies. For France, based on comparable scopes and concepts, we estimated the additional investment needed to achieve the targets of the previous National Low-Carbon Strategy (SNBC 2) at around €70 billion (in 2021 euros) per year, or 2.5 percentage points of GDP, by 2030.[1]

These investment amounts can be obtained in one of two ways. This first is to take a top-down approach, which involves broad-based simulations carried out via macroeconomic models on the basis of assumptions made about the instruments used (often, in practice, carbon pricing). The second is to aggregate sectoral investment amounts (i.e. a bottom-up

[1] See Pisani-Ferry J. and Mahfouz S. (2022), "L'action climatique : un enjeu macroéconomique", op. cit., box 1. Following harmonisation, the authors compared the estimates produced by ADEME (2022), Rexecode (2022), Quinet (2019) and I4CE (2022), although the latter were not directly comparable with the others. Institute for Climate Economics (I4CE) (2022), *Landscape of Climate Finance in France – 2022 Edition*, October; ADEME and CGDD (2022), "Évaluation macroéconomique de la SNBC 2 avec le modèle ThreeME", Working Paper, February; Quinet A. (2019), *La valeur de l'action pour le climat*, op. cit.; Rexecode (2022), "Enjeux économiques de la décarbonation en France : une évaluation des investissements nécessaires", Working Paper, No. 83, May.

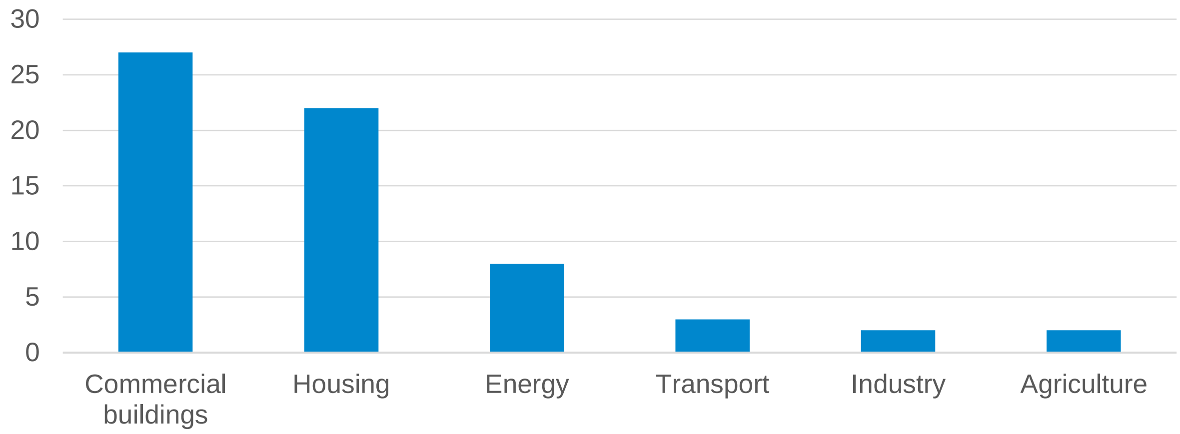
approach). The first method has a dual advantage: it is consistent with macroeconomic assessments and it factors in – at least implicitly – both indirect investments (e.g. in factories producing electric rather than conventional vehicles) and closure effects. However, it generally does not provide a way to ensure that the estimated amounts are consistent with the precise measures envisaged in each sector. Conversely, the bottom-up approach, which is based on precisely specified measures, provides greater transparency with respect to both sectoral trends and the baseline scenario. The drawback in this case is that indirect investments have to be estimated separately.

For the forthcoming SNBC 3, the measures detailed in the previous chapter allow us to use the bottom-up approach, and to assess the required investments with greater precision than was the case for the previous strategy (SNBC 2), for which the envisaged levers were not always specified. The required amount of investment necessary to implement each of these measures in the various sectors are estimated here (e.g. the cost of fast-tracking the replacement of oil-fired boilers with heat pumps). These amounts are then compared with the investments that would have been made between now and 2030 without the measure in question (e.g. replacing end-of-life oil-fired boilers with oil- or gas-fired boilers). The resulting reduction in carbon-intensive investments (in this example, oil- or gas-fired boilers) is also reported.

2. A sector-by-sector inventory of required investments

This approach, which can be applied to all key sectors, produces the results summarised in Figure 14 below.

Figure 14: Net additional investment required to reach the 2030 target
versus a business-as-usual scenario with no greening of the economy (in billions of 2023 euros)



Note: Sea and air transport and the waste sector are not covered here, which reduces the total investment required.

Source: authors

In the *road transport sector*, the transition requires several types of investment: replacing internal-combustion-engine vehicles with more expensive electric models, building charging stations, and developing infrastructure to support the modal shift to cycling, public transport and rail freight. The electrification of the vehicle fleet also presupposes a change in investment in the automotive industry and associated sectors (batteries, etc.), which is not included here.[1]

Electrification measures are expected to increase the share of electric vehicles in registrations from 12% today to 66% in 2030. Even if their price falls, electric vehicles will still be more expensive than internal-combustion-engine models. This substitution will therefore lead to an estimated additional annual cost of €8 billion[2] in 2030, assuming no change in the total number of registrations[3] (annual purchases of electric vehicles would be €28 billion higher than at present in 2030, while annual purchases of internal-combustion-engine vehicles would be €20 billion lower).

If, as we assume here, the electrification of the vehicle fleet is accompanied by lower growth in total registrations,[4] due in particular to sufficiency and modal-shift measures, investment in passenger cars is likely to fall significantly: the total amount of this investment could even be lower – by €8 billion – than it would have been in the absence of transition measures.

Similar estimates for HGVs and LCVs result in net additional investment requirements of €2 billion and €3 billion respectively in 2030, with purchases of more expensive electric or hydrogen-powered vehicles partly offset by a reduction in sales of non-electric vehicles.

Additional investment in charging infrastructure is estimated at €2 billion per year by 2030. The additional expenditure on cycling and public-transport infrastructure associated with increased modal shift is estimated at €3 billion and €1 billion respectively, while additional investment in the rail network is assumed to be less than €1 billion per year.[5] The potential reduction in road infrastructure investment is not taken into account here.[6]

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[1] Other measures that may require investment include reductions in mobility linked to the densification of living spaces, and reductions in freight transport made possible by the reorganisation of supply chains. These measures, which are more akin to sufficiency measures, are not covered here.

[2] Unless otherwise indicated, all investment amounts in this chapter are in constant 2023 euros, in the sense that unit costs are kept constant over the period.

[3] Assuming that, in the absence of any measures to accelerate the electrification of the vehicle fleet, the share of electric vehicles in registrations would be 30% in 2030, and assuming an average number of registrations rising to 2.3 million in 2030, and a price differential of around €9,000 on average between 2024 and 2030.

[4] Stagnation at around 1.8 million a year, rather than an increase to 2.3 million.

[5] All of these assumptions are taken from the work of I4CE, and are given as rounded figures.

[6] Based on the work of I4CE, it would be less than €2 billion by 2030.

Altogether, road transport-related investment will likely increase by 2030,[1] but not significantly more than in a no-transition scenario, provided that such a scenario includes a reduction in car use and, therefore, in new vehicle purchases. Emissions-reduction measures would therefore involve additional investment of €3 billion per year in 2030. It is worth noting, however, that were the total number of passenger car registrations not to stagnate, this amount would be close to €20 billion per year in 2030 – which illustrates the sensitivity of the results to the underlying assumptions.

In the *residential building sector*, the transition requires investment in replacing heating vectors (oil and gas) and in thermal insulation. The investment needed to replace three-quarters of the 3 million residential oil-fired boilers with heat pumps by 2030 is estimated to be close to €5 billion a year in 2030. However, the additional investment amounts to only €3 billion per year, considering that some of these boilers would have been replaced anyway.[2] Assuming that half of all oil-fired boilers would be replaced before reaching the end of their life,[3] the corresponding stranded capital would total €4 billion between 2024 and 2031, or €0.5 billion per year on average.

Were the installation of new gas-fired boilers to be banned from 2026, almost one-quarter of the 12 million such boilers in residential buildings would be replaced with non-carbon alternatives by 2030.[4] Replacing these boilers with air-to-water heat pumps represents a total investment of almost €8 billion a year by 2030,[5] although the additional investment is lower, at €3 billion per year.[6] Insofar as boilers would not be replaced before they reach the end of their life, and at the rate at which this occurs, there would be no associated stranded capital.

These changes in heating systems have implications for the power generation and distribution sector (gas, oil and electricity), as well as for the production of associated equipment (boilers and heat pumps). The investment associated with adjusting the share of different sources in the overall energy mix are accounted for under the energy sector (see below). However, the effects on equipment suppliers are more difficult to estimate, as they depend on domestic production trends and on the proportion of imported equipment. These effects are not included here.

[1] Increase of €13 billion between 2023 and 2030.

[2] Here, the additional investment reflects both the price differential and an accelerated pace of replacement.

[3] An average of 5.8 years before the end of their life.

[4] Some 600,000 boilers reach the end of their life each year, assuming an average lifespan of 20 years.

[5] Specifically, €8 billion per year from 2026 onwards.

[6] The additional investment here corresponds solely to the price differential (€13,000 instead of €8,500).

In terms of energy retrofitting work to energy-inefficient homes (i.e. those rated F or G), if such work is limited to homes heated by oil (1.6 million) and gas (1.5 million),[1] the associated investment cost will depend on the extent of the retrofitting work and the associated unit costs. Based on the assumptions used here,[2] this cost would stand at €15 billion in 2030, considering all retrofitting work to these energy-inefficient homes as additional investment linked to the transition.

The additional investment associated with emissions-reduction measures in the residential sector would therefore be €21 billion per year by 2030.

In the *commercial buildings sector*, the total investment required to carry out energy retrofitting work on properties subject to the “tertiary decree”,[3] assuming near-perfect compliance with the requirements of the decree, could be as high as almost €30 billion per year by 2030, including around €10 billion for public buildings.[4] The additional investment, compared with a baseline scenario in which it is assumed that this investment would not be made, would therefore be €27 billion in 2030.

The additional investment associated with reducing emissions from buildings would therefore be in the region of €48 billion. This total assumes that the energy retrofitting work to energy-inefficient buildings and commercial properties quantified here does not replace other renovation work that would have been carried out in the absence of emissions-reduction efforts.[5]

Moreover, the required investment amounts do not take into account any reduction in the construction of new buildings. If such a reduction is purely the result of demographic changes and not of transition-related policies, it will not lead to a reduction in investment compared to a baseline (no-transition) scenario, even if it may lead to fewer new buildings being constructed than at present. On the other hand, if measures make it possible to

[1] It is assumed here that only energy-inefficient homes with oil- and gas-fired heating systems undergo retrofitting work, in conjunction with boiler changes, in order to avoid an increase in electricity consumption and/or a drop in temperature.

[2] Half of all retrofits are to an A or B rating (costing €37,000 on average), and half to a C or D rating (€20,000).

[3] As a reminder, decree 2019-771 of 23 July 2019, also known as the Tertiary Eco-Energy Scheme (DEET), requires all commercial buildings of 1,000 m^2 or more to reduce their final energy consumption by 40% by 2030 and by 60% by 2050.

[4] The cost assumptions for the commercial buildings sector are somewhat uncertain, but this order of magnitude was already mentioned in the DEET impact assessment (p. 35). This investment does not include any reallocations of current and capital expenditure usually made by commercial property owners and occupiers.

[5] This assumption is open to discussion: I4CE considers that transition-related retrofitting work will partly replace work that would otherwise have been carried out. Since we are only estimating the cost of changing heating systems and conducting retrofitting work on the 3.1 million oil- and gas-heated energy-inefficient buildings, and not renovation work carried out on the entire housing stock, the possibility of substitution seems more limited. The question is more open for the commercial sector, for which little information is available.

reduce the housing vacancy rate, increase the number of people per dwelling or reduce floor space in the commercial sector, the investment requirements will be lower.

For the *industrial sector*, it is difficult to estimate the investment requirements precisely. The investment figures for this sector cover three components: the 50 highest-emitting industrial sites, other, smaller industrial sites, and a share of projects linked to green reindustrialisation. For the highest-emitting sites, the government has announced a public funding package worth approximately €10 billion (see Box 8 below), or €1 billion per year for investments spread over 10 years. I4CE, meanwhile, estimates that between €3 billion and €14 billion in investment will be needed between now and 2050 to decarbonise the sites of four branches of heavy industry that together account for around half of industrial emissions (steel, cement, alkenes and aromatic compounds, and ammonia).

These amounts should be compared with an increase of €5.5 billion under the baseline scenario. The upper bound of the range, which corresponds to a scenario in which the transition is based on technology (ADEME's S4 scenario), therefore implies additional investment of over €1 billion per year, if all these investments are made by 2030. Emissions-reduction costs will, however, be higher for new projects involving industries that are difficult to decarbonise, or involving less-mature technologies. Overall, the additional investment is assumed to be equal to €4 billion per year in 2030, when compared to a baseline (no-transition) scenario.

Box 8: Government support for decarbonising industry

Industry decarbonisation measures from the France Relance recovery plan

The calls for proposals launched under the France Relance-backed Industry Decarbonisation Fund have supported the decarbonisation of industry to the tune of €1.3 billion (awarded to 241 successful proposals), for a total investment of €4.3 billion. The supported projects should enable emissions to be reduced by an additional 5 MtCO_2e per year, which corresponds to a 6% reduction by 2030 compared with 2015 levels. For comparison, the SNBC 2 targets a reduction of 35%.[1]

The average socio-economic abatement cost of 121 winning projects under the "decarbonisation of processes and utilities" component is €26 per tCO_2e. Considering that calls for proposals are subsidised in order of profitability and efficiency, the abatement cost of future projects is expected to rise as decarbonisation becomes increasingly difficult.

[1] Directorate General for Enterprise (DGE) (2023), "L'action de l'État en faveur de la décarbonation de l'industrie", *Les Thémas de la DGE*, No. 8, March.

France 2030

The France 2030 plan aims to reduce industrial emissions by 8% between 2015 and 2030 by earmarking €5.6 billion for decarbonisation measures. The plan proposes to dedicate €4 billion to deep, large-scale decarbonisation projects and a further €1 billion to the deployment of low-carbon technologies for smaller or emerging industrial firms. As announced by President Macron, twice this amount could be made available if industrial firms double their decarbonisation efforts (targeting a reduction of 20 $MtCO_2e$ instead of 10 $MtCO_2e$ by 2030) within 18 months.

Hydrogen strategy

As part of its National Strategy for the Development of Decarbonised Hydrogen,[1] the French government will deploy €7 billion and €1.9 billion respectively to promote the production and use of decarbonised hydrogen in industry, and in heavy industry in particular (some of which will be deployed through the France 2030 and France Relance plans). The strategy is set to be updated in 2023.

Source: French Treasury

For *agriculture*, there are very few assessments of the investment needed to support the transition. The levers identified to reduce GHG emissions (reducing the use of emissions-intensive inputs, lowering methane emissions from livestock farming, and upgrading farm machinery) vary greatly from one agricultural subsector to another. Moreover, the transition also presupposes major changes in agricultural practices, which will require research and development, support for the adoption of more eco-friendly farming methods, and more. For illustrative purpose, we have assumed an increase in investment of €2 billion per year by 2030.

Finally, additional investment in the *power generation and distribution sector* is expected to amount to €8 billion per year by 2030, divided roughly equally between nuclear power generation, renewable energy production and grid infrastructure.[2]

Total additional investment across all sectors would therefore amount to around €66 billion per year by 2030, or 2.3 percentage points of GDP, compared to a scenario without the transition measures in question. As we have seen, this assessment is quite sensitive to a number of assumptions. For instance, if total sales of passenger cars continued to rise (with a shift towards more electric vehicles), the total additional investment could be close to €80 billion.

[1] French Government (2023), "Accélérer le déploiement de l'hydrogène, clé de voûte de la décarbonation de l'industrie", press kit, February.

[2] Lower bound of the RTE range, Rexecode and ADEME S2 estimates (source: French Treasury).

Conversely, if "spontaneous" retrofit investments in the commercial buildings sector accounted for half of the required amount, the total would be reduced by almost €15 billion.

It is also important to clarify that the scope is limited to the identified and quantified measures. Moreover, this estimate does not include:

- The investments needed to produce "green" goods (heat pumps and electric vehicles)
- The air and sea transport sectors
- The investments needed to maintain the carbon sink constituted by the LULUCF sector, which may be substantial

Conversely, the estimate does not take into account any reduction in new residential and commercial construction.

These amounts may appear slightly lower than the estimates of investment needs associated with the SNBC 2, as summarised in the November interim report.[1] However, we have seen how sensitive they are to the underlying assumptions, as well as the significant margins of uncertainty. The order of magnitude remains the same, and the approach adopted here provides a detailed breakdown by sector and measure, thereby supporting detailed consideration of how these investments will be financed.

3. How and when: the emissions-reduction strategy

Through which channels and at what pace should these changes take place? These questions do not arise in a price-driven strategy. In principle, all we need to do is to set a carbon-price trajectory for the future that ensures that the target is met. Of course, there are many issues to be resolved even in this case, the first of which is to choose a method for determining the optimal price. There is a considerable gap between the social cost of carbon as derived from Nordhaus-style intertemporal optimisation, and the value of climate action, which is defined – theoretically at least – as the dual value of the quantity constraint resulting from the Paris Agreement.[2]

In practice, the EU and France have adopted a mixed strategy, combining regulation, subsidies and carbon pricing. The advantage of such a strategy is that it ensures a more direct match between objectives and means. As we have just seen, a sector-by-sector

[1] Pisani-Ferry J. and Mahfouz S. (2022), "L'action climatique : un enjeu macroéconomique", op. cit.

[2] For an overview of the discussion on this point, see Nordhaus W. (2018), "Projections and uncertainties about climate change in an era of minimal climate policies", *American Economic Journal: Economic Policy*, Vol. 10, No. 3, pp. 333–360; Stern N., Stiglitz J. and Taylor C. (2022), "The economics of immense risk, urgent action and radical change: towards new approaches to the economics of climate change", *Journal of Economic Methodology*, Vol. 29, No. 3, pp. 181–216; and Quinet A. (2019), *La valeur de l'action pour le climat*, France Stratégie, February.

estimate of investments can theoretically be used to ensure that the requisite funding is available and, therefore, to steer convergence towards the emissions target. In the event of a deviation, it can be used to correct the trajectory by stepping up efforts. The drawback of this approach is that it does not necessarily help to achieve decarbonisation at the lowest possible cost. This is because abatement costs can vary considerably from one sector to another, and even from one year to the next.

As we stressed in the November 2022 interim report, it is important, for reasons of effectiveness, that the planning process be based on an explanation of present and anticipated abatement costs, set against a trajectory of implicit carbon prices. Such an approach will inform public decision-making and ensure that choices are made across sectors and time frames on a rational basis. Thanks to the work led by France Stratégie (the Quinet and Criqui commissions),[1] France is equipped with high-quality tools for this purpose.

However, it is important to bear in mind the constraints on the distribution of efforts over time and between sectors. Even if the optimal strategy would be to wait to benefit from an anticipated reduction in abatement costs, this is not always realistic. It will inevitably take several decades to complete retrofitting work on all energy-inefficient buildings, to change heating systems and to electrify vehicle fleets, because the skills required to carry out the corresponding work are in short supply and because equipment renewal is by nature a gradual process. Failing to invest in decarbonising the residential sector because the abatement costs are higher than in industry would also be a foolhardy approach, since it is not possible to simply shift the burden of responsibility for emissions reductions from one sector to another. All sectors must contribute to this effort, and without delay.

The path of the self-imposed constraints themselves is another matter worth questioning. The global rise in temperatures by the middle of this century will depend on cumulative emissions over the next three decades. Logic therefore dictates that the Paris Agreement's climate target should have been associated with a carbon budget (i.e. a total of cumulative emissions not to be exceeded over a given period), not only a target level of emissions (e.g. net zero) in a given year. But the international negotiations behind the process did not allow for this. France has adopted[2] carbon budgets covering five-year periods, with no obligation to make up any shortfalls over subsequent periods, thereby going against the recommendations of the High Council for Climate Action.[3] However, delaying the transition only to abruptly downgrade fossil-fuel-intensive capital as the deadline approaches would be an economically irrational choice, as demonstrated by an exploratory model currently being developed by INSEE (see Box 9).

[1] See the work of the commission on abatement costs led by Patrick Criqui.

[2] Article L222-1-A of the Environment Code, from Article 173 of the Energy Transition and Green Growth Act 2015-992 of 17 August 2015.

[3] High Council for Climate Action (HCC) (2019), *Agir en cohérence avec les ambitions*, first HCC annual report, June: see recommendation 7.

Box 9: Some lessons from a stylised model of decarbonisation through capital[1]

In many sectors – electricity, agriculture, industry, transport and housing – production relies heavily on capital associated with GHG emissions (so-called “fossil-fuel-intensive” capital). From the perspective of the transition, this capital will eventually need to be eliminated and be replaced by so-called “green” capital (i.e. capital not associated with GHG emissions). This transition from one type of capital to another will primarily be achieved by limiting or halting fossil-fuel-intensive investment. But it may also involve the abrupt scrapping of fossil-fuel-intensive capital (thus creating stranded assets).

We assume here that the economy uses two forms of capital – fossil-fuel-intensive and green – in order to produce a single final good, based on a constant elasticity of substitution (CES) production function. This highly simplified representation allows for imperfect substitutability between the two types of capital, reflecting, at a given date and in the absence of any other constraints, the coexistence of fossil-fuel-intensive and green investments. At each given date, what is produced is used either to invest or to consume. The present level of consumption is the only determinant of the level of utility.

This model examines how optimal trajectories for consumption, and for fossil-fuel-intensive and green investment, are affected by three climate policy options:

- A requirement to achieve net-zero emissions in 2050, with no constraints for other years
- An additional emissions limit for 2030, which reflects the strategy adopted by the EU and France
- A carbon budget (an upper limit on cumulative emissions), which is consistent with limiting global warming

What all three options have in common is that they require the complete greening of the capital stock from 2050 onwards. However, they differ in terms of constraints applied to earlier years, and may therefore lead to continued investment in fossil-fuel-intensive capital before such capital is scrapped as 2050 approaches.

The ramping-up of decarbonised modes of production, which in the model translates into the substitution of green capital for fossil-fuel-intensive capital, is highly dependent on how the constraint is specified:

- If a carbon budget is imposed from the outset, the transition implies the immediate scrapping of a share of fossil-fuel-intensive assets and the cessation

[1] This box summarizes the findings of modelling work undertaken at INSEE by Riyad Abbas, Nicolas Carnot, Matthieu Lequien, Alain Quartier La Tente and Sébastien Roux, which will soon be published.

of all new fossil-fuel-intensive investments. The remaining fossil-fuel-intensive capital then diminishes through gradual obsolescence. Green investment rises sharply in the initial period and continues to increase thereafter.

- Conversely, when the constraint takes the form of an emissions limit at a distant time horizon (in this case, net-zero emissions by 2050), cumulative emissions are ultimately more than twice as high as in the previous case. The constraint has very little effect for the first decade, with fossil-fuel-intensive investment declining slightly compared with the business-as-usual scenario (the 2019 baseline), while there is no sharp uptick in green investment. Since the constraint comes into effect a long way into the future, some of this fossil-fuel-intensive investment is naturally depreciated before 2050. Meanwhile, its additional productivity, accumulated over a long period, makes it worthwhile to strand the remaining large share of this capital just before the 2050 deadline. There is no sharp uptick in green investment until just under two decades before the deadline (i.e. in the early 2030s), at which point fossil-fuel-intensive investment declines rapidly.
- Adding an intermediate emissions constraint in 2030 (the "Fit for 55" scenario) allows the transition to start more quickly than with the 2050 constraint alone. However, under this scenario, the transition follows a "stop-and-go" pattern: the accumulation of fossil-fuel-intensive capital starts to increase again once the 2030 stage has been passed. This scenario also differs significantly from the carbon-budget scenario in terms of both cumulative emissions over 30 years and the time profile of the transition.

Table 1: Main characteristics of the three scenarios

	Inaction	Terminal emissions constraint in 2050	Emissions constraints in 2030 and 2050 (Fit for 55)	Emissions constraint in 2050 and carbon budget
Cumulative emissions, 2020–2050	100	75	65	33
Discounted value of consumption, 2020–2050	100	90	89	85

Overall, imposing a zero-emissions constraint from 2050 reduces cumulative emissions by 25% and the present value of consumption by around 10%. Setting a carbon budget consistent with the Paris Agreement target reduces cumulative emissions by 67% and the present value of consumption by 15%.

This observation underscores the conclusion that policy options for achieving an optimal emissions-reduction trajectory must include a set of constraints, i.e. not just the single constraint of achieving net-zero emissions by 2050. From this point of view, it would be useful for France and the EU not only to adhere to the 2050 and 2030 targets, but also to set a carbon budget, i.e. a constraint on the accumulation of future emissions. This would be more in line with the target of limiting global warming and would provide a greater source of motivation.

Table 2: Additional investments required to reach the 2030 target

Emissions-reduction measures	Change in emissions (in $MtCO_2e$)	Lever	Additional investment (fossil-fuel-intensive and green) compared with a no-transition scenario
in billions of 2023 euros	2030–2021		in 2030
TOTAL (for new measures)	**-138**		**66**
of which green			**101**
of which fossil-fuel-intensive			**-35**
TRANSPORT * (new measures)	**-52**		**3**
of which green			**32**
of which fossil-fuel-intensive			**-29**
Passenger cars	**-23**		**-2**
Electrification of the passenger car fleet, with reduced travel	-11	Sub. K F	-8
[Reminder: Electrification of the fleet, without reduced travel]		*Sub. K F*	*8*
Charging stations		Sub. K F	2
Reduction in the modal share of cars	-6	Sub. K F	4
Cycling infrastructure		Sub. K F	3
Public-transport infrastructure		Sub. K F	1
Increase in passenger car occupancy	-3	Suff.	0
Reduced travel	-3	Suff.	0
Heavy goods vehicles (HGVs)	**-16**		**3**
Electrification of the HGV fleet	-2	Sub. K F	2
Energy efficiency (included in electrification)	-4	Sub. K F	
Modal shift	-4	Sub. K F	1
Slowdown in freight traffic	-5	Suff.	0
Increase in fill rates	-1	Suff.	0

Emissions-reduction measures	Change in emissions (in $MtCO_2e$)	Lever	Additional investment (fossil-fuel-intensive and green) compared with a no-transition scenario
in billions of 2023 euros	2030–2021		in 2030
Light commercial vehicles (LCVs)	**-7**		**3**
Electrification of the LCV fleet	-3	Sub. K F	3
Energy efficiency (included in electrification)	-2	Sub. K F	
Demand management	-2	Suff.	0
** In addition to these measures, other factors include the replacement of old internal-combustion-engine vehicles with newer models, and the increased use of biofuels*	*-6*	*Sub. K F*	
BUILDINGS (new measures)	**-44**		**48**
of which green			**54**
of which fossil-fuel-intensive			**-6**
Residential	-28		**21**
of which green			27
of which fossil-fuel-intensive			-6
Sharp reduction in heating oil consumption	-10	Sub. K F	3
Gradual reduction in gas consumption	-8	Sub. K F	3
Insulation of oil- and gas-heated energy-inefficient properties (to C rating)	-8	Sub. K F	15
Reduced energy consumption	-2	Suff.	0
Commercial	**-16**	**Sub. K F**	**27**
Energy retrofits and boilers	-14	Sub. K F	27
Reduced consumption	-2	Suff.	0
INDUSTRY (new measures)	**-35**		**4**
Decarbonisation of the highest-emitting industrial sites	-23	Sub. K F	
Decarbonisation of other, smaller industrial sites	-12	Sub. K F	
Deployment of decarbonisation infrastructure		Sub. K F	
Industrialisation		Sub. K F	

Emissions-reduction measures	**Change in emissions** (in $MtCO_2e$)	**Lever**	**Additional investment (fossil-fuel-intensive and green) compared with a no-transition scenario**
in billions of 2023 euros	2030–2021		in 2030
ENERGY (new measures)			**9**
Renewables		Sub. K F	3
Nuclear		Sub. K F	3
Grids		Sub. K F	4
AGRICULTURE (new measures)	**-7**		**2**
Reduction in livestock farming	-2	Suff.	0
Reduction in fertiliser use for field crops	-3	Suff.	0
Decarbonisation of farm machinery	-2	Sub. K F	2

Note: The drastic reduction in heating-oil consumption would reduce GHG emissions by 10 $MtCO_2e$ by 2030. This measure, which involves the substitution of capital for fossil fuels (Sub. K F), requires additional investment of €3 billion per year by 2030. This additional investment is net of the associated reduction in investment in carbon-intensive equipment. Sufficiency measures (Suff.) do not require additional investment. Emissions reductions linked to the decarbonisation of energy are ultimately reflected in the reductions attributable to energy-using sectors.

Source: DGEC, authors' calculations. The measures and associated emissions reductions are indicative.

CHAPTER 8

AN UNCERTAIN MACROECONOMIC IMPACT

1. Investment will not necessarily increase potential output

While there is still some uncertainty about the exact amount and how it will be financed, there can be no doubt that the transition to a low-carbon economy will require substantial investment. However, the economic impact of this additional investment is less clear-cut. In most macroeconomic assessments, this shock takes the form of a surge in demand which, under a Keynesian model, normally leads to an increase in activity. However, this overlooks the fact that we are talking here about a rather special kind of investment, which is aimed not at increasing the economy's productive capacity, but rather at reducing GHG emissions, and which can therefore adversely impact supply.

It is therefore necessary to consider three related questions: how profitable these investments will be, how they will be financed, and how they will affect productivity.

The answers to the first two questions (on profitability and financing) depend in part on the policies implemented to trigger the necessary investments.

- Regulatory constraints can be likened to implicit prices (which are not paid by the agents, but which trigger investment). But they do not really alter the profitability of projects: measures such as banning new oil-fired boilers or internal-combustion-engine vehicles, or making energy retrofitting mandatory, do not make the associated expenditure more profitable.
- With carbon pricing, raising the price of fossil fuels can make projects that would not have been profitable at a lower carbon price suddenly worth the investment. But while households and businesses may have a greater incentive to invest in low-carbon equipment, there is no increase in their ability to finance these projects. Overall, they are not richer than they would have been in a world without carbon taxation, even if the tax revenues are redistributed.

- Public investment subsidies shift the financial burden from private agents to the State. But they do not necessarily direct investment towards the most profitable projects or to those with the lowest abatement costs.

Meanwhile, the answer to the third question (on the productivity of the economy as a whole) depends on whether these investments are additional to existing investments, or whether they merely replace them without increasing the total volume of investment:

- In the first case, the impact on productivity could be neutral or slightly positive. However, questions remain about the affordability of such additional investments for businesses, households and governments.
- In the second case, the current consensus is that the transition will have an adverse impact – albeit temporary – on productivity, with investments in energy efficiency taking place at the expense of investments in productivity. The orders of magnitude are uncertain, but a loss of around one-third of a percentage point of GDP per year is a reasonable approximation (see Box 10).

Overall, the transition represents a negative supply shock, with an accompanying need to finance investments whose profitability cannot be taken for granted. In other words, by putting a price – financial or implicit – on a free resource (the climate), the transition increases production costs, with no guarantee that the reduction in energy costs will eventually offset them, while the investments it calls for do not increase productive capacity but must nevertheless be financed.

Box 10: How will the energy transition affect productivity?

Climate neutrality can only be achieved by radically transforming our production, travel, heating and consumption practices. In order to the determine the path of economic growth that is compatible with the transition, it is necessary to quantify its impact on labour productivity (value added per hour worked) or on total factor productivity (value added per unit of capital-labour mix).[1]

A review of the empirical and theoretical economic literature on this subject shows that the energy transition is likely to be accompanied by a significant slowdown in productivity.[2] It is difficult to put a precise figure on this slowdown, in part because

[1] The effects of global warming itself are discussed in Chapter 1 and in the *Dommages et adaptation* (Loss and Damage and Adaptation) thematic report.

[2] See France Stratégie (2023), *Les incidences économiques de l'action pour le climat. Productivité*, thematic report coordinated by Anne Epaulard, May. See also Alestra C., Cette G., Chouard V. and Lecat R. (2020), "Long-term growth impact of climate change and policies: the Advanced Climate Change Long-term (ACCL) scenario building model", *Working Paper*, No. 759, Banque de France, April.

it depends on the policies put in place to trigger and support the transition. A very rough figure obtained from U.S. data suggests that a 1% annual improvement in fossil-fuel efficiency has, in the past, resulted in a 0.1 percentage-point slowdown in total factor productivity.[1] Figures based on models calibrated on French, U.S. or global data confirm the existence of a trade-off between productivity and reduced fossil-fuel consumption. Using French data, Henriet et al. (2014) estimate a potential average slowdown of one-third of a percentage point per year during the transition period.[2]

This somewhat pessimistic picture is tempered, however, by three observations. First, the same empirical and theoretical studies conclude that, once the energy transition has been completed, growth in labour productivity (or total factor productivity) will return to, or even exceed, its pre-transition pace. The slowdown would therefore be temporary. Second, the right mix of carbon taxation and R&D subsidies can limit the productivity cost of the energy transition. And third, the studies reviewed here generally assume that the economy produces a single good.

These conclusions can be drawn from several different types of sources:

- Econometric studies of the impact of environmental regulations (understood here as standards and/or carbon taxation) based on firm and sectoral data now conclude that the best-performing companies have in fact increased their productivity following the introduction of tighter regulations. This appears to be especially true of companies that have access to credit and operate in countries where environmental policies already exist (and, therefore, are aware of the existence of abatement technologies). These results do not hold for companies in energy-intensive sectors, or for those outside the best-performing bracket.
- Macroeconomic models of endogenous growth incorporating “directed technical change” (Acemoglu et al., 2012)[3] reach similar conclusions. In these models, the energy transition is costly in terms of productivity growth because of the need to direct progress towards the development of green or energy-saving technologies, rather than towards labour-saving innovations. When past efforts to improve the productivity of fossil-fuel-intensive technologies are factored into the equation, the shift towards green technologies temporarily reduces growth. But this effect is temporary and there is nothing to suggest it cannot be reversed once the transition is complete.

[1] Hassler J., Krusell P. and C. Olovsson (2021), “Directed technical change as a response to natural resource scarcity”, *Journal of Political Economy*, Vol. 129, No. 11, November, pp. 3039–3072.

[2] Henriet F., Maggiar N. and K. Schubert (2014), “A Stylized Applied Energy-Economy Model for France”, *The Energy Journal*, Vol. 35, No. 4, pp. 1–37.

[3] Acemoglu D., Aghion P., Bursztyn L. and Hémous D. (2012), “The environment and directed technical change”, *American Economic Review*, Vol. 102, No. 1, February, pp. 131–166.

- The optimal policy option is therefore to introduce a carbon price, which can either stand alone (as in Hassler et al., 2021) or be accompanied by R&D subsidies in the energy or clean technology sectors (as in Acemoglu et al., 2012).
- If carbon pricing is not feasible – for political acceptability or other reasons – and the authorities instead rely exclusively on subsidies, the well-being cost of the transition and its impact on productivity growth are higher (see, for example, Pommeret, Ricci and Schubert, 2023,[1] and Bistline et al., 2023).[2]

2. The macroeconomic effects of emissions-reduction policies are difficult to assess

In order to assess the combined macroeconomic effects of the negative supply shock and the positive demand shock induced by the transition, as well as their related spillover effects, it is necessary to rely on simulations carried out using macroeconomic models. Such work has been performed in France (for the assessment of SNBC 2), at the EU level (for the impact assessment for the "Fit for 55" package), in the United Kingdom, and on a global scale. Where such assessments do not assume that the transition is based on carbon taxation, either explicit or implicit (i.e. when regulations are introduced in the form of an implicit carbon price), they treat the transition as an investment shock without examining the nature of this investment. As a result, they conclude that the impact of the transition is positive in terms of economic activity or employment under Keynesian models (and virtually zero under neoclassical models).[3]

It is difficult to assess the economic impact of the transition without first specifying the policies that will be implemented to achieve it. However, the corresponding measures are by no means always spelled out in the assessments other than in generic terms such as "carbon pricing", "subsidies" or "regulations".[4] It is clear that not all policies that will be implemented

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[1] Pommeret A., Ricci F. and Schubert K. (2023), "Confronting the carbon pricing gap: Second best climate policy", forthcoming.

[2] Bistline J., Mehrotra N. and Wolfram C. (2023), "Economic implications of the climate provisions of the Inflation Reduction Act", *Brookings Papers on Economic Activity*, Spring.

[3] For France, see Ministry for the Ecological and Inclusive Transition (2020), *Rapport d'accompagnement de la SNBC 2*, and Table 2 in the November 2022 interim report, which summarizes its findings (Pisani-Ferry J. and Mahfouz S., "L'action climatique : un enjeu macroéconomique", op. cit.). For the EU, see European Commission (2020), *Investing in a Climate-Neutral Future for the Benefit of our People, Impact Assessment*. For the United Kingdom, see Cambridge Econometrics (2020), *Economic Impact of the Sixth Carbon Budget*.

[4] Some studies are more explicit in taking account of emissions-reduction constraints. See, for example, for the energy sector: Chateau J., Jaumotte F. and Schwerhoff G. (2022), "Climate policy options: a comparison of economic performance", *IMF Working Papers*, No. 2022/242, December.

between now and 2050 can be precisely specified, in part because new technologies are likely to emerge. But this is much less the case for the period between now and 2030.

Some studies, lacking a better option, have attempted to assess the economic impact of the transition without first specifying the policies that will be implemented. But such an approach is unsatisfactory because the economic impact of policies leading households to replace their boilers or to take public transport more often, or that lead to the construction of wind turbines, is unlikely to be the same.

The approach we adopted here is consistent with the bottom-up method we used earlier to estimate investment amounts (see Chapter 7), namely to identify and then simulate very precisely defined measures that would help France achieve its 2030 targets under the forthcoming SNBC 3 (such as a ban on the installation of new oil-fired boilers, and a requirement to replace them with heat pumps, with or without government support). Our aim, in doing so, was to determine the most accurate way to model the impact of these measures. As we will see, using concrete measures as our starting point allows us to better appreciate how realistic the simulated effects are.[1]

We have also gone to great lengths to be absolutely clear about the baseline scenario against which these measures are assessed. If a large portion of the emissions reductions are achieved in the baseline scenario (because it incorporates policies that have already been deployed), and if we were to only examine the economic effects of increased effort, then we would be failing to measure the total economic impact of emissions-reduction policies. Importantly, such an approach could lead us to underestimate the impact of investment on debt ratios and, therefore, on the solvency of businesses and households. The “Fit for 55” impact assessment, which focuses on the effects of additional effort, thus uses a baseline scenario in which emissions have already been reduced by 40% by 2030.[2]

In order to assess the economic impact of the transition, we will endeavour, as far as possible, to simulate the economic impact of all emissions-reduction policies. It would be preferable, from an economic policy-making and public-finance forecasting perspective, to build a picture of economic developments that incorporate the impact of the transition rather than to focus on the economy’s deviations from a baseline scenario (i.e. to use a central account rather than a variant as our starting point). However, this more demanding task has not been completed at this stage.

[1] These simulations are for illustrative purposes only and do not prejudge the choices that will be made for the SNBC 3.

[2] In the simulations presented here, we will specify when a portion of the emissions reduction is included in the baseline scenario (for example, in the case of retrofitting work on energy-inefficient buildings).

ADEME ran a series of simulations[1] using the ThreeME model[2] in order to illustrate the economic mechanisms in play at the national level, and to quantify the macroeconomic effects of the sectoral emissions-reduction measures detailed in Chapter 6. International aspects, such as the effects of the CBAM, are addressed in Chapter 12 and in the *Compétitivité* (Competitiveness) thematic report. We assume here that France's trading partners do not pursue the same policies, leading to a deterioration in foreign trade. Monetary policy is assumed to react to higher inflation (according to a Taylor Rule). Full scenarios incorporating all measures were also simulated, taking into account the potentially negative effects of the transition on productivity as mentioned above. Here, we will limit ourselves to a detailed account of two sample measures, in order to explain the mechanisms involved and how they are modelled in the simulations. We will then present a full simulation of the macroeconomic impact of transition policies.

The *simulated ban on the sale of passenger cars with internal combustion engines in 2035* accelerates the uptake of electric vehicles, which represent 66% of new registrations in 2030, up from 12% at present and compared with 30% in the absence of this measure. The greening of the fleet as a whole naturally proceeds at a much slower pace: electric vehicles represent approximately 15% of all passenger cars on the road in 2030.

A somewhat technical question arises concerning the volume/price split of the extra cost of these vehicles. In national accounting terms, the price differential between electric and internal-combustion-engine vehicles is considered to reflect an improvement in quality, and therefore corresponds to an increase in the volume of cars and not to an increase in their price.[3] The underlying idea is that consumers are willing to pay more because they value the difference between electric and internal-combustion-engine vehicles. Again in national accounting terms, the increase in expenditure caused by the rise in the share of electric vehicles in sales therefore leads to an increase in the volume of automobile consumption[4] and not to an increase in the average price.

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[1] Gaël Callonec and Alma Monserand ran all of the simulations presented in this chapter and in the *Simulations* supplement. We would like to thank them for completing this substantial volume of work in such a short space of time, and for their constructive insights, which allowed us to move forward together on these difficult modelling issues.

[2] For a brief presentation of the ThreeME model, see, e.g., Box 2 in the *Modélisation* (Modelling) thematic report coordinated by Jérôme Trinh. For a more detailed presentation, see *ThreeME V3 (2021): ThreeME Version 3 - Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policy - A full description* on the ThreeME Model website.

[3] France Stratégie (2023), *Les incidences économiques de l'action pour le climat. Inflation*, thematic report coordinated by Stéphane Dees, May.

[4] In other words, an increase in real-terms value.

This reasoning can be called into question when regulatory changes force consumers to switch to electric vehicles that do not necessary provide them with greater utility, even if they are cheaper to run per kilometre. When it comes to assessing the economic effects of the increased uptake of electric vehicles, this convention also has some counter-intuitive effects: it leads to an increase in volume demand in the automotive sector without a corresponding price increase and, therefore, to an increase in output and added value, which in turn pushes up employment in the automotive industry.

This result is somewhat inconsistent with the expected consequences of electrification, which is expected to lead to a reduction in employment in the sector. These effects on employment therefore need to be set against a positive shock to labour productivity in the automotive industry. However, this leads to a further reduction in prices in the sector, and does not neutralise the induced effects of the rise in automotive production on other sectors. It would be more satisfactory to model the additional cost of replacing internal-combustion-engine vehicles with electric vehicles as a shock to the price of inputs, in this case batteries. But such an exercise would also be more complicated, as it would mean revising the volume/price split used in national accounting. The results that follow therefore only partially correct for this volume/price split effect.

Beyond these technical difficulties, the macroeconomic effects of this measure ultimately depend on three factors:

- The ability of households to afford more expensive electric vehicles[1]
- The proportion of these vehicles (or of their components) that are imported
- The level of government subsidies

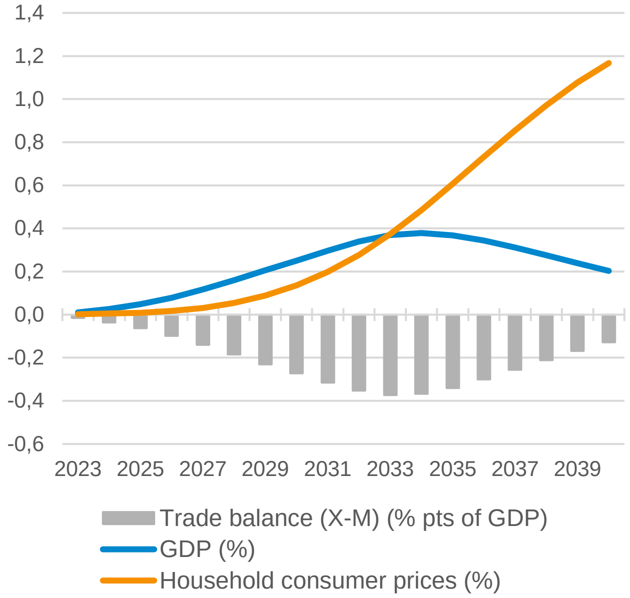
If government subsidies for the purchase of electric vehicles (green bonus and car scrapping bonus) increase in line with sales (an increase of around €5 billion by 2030), if households can afford the additional costs (almost €10 billion in 2030 in the simulation, despite subsidies),[2] and if the majority of batteries are not imported, then the ban on the sale of internal-combustion-engine vehicles could lead to a slight increase in activity (see Figure 15a below).

[1] Although new vehicles are primarily purchased by companies, while households buy used vehicles, the rise in prices is passed on to the used market as electric vehicles enter this market, and is therefore ultimately borne by households.

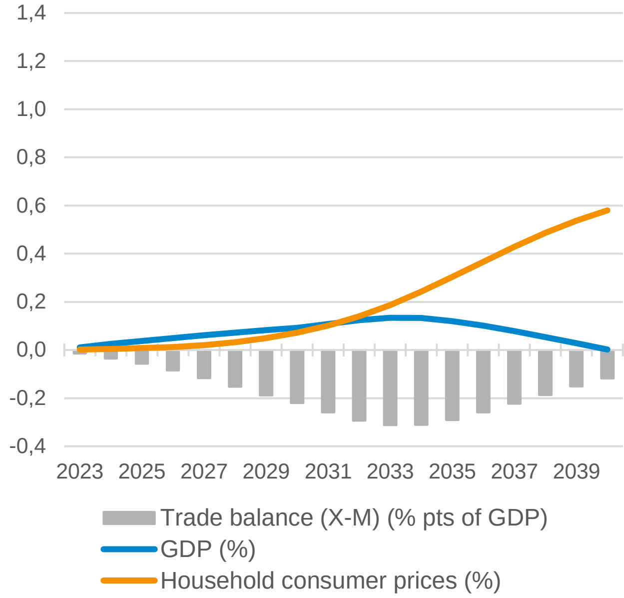
[2] These amounts differ from those presented in Chapter 7 because the ThreeME model does not use the same underlying assumptions, especially for total vehicle registrations, and incorporates macroeconomic closure effects.

Figure 15 (a, b, c, d): Macroeconomic effects of banning the sale of internal-combustion-engine vehicles in 2035, under different assumptions (versus the baseline scenario)

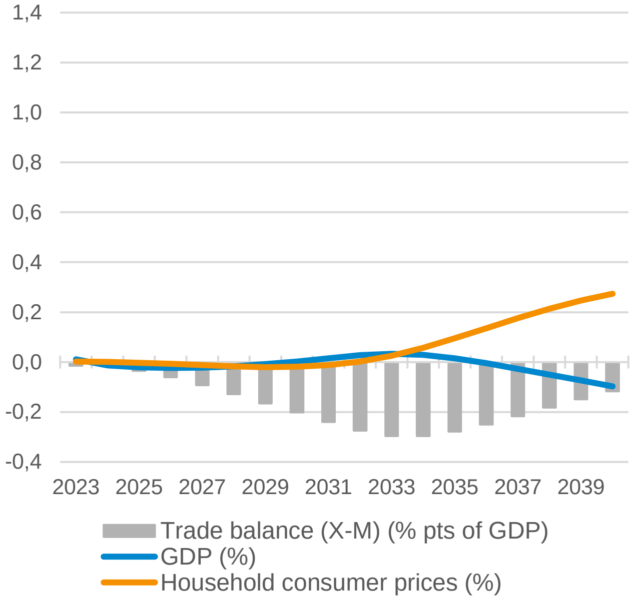
a) With no reduction in subsidies, no household liquidity constraints and no imported batteries



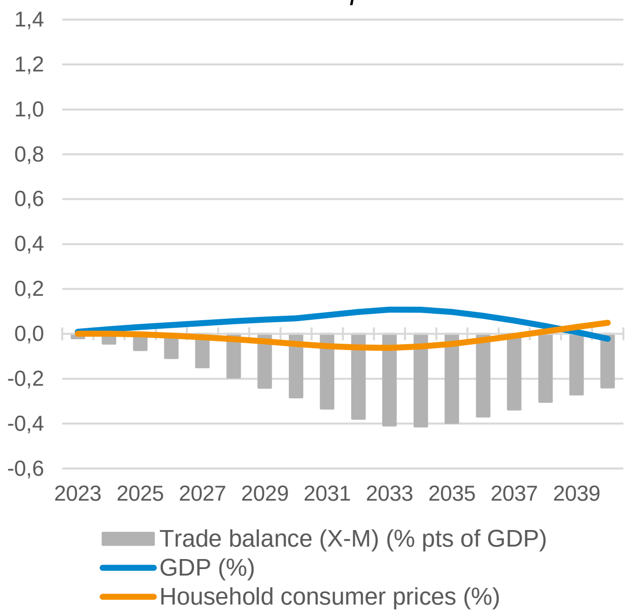
b) With a reduction in subsidies only



c) With a reduction in subsidies and with household liquidity constraints



d) With a reduction in subsidies and with imported batteries



How to read these charts: Assuming no reduction in subsidies for the purchase of electric vehicles, no household liquidity constraints, and the use of non-imported batteries for these vehicles, a ban on the sale of internal-combustion-engine vehicles in 2035 would lead to a slight increase in GDP, higher prices and a widening trade deficit (a). These effects would be substantially mitigated, or even reversed, if subsidies were to be reduced (b), if households faced liquidity constraints (c) or if batteries were imported (d).

Source: ADEME, simulations using the ThreeME model.

If, on the other hand, the total volume of government subsidies is constrained, this positive effect is greatly reduced (Figure 15b). Moreover, if households face affordability constraints (Figure 15c), or if batteries are predominantly imported (Figure 15d), the effect on growth could be zero or even slightly negative. This measure, when considered in isolation (and ignoring the effects of the decarbonisation of electricity), would reduce emissions by 6 $MtCO_2e$ in 2030.

The same measure can therefore have very different effects depending on the conditions under which it is implemented. A ban on the sale of internal-combustion-engine cars is expansionary if it is accompanied by a policy to expand the battery industry, if households receive adequate assistance, and if they can draw on their savings to absorb the extra costs. It also requires the seamless retraining of the existing workforce: the overall effects on employment are limited (a net loss of 20,000 jobs by 2032 if batteries are imported), but these losses are concentrated in the automotive industry (a net loss of 30,000 jobs, or 15% of the existing workforce, by 2033). Conversely, this measure would be recessive if these conditions are not met.

A second example concerns the residential sector, for which two measures were simulated:[1]

– *Banning the installation of new oil-fired boilers* starting in 2022, which would lead to the replacement of three-quarters of such boilers with heat pumps (most of which are imported)
– *Increasing support for energy retrofitting work* on energy-inefficient buildings (the MaPrimeRénov' scheme and energy saving certificates, for homes rated F or G)

In the baseline scenario used in the ThreeME model, and in the absence of any measures, the housing stock already undergoes extensive energy-retrofitting work: the number of dwellings on which such work is completed increases from 800,000 in 2023 to 1.4 million in 2030, with annual costs for this work rising from €20 billion to €35 billion over the same period. As a result, in the baseline scenario, the proportion of homes that are energy-inefficient falls from 13% to 8% between 2023 and 2030, and to 2% by 2050.

The first measure requires additional investment of roughly €3 billion per year between now and 2030 (see Chapter 7).

Although the housing stock and energy-retrofitting choices are modelled in a highly granular manner in ThreeME, it was necessary to modify the model in order to simulate

[1] Only the first measure is detailed in this chapter. The second is presented in the *Simulations* supplement.

boiler replacement (see the *Simulations* supplement).[1] The ban on the installation of new oil-fired boilers is therefore modelled as a shock to the intermediate consumption of capital goods in the construction sector (to reflect the substitution of heat pumps for boilers) and as a shock to household heating-related energy consumption, with or without a shock to government energy-retrofitting subsidies, which is reflected in the total value of energy-retrofitting work carried out by households. The advantage of this modelling choice over the use of a rise in the implicit price of heating oil lies in the fact that it makes explicit the investment needs associated with the change in heating energy.

This measure would lead to the replacement of three-quarters of the 3 million oil-fired boilers with air-to-water heat pumps, which would reduce oil consumption for heating in 2030 while increasing electricity consumption. In turn, this would reduce GHG emissions from buildings by 6 $MtCO_2e$ by 2030.[2]

From an economic point of view, a ban on the installation of oil-fired boilers would lead to an increase in household investment, financed by the widening fiscal deficit under the assumption of government support, and benefiting above all imports in the – albeit extreme – hypothesis that all heat pumps would be imported. The effect on GDP, public finances and the trade balance would initially be negative, since heat pumps are assumed to be imported (as is mostly the case today). However, this negative effect would be reversed or cancelled out in a second phase (once replacements are completed) owing to the reduction in fossil-fuel imports (see Figure 16 below). If heat pumps were to be produced locally, the effect on GDP would be positive, which would reduce the negative effect on public finances, and the trade balance would be better off.

Moreover, the associated investments would increase household expenditure (owing to the purchase of heat pumps) but would lead to no improvement in either utility or well-being, since the heating service provided to households by an oil-fired boiler or a heat pump is broadly the same.[3] If the government were to finance additional subsidies to households by raising taxes or reducing other forms of household support, the associated utility would ultimately be reduced. There can therefore be something of a disconnect

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[1] In ThreeME, the choice of heating energy depends on the relative price of energy, which is not affected by the ban on the installation of new oil-fired boilers.

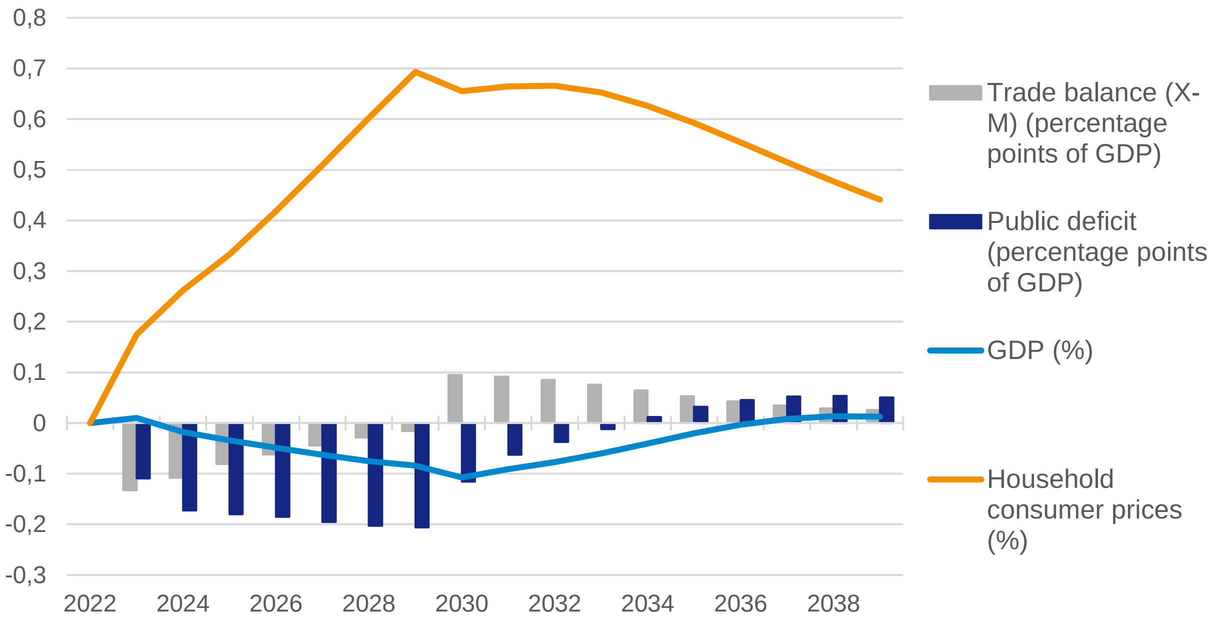
[2] This measure also has an indirect, and somewhat paradoxical, effect on energy-retrofitting work, because the installation of heat pumps reduces energy costs and therefore makes future retrofitting less cost-effective. As a result, both the number of homes on which such work is carried out (excluding the installation of heat pumps) and the total cost of such work (again excluding heat pumps) are lower in the simulation than in the baseline scenario.

[3] In practice, the situation could potentially be even worse without insulation. While heat pumps reduce energy bills in the longer term, this reduction is not enough to prompt households to spontaneously replace their boilers.

between the economic effects of regulations as measured by GDP or household consumption, and the effects felt by these same households.

These two examples illustrate the need for a granular approach that takes into account the nature of both the levers used and the corresponding economic mechanisms.

Figure 16: Effects of a ban on the installation of new oil-fired boilers, assuming that heat pumps are imported, and with government support (versus the baseline scenario)



How to read this chart: The replacement of oil-fired boilers by 2030 with 100% imported heat pumps, entirely financed by government subsidies, would slightly reduce activity and, initially, lead to an increase in the public deficit and a widening of the trade deficit. The trade balance would later improve because of a reduction in the use of imported fossil fuels.

Source: ADEME, simulations using the ThreeME model.

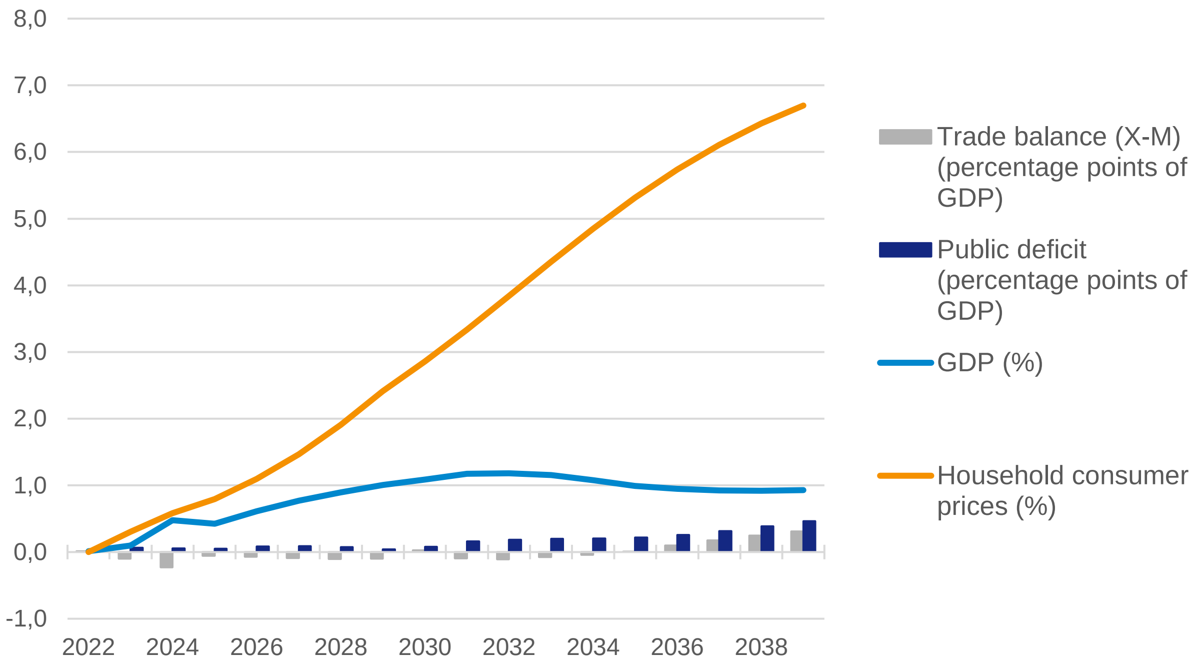
We adopted the same approach for all the levers mobilised by the climate transition (see Chapter 7). The simulations included:

- Tax measures: EU ETS 2 for the transport and building sectors, as well as the indexation to inflation of domestic taxes on energy consumption after 2030
- Road transport: investments in infrastructure to encourage modal shift, in addition to the ban on the sale of internal-combustion-engine vehicles described above
- Buildings: an increase in subsidies for energy-retrofitting work on energy-inefficient buildings and compliance with the requirements of the “tertiary decree”, in addition to the ban on oil-fired boilers
- Industry: subsidies for energy-efficiency investments
- Energy production: the investments necessary to change the energy mix

The detailed results are presented in the *Simulations* supplement. More traditional subsidy measures and tax increases (i.e. the implementation of the EU ETS in the building and transport sectors) are easier to model than regulatory measures.

The results of this simulation are shown in Figure 17. In Figure 18, the effects of a negative shock to productivity are added in order to illustrate the risk of a slowdown in productivity as discussed earlier, which is not taken into account in the previous simulations (since trend productivity is exogenous in the ThreeME model). In both cases, GHG emissions would be approximately 110 $MtCO_2e$ lower in 2030 than in 2020, and 150 $MtCO_2e$ lower in 2035.

Figure 17: Effects of all measures, with no impact on productivity (versus the baseline scenario)



How to read this chart: In 2040, GDP would be 1 percentage point higher than it would have been in the absence of emissions-reduction measures, prices would be 7 percentage points higher, the trade balance would improve by around 0.5 percentage point, and the public deficit would deteriorate slightly.

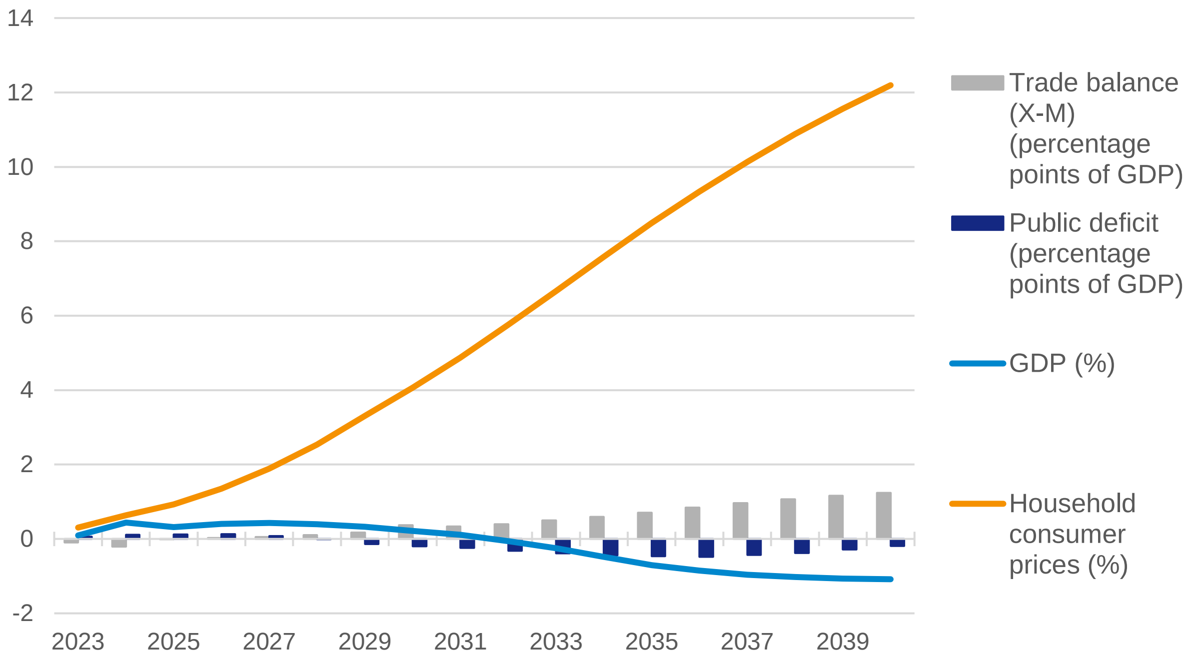
Source: ADEME, simulations using the ThreeME model.

In the absence of a shock to productivity, all of these measures would have a slightly positive impact on growth by 2030 or 2040, while negatively impacting the trade balance and the public deficit.[1] An "unchanged public deficit" simulation would therefore lead to less

[1] More detailed results for consumption, investment, employment and other aspects are presented in the *Simulations* supplement.

positive growth outcomes. The effects on prices would be very significant.[1] The negative supply shock represented by the transition would progressively erode the growth surplus. It would also compound inflationary effects owing to the higher unit production costs resulting from lower productivity.

Figure 18: Effects of all measures, with a negative impact on productivity (versus the baseline scenario)



How to read this chart: In 2040, GDP would be 1 percentage point lower than it would have been in the absence of emissions-reduction measures and a negative impact on productivity, prices would be 12 percentage points higher, the trade balance would improve by 1.2 percentage points, and the public deficit would deteriorate slightly.

Note: For a shock to productivity of -0.3 percentage point between 2024 and 2030, then -0.2 percentage point over five years, then -0.1 percentage point over five years.

Source: ADEME, simulations using the ThreeME model.

In conclusion, all of the emissions-reduction policies – taxes, subsidies and regulations – have common macroeconomic effects:

- They trigger an increase in investment and expenditure on capital goods by businesses and households. If the corresponding goods – electric vehicles, heat pumps or wind turbines – are produced in France and can be financed without crowding out other spending, this extra investment boosts GDP and employment.

[1] Some results from simulations finalised only very recently may call for further work.

As these investments do not typically generate additional wealth, financing them necessarily initially worsens the financial situation of the companies or households that make them. The impact on public finances is similarly adverse if these investments are made with government support.

- Reducing the use of imported fossil fuels gradually improves the balance of trade and national income. From a macroeconomic point of view, this is a benefit that can only be seen gradually. Initially, the investment effect dominates.
- These positive demand-side effects would be more than offset by the negative effects of the slowdown in productivity induced by the substitution of energy-efficiency investments for investments in productive capital. This mechanism, which is difficult to quantify, could lead to a decline in potential GDP of 1.5–2 percentage points by 2030, assuming a 0.25–0.3 percentage-point reduction in productivity growth and a decline in actual GDP of roughly 1 percentage point, accompanied by higher inflation.
- Ultimately, the balance between positive demand-side effects and negative supply-side effects largely depends on the conditions under which investments are financed and their implications for the financial situation of the households and companies that make them. For very micro-sectoral measures, assuming that households and companies are able to finance the necessary investments without this crowding out other spending, is not satisfactory if these investments are largely unproductive.
- More generally, this brings us back to the question of the profitability of the investments needed for the transition posed at the beginning of this chapter. Whatever policy is implemented, one specific feature of investments in energy efficiency is that, as a general rule, they do not support additional wealth generation. Instead, their profitability lies in the fact that they reduce future energy expenditure, as well as operating costs more broadly. Their profitability is therefore highly dependent on future energy prices and the actual energy savings that are achieved, which in turn makes financing them a more uncertain proposition.
- The risks associated with the reallocation of capital and labour within sectors are inadequately taken into account. These include risks of sectoral labour-market tensions, risks of supply disruptions for certain critical inputs, risks of stranded capital, and so on (see Box 11 in Chapter 9, and Chapter 11).
- Macroeconomic aggregates do not always accurately reflect reality and/or household perceptions. This is the case, for example, for the volume/price split of electric vehicles, or for the fact that an increase in household spending (heat pumps versus oil-fired boilers) is not necessarily accompanied by an increase in household well-being.

3. A method for assessing the economic implications of the transition

The simulations presented in this chapter are not intended to close the discussion on the macroeconomic implications of the climate transition, but rather to inform this debate and to shed light on the key issues and considerations at play. The section that follows provides some methodological comments in this respect.

First of all, it is worth recalling that it is only possible to assess the economic effects of emissions-reduction policies if the policies in question are precisely defined. As we have seen, not all measures have the same effects, and it is difficult to properly model the effects of "regulations" without knowing what these regulations cover. Modellers cannot be blamed for not properly assessing what decision-makers have not properly specified. This condition, it should be remembered, has not always been met in the past. And the more distant the time horizon, the more difficult it is to meet. It is only natural that future instruments and policies should remain partly undefined. However, it is incumbent on those involved in ecological planning – and, therefore, the General Secretariat for Ecological Planning (SGPE) – to ensure that policies intended to achieve the targets for 2030, at the very least, are clearly identified.

Once the measures have been defined, the next step is to scrutinise their effects on agents' behaviour. Given the sector-specific nature of the measures and the uncertainty surrounding the effects of regulations on behaviour, precise microeconomic analyses are needed on a case-by-case basis. These analyses must, of course, draw on sector-specific technical and economic models, which are essential for determining the physical changes induced by the measures. But it is also important to examine other dimensions, especially the affordability of the related investments for different types of agents, the availability of the skills needed to implement the measures, and the finely-tuned dynamics of reallocation and innovation. What will slow down energy-retrofitting work or push up its cost is not a lack of government financing or excessively low national unemployment, but rather other factors such as the inability of some or all households to finance the work, or a lack of qualified labour in the energy-retrofitting or nuclear sectors.

Importantly, such an analysis must take into account the fact that households and businesses are not a homogeneous group. Models with heterogeneous agents can therefore prove useful, as long as they are capable of representing highly sector-specific measures such as those described here. It should also be possible to analyse the very local nature of certain shocks.

Should we seek to integrate these microeconomic analyses into macroeconomic models, as has been done with the ThreeME model, which includes a hybrid module, in the sense that it supports the combined analysis of physical quantities (such as the number of vehicles or houses, or the volume of emissions) and economic variables?[1] The advantage of this integrated approach, which avoids the iterations and difficulties of connecting multiple models, comes at the price of size and complexity, which make the model unwieldy and difficult to understand. This is especially problematic as it is often necessary to tweak the model to take full account of the planned measures. An intermediate solution would be to isolate sectoral modules (by making all other variables exogenous) so as to analyse sectoral dynamics before integrating them into the overall model. Simulating and analysing measures one by one, as we have done here, is also a useful precaution.

Last but not least, the work reflected in this report has shown that highly simplified parallel models (so-called "toy models") can be a useful way to capture the effects of the transition on productivity and on the risk of stranded capital, as well as the economic implications of sufficiency. These models, like the one in Box 9, are not designed with realism in mind. But they do help to better conceptualise and understand the mechanisms at play.

The climate transition poses new challenges for economic analysts. After a long period during which the emphasis has been placed successively on behavioural rationality and representational coherence, it marks a renewed focus on the concrete in macroeconomic concerns. The question of the instruments on which this analysis can be based arises in France. But it also arises elsewhere, in practically the same terms, as demonstrated most vividly in a recent White House publication.[2]

[1] This is also the intention of the "GreenREFORM" model currently being developed in Denmark.

[2] Council of Economic Advisers and Office of Management and Budget (2023), "Methodologies and considerations for integrating the physical and transition risks of climate change into macroeconomic forecasting for the president's budget", White Paper, March, 48 pages.

CHAPTER 9

WHY FAIRNESS MATTERS

1. The climate transition is inherently a source of inequality

In France, as in other advanced countries, it is clear that everyone will be called upon to make an effort. Climate policies are therefore required to be not only effective but also fair. The degree of support that these policies enjoy can be explained almost as much by opinions on their distributive impacts as by judgements on how effectively they reduce emissions.[1] Moreover, these attitudes are remarkably similar from one country to the next: while the Gilets jaunes (Yellow Vests) protests against fossil-fuel tax rises made headlines in France, heightened sensitivities to the distributive effects of climate policies have been a feature of other countries, as demonstrated by the fuel protests that swept across Sweden in 2018.[2]

This demand for fairness is a key factor in the rejection of carbon taxation and, more broadly, in the sense of hostility towards all climate policies that are considered unfair. The concept of a "fair transition" is therefore an imperative with which public policies must comply if they are to stand any chance of being accepted. However, there is no precise definition of what a "fair transition" actually entails.

Household contributions to global warming are themselves very unevenly distributed, with higher-earning households evidently producing more emissions. Based on strong assumptions, Chancel (2022) attributes 17% of global emissions to the top 1% of the income distribution, and 48% of emissions to the top 10%.[3] In France, the carbon footprint

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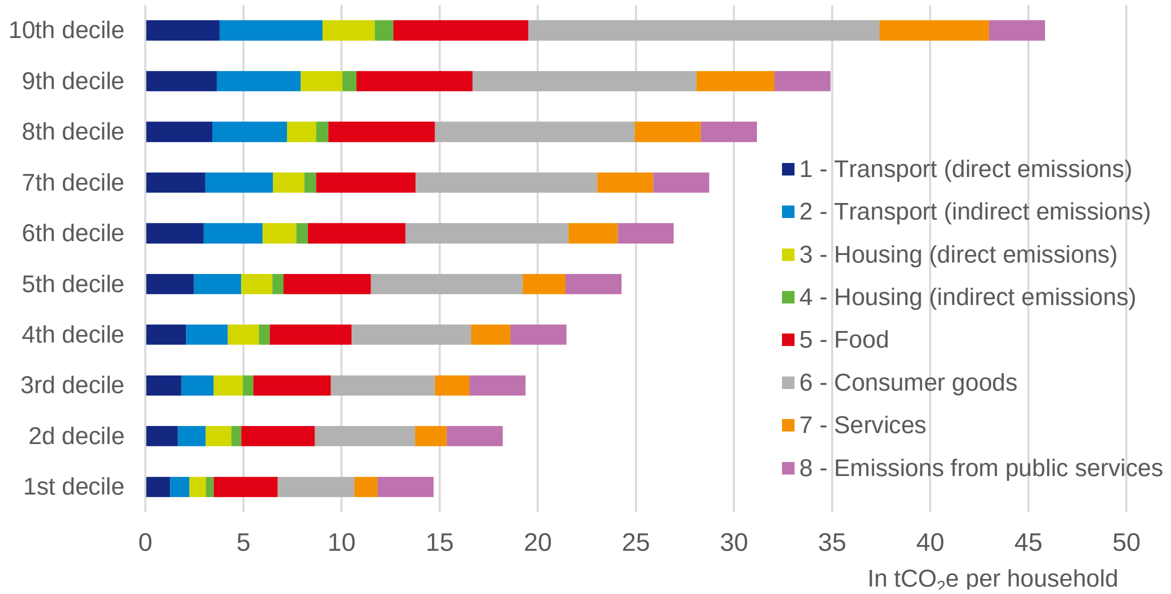
[1] See Dechezleprêtre A. et al. (2022), "Fighting Climate Change: International Attitudes Toward Climate Policies", *NBER Working Paper*, No. 30265, National Bureau of Economic Research, July.

[2] See, for example, Anne-Braun J. (2022), *Le consentement à la fiscalité environnementale*, report of the Conseil des prélèvements obligatoires.

[3] See Chancel L. (2022), "Global carbon inequality over 1990-2019", *Nature Sustainability*, Vol. 5, pp. 931–938, November. The methodological choice of allocating companies' emissions to their shareholders (and, therefore, to households) is debatable. Generally speaking, allocating emissions to different household income categories relies unavoidably, at least in part, on simplistic assumptions. This is currently done on the

of household consumption (including imports) likewise increases with income, varying by a factor of three between the first and last deciles (see Figure 19).[1] As noted in the *Enjeux distributifs* (Distributive Issues) thematic report, GHG emissions from air travel by the richest households alone (10th decile) are on average equivalent to GHG emissions from all transport by the poorest households (1st decile). Quantitatively speaking, therefore, what may seem to be the privilege of some has the same climate implications as what is essential for others.

Figure 19: Household carbon footprint by income decile group and by consumption item (in tCO_2e)



How to read this chart: For households in the third income decile, spending on food represents a carbon footprint of 4 tCO_2e.

Source: Malliet P. (2020), La contribution des émissions importées à l'empreinte carbone de la France*, Paris, Sciences Po publications, 14, p. 36.*

Last but not least, low-emission or even carbon-neutral durable goods (such as electric vehicles, heat pumps and energy-efficient appliances) are significantly more expensive than their carbon-intensive equivalents. Even though these goods have a lower cost of use (i.e. reduced energy bills) and can bring health and other co-benefits (such as reduced

basis of unsatisfactory and, again, over-simplistic assumptions about the carbon content of each euro spent on a given category of goods. For more discussion on these points, see the *Enjeux distributifs* (Distributive Issues) thematic report: France Stratégie and CGDD (2023), *Les incidences économiques de l'action pour le climat. Enjeux distributifs*, thematic report coordinated by Vincent Marcus, May.

[1] This ratio is a slight overestimate, since the price differences between goods of the same nature consumed by different categories of households are not neutralised, whereas a glass of wine that costs five times as much as another glass is not responsible for five times the volume of emissions.

pollution and thermal comfort), households need to be willing and able to make an upfront investment that will only pay for itself in the long term. This is not a problem for well-off households, which can finance the investment from their savings or by borrowing. But it is much more difficult for a lower-income households that has minimal savings and has no access to credit, or at least not under the same terms. Overall, in the absence of government subsidies, the investment cost of the transition can easily become prohibitive for households in the lowest income deciles (see Table 3).

Table 3: Gross cost of the climate transition for typical households

Operation	Gross investment (€)	Effort rate (annual) Very-low-income households (D1–D2)	Effort rate (annual) Middle class (D4–D5)
Home energy-retrofitting	24,000	146% (6%)	82% (3%)
Change of heating vector	13,000	79% (3%)	44% (2%)
Purchase of an electric vehicle	35,000	213% (13%)	120% (8%)

Note: The effort rate is defined as the ratio between the cost of buying an item of equipment and the household category's annual disposable income. It gives an idea of the total financial effort involved. The annual effort rate divides this ratio by the lifetime of the item of equipment (25 years for home energy-retrofitting work, 16 years for vehicles). Assumptions: €13,000 for the average cost of an air-to-water heat pump; €24,000 for the average cost of energy-retrofitting work to achieve a C rating for an energy-inefficient property; €35,000 for the cost of an electric vehicle; €16,450 (2019 figures) for the average annual income of households in the first two deciles (D1–D2) and €29,235 for those in deciles 4 and 5.

How to read this chart: Home energy-retrofitting work costs €24,000 on average, which represents 146% of the average annual income of a household in the first two deciles and 82% for a household in deciles 4 and 5. If this cost is spread over the lifetime of the investment, it represents an effort of 6% of income per year (over 25 years).

Source: DGEC for costs and INSEE for income values.

These costs are all the more significant because they are often not offset by any improvement in perceived utility. Of course, conducting energy-retrofitting work on an energy-inefficient property improves comfort and should reduce the cost of use. Despite the investment, however, the service provided by the heating system does not change substantially after a change of vector, just as there is no difference in the mobility service provided by an electric vehicle versus an internal-combustion-engine model. Unlike globalisation, which brought immediate benefits in terms of purchasing power, there are not many gains to be shared in this case. Compared to the status quo, the additional cost is a collective loss of well-being (at least as conventionally measured), which needs to be shared out. Given that advanced economies have not been able to distribute the gains of globalisation equitably, it is only right to be sceptical about their ability to distribute the costs of the transition fairly.

2. At the same income level, there is significant disparity between households

It would be a mistake, however, to think only in terms of income. Income is only one of the dimensions of household differentiation. In terms of the costs of the transition, it is far from satisfactory as a proxy for the other dimensions. As detailed in the *Enjeux distributifs* (Distributive Issues) thematic report, there are three other important dimensions at play:[1]

– The type of dwelling (collective, individual), as well as the related factors of the occupant's status (tenant, owner) and the property's heating system (oil, gas, electric, heat pump, district heating)

– The type of municipality (urban, suburban, rural), which largely determines households' dependency on passenger cars

– The age of the household head

Overall, only 12% of the total variance in household emissions is explained by differences between income deciles. This high degree of horizontal dispersion – i.e. between households of the same income level – makes redistributive policies particularly difficult to design and implement, especially when it comes to allocating carbon tax revenues. This observation is what led Bureau, Henriet and Schubert (2019) to advocate for the full redistribution of the revenues of any carbon tax based not only on income criteria but also on geographical criteria.[2] However, an approach combining location and income alone does not allow for satisfactory targeting.[3] It may also be effective, from an economic and distributive point of view, to allocate a share of tax revenues to limiting the increase in production costs and, therefore, prices (see the *Enjeux distributifs* (Distributive Issues) thematic report).

Similar questions arise in terms of employment: the transition will simultaneously create and destroy jobs, and this will happen unevenly across sectors and regions (see Box 11 below). The net effects of the transition will depend on the capacity of economies to reallocate jobs and on the effectiveness of government measures to support these reallocations between and within sectors.

[1] France Stratégie and CGDD (2023), *Les incidences économiques de l'action pour le climat. Enjeux distributifs*, op. cit.

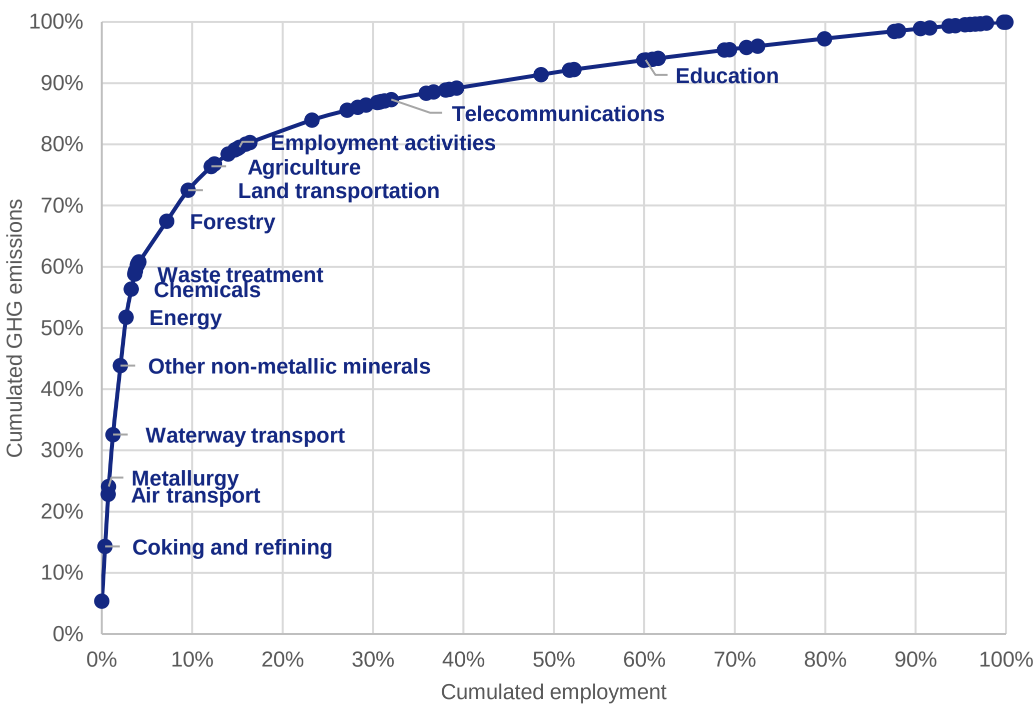
[2] Bureau D., Henriet F. and Schubert K. (2019), "Pour le climat : une taxe juste, pas juste une taxe", *Les notes du conseil d'analyse économique*, No. 50, March.

[3] See, for example, Douenne T. (2020), "The vertical and horizontal distributive effects of energy taxes: a case study of a French policy".

Box 11: Limited effects on employment, but risks remain

Economic sectors differ markedly in terms of their carbon intensity. Figure 20, which is taken from the *Marché du travail* (Labour Markets) thematic report,[1] illustrates this fact in stark detail: high-emitting industries are few in number (80% of emissions are produced by sectors accounting for 10% of employment) and are relatively well-protected by existing mechanisms (free allowances under the EU ETS at present, and the CBAM in the future).

Figure 20: Distribution of GHG emissions and employment by sector



How to read this chart: In 2021, the highest-emitting sectors together accounted for 80% of GHG emissions but only 10% of employment in France.

Source: For emissions: annual greenhouse gas emissions disclosures, Eurostat; for employment: Labour Force Survey, Eurostat.

However, this reassuring observation does not provide a complete picture:

- Beyond these very-high-emitting sectors, employment will be affected in all sectors producing goods that themselves use fossil fuels (internal combustion engines) – even if their production is not in itself emissions-intensive – or that use carbon-intensive inputs.

[1] France Stratégie and DARES (2023), *Les incidences économiques de l'action pour le climat. Marché du travail*, thematic report coordinated by Carole Hentzgen and Michaël Orand, May.

- Experience shows that, following lay-offs, it is very difficult to reallocate jobs between firms. An employee who is laid off is 21 percentage points less likely to be in a real job one year later when compared with an employee who kept their job. And six years later, this gap remains at 7 percentage points. The same principle applies between local employment markets.[1]
- While the number of jobs affected by inter-sectoral reallocations is relatively small (2% to 3% of total employment), the impact is likely to be rapid, affecting local employment markets that are isolated, have limited retraining opportunities or demand specific skills.
- In many sectors, the transition will entail a transformation of jobs and the acquisition of new skills, and is likely to accentuate recruitment problems in occupations where labour is already in short supply.
- The automotive industry will experience a particularly violent shock. An electric vehicle requires far fewer individual jobs to manufacture than an internal-combustion-engine vehicle, and the nature of these jobs is not the same. If the market share of local manufacturers remains constant, the impact on total employment will inevitably be negative.
- On a more general note, the EU has taken a risky industrial gamble: it has set itself the goal of becoming a leader in green industries even though its comparative advantages tend to be fossil-fuel-intensive and it has no strong positions from which to build, except perhaps in wind power. We will address this issue in more detail in Chapter 12.

3. The conditions for a fair transition

The need for a fair transition is now widely recognised and significant resources have been allocated to it, amounting to €8.5 billion in 2023 in national budgetary support alone (see Table 4). However, more resources will be required and, more importantly, these resources will need to be used more efficiently. At present, there are many different types of support schemes, which differ not only in their aims but also – and this is harder to understand – in terms of the fairness criteria on which they are based.

[1] See Arquié A. and Grjebine T. (2023), "Vingt ans de plans sociaux dans l'industrie : quels enseignements pour la transition écologique ?",*La lettre du CEPII*, No. 435, March.

Table 4: Main transition support schemes for households

Scheme	Aim	Budget cost (2023)	Amounts	Eligibility criteria: Means-tested?	Eligibility criteria: Restrictions based on occupancy status or vehicle type?
Green bonus	Support for the purchase of new or used vehicles that do not emit CO_2	€1.9 billion	Up to €5,000 for a car and €6,000 for a van + €2,000 top-up for households with a base taxable income per member of €14,089 or less	Yes, for amounts received	For new vehicles, the purchase cost must be less than €47,000 and, for electric vans, the weight must be less than 2.4 tonnes
Scrapping bonus	Support for the purchase or lease of a low-pollution vehicle, in exchange for scrapping an old diesel or petrol vehicle		For electric or hydrogen-powered passenger cars: • 80% of the purchase cost, up to €6,000 if base taxable income per household member is less than €14,089 and commuting distance is greater than 30 km, or if base taxable income per household member is less than €6,358 • €2,500 in other cases For Crit'Air 1 passenger cars and vans: caps reduced to €4,000 and €1,500	Yes, for amounts received	Electric or hydrogen-powered passenger cars Crit'Air 1 passenger cars and vans
MaPrime Rénov'	Support for energy retrofitting work for homeowners	€2.6 billion	Four scales (blue, yellow, violet and pink) according to income level. Amounts depend on the work involved, but cannot exceed approximately €20,000 + MaPrimeRénov' Copropriétés.	Yes, for amounts received	Yes: owners, lessors or occupants Homes over 15 years old (2 years for oil-fired boilers)
MaPrime Rénov' Sérénité	Advice and financial assistance to help low-income households undertake comprehensive energy retrofitting work		Cannot be combined with MaPrimeRénov'	Yes	Yes: owner-occupiers and comprehensive energy retrofitting
Energy saving certificates	Incentives for energy suppliers to finance energy-efficiency investments	€2 billion	The cost is borne by energy suppliers and ultimately passed on to energy consumers	Yes, for fuel poverty energy saving certificates	No
Eco-PTZ	Interest-free loan to finance energy retrofitting work on residential properties, with no cash advance	€43 million	Up to €50,000 Can be combined with MaPrimeRénov'	No	Yes: owners, lessors or occupants Joint-ownership properties Some non-trading companies
VAT at 5.5%	Promoting energy retrofitting work	€1.9 billion	Reduced VAT rate compared with the 10% rate applicable to other types of renovation work	No	No: owners or tenants Homes over 2 years old List of eligible works

Source: Authors.

France cannot afford not to consider the principles of a fair transition. In particular, this reflection should address the following issues:

- *Equality in the individual sacrifices required in the transition to a carbon-neutral economy*. The transition will require everyone to make a substantial effort to adapt their lifestyles. It would be ethically unacceptable for the better-off to exempt themselves by simply paying more for the same consumption. This widely shared feeling is reflected in the widespread rejection of carbon taxation. It is also expressed in the idea, popularised by Jean-Marc Jancovici, of an individual air travel quota, or the more elaborate idea of individual carbon accounts.[1]

  Of course, these ideas are by no means directly applicable. But they do reflect an imperative that cannot be ignored. With humanity facing such an immense and pressing challenge, the question of how to fairly distribute the sacrifices is as important now as it was when people were called upon to defend France's territory in the past.

- *The extent and conditions of public support for household efforts.* The added individual cost of the transition can be defined as the discounted amount of expenditure a household will have to make to achieve carbon neutrality without having to modify its lifestyle any more than the average household does. This raises the question of the criteria used to determine what fraction of this cost should be borne by society as a whole. This question is particularly acute when public policy takes the form of bans (such as phasing out oil-fired boilers, introducing low-emission zones or bringing in a future ban on the sale of internal-combustion-engine vehicles), which require some households to make investments they simply cannot afford.

  Many government support schemes, such as MaPrimeRénov', are now means-tested (see Table 4). However, a number of questions remain unanswered. Should the corresponding investments by households in the lowest income deciles be fully subsidised? At what income level should households no longer be eligible for the scheme? When government-supported measures increase the value of a property, is it legitimate for the state to benefit from a share of any capital gains when the property is sold or transferred? Should the reverse apply in the event that the property loses value?

- *The feasibility of dual pricing for carbon-intensive energy.* The loss of utility associated with a reduction in individual emissions is greater at the bottom of the income scale than at the top (i.e. abatement costs decrease convexly with income).

[1] See, in particular, https://comptecarbone.cc/.

> From both a social and an economic point of view, a dual pricing system would therefore present numerous advantages – but only if it were feasible.[1] Guaranteeing every household access to a fixed amount of energy at a price set by the government would be consistent with the imperative of fairness. Since additional carbon-intensive energy above this quota would be priced at a higher level, and provided of course that this price is well-perceived by users, such a measure would also encourage businesses and households to save energy and would render the corresponding investments cost-effective. Germany is trialling this type of dual pricing model for electricity, gas and heat.[2]

The need for the transition to be fair raises new questions to which our usual criteria of social justice and territorial equity do not provide ready-made answers. If we fail to carefully consider the fairness criteria on which public policy should be based, and if we fail to build a consensus around a shared concept of climate equity, there is a real risk that we could end up with a solution that is neither economically efficient nor socially just. There is therefore an urgent need to rethink our approach.

[1] Such an approach is far from straightforward, not least because businesses and households frequently use multiple energy suppliers and sources.

[2] See ExpertInnen-Kommission Gas und Wärme (2022), *Sicher durch den Winter*, report, October. Dual pricing was introduced at the beginning of 2023.

CHAPTER 10

THE TRANSITION TO NET ZERO WILL HAVE A MAJOR IMPACT ON PUBLIC FINANCES

1. The basic parameters

Discussions on the implications of the transition for public finances have long been framed in terms of the so-called “double-dividend” hypothesis, which states that putting a price on an externality would both redirect behaviour and, temporarily at least, generate revenue. In turn, this would make it possible to reduce other inherently distorting taxes, particularly on labour. Both of these outcomes would therefore generate a collective gain.

With a few notable exceptions, however, policies based on this hypothesis have been quickly rejected both socially and politically, for the reasons discussed in Chapter 9. Even where carbon pricing is still on the agenda, it is widely accepted that it will not generate significant net revenues, given the political necessity of redistributing the proceeds of any such taxation to taxpayers in one form or another. In Europe, this kind of pricing model is being implemented through the EU ETS. But the corresponding revenues are still very low relative to the cost of the transition for public finances in the EU.

On the expenditure side, the transition is likely to represent a significant burden. Of course, public spending is not the instrument of choice for achieving progress towards climate neutrality. Carbon pricing and regulation are inherently preferable. Public spending is, however, an unavoidable part of the public policy response and must be assumed as such. Specifically, this spending includes:

– the direct cost borne by government bodies (energy retrofitting work on public buildings, infrastructure, government-backed research)

– the cost of investment and equipment support schemes for households and very small businesses

– the cost of supporting the transition to a green economy (subsidies for deep industry decarbonisation projects, vocational training, support for retraining)

– the cost of adaptation investments, which will likely be largely borne by government bodies

Table 5: Annual cost of the climate transition to the public purse, 2030

In billions of euros	Additional investments in 2030	Public share	
		Constant share of public funding	Optimal scenario
Public buildings	10	10	10
Infrastructure	7	4	4
Energy retrofitting of housing stock (heating and insulation)	21	10	14
Energy retrofitting of privately owned commercial buildings	17	0	2
Purchase of electric vehicles by households	-8	-2	-2
Purchase of electric vehicles, HGVs and LCVs by businesses	4	0	1
Business investment (including energy)	13	3	4
Adaptation	3	N/A	1
TOTAL (including adaptation, excluding agriculture)	67	25	34

Note: As a reminder, the additional investments (column 2) are the investments associated with the main emissions-reduction measures identified for implementation between now and 2030. The negative additional investment in electric vehicles for households can be explained by the combined impact of modal shift (to cycling public, transport, etc.) and the reduction in mobility, which would result in households buying fewer vehicles in total than they would have done in the absence of the transition. Consequently, households would spend less overall on vehicles, even though electric vehicles are more expensive to buy (see Chapter 7). The public share is the amount financed from the public purse, with the remainder financed by the private sector.

Source: Authors' estimates.

Overall, the climate transition is expected to induce additional public expenditure of between €25 billion and €34 billion per year by 2030. The exact amount depends on whether we assume that the share of the total additional cost borne by the public purse will remain constant, or whether we instead take the view that support schemes will be adapted to ensure the best use of public funds in terms of both efficiency and fairness (see Table 5).

The transition will also have a significant impact on the revenue side. First of all, it will entail the gradual loss of revenues from excise duties on fossil fuels, which still amounted to €35 billion in 2021.[1] As demonstrated by the work of the Inspectorate General of Finance (IGF) task force on the macroeconomic and budgetary implications of carbon neutrality, the current revenue structure exposes public finances to a substantial risk, with an estimated impact on public debt amounting to 13 percentage points of GDP by 2050.[2]

On the other hand, carbon pricing under the EU ETS will increase revenues, which go mainly to EU Member States, owing to rising market price, the phasing-out of free allowances, the creation of the CBAM, and the creation, from 2027–2028, of the EU ETS 2 for the transport and building sectors. Assuming a stabilised carbon price of €100 per tonne within the EU ETS, and knowing that the price will be capped at €45 per tonne within the EU ETS 2, projections suggest that France can expect revenues of between €10 billion and €15 billion by the end of the decade. EU legislation provides that these revenues should be allocated to actions in favour of the climate transition.

There are three factors that add nuance to this general picture, albeit to varying degrees. This first is the fact that at least some climate-related investment will prove economically cost-effective in the long term (for public buildings, for example, but also for private buildings and vehicles). In an economy characterised by a higher capital stock and lower operating costs, the government will benefit directly from the lower operating costs (in heating and air conditioning) made possible by its own investments. It would also be justified in asking private agents (businesses and households) for a return on the savings it would have enabled them to achieve and, therefore, in prioritising the use of dedicated financial instruments such as equity loans in order to support their investments. Quantitatively speaking, however, we cannot expect a significant net revenue flow, at least by 2030, given the limited rate of return on investments and the slow pace at which they are ramped up.

[1] Source: *Budget vert pour 2023*, reported appended to the budget bill.

[2] Mahfouz S., Murciano C., Brand T. and Costa de Beauregard A. (2022), *Enjeux macroéconomiques et budgétaires de la neutralité carbone*, report of the Inspectorate General of Finance (IGF), August.

The second factor relates to the timing of the expected effects. By 2030, expenditure effects will certainly be predominant: the impact of attrition in excise revenues will be limited, while the ramp-up in revenues from the auctioning of emissions allowances will also be gradual. In the long term, however, investment in decarbonisation is likely to decline, which will also see the burden on the public purse fall accordingly (even though the marginal cost per tonne of carbon avoided will increase). At the same time, revenue losses will continue to grow (owing to the reduction in energy consumption and, therefore, the corresponding fall in government revenues, whether from excise duties or from the sale of emissions allowances). The challenge is that the associated timings are hard to anticipate, which will complicate the planning of public finances.

The third factor relates to the risk of a slowdown in potential growth – and the consequent loss of tax and social security revenues – resulting from the redirection of investment and research efforts away from the fossil-fuel economy (see Chapter 8 and the *Productivité* (Productivity) thematic report). The figures here are obviously much more uncertain.

In the remainder of this report, we assume that the loss of revenue caused by the attrition of the fossil-fuel excise tax base will be gradually offset by the introduction of new taxes adapted to a low-carbon economy. On this basis, the risk to public debt by 2040 can be estimated at around 25 percentage points of GDP (see Figure 21 below):

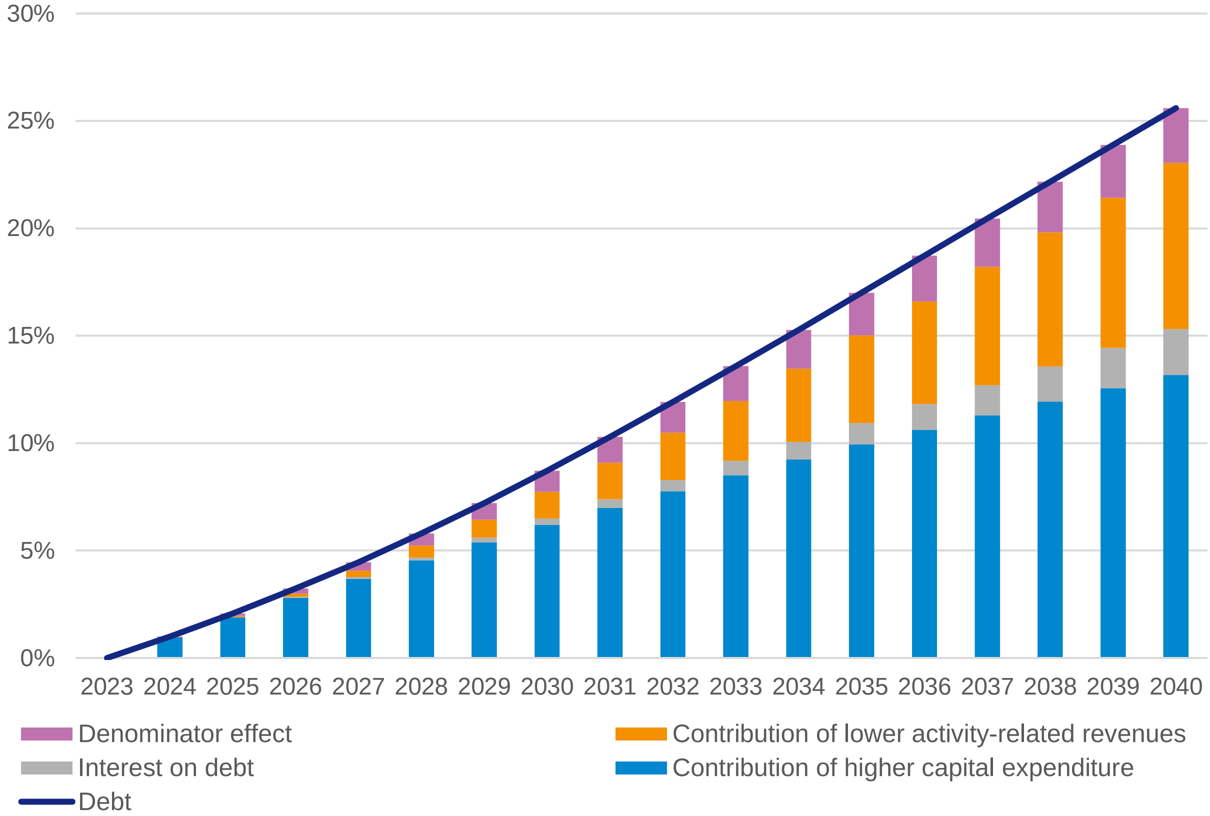
- Approximately 13 percentage points for cumulative public expenditure between now and 2050, net of revenues from emissions allowance auctions[1]
- Approximately 8 percentage points for the loss of revenue resulting from the slowdown in potential growth[2]

This is a significant sum, and the estimate is obviously subject to considerable uncertainty.

[1] Expenditure-related assumption: 1 percentage point of GDP per year until 2040, with a linear reduction between 2041 and 2050 and complete elimination in 2050. Although revenues from the sale of emissions allowances are highly uncertain, we can estimate them at between €10 billion and €15 billion by the end of the decade.

[2] Assumptions: a slowdown in potential growth of 0.3 percentage point per year between 2024 and 2030, then 0.2 between 2031 and 2035, and 0.1 between 2035 and 2040. Unit elasticity of revenues to GDP. Real interest rate equal to growth rate.

Figure 21: Contributions to the increase in public debt (in percentage points of GDP) (versus the baseline scenario)



Note: We assume here that the loss of energy-related excise revenues would be offset by new taxes, in order to maintain a constant aggregate tax and social security contribution rate. The so-called “denominator effect” is linked to the fact that GDP (the denominator of the debt ratio) also changes.

How to read this chart: In 2030, public debt would be 9 percentage points higher, with 6 of these percentage points attributable to additional capital expenditure and a little over 1 percentage point to revenue losses caused by lower growth.

Source: Authors’ calculations.

2. Debt financing should not be ruled out

Obviously, the first source of financing is the redeployment of budgetary and tax expenditures. According to the Budget vert pour 2023 (2023 Green Budget), government spending that is unfavourable to the environment (i.e. fossil-fuel-intensive spending) will amount to over €10 billion in 2023, excluding exceptional measures to protect consumers against energy price rises, around €6 billion of which be fossil-fuel-intensive tax expenditure (essentially fuel tax rebates for certain sectors and occupations). However, this figure represents a lower bound, since only explicit rebates that are not subject to ordinary law are classified as tax expenditure. The cost of not taxing kerosene, for example, is not included.

Moreover, these figures only concern central government. As far as local authorities are concerned, no similar source can be mobilised. We can, however, attempt an approximation based on their gross fixed capital formation[1] for 2021 (approximately €50 billion, of which around €9 billion in fossil-fuel-intensive expenditure). Total government spending, including fossil-fuel-intensive tax expenditures, would therefore amount to around €25 billion per year, suggesting substantial potential for redeployment.

However desirable it may be, financing the necessary expenditure through redeployment alone – i.e. by cutting spending, fossil-fuel-intensive or otherwise – seems to be an unrealistic proposition. The remaining options are inflation, debt or taxation.

As a starting point, inflation is never a good way to finance additional spending. It may prove necessary down the line as a way to devalue the debt, but announcing it as a policy option upfront would only raise expectations of price increases, with no effect on the financing of future spending.

As Ragot (2023)[2] reminds us, debt financing is in principle desirable if the interest rate is lower than the nominal growth rate. The financial context is obviously very different from what it was 18 months ago, but recent concerns about rising rates are overblown, and the structural factors that kept interest rates low for so long remain with us today.[3] At 2.3%, the long-term risk-free rate is still below, or at most equal to, the nominal growth rate of the economy. The OAT-Bund spread remains at around 60 basis points, unchanged from a year ago. The problem with France's public finances does not stem from the scale of the effort now required to protect the climate. Instead, it stems from our inability to maintain, over the long term, an aggregate tax and social security contribution rate that is consistent with our high level of public spending – or to accept a reduction in spending consistent with the desired level of the tax burden.

Speaking purely in terms of the effective use of public funds, climate investment must be planned over three decades, and the financing of the investment must be considered over the same time frame. Delaying mitigation efforts in order to keep a lid on public debt would be counter-productive: it would only improve things superficially, without any substantive benefit.

[1] Gross fixed capital formation comprises fixed asset acquisitions minus disposals by resident producers.

[2] Ragot X. (2023), "Quel policy-mix pour la politique climatique : dettes, taxes, inflation ?", forthcoming.

[3] See Blanchard O. (2023), *Fiscal Policy under Low Interest Rates*, Cambridge, The MIT Press, January. It can be argued that a global increase in climate investment of 2 percentage points of GDP would change the terms of the saving and investment equilibrium and would affect the equilibrium real interest rate (r*).

Box 12: Can we talk about climate debt?

As Ragot (2023) reminds us, the notion of climate debt is important yet difficult to define and even harder to measure. It is often invoked as a counterpoint to financial debt, but the lack of a sufficiently precise definition makes this comparison meaningless.

Here, we aim to provide a simple, practicable definition of climate debt – one on which economic entities of all kinds (central governments, businesses and local authorities) can base their calculations and communications, and which can be used as a basis for setting rules of behaviour.

Quantities

The debt in terms of quantities (tonnes of carbon equivalent) is easy to define with reference to an emissions trajectory target. Let us take $\tilde{E}_t$, where $t = 1...T$ is the trajectory of future emissions in line with a given target, from date *0* (which may, for example, be the date on which the EU adopted its climate-neutral target) to date *T*. It is natural to take *T* as 2050, although other dates are evidently possible, especially for entities that set themselves shorter-term emissions-reduction targets.

We will assume that this trajectory satisfies a carbon budget (*B*), so that $\sum_1^T \tilde{E}_t = B$.[1] As a result, deviations from the planned emissions trajectory must be made up for (which rules out, for example, a trajectory where efforts are postponed until the eve of the final deadline). For any actual emissions trajectory E_t, we can define at date τ the accumulated public investment deficit for the climate as follows:

$$\Gamma_\tau = \sum_1^\tau [E_t - \tilde{E}_t]$$

This accumulated deficit builds up over time in the case of inaction, or decreases in the case of investment in excess of the target trajectory. In this respect, it can be characterised as a debt.

Valuation

In order to be able to compare financial debt and climate debt, we must talk not in terms of quantities but in terms of euros. In order to calculate the value of Γ_τ, we therefore need to know the future trajectory of carbon prices. For France, a useful starting point is the Quinet report, which has the advantage of being consistent with

[1] As indicated in Chapter 7, a carbon budget would be the best operational translation of the collective commitments to limit global warming made under the Paris Agreement. However, nationally determined contributions (NDCs) do not take this form. In particular, the EU does not have such a budget, but only emissions caps for 2030 and 2050. A carbon budget can, however, be derived from this, assuming a linear trend in emissions between now and 2030 and between 2030 and 2050. France has set itself five-year carbon budgets.

our approach here.[1] However, the future carbon shadow prices it proposes date from 2019, and these figures may need to be updated to take account of both the shrinking carbon budget and the technological progress observed since then. Changes could also come from the introduction of a so-called “backstop technology”, such as direct air capture, which would limit the price trajectory and avoid excessively high values.[2]

There are two possible approaches to this valuation: either a “market value” approach, in which the current shadow price of carbon is applied to the entire accumulated deficit each year, or a historical cost approach, in which the value of past deficits is not revised each year. The second approach is preferable. First, it avoids abrupt variations and is consistent with the usual method of valuing public debt. Second, and more importantly, there is no reason to suppose that a decarbonisation investment not made in year *t* could not be made with the same technology and at the same cost (or even at a lower cost) in year *t+1.* This is therefore the assumption that should be made (although a discount factor should be applied to reflect the general rise in prices).

This would therefore give the following equation:

$$C_\tau = \sum_{1}^{\tau} p_t(1 + h_t^\tau)[E_t - \tilde{E}_t]$$

Here, p_t is the shadow price of carbon and h_t^τ is the discount factor.

Utilisation

This climate debt as expressed by C_τ is comparable with a financial debt and its value is calculated on a similar basis. It could:

- be calculated and published each year by INSEE, for both central government and all government bodies
- serve as a basis for setting EU rules on the conditions for partial fungibility between climate debt and financial debt, subject to the sustainability of the latter
- be calculated and published annually by local authorities, based on targets they have set themselves, enabling them to report on their climate protection efforts, and on the implications of these efforts for the trajectory of their financial debt[3]

[1] Since it derives from a quantity constraint rather than from a trajectory of the social cost of carbon resulting from intertemporal optimisation. See Quinet A.(2019), *La valeur de l’action pour le climat*, op. cit.

[2] This is the approach adopted by Gueret A., Malliet P., Saussay A. and Timbeau X. (2018), “Une évaluation exploratoire de la dette climatique”, *OFCE Policy Brief*, No. 44, December.

[3] Local authorities currently have no emissions-reduction targets and, therefore, no corresponding trajectory. Given the heterogeneous nature of these authorities, it would be unwise to set such targets in a top-down manner. On the other hand, we could set an overall target for all local authorities, ask them to adopt their own quantified targets and proceed by aggregation, which is the approach currently used under the Paris Agreement.

In order to aggregate climate liabilities and financial debt, we could technically use a constant-elasticity-of-substitution function, setting an elasticity coefficient that corresponds to collective preferences and the weighting of risks between climate sustainability and financial sustainability. In practice, we could imagine the entities in question setting (or being given) a coefficient (Θ) that reflects their relative aversion to climate and financial risks, and planning the future trajectory of their aggregate debt ($C_\tau + \Theta D_\tau$) on this basis.

Another option would be to create an emissions trading system between public entities, so as to minimise the overall cost of decarbonisation at a given point in time.

3. A temporarily increase in the tax burden will likely be necessary

There are, however, a number of arguments in favour of financing the climate transition through taxation:

- EU rules, which are currently being reformed, are unlikely to create sufficient headroom for financing through public debt. As discussions currently stand, there will be no additional room for manoeuvre, when compared with the current situation, in the fiscal policies of countries with public deficits exceeding 3% of GDP.[1] In particular, there are no plans for special treatment for green investment.
- A global increase in climate investment of 2 percentage points of GDP would change the terms of the saving and investment equilibrium and would affect the equilibrium real interest rate (r*).
- In 2022, France's public deficit equalled 4.7% of GDP (including a primary balance of 2.7%, excluding interest charges), which is still far from a healthy situation. In the future, the government may need to borrow more in order to finance temporary increases in spending and avoid sharp rises in taxation, as it did in response to the Covid-19 crisis of 2020–2021 and the financial crisis of 2008–2010. Amid uncertainty over interest rates, it is important to maintain some leeway for financing unforeseen expenditure through debt. Uncertainty about the future of the climate and the cost of future damage and loss is also a factor.

[1] See the European Commission's legislative proposals for new economic governance rules (26 April 2023).

- Last but not least, France's net international investment position stands at approximately -40% of GDP. Financing the transition through debt rather than additional savings would risk worsening an already precarious situation.

Consequently, financing the transition through a temporary increase in the tax burden cannot and must not be ruled out. As Ragot (2023) reminds us, economic analysis shows that the optimal response to prolonged exogenous shocks to public spending is to introduce exceptional and explicitly temporary levies on capital.[1]

Such a response is also consistent with the imperative of fairness – and, as we stressed in Chapter 9, fairness is an essential precondition for public acceptance of the efforts that the climate transition will require. It could take the form, for instance, of a one-off levy on the financial assets of the most affluent households. The magnitude of this one-off levy would depend on the anticipated public finance cost of the climate transition.[2] Given the negative effect of climate change on the value of a portion of real-estate assets, and given that the burden of mitigation costs falls on property owners, this could be seen as a form of fairness between holders of different types of assets.

More broadly, we will need to think carefully about the implications of the climate transition for the structure of taxation. Although carbon tax rises have been shelved, the use of taxation as an incentive remains preferable in many respects to regulatory instruments or subsidies. Developments such as the implementation of EU ETS 2, the search for substitutes for fossil-fuel excise duties and the elimination of fossil-fuel-intensive tax loopholes all call for a rethink of taxation in order to bring its structure in line with the demands of a carbon-neutral economy.

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[1] This observation, which was established under a simplified model where the government can incur debt but only has two types of tax revenue, is attributable in particular to Farhi E. (2010), "Capital taxation and ownership when markets are incomplete", *Journal of Political Economy*, Vol. 118, No. 5, October, pp. 908–948.

[2] Household total net worth stood at €4.7 trillion in 2021, with the net worth of the top 10% of household alone amounting to €3 trillion. A one-off, flat-rate levy of 5% would therefore yield €150 billion in total, or a little over 5 percentage points of GDP. Actual payments could be spread out over up to 30 years. Source: *Banque de France* for household total net worth and INSEE for wealth distribution.

CHAPTER 11

THE TRANSITION TO NET ZERO INVOLVES A RISK OF SIGNIFICANT INFLATIONARY PRESSURE THROUGH TO 2030

1. From the Great Moderation to the Great Volatility?

Between the late 1980s and the financial crisis of 2008, the global economy was in the grip of the Great Moderation – a period of two decades of limited GDP and price volatility. Then, between 2008 and 2021, came a prolonged period of very low inflation, during which monetary policy focused on countering the risk of deflation. This long sequence – lasting for one-third of a century– came to an end in 2021 when inflation abruptly took off again. For a time, it was thought that this might be a temporary surge as the world emerged from the Covid-19 crisis. Gradually, however, we began to wonder whether it might not be a sign of a deeper shift – one in which the climate transition could well play a significant part.[1]

The Great Moderation was caused by a combination of factors.[2] In part, it was the result of a learning curve for governments and central banks, following years of failure to fight inflation. It was also partly the result of structural factors, such as the "doubling of the global workforce" triggered by China's entry into international trade.[3] Consequently, or perhaps additionally, employees saw their bargaining power weakened in some economies.[4] From the mid-2000s, the exploitation of shale gas and oil added to these

[1] See, in particular, "Monetary policy and the Great Volatility", speech by Isabel Schnabel at the Jackson Hole Economic Policy Symposium, 27 August 2022.

[2] For a discussion of the factors underlying this performance, see Bernanke B. S. (2004), "The Great Moderation: Remarks at the meetings of the Eastern Economic Association", 20 February.

[3] See Freeman R. (2008), "The new global labor market", *Focus*, No. 26, University of Wisconsin–Madison Institute for Research on Poverty, summer-autumn.

[4] See Stansbury A. and Summers L. (2020), *The Declining Worker Power Hypothesis: An Explanation for the Recent Evolution of the American Economy*, Brookings Papers on Economic Activity, spring.

factors, helping to stabilise hydrocarbon prices by countering the market power held by members of the Organization of the Petroleum Exporting Countries (OPEC). For more than a decade, the world was therefore able to count on a highly elastic supply of fossil fuels at a moderate price.[1]

In the long term, the switch from an energy system based on fossil fuels to one based on renewables (and, to a lesser extent, on nuclear power) will certainly contribute to reduced inflation volatility in Europe. This shift promises to take us out of energy scarcity, with all its implications in terms of the risks associated with the concentration of supply in the hands of a small number of producing countries. Today, the world's top three oil-producing countries (the United States, Russia and Saudi Arabia) and the top four gas-producing countries (the United States, Russia, China and Iran) account for 42.9% and 52.1% of total output respectively.[2]

In fact, RTE's projections for 2050 suggest that the cost of renewable electricity will continue to fall, albeit at a slower pace, and that the overall cost of electricity will rise moderately once grid costs are taken into account.[3] At the same time, the short-term price volatility induced by the intermittent nature of renewables should be resolved through the development of electricity storage technologies.

In the next decade, however, the transition will not be smooth. Global energy supply is likely to be constrained by the current low level of investment. As the IEA has repeatedly pointed out, global investment in fossil fuels has fallen significantly but investment in renewables has not increased by the same margin, owing to a lack of clarity over the economic conditions surrounding their exploitation, as well as to financing constraints, particularly in developing countries. In order to achieve carbon neutrality by 2030, we therefore need to double the volume of energy investment in advanced economies, and multiply it by a factor of 2.5 in developing and emerging economies, as well as redirect efforts towards renewables.[4] It will be several years before investment flows reach a rational balance, and several more before production volumes for various energy sources catch up with demand.

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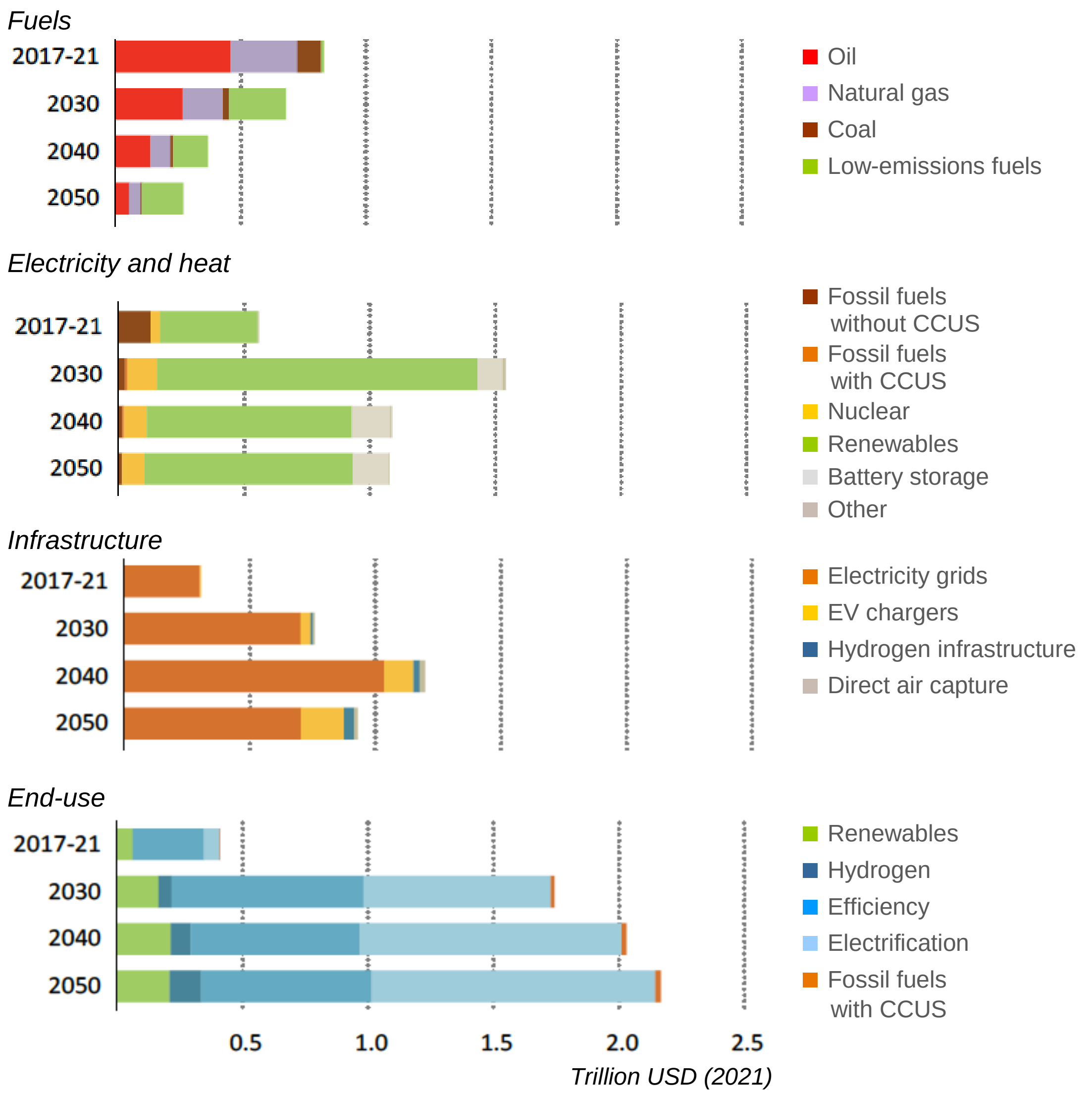
[1] See in particular Balke N., Jin X. and Yücel M. (2020), "The shale revolution and the dynamics of the oil market", Working Paper, No. 2021, Federal Reserve Bank of Dallas, June.

[2] Source: *BP Statistical Review*, 2022.

[3] See the *Inflation* thematic report.

[4] See IEA (2022), *World Energy Outlook 2022*, October. To put things into perspective, the volume of energy investment in advanced economies will need to rise from just under $1 trillion per year in 2017–2021 to $2 trillion in 2030. Over the same period, in developing and emerging economies, this investment will need to increase from a little over $1 trillion to more than $2.5 trillion per year. Based on this trajectory, total energy investment is set to rise from 2% to 4% of global GDP.

Figure 22: Global energy investment: recent situation and needs between now and 2050 under a carbon-neutral scenario



How to read this chart: Between 2017 and 2021, investment in oil stood at $400 billion; by 2050, this will need to fall to approximately $100 billion.

Source: IEA (2022), World Energy Outlook 2022, October, Fig. 3.22, p. 163.

The rapid transition to renewables is also putting considerable pressure on the markets for critical raw materials. Demand for more than a dozen metals and minerals used in the wind, solar and battery industries is set to rise sharply in the years ahead. Although these materials are not intrinsically rare, and although the unit value of European imports is low, China dominates the market for a good number of these critical raw materials – either at the extraction stage or, more often, at the refining or final integration stage.[1] Against a backdrop of geopolitical tensions, the next decade is likely to see frequent shortages, the disruption of value chains and, therefore, price volatility.[2]

As the transition from an energy system based on fossil fuels to one based on renewables (and, to a lesser extent, on nuclear power) proceeds at an historically unprecedented pace, these various factors are likely to lead, at least temporarily, to a rise in the relative price of energy resources. It is highly likely that this rise will be accompanied by growing volatility in the prices of various energy sources.

2. Domestic inflationary pressures

These global factors will be compounded by domestic inflationary pressures. As detailed in Chapter 8, the transition to climate neutrality means that we will have to invest more to produce more or less the same quantity of goods and services. This transition therefore bears all the characteristics of what economists call a negative supply shock. The transition will also lead to labour-market tensions, since it will both create and destroy jobs, except that the newly created jobs will not require the same skills or be located in the same places. Last but not least, it will force fossil-fuel-intensive capital – physical or intangible – to be scrapped before it has reached the end of its economic life, in order to be replaced by new "green" capital. Here again, the effect on supply will be negative.

As we discussed in previous chapters, there are various reasons for this:

- In order to decarbonise the economy, a part of the investment (tangible or intangible) that was going into expanding production capacity or improving labour productivity will need to be allocated either to the substitution of renewables for fossil fuels, or to energy-efficiency initiatives (e.g. redirected from new-build construction to energy retrofitting). Unless the overall investment effort is substantially increased, these developments can only have a negative impact on potential GDP, since the volume of investment devoted to increasing GDP will be lower. Of course, there is nothing to suggest that total investment will remain constant. It is quite possible that the volume of investment could increase in order to maintain aggregate supply at the same level as in the baseline scenario. But under such circumstances, demand will increase. This remains a typically inflationary configuration.

[1] On this point, see Le Mouel M. and Poitiers N. (2023), *Why Europe's critical raw materials strategy has to be international*, *Bruegel Analysis*, April.

[2] See the *Inflation* thematic report.

- The same will apply, in the longer term, to the redirection of R&D efforts towards energy efficiency and the development of renewables. These changes will have similar effects on the volume of supply and, barring major external effects of R&D on energy input costs, the impact on production costs should follow a comparable pattern.[1]
- Owing to sectoral or geographical supply-demand mismatches, the climate transition is likely to increase the need to reallocate labour between sectors and occupations. It is also likely to compound pre-existing difficulties, such as the supply-demand mismatch for certain occupations (especially in terms of qualifications), the need for professional and geographical mobility, and the unattractive pay and conditions associated with some jobs. While not alarming, these frictions are likely to be significant enough to exacerbate recruitment difficulties in occupations facing labour shortages and, therefore, fuel inflationary pressures.[2]

On the other hand, the accelerated obsolescence of productive or residential capital does not appear to be a major concern. From a qualitative standpoint, the accelerated scrapping of fossil-fuel-intensive equipment (such as boilers and coal-fired power plants) and energy-inefficient buildings, as well as the scheduled shutdown of certain industrial sectors (such as internal combustion engines), will reduce aggregate supply. In quantitative terms, however, these developments will have less of an impact in France than in other countries, since the majority of the electricity we produce is already carbon-neutral, and because industry only represents a small portion of total added value.[3]

The *Banque de France* recently simulated four climate transition scenarios over a five-year time horizon. These scenarios differ in terms of the underlying instruments (carbon taxation, public investment, private investment) and the predictability of public policy.[4] In two out of four cases (carbon taxation and public investment), the inflationary impact would be significant – as it would also be in the case of a negative uncertainty shock – given that inflation would fall by much less than GDP. The only positive scenario is one in which the transition is driven by private investment and generates significant productivity gains.

It should also be noted that these studies generally assume that a carbon pricing policy is more inflationary than a regulatory policy, or even that the latter could have a disinflationary effect. However, this effect is largely due to measurement conventions: in line with

[1] See the *Productivité* (Productivity) thematic report.

[2] See the *Marché du travail* (Labour Markets) thematic report.

[3] See the *Marché du capital* (Capital Markets) thematic report.

[4] See Dees S. et al. (2023), "Transition vers la neutralité carbone : quels effets sur la stabilité des prix ? ", *Bulletin de la Banque de France*, No. 245/3, March-April; and the *Inflation* thematic report, which summarises the main features of the corresponding scenarios.

international and European standards, official statistics generally do not take into account the rise in costs induced by regulation, but instead attribute it to a quality effect. Conversely, any reduction in the associated cost of use (for instance due to lower fuel consumption) is also not reflected in prices. Price statistics can, however, capture the effects of a price drop on new goods after they have been added to the index. Consequently, the future fall in the price of electric vehicles will be taken into account, as technological progress and the effects of experience materialise.

3. The challenges for monetary policy

The potential disturbances we have identified, both global and domestic, are likely to be temporary. From 2030 onwards, they should ease off and give way to more favourable trends. At the very least, the gradual reduction in dependence on fossil fuels should result in revenue gains and bring into play disinflationary mechanisms, which will likely have powerful effects. In the meantime, however, dexterity will be needed in the design and implementation of the monetary policy response.

The appropriate monetary response to an inflationary shock depends not only on its magnitude, but also on its persistence and nature.[1] In principle, a temporary shock does not call for a reaction unless it is likely to upset inflation expectations: this is the so-called "look-through" doctrine. As for the nature of the disturbance, a demand shock does not force a central bank to juggle competing objectives, whereas a supply shock does. In this case, it is generally accepted that the right response is to react to the supply shock with a proportionate increase in policy rates.

Eurosystem central banks have demonstrated concern for the climate and made clear their desire to contribute to EU climate action within the framework of their mandate. But at no time have they suggested abandoning their priority of maintaining price stability. Indeed, if they were to do so, they would contravene Article 127 of the Treaty on the Functioning of the European Union (TFEU), which states that the primary objective of the Eurosystem is to maintain price stability. Its support for the EU's general economic policies, as defined in Article 3 of the Treaty on European Union (TEU), including working for "the sustainable development of Europe", is "without prejudice to the objective of price stability".

It is important to draw attention to this point because almost a decade of unconventional policy has muddied the waters and led to the belief that the European Central Bank (ECB) might place climate protection among its top priorities. However, monetary policy is a very indirect tool for climate action, coming a long way behind taxation, regulation and subsidies

[1] See the *Inflation* thematic report.

in the hierarchy of instruments. The reawakening of inflation soon made us forget earlier discussions about the possible arrangements for green quantitative easing (so-called "Green QE").[1]

Discussions on the trade-off between climate and price-stability objectives therefore boil down to three questions:

- A question about how inflation is measured. In an environment of structural change and instability, should statistical institutes and central banks revise their inflation indicators?
- A question about inflation targeting. The debate about the suitability of the 2% target set by the ECB (and by most other central banks) was opened back in 2010 by Olivier Blanchard, then IMF Chief Economist. Since the transition calls for sharp changes in relative prices, it gives new weight to the criticism that this target is too low.
- A question about intertemporal choice. Can central banks "look through" temporary disruptions? If monetary policy somehow stands in the way of climate action, does it run the risk of inducing greater price instability in the longer term?

There is no unequivocal answer to the first question, other than to underscore the risk that the usual definition of price stability may become outdated. We have already touched upon the measurement problems posed by taking into account the environmental quality of the goods included in the index, and the comparative effects of taxes and standards.

It is impossible to overemphasize the urgent need for in-depth work on the questions of how inflation is measured and how the price stability target is set. Experience shows that a gap between inflation as it is officially measured and as it is actually perceived can foster suspicion towards public institutions (governments, central banks and statistical institutes). Rather than restricting the debate to experts, it is important – at a time of deep mistrust towards these institutions – for these underlying problems to be addressed openly and in a collaborative manner.

The second question takes on new relevance in the context of an inflationary shock. For as long as changing the inflation target implied a sudden and hard-to-justify rethink of the definition of price stability, the argument that a higher target would counter the risks of deflation and provide more room for relative price adjustment appeared unconvincing.

[1] See NGFS (2021), "Adapting central bank operations to a hotter world: Reviewing some options", Network for Greening the Financial System, March. We are not referring here to prudential policy, which is a separate responsibility of central banks. Nor are we referring to their role in credit allocation, which is an important issue at a time when investment needs are significant in the sectors hit hardest by the climate transition. However, while credit allocation remains an important responsibility of central banks in emerging and developing economies, this responsibility has been transferred to development banks, investment banks and other entities in advanced economies.

But this does not hold true in a context where the climate transition is expected to induce sharp changes in relative prices. Olivier Blanchard recently called for the target to be raised to 3%.[1] Opening up this debate now would be tantamount to central banks conceding defeat. But the question is likely to come up again once inflation is back towards 3%.

The third question, which complements the previous one, is forcing central banks to take a longer-term view than usual and to include considerations they are not accustomed to. If the analysis presented in this chapter is correct, climate action will reinforce inflationary risks owing to the slowdown in productivity and the costs of building a more resilient economy.

Overall, aiming to quickly bring inflation back towards the 2% target would undoubtedly avoid “disanchoring” expectations. But an overly vigorous monetary-policy response would run the risk of compounding negative sentiment towards climate action, which in turn would delay efforts to build a low-carbon economy and, therefore, increase the risk of a disorderly transition. For institutions whose purpose is to maintain stability, this would be a Pyrrhic victory. The climate transition will be testing for central bankers. At the very least, they will have to conduct monetary policy with dexterity. They should even consider temporarily raising their inflation targets.

[1] Blanchard O. (2022), “It is time to revisit the 2% inflation target”, *Financial Times*, 28 November.

CHAPTER 12

EUROPE IS DEVELOPING POLICY INSTRUMENTS TO TACKLE ITS COMPETITIVENESS PROBLEM, BUT THESE MAY NOT BE ENOUGH

1. The handicap of high energy prices

Climate competitiveness is a major challenge for the EU today, on several levels:

– *Energy prices*, especially gas prices, which are currently much higher than those of our main competitors, particularly the United States

– *Carbon leakage* to countries whose decarbonisation efforts are more limited than ours, especially emerging and developing economies

– The *uneven playing field* between the EU and countries whose decarbonisation efforts are similar to ours but based on different instruments (the U.S. IRA raised this very issue, although it is much broader)

– The need to build a *competitive green industrial base*, given that the EU is lagging worryingly behind China and the United States (as discussed in Chapter 3)

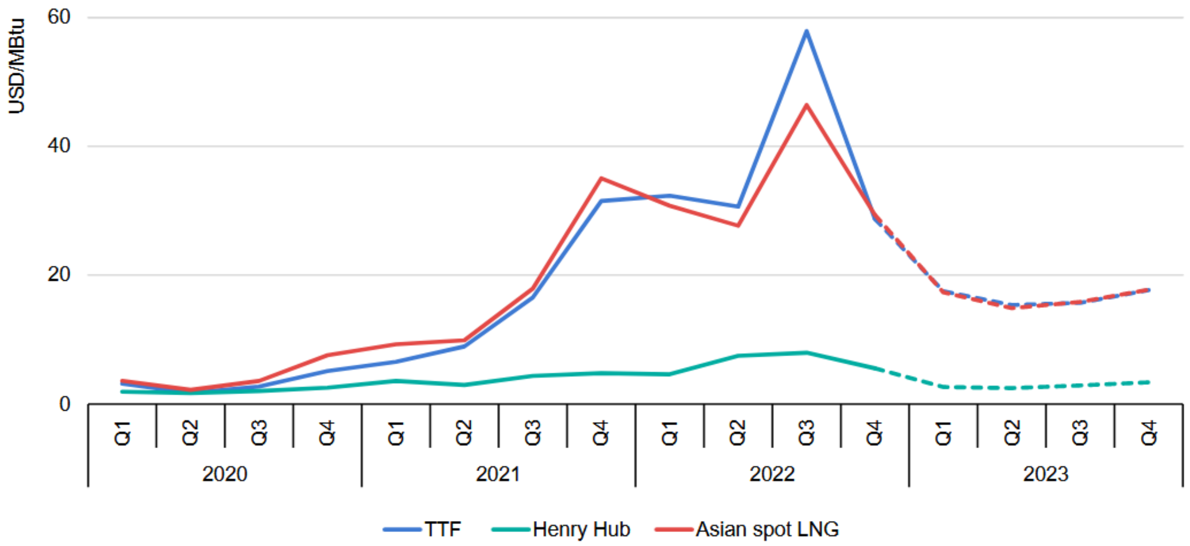
Since these challenges are distinct from one another, it is important to clarify which one a given measure addresses as a priority. But because they are interdependent, the various measures must be part of a coherent strategy.

Energy prices are an important determinant of global competitiveness, especially in energy-intensive sectors. Studies based on individual company data show that a rise in the price of electricity or gas is fully passed on in export prices, resulting in a fall in exports, output and employment. A 10% rise in the price of electricity reduces exports by around

2%, while output and employment fall by 1.5%. In the case of gas, the average impact is only around half this level in France, given the low share of gas in our energy mix.[1]

The low cost of nuclear electricity has long been an advantage for the French economy, just as the price of Russian gas was for German industry. More recently, however, doubt has been cast on these historical advantages. Since 1996, the price of electricity for industrial buyers has been indexed to the price of marginal energy, often gas, given its role as a back-up source of primary energy for the electricity system. On top of this, gas prices have risen sharply since mid-2021 as a result of Russian export restrictions. Conversely, U.S. gas prices have remained much more stable. Europe has therefore faced a sudden and massive energy competitiveness problem.

Figure 23: Gas prices on European, Asian and American markets



How to read this chart: In the third quarter of 2022, the price of natural gas on the European market (TTF) reached almost $60 per million British thermal units (MBtu), while the price on the U.S. market (Henry Hub) was less than $10 per MBtu.

Source: IEA (2023), Gas Market Report, Q1-2023, February, p. 50.

The recent fall in gas prices is the result of efforts to reduce consumption and diversify supplies, combined with the effects of a mild winter.[2] There is no doubt, however, that recurring tensions over gas prices will persist as long as the EU remains dependent on

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[1] See Fontagné L., Martin P. and Orefice G. (2023), "*The many channels of firms' adjustment to energy shocks: Evidence from France*", paper presented to the *Economic Policy* panel, April.

[2] Available data does not give a precise picture of the cost of supplying the European economy. Spot prices do not reflect the reality of a market where a share of gas purchases continue to be made under long-term contracts between suppliers and buyers.

imported fossil fuels. The fact that Chinese purchases have resumed could soon compound this situation.

For the time being, Europe has two levers at its disposal to limit the impact of these tensions on its competitiveness, both of which have been activated. The first lever is group purchasing, although its impact will nevertheless remain modest. The second, more structural lever concerns the reform of the electricity market. This issue has been the subject of a long battle between those, including France, who feared price instability and those, such as Germany, who feared physical shortages and therefore wanted to preserve market efficiency. Under the compromise proposed by the Commission, prices remain indexed on the cost of marginal energy. However, Member States are encouraged to introduce contract-based instruments for decarbonised energy sources. The widespread uptake of these instruments should substantially limit price volatility.[1] This draft proposal, which must now be agreed by the Council and approved by the Parliament, is expected to come to fruition the coming quarters, putting an end to a long controversy within the EU. If this happens, the impact of rising gas prices on the EU's competitiveness will be lessened. However, this impact can only be eliminated by decarbonising electricity supply and weaning industry off fossil fuels altogether. We will have to live with this problem for at least a decade.

2. Unconvincing responses to carbon leakage and diverging strategies

The risk of carbon leakage has long been recognised: in the absence of a global carbon price, emissions pricing or equivalent regulatory measures are likely to cause high-emitting companies and the associated jobs to relocate to countries with lower prices or less stringent regulations, without any benefit for the climate. This is why economists have argued for a global carbon price, and why some courageously continue to do so despite political aversion to the idea.[2]

The Paris Agreement recognised the unrealistic nature of both this proposal and its underlying vision, according to which countries would be subject to increasingly stringent constraints as they developed. As detailed in the *Compétitivité* (Competitiveness) thematic report, this is what led the EU to first allocate free allowances to carbon-intensive industrial sectors subject to the EU ETS, and then to legislate for the creation of a CBAM, which is

[1] See the Commission proposal of 14 March 2023. The main instruments are Power Purchase Agreements with suppliers for industrial customers, and two-way Contracts for Difference for additional non-fossil electricity generation (i.e. renewables and nuclear power).

[2] See Gollier C. (2019), *Le Climat après la fin du mois*, Paris, Puf.

intended to replace free allowances and to eliminate carbon leakage by compensating for cost differentials. The need for such a mechanism was all the greater in view of the fact that the price of carbon on the allowance market had reached €100 per tonne, and was set to rise further with the planned tightening of allowance allocations.

The principle behind the CBAM is simple: the importer of a product (such as steel) subject to the EU ETS must purchase "CBAM certificates" at the EU ETS market price, in proportion to the allowances that would have been purchased on the market if the product had been manufactured in Europe. Where the country of origin has explicit carbon pricing, the importer will be able to deduct the amount already paid by the exporter, and only pay for its certificate on the basis of the difference between the EU ETS market price and the carbon price in the country of origin. The CBAM is therefore a mechanism for levelling the playing field between countries with different emissions-reduction efforts.

The CBAM was designed to be compatible with WTO rules, which allow for exceptions on environmental grounds, provided these are not "applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade".[1] However, the mechanism still remains the subject of criticism, both from emerging countries that do not have the same level of ambition as the EU and have been quick to see it as a form of disguised protectionism, and from countries (including the United States) whose decarbonisation strategy relies on instruments other than carbon pricing.

At the same time, the mechanism has come under fire for different reasons within Europe, especially from sectors and companies that consider themselves insufficiently protected:

- The CBAM does nothing to address issues around the distortion of competition on export markets (in fact, it exacerbates these issues, since exporters previously benefited from free allowances). With a similar carbon content, a tonne of exported steel will cost more if it is produced in the EU.
- Given its current scope, the CBAM is only a partial response to issues around the distortion of competition in downstream sectors. A car made in the EU with European steel will incur an additional cost due to its carbon content, but the same will not apply to a car imported from China.

Measuring the carbon content of imported products also poses a technical challenge. Emerging economies are generally dual economies, where ultra-modern companies exist alongside businesses that are far from the cutting edge of technology. Applying the characteristics of medium-sized companies to exporters in these countries risks putting them at an unfair disadvantage. Conversely, using actual carbon content data on a site-

[1] General Agreement on Tariffs and Trade (GATT), Article XX.

by-site or company-by-company basis runs the risk of specialisation: for instance, high-performance steel mills might specialise in supplying export markets with CBAM-style mechanisms in place, while less advanced operations might focus instead on supplying other markets. This kind of “reshuffling”, which is not yet entirely ruled out by EU provisions, would of course be nothing more than a mere artefact.

Faced with these difficulties, the OECD and the IMF have explored the possibility of developing a common metric to assess the level of ambition of national climate policies. This approach could be promising, despite the many technical difficulties it poses, if it established an objective basis for the delimitation of Nordhaus-style “climate clubs” (Nordhaus, 2015) and if a penalty – in the form of a customs tariff – were imposed for countries that failed to contribute to the common cause. Considering current international treaties, however, the formation of such clubs would not be compatible with WTO rules.

In the short term, therefore, there is no alternative to the CBAM, even if it remains an imperfect instrument. The simulations carried out for this report using the ThreeME, Vulcain and Mirage models provide an approximate idea of its effects on carbon leakage, on the EU economy and on partner countries:[1]

- Overall, the gradual phasing-in of the CBAM for all sectors subject to the EU ETS, in parallel with the elimination of free allowances, would eliminate around half of carbon leakage, which is a significant outcome (Mirage simulation).[2] These effects would be concentrated on the major emerging exporters of intermediate goods (India, Russia and, to a lesser extent, China).[3]
- From a macroeconomic point of view, the introduction of the CBAM would have a non-linear effect (Vulcain simulations): it would slightly reduce the economic cost of a limited reduction in territorial emissions, but a greater reduction in emissions would carry an increased economic cost. The reason for this is fairly intuitive: for low levels of constraint, the CBAM would slightly limit GDP losses, notably by sharply reducing losses of competitiveness in the industrial sector. Conversely, at a high EU ETS allowance price, the mechanism would force the European economy to produce costly decarbonised goods, whereas the absence of a CBAM would have left open the option of importing equivalent goods that emit more carbon but are less costly.
- From a public finance point of view, the revenue generated by the sale of CBAM certificates would be limited: around €10 billion per year in 2030, for the EU as a whole,

[1] See the *Compétitivité* (Competitiveness) thematic report.

[2] More specifically, it would eliminate around 60% of carbon leakage compared with a baseline scenario with no free allowances, and around 40% compared with a baseline scenario with free allowances.

[3] See Bellora C. and Fontagné L. (2023), “EU in search of a carbon border adjustment mechanism”, *Energy Economics*, forthcoming.

with a carbon price of €100 per tonne, assuming that the mechanism encompasses all imports of intermediate goods and services, and that the certificates cover all the corresponding direct and indirect emissions (ThreeME simulation). Given the chosen configuration of the CBAM, this is likely an upper bound.

There are many obstacles still to overcome if we are to limit the scale of carbon leakage and enable Europe to implement a stringent climate policy. The CBAM is by no means a magic bullet. But it stands a chance of being recognised as a legitimate instrument by our trading partners and, therefore, of helping to redress the balance in international law between protecting international trade and preserving the climate. In this respect, it is worth defending.

In August 2022, the adoption of the U.S. IRA brutally dispelled the illusion that the only climate challenge the EU was facing was one of unequal ambition.[1] The other side of the equation – namely that of diverging strategies – has long been ignored but is now coming to the fore. As we pointed out in Chapter 2, the possibility for strategies to diverge was enshrined in the Paris Agreement and is now here to stay.

The problem does not lie so much in the IRA's local content clauses. These are clearly contrary to international trade law, and it is up to the United States' partners to oppose them using the means available to them under WTO rules. Obviously, this is not an easy undertaking in the current climate, with the multilateral system in decay and with geopolitical concerns taking precedence over economic considerations. But, at least in principle, the answer is easy to identify.

A deeper problem concerns the diverging strategy choices made by the world's major powers. There are, of course, many possible strategies for achieving climate neutrality. But these can be distilled down to different combinations of components from three "pure" models:

- *Putting a price on carbon and other GHGs.* This is the approach favoured by economists, because it is based on a price signal, generates revenues that can be redistributed and, provided it is credible, guarantees that businesses and households will make efficient choices. It is a demanding approach, however, because it requires a mechanism for setting a shadow price that guarantees the achievement of climate neutrality by the target date.[2]

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[1] The United-States' climate target nevertheless remains significantly less ambitious than the EU's.

[2] Carbon pricing is not necessarily derived from intertemporal optimisation. Instead, it can be based on a quantitative target, such as that set by the Paris Agreement, or on the implementation of a carbon quota mechanism. On this point, see Stern N., Stiglitz J. and Taylor C. (2022), "The economics of immense risk, urgent action and radical change: towards new approaches to the economics of climate change", *Journal of Economic Methodology*, Vol. 29, No. 3, pp. 181–216.

- *Planning emissions trajectories sector by sector*. This strategy can only be cost-effective if decision-makers are well-informed about abatement costs and their future trends. It can be based on regulatory tools. But, especially in developing countries, it can equally be based on credit allocation mechanisms.
- *Using tax credits or subsidies to incentivise emissions reductions*. Unlike the previous two strategies, this approach does not guarantee that the target will be achieved by a given date. But it can be adjusted over time according to results. It also allows for differentiation between research subsidies and production subsidies. It is, however, much more costly to the public purse than the other two strategies (see Table 6).

The choice between these three approaches goes back to long-standing debates on the right instruments for steering a reduction in pollution. In principle, there is no unequivocal answer to this question.[1]

Table 6: Three strategies for achieving climate neutrality

	Carbon pricing	**Planning**	**Incentives**
Advantages	Economic efficiency Tax revenues	Consistency with a quantitative target	No constraints for economic agents
Drawbacks	Low political acceptability Low credibility	Potential economic costs Uncertain political acceptability	No direct link with the target Potentially high fiscal cost

Source: Authors.

In practice, the approaches taken by the world's major powers borrow components from these three "pure" strategies. With the EU ETS, the EU has had a carbon pricing instrument since 2005. It has recently decided to extend its scope, initially by applying the same type of mechanism to other sectors but without seeking immediate harmonisation. Carbon pricing is therefore at the heart of its strategy. But the EU also uses both regulation (such as the ban on the sale of internal-combustion-engine vehicles from 2035 onwards) and subsidies (with support for renewables, for the greening of industry and for the purchase of electric vehicles).

[1] See Weitzman M. (1974), "Prices vs. Quantities", *The Review of Economic Studies*, Vol. 41, No. 4, pp. 477–491.

Although China's climate policy also officially promotes a balance between these three models, it is in reality based largely on the latter two options.[1] The development of renewable electricity production has relied heavily on a policy of buying back electricity at favourable prices and on preferential access to financing from public investment banks. Similarly, the development of clean vehicles has largely been achieved through purchase-subsidy policies and progressively stricter standards, which are often applied on a province-by-province basis.

In terms of price-signal policies, the Chinese government launched an emissions trading scheme in 2017, although it only officially came into force in 2021 after being postponed several times. While this system covers electricity generation, it does not currently appear to be having much impact on reducing emissions, partly due to an overly generous supply of allowances and the absence of a strict cap on emissions.[2]

The United States, for its part, has taken an approach that draws heavily on the third strategy. The adoption of the IRA marks a decisive step in this direction, with the introduction of transferable tax credits in order to spur renewable energy production by businesses and households, as well as to stimulate carbon capture and storage, electric or hydrogen-powered vehicles, and green industry. A key feature of these subsidies is that there is no fixed budget: the total amount of subsidies will depend on demand. Preliminary estimates by the Congressional Budget Office suggest that the total will reach $271 billion by 2030, but independent assessments – such as that by Bistline et al. (2023)[3] – give considerably higher orders of magnitude (between $780 billion and $1.070 trillion). Ultimately, the total amount will depend on the success of the scheme. There is no *ex ante* limit.

Average carbon prices clearly reflect these diverging strategy approaches: they are higher in Europe (European Economic Area and United Kingdom) than in the United States (where there is no federal price, but state-by-state pricing initiatives), and they are close to zero in China (see Table 7).

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[1] See sections V.3 and V.4 of *Action Plan for Carbon Dioxide Peaking Before 2030*, National Development and Reform Commission (NDRC), People's Republic of China.

[2] The system was also supposed to be extended to other industrial sectors (such as cement, steel and aluminium) in 2022, but this measure has now been postponed until 2023.

[3] Bistline J., Mehrotra N. and Wolfram C. (2023), "Economic implications of the climate provisions of the Inflation Reduction Act", *Brookings Papers on Economic Activity*, Spring.

Table 7: Average carbon price in 2021 – European Economic Area, United Kingdom, United States and China

	Share of emissions covered by a pricing instrument	Average explicit price of covered emissions ($)	Average revenue per tonne of carbon for covered emissions ($)	Average effective price ($)
EEA	50%	$64.30	$32.80	$32.10
United Kingdom	43%	$55.50	$45.20	$23.90
United States	7%	$21.20	$13.00	$1.50
China	36%	$7.10	$0.00	$2.50

Note: The average explicit price of covered emissions (column 3) takes into account free allowances. The average effective price (column 4) provides an estimate of the opportunity cost faced by companies.

Source: I4CE calculations based on Global Carbon Accounts in 2022.

3. Europe at a crossroads

In 2019, the EU set the goal of transitioning to a climate-neutral economy by 2050. Over the past four years, it has methodically put in place the legislative and regulatory instruments to achieve this ambition. Today, the task for the EU is no longer to design and define a strategy, but to implement it.

The international landscape has changed a lot in the past four years. The challenge now is to promote the development of a European green industrial base, at a time when our major competitors – the United States and China – have chosen to support their own companies and to pay scant regard to the acceptability of their policies in terms of the norms of international trade or their cost to the public finances. Even if these countries' policies do allow free competition between domestic and foreign market participants – and this is obviously not guaranteed – the main beneficiaries of production and investment subsidies are likely to be domestic economic agents (employees, subcontractors, research laboratories, etc.). And they may end up gaining a lasting advantage as a result of the learning effect.

For Europe, there are two pressing questions. The first is whether the EU can achieve its objectives within its self-imposed constraints. In its quest to win the race to build a new model for green growth – i.e. to set tomorrow's standards and to establish a strong position in the industries of the future – Europe runs the risk of hobbling itself on more than one front, with its industrial backwardness, its high energy costs, its exposure to carbon leakage and its determination to maintain fiscal discipline. While some constraints, such as those on energy prices, are imposed on the EU by the international context, other factors, such as fiscal discipline, are the result of its own decisions.

The key question is whether Europe, faced with major rivals who are not subject to the same constraints and do not set themselves the same disciplinary rules, might be locking itself into an excessively risky equation. The EU cannot be a champion of the climate, a champion of multilateralism and a champion of fiscal virtue all at once. For the time being, it does not want to choose which of these constraints to take liberties with. But it may soon be forced to do so.

Based on the current state of discussions, the reformed European fiscal framework will not provide sufficient scope for significant climate investment financing through public debt. At Germany's insistence, the Commission's latest legislative proposals represent a backward step when compared with the initial guidelines, which were themselves rather timid.[1] As stressed in Chapter 10, public debt is not the main instrument for financing the climate transition. However, excessively restricting its use could further complicate the task for policy-makers.

The second issue has to do with the governance of climate policy. As things stand, the EU sets the overall objectives and rules, but leaves a large part of the corresponding political and financial costs to Member States. For instance, EU law bans the sale of internal-combustion-engine cars from 2035 onwards, but responsibility for decarbonising the existing car fleet remains largely in the hands of national governments. The same applies to the replacement of heating vectors.

While the EU's climate ambitions are clear, the actual results will largely depend on the actions of individual states. Yet the current system of governance is essentially based on indicative coordination, with neither sticks nor carrots. Past experience – from the Lisbon Strategy, the Broad Economic Policy Guidelines and the Macroeconomic Imbalance Procedure, for instance – teaches us that indicative coordination is at best moderately effective. What will happen if countries fail to meet their targets? Despite the existence of national energy and climate plans, the EU has only a limited view of what countries are actually doing to achieve the agreed decarbonisation targets. What will happen if countries simply give up on these targets? The EU cannot afford to put forward a grand climate strategy while remaining vague about its actual implementation. It needs to define and implement a new climate governance framework that matches its ambition.

[1] See the proposals published on 26 April 2023 by DG ECFIN.

APPENDICES

APPENDIX 1

ENGAGEMENT LETTER

La Première Ministre

Paris, le 12 SEP. 2022

à

Monsieur le Professeur Jean PISANI-FERRY

Objet : Evaluation des impacts macroéconomiques de la transition écologique

Monsieur le Professeur,

Le Président de la République a souhaité marquer dans l'organisation gouvernementale la priorité donnée à la planification écologique et à la prise en compte, dans l'ensemble des politiques publiques, des implications de la transition climatique. Il a ainsi clairement indiqué que la transition climatique n'est pas une politique sectorielle mais une orientation d'ensemble porteuse de fortes conséquences macroéconomiques et sociales.

Beaucoup d'études ont été menées ces dernières années qui ont permis d'améliorer la compréhension de l'impact sectoriel de la transition climatique. Les évaluations de son impact macroéconomique n'ont pas encore atteint le même degré de maturité, alors même que les objectifs que nous nous fixons sont très ambitieux, et vont conduire à un changement en profondeur de notre économie et de nos comportements collectifs.

Les évaluations macroéconomiques de la transition climatique aujourd'hui disponibles présentent souvent la transition comme une relance de l'investissement auto-entretenue sur plusieurs décennies et ne tiennent pas suffisamment compte de la diversité des mécanismes en jeu, avec des conséquences différentes selon les secteurs, au-delà du surcroît d'investissement nécessaire : frictions dans la réallocation du marché du travail, impact sur l'environnement extérieur et sur la compétitivité, rôle de l'innovation verte, augmentation du coût du capital lié à l'incertitude, obsolescence accélérée d'une partie du capital installé, risque d'inflation « verte », etc. La plupart des simulations correspondent en effet à des scénarios qui partent de l'hypothèse d'une transition qui se déroule dans les meilleures conditions possibles (coordination internationale des actions ; flexibilité sur le marché du travail ; technologies disponibles ; fiscalité optimale etc.). Si ces exercices de prospective montrent qu'une transition bien mise en œuvre peut apporter des « doubles dividendes », ils apportent peu d'enseignements sur comment procéder pour qu'elle se déroule effectivement dans un contexte favorable.

Dans ce contexte, je souhaite vous confier la mission d'améliorer notre compréhension de ces mécanismes, de sorte que les décisions qui devront être prises soient le mieux informées possible.

Dans un premier temps, vous réunirez les administrations et institutions qui travaillent sur des modélisations macroéconomiques prenant en compte les conséquences des politiques de lutte contre le réchauffement, afin de leur permettre de prendre connaissance de leurs travaux respectifs ; vous me remettrez une note d'étape sur les simulations et modélisations effectuées actuellement avec les modèles macroéconomiques existants, leurs caractéristiques et leurs limites. Vous proposerez au début de l'automne 2023 un plan d'action pour la suite de votre mission, avec le cas échéant des demandes de moyens (humains et/ou financiers) documentés.

Dans un second temps, début 2023, vous remettrez un rapport qui présentera les résultats des modélisations qui auront été effectuées, identifiera les points d'attention prioritaires en termes d'impact macroéconomique et indiquera ce qui doit encore faire l'objet d'investigations complémentaires. Ce rapport permettra de nourrir l'évaluation macroéconomique de la nouvelle stratégie française sur l'énergie et le climat qui sera publiée par le Gouvernement, et plus généralement les arbitrages nécessaires à sa finalisation.

Pour mener à bien cette mission, vous vous appuierez sur les équipes de France Stratégie, qui en assurera le secrétariat, ainsi que sur les administrations et opérateurs concernés qui vous apporteront leur concours (en particulier la direction générale de l'énergie et du climat, le commissariat général au développement durable, l'Agence de l'environnement et de la maîtrise de l'énergie, l' Institut national de la statistique et des études économiques, la direction générale du Trésor et l'inspection générale des finances).

Je vous invite à associer à vos réflexions les experts sur le sujet, ainsi qu'à porter une attention particulière aux travaux équivalents effectués chez nos principaux partenaires étrangers et dans les organisations internationales. Il sera utile également de consulter les partenaires sociaux, les organisations non gouvernementales, les associations de consommateurs et les entreprises des secteurs concernés, pour recueillir leurs attentes.

Vous tiendrez le secrétaire général à la planification écologique régulièrement informé de l'avancement de vos travaux.

Bien sincèrement

Elisabeth BORNE

APPENDIX 2
THEMATIC REPORTS

This report, entitled *The Economic Implications of Climate Action*, was informed by the work of 11 working groups coordinated by the authors of this report and bringing together a large number of organisations. The corresponding thematic reports are published at the same time as this report and are available on the France Stratégie website (in French).

This report also draws on the work of a “Simulations” working group, which contributed in particular to the content of chapters 6 and 8.

- **“Simulations” working group**

Selma Mahfouz, Inspectorate General of Finance (IGF), *coordinator*

Gaël Callonec, French Environment and Energy Management Agency (ADEME)
Alma Monserand, ADEME
Benoît Campagne, French Treasury
Anne Epaulard, Université Paris Dauphine-PSL and France Stratégie
Frédéric Ghersi, International Centre for Research on Environment and Development (CIRED)
Pierre-Louis Girard, French Treasury
Julien Lefevre, CIRED
Boris Le Hir, Department of the Commissioner-General for Sustainable Development (CGDD)
Nicolas Riedinger, France Stratégie
Xavier Timbeau, French Economic Observatory (OFCE)
Jérôme Trinh, French Treasury

- ***Bien-être*** **(Well-being) thematic report**

Didier Blanchet, Measurement in Economics Chair, Paris School of Economics (PSE), *coordinator*

Craig Pesme, Measurement in Economics Chair, PSE

Aude Pommeret, Université Savoie Mont Blanc and France Stratégie

- ***Compétitivité*** **(Competitiveness) thematic report**

Lionel Fontagné, Banque de France, *coordinator*

Vincent Aussilloux, France Stratégie

Antoine Bouët, Center for Prospective Studies and International Information (CEPII)

Mathieu Fouquet, CGDD

Sébastien Jean, Paris National Conservatory of Arts and Trades (CNAM)

Frédéric Ghersi, CIRED

Alexandre Godzinski, CGDD

Christophe Gouel, French National Research Institute for Agriculture, Food and Environment (INRAE) and CEPII

François Langot, Le Mans Université and Centre for Economic Research and its Applications (CEPREMAP)

William L'Heudé, French Treasury

Paul Malliet, OFCE

Erica Perego, CEPII

Aude Pommeret, Université Savoie Mont Blanc and France Stratégie

Romain Schweizer, France Stratégie

Fabien Tripier, Université Paris Dauphine-PSL and CEPREMAP

Vincent Vicard, CEPII

- ***Dommages et adaptation*** **(Loss and Damage and Adaptation) thematic report**

Xavier Timbeau, OFCE, *coordinator*

Gaël Callonec, ADEME

Adrien Delahais, CIRED

Vivian Dépoues, Institute for Climate Economics (I4CE)

Logan Gourmand, French Treasury

Morgane Nicol, I4CE

Aude Pommeret, Université Savoie Mont Blanc and France Stratégie

Félix Rannou, CGDD

Alice Robinet, France Stratégie

Mathilde Viennot, France Stratégie

- ***Enjeux distributifs* (Distributive Issues) thematic report**

Vincent Marcus, CGDD, *coordinator*

Emmanuel Combet, ADEME/CIRED
Frédéric Ghersi, CIRED
Meriem Hamdi-Cherif, OFCE
Paul Malliet, OFCE
Matthieu Lequien, French National Institute of Statistics and Economic Studies (INSEE)
Boris Le Hir, CGDD
Caroline Pinton, CGDD
Mathilde Viennot, France Stratégie

- ***Indicateurs et données* (Indicators and Data) thematic report**

Nicolas Carnot, INSEE, and **Nicolas Riedinger**, France Stratégie, *coordinators*

Sylvain Larrieu, INSEE

- ***Inflation* thematic report**

Stéphane Dees, Banque de France, *coordinator*

Elie Bellevrat, French electric transmission system operator (RTE)
Annabelle de Gaye, Banque de France
François Geerolf, OFCE
Matthieu Lequien, INSEE
Romain Schweizer, France Stratégie
Athiana Tettaravou, Peterson Institute for International Economics (PIIE)
Oriane Wegner, Banque de France

- ***Marché du capital* (Capital Markets) thematic report**

Pierre-Louis Girard, French Treasury, *coordinator*

Riyad Abbas, INSEE
Romain Schweizer, France Stratégie
Jérôme Trinh, French Treasury

- ***Marché du travail* (Labour Markets) thematic report**

Carole Hentzgen and **Michaël Orand**, Directorate for Research, Studies and Statistics (DARES), *coordinators*

Camille Cousin, DARES

Hélène Garner, France Stratégie
Raphaël Janelli, DARES
Cécile Jolly, France Stratégie
Jérôme Lê, DARES
Pierre Villedieu, DARES

- ***Modélisation* (Modelling) thematic report**

Jérôme Trinh, French Treasury, *coordinator*

Mathieu Fouquet, CGDD
Pierre-Louis Girard, French Treasury
Miquel Oliu-Barton, Université Paris Dauphine-PSL and France Stratégie
Mathilde Viennot, France Stratégie

- ***Productivité* (Productivity) thematic report**

Anne Epaulard, Université Paris Dauphine-PSL and France Stratégie, *coordinator*

Aude Pommeret, Université Savoie Mont Blanc and France Stratégie
Katheline Schubert, PSE and Paris 1 Panthéon-Sorbonne

- ***Sobriété* (Sufficiency) thematic report**

Aude Pommeret, Université Savoie Mont Blanc and France Stratégie, *coordinator*

Miquel Oliu-Barton, Université Paris Dauphine-PSL and France Stratégie
Alice Robinet, France Stratégie
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