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THE ECONOMIC CHALLENGES OF THE NET ZERO TRANSITION

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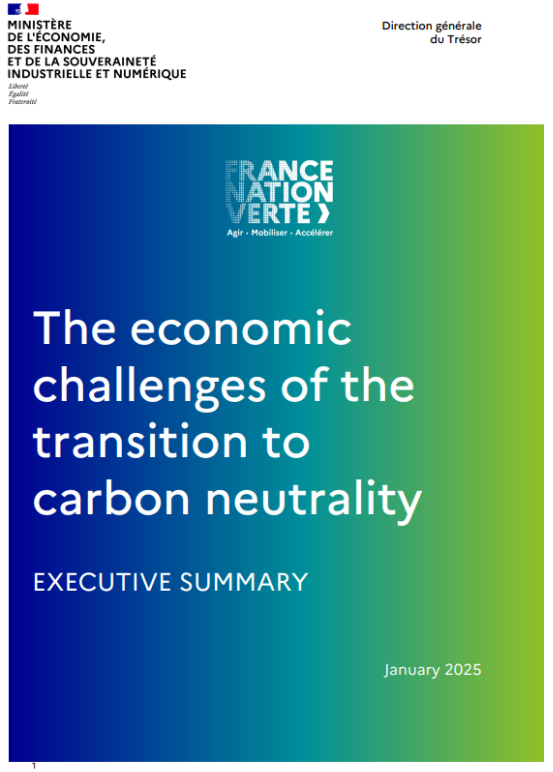
This report from the French Treasury completes the understanding of the challenges of the transition to a net-zero world : it offers sectoral insights and deepens some of its qualitative and quantitative implications for the French economy

- Inspired by the *Net Zero Review* published in 2021 by the UK Treasury
- This report analyses the **key economic challenges of the net zero transition for the French economy**, adressing macroeconomic and sectoral dimensions, and outlining the main challenges for competitiveness, households and public finances
- It draws lessons from **international comparisons** and the **economic literature**
- The publication **follows work carried out by the taskforce led by Jean Pisani-Ferry and Selma Mahfouz** on the "Economic implications of climate action"
- An interim report has been published end of 2023
- This edition constitutes the final report, published on January 27, 2025.



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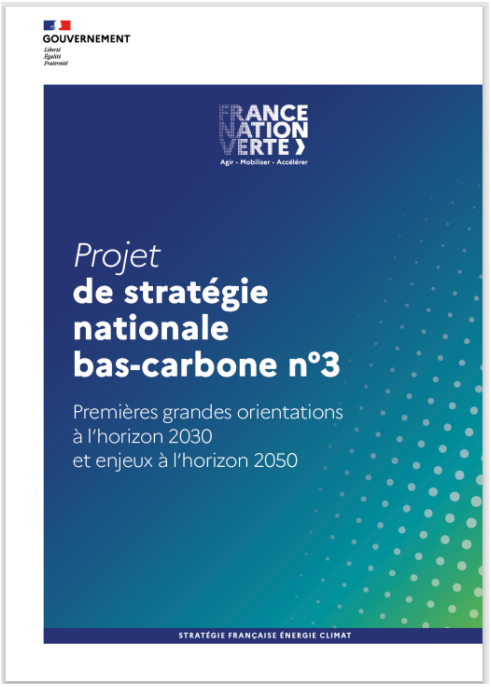
The French Treasury strengthens its analysis capacities of the ecological transition in order to be able to contribute to ecological planning exercises

A strengthening of the French Treasury on green issues…

- Creation of an "Ecological Transition" department (TRECO) in 2023
- Mobilization of many other Treasury units for environmental policy analysis

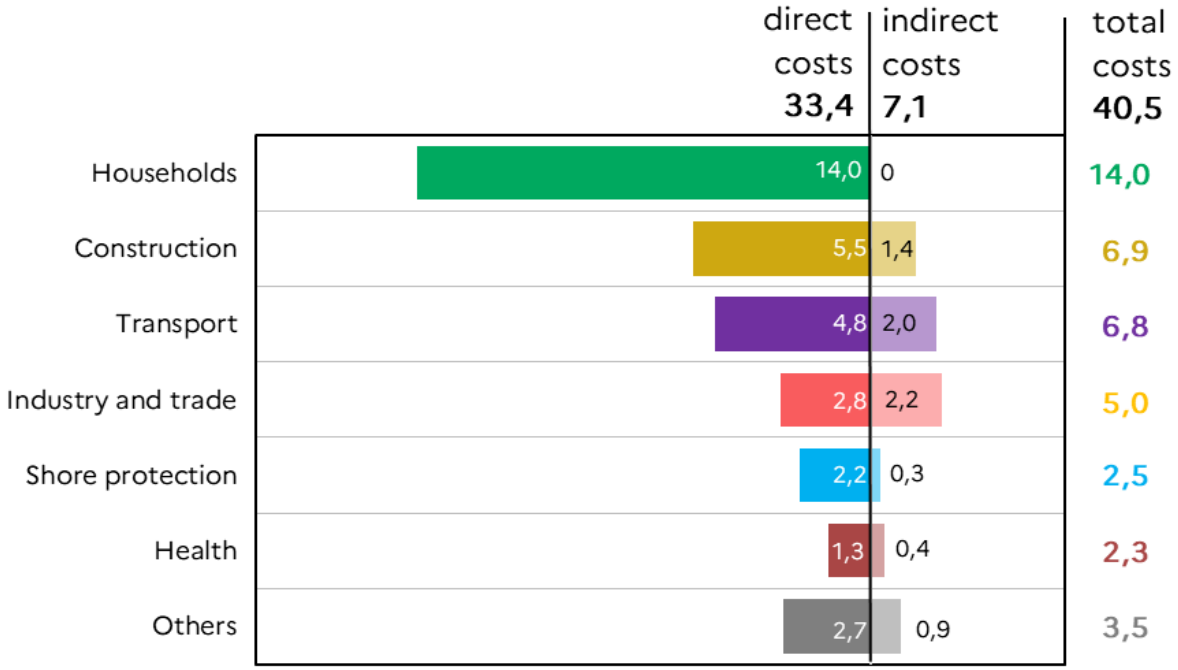
…to contribute to ecological planning



1. Key takeaways from the 2023 interim report

Limiting global climate change mitigates its deleterious economic, health and physical effects

July 2021 floods in Germany: distribution of direct and indirect monetary costs (in € billion)



- **The physical effects of climate change are diverse and are already being felt.** The main effects are increased frequency and intensity of extreme weather events (heat waves, droughts, extreme rainfall, storms, etc.) and damage to ecosystems.
- **Global warming affects the socio-economic sphere,** through productivity losses, disruption of value chains, destruction of natural and physical capital or mortality. Europe is already experiencing these consequences (*e.g.* drought in 2022 in France, floods in 2021 in Germany, 2024 in Spain, cyclone in Mayotte in 2024). According to the IPCC, a temperature rise of around +4°C in 2100 would reduce global GDP by 10% to 23%.
- **The economic effects of climate change for France are still insufficiently known, but would be significant** according to the Network for Greening the Financial System (NGFS v5).

Sources: Trenczek et al. (2022), "Damage from flash floods and floods in July 2021 in Germany" , BMWK "Costs of Climate Change" project ; NGFS (2023), Technical Documentation V4, Climate Scenarios Database.

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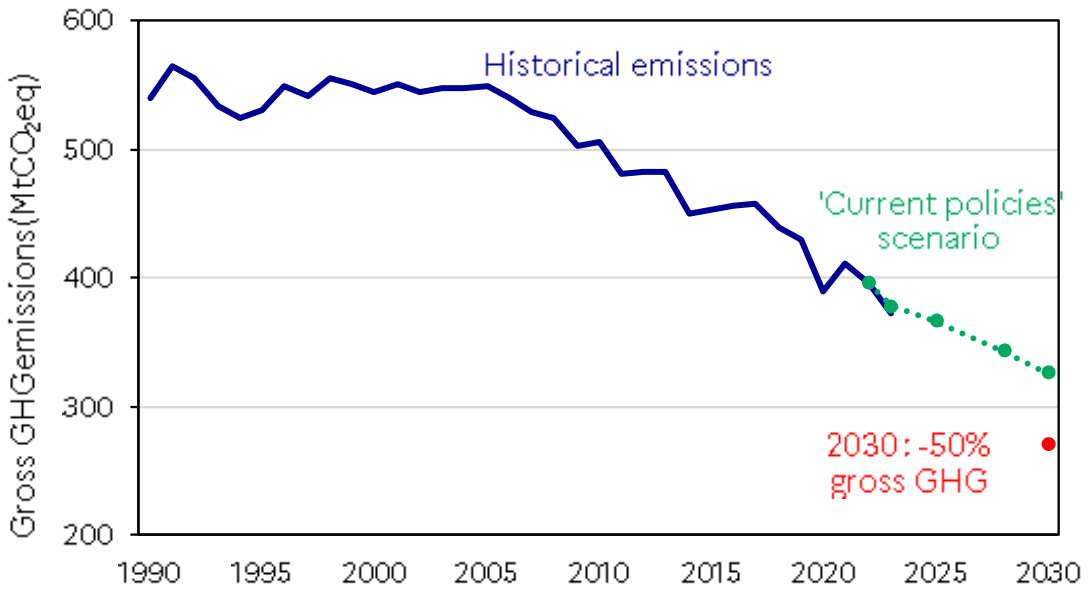
France is committed to achieving carbon neutrality by 2050, which requires an acceleration of efforts

France's gross GHG emissions and climate targets



To limit global warming to +1.5°C, France and the European Union have made ambitious commitments to reduce their greenhouse gas emissions:

- Gross emissions must decrease by 50% in 2030 compared to 1990 – or 55% in net emissions.
- Carbon neutrality must be achieved by 2050.

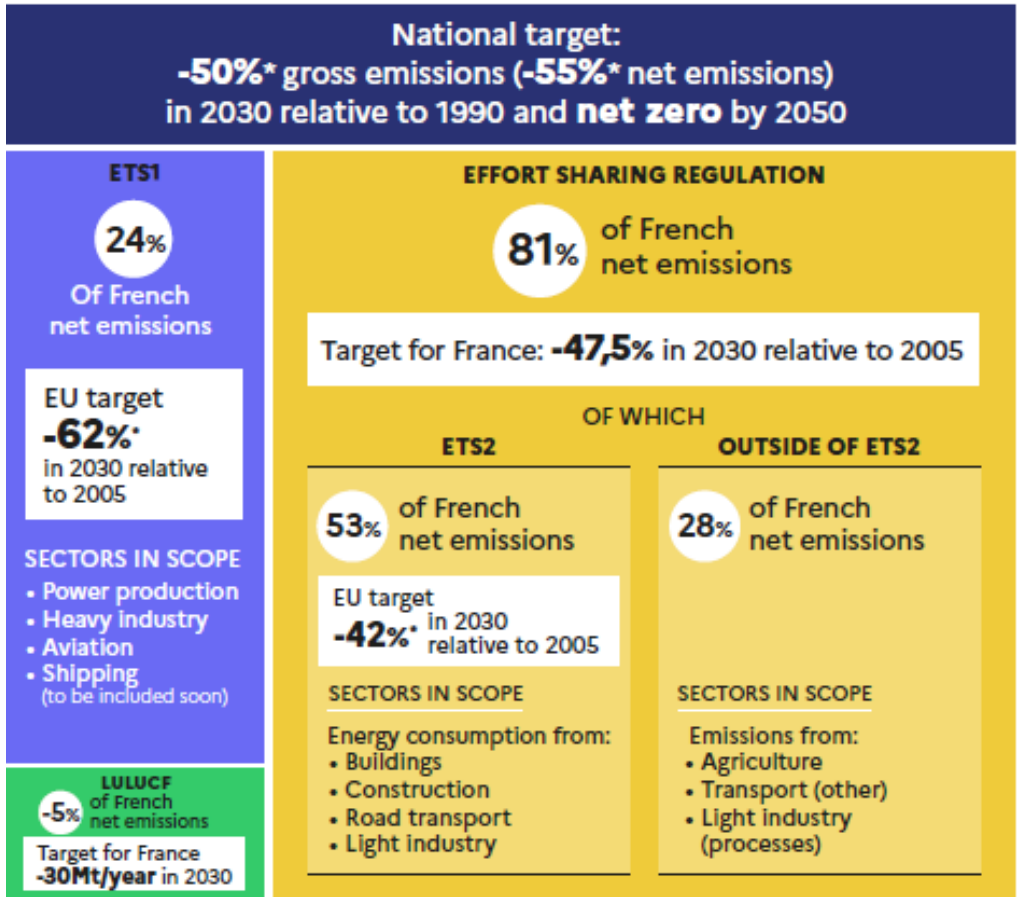
Achieving these goals requires an amplification of decarbonization efforts:

- The 2030 emissions reduction target requires doubling the rate of emissions reduction compared to that observed between 2019 and 2022.
- Some recent developments are encouraging, such as the rapid reduction in emissions observed between 2022 and 2023, but at least a third of which would be due to cyclical factors, according to the High Council for Climate.
- Achieving carbon neutrality by 2050 will require continued efforts after 2030. It is made more difficult by the recent degradation of natural carbon sinks, which would continue by 2050 according to scientific projections.

The SNBC3 project, the public consultation of which ended on 16/12/2024, **aims to break down this trajectory in a sectoral manner and to provide indications for 2050.**

Sources : CITEPA and SDES; SGPE
Notes : AME 2024 corresponds to the emissions scenario " with existing measures » of the SNBC-3 project in consultation; it integrates all the measures adopted until the end of 2023. The emissions figures presented correspond t net emissions (from the absorption of carbon sinks).

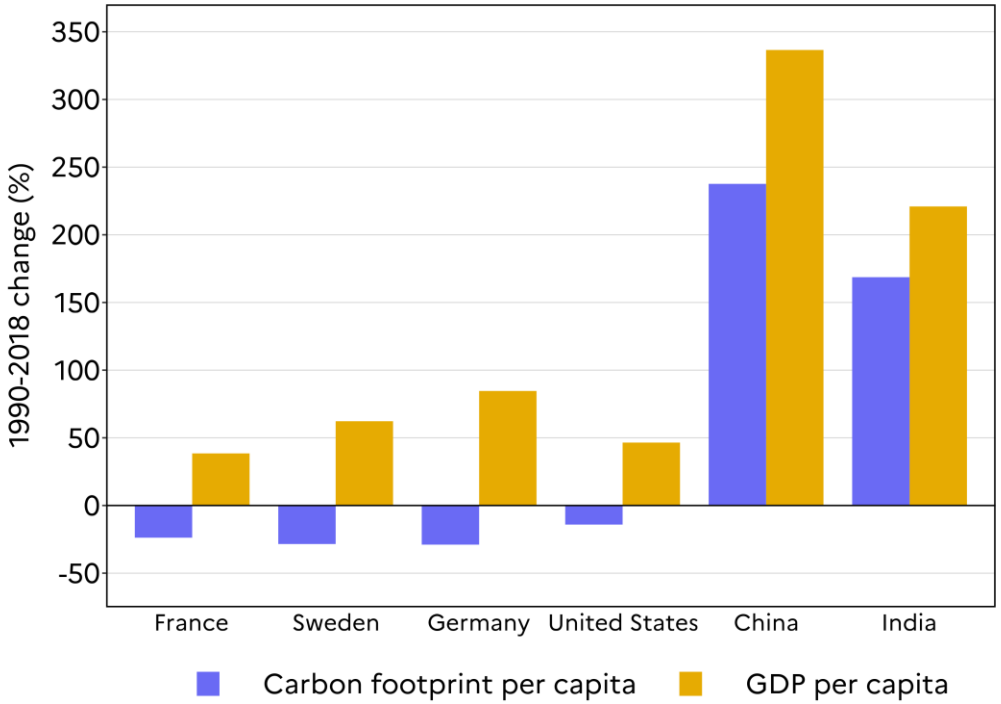
France has set ambitious targets, and European and French climate policies are already determining the direction of emissions reductions



Notes: These illustrative targets are based on the assumption that French emissions covered by a European emissions trading system (SEQE 1 and SEQE 2) evolve at the same rate as the EU average. The surface area of the boxes is proportional to the share of French net emissions covered by the instrument. The sectoral scope of the ETS presented here corresponds to European Directive 2023/959. Only air journeys made within the European Economic Area are covered by SEQE 1. The objective of capturing 30 Mt CO_2 eq /year by natural carbon sinks, provisional, is calculated according to recent estimates of their absorption capacity.

Decoupling between economic growth and emissions is possible, it must be strengthened to achieve carbon neutrality

Evolution of the carbon footprint and GDP per capita between 1990 and 2018



Decarbonisation is compatible with growth if GHG emissions are sufficiently decoupled from economic activity:

- Decoupling has been initiated by France and other advanced countries…
- … yet at an insufficient pace to achieve carbon neutrality

During the transition, economic growth could however slow down, temporarily and moderately, due to the increase in costs that it induces *(see Macroeconomic Analysis Chapter)* .

Well-designed climate policies could reduce the costs and maximise the benefits of the net zero transition.

Sources: OurWorldInData (2022); Pisani-Ferry J. and Mahfouz S. (2023) "The economic impacts of climate action", France Stratégie report.
Notes: countries are ordered by increasing variation in the carbon intensity of GDP over the period 1990-2018. France is the country whose carbon intensity has decreased the most over the period 1990-2018.

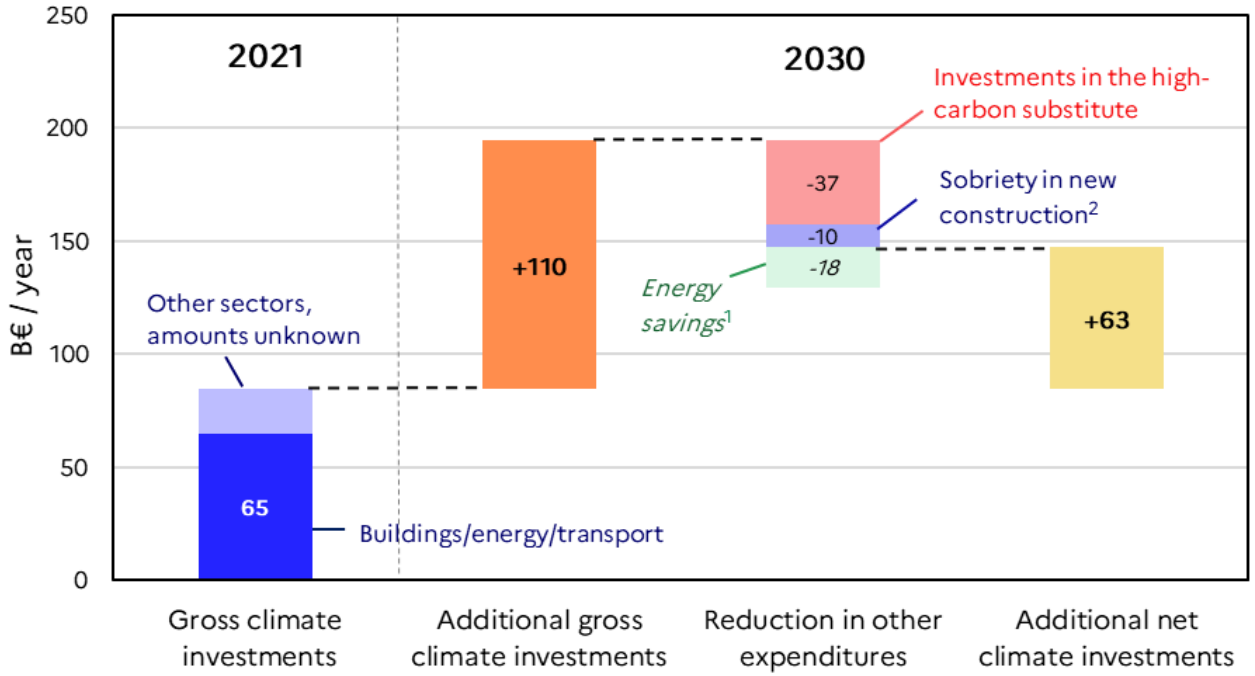
In the long term, climate change mitigation policies induce benefits compared to a scenario of inaction

- **Adverse effects of climate change avoided** *(see Macroeconomic Analysis Chapter)*
- **Productivity gains from low-carbon technologies** *(see Macroeconomic Analysis Chapter)*
- **Improvement of several dimensions of security of supply and energy sovereignty, because in France, fossil products are essentially imported** *(cf. Energy Chapter)*:
  - Reduction of this item in the trade balance (imports of fossil products represented €75 billion in 2023)
  - Reducing the economy's exposure to price shocks determined on global markets.
- Possible improvement in **well-being** , especially **health** *(cf. Sectoral Chapters)*
- **The resilience of French industrial activity during the 2022-2023 energy crisis shows the ability of certain companies to adapt to increases in energy prices**, through low-carbon and energy efficiency investments and the adoption of energy conservation practices.

Insee (2022), “Companies facing rising energy prices: contrasting situations and reactions”, Economic report of December 2022.

The mitigation trajectory planned by the national long-term decarbonisation strategy implies a significant increase in climate investments, partly offset by the reduction in other expenditures

Additional climate investment needs in the French national long-term decarbonisation strategy (AMS, 2023)



- **The need for additional low-carbon investments is estimated at €110 billion by 2030, compared to 2021** (Working document, Gourmand , 2024)
- **The order of magnitude is consistent with the conclusions from the Jean Pisani-Ferry/Selma Mahfouz mission,** and this study covers more sectors
- **The first Multi-annual Strategy for Financing the Ecological Transition (SPAFTE) published in October 2024 presents an assessment of low-carbon investments in France and provides an overview of the financing provided by all players in the economy.**
- **Achieving the objectives requires effective mobilization of all public and private stakeholders,** to ensure partnership financing of the transition.

Sources : Gourmand, 2024 , calculations French Treasury
Notes : 1. Energy savings compared to 2021 caused by the substitution of electric cars for thermal cars (excluding sobriety behaviors) and the renovation of buildings; 2. Sobriety in new construction in the AMS scenario reduces climate investments linked to new construction compared to 2021; 3. Ecological planning scope; These amounts are based on estimates by the authors on the basis of the first technical round of SNBC-3 for road transport and residential, as well as by the General Directorate of Enterprises for industry. They are supplemented by an estimate by the authors on the cost of forest renewal and, for the remaining sectors, by a literature review of the investment needs associated with the decarbonization trajectory planned by SNBC-2 and SNBC-3.

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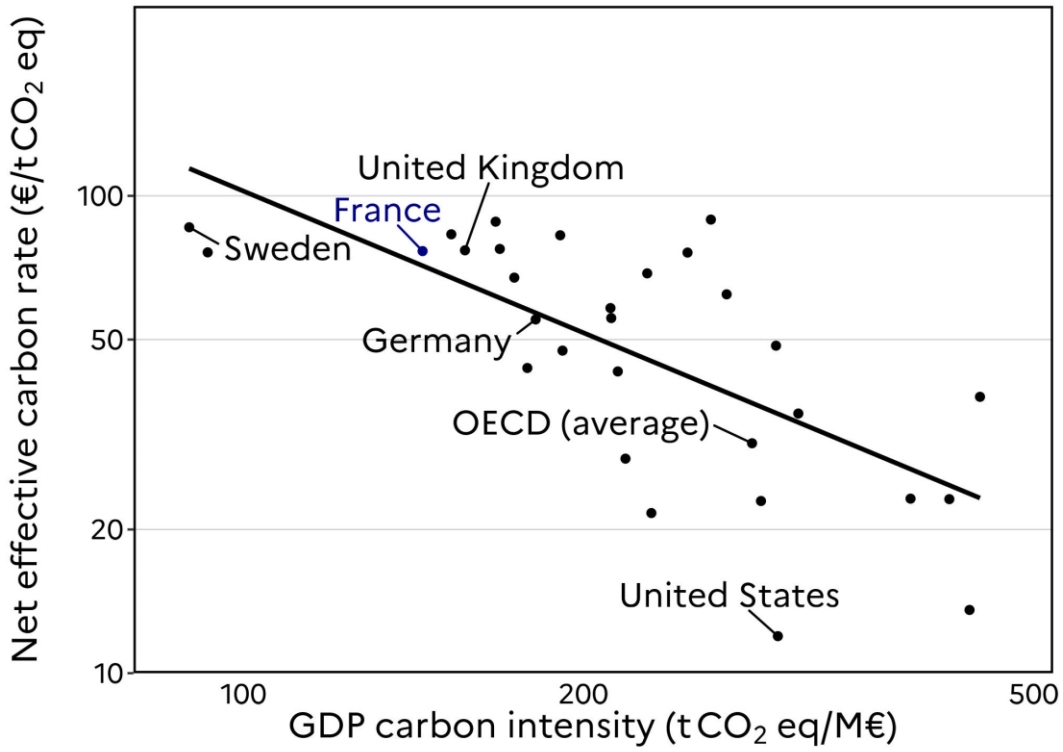
Putting a price on carbon is a powerful tool to decarbonize the economy at low cost, but has distributive effects that risk reducing its acceptability in the absence of support measures.

Global net effective carbon pricing and carbon intensity of GDP, 2018



Carbon pricing is a powerful tool because it:

- **has empirically proven effectiveness** in reducing GHG emissions (*eg* EU-ETS, Sweden);
- is positively correlated with lower **carbon intensity of GDP;**
- triggers **cost-effective decarbonization actions**, without their costs needing to be known in advance by the public authorities;
- stimulates low-carbon **innovation;**
- generates **public revenue** that can be used (without this being the primary objective).

However, carbon pricing has **distributive effects** on households and raises issues of acceptability.

Uneven levels of carbon pricing around the world also create a risk of **carbon leakage** for companies exposed to international trade.

Sources : OECD; Blanchard, Olivier, Christian Gollier , and Jean Tirole (2023) "The portfolio of economic policies needed to fight climate change" Annual Review of Economics.

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Decarbonisation must overcome several market and behavioral failures as well as other barriers, which calls for complementary instruments to carbon pricing

Several market and behavioral failures as well as other barriers stand in the way of decarbonisation…	…Public authorities have reacted and put in place several instruments to overcome them (examples)
Underpricing of climate externalities	**Carbon pricing** *See above*
Risk of carbon leakage	**European Carbon Border Adjustment Mechanism (CBAM)**
Obstacles to low-carbon innovation: knowledge spillovers, path dependence, long time horizon with high risk, coordination between players	**Subsidies for low-carbon innovation** : France 2030 program (€54 billion until 2030), European Funds (€67 billion for the EU between 2021 and 2027)
Information asymmetry	**Information:** Energy Performance Certificate
Behavioral biases : inattention to energy prices, household myopia, non-rational expectations	
Financing constraints	**Guarantees and risk sharing schemes:** green zero-interest rate loan, Bpifrance, concessional loans

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The following analytical framework ("ABCDE" in French) would be useful to design climate mitigation policies effectively, in particular by taking into account abatement costs

Example: a subsidy for switching from an oil boiler to a heat pump

Criteria	Principle	Example: subsidy to support the switch from oil boilers to heat pumps
Abatement	What are the abatement costs and the abatement potential of the encouraged action?	Abatement cost : additional cost incurred due to converting an oil boiler to a heat pump, per tCO2 avoided Abatement potential : all emissions avoided by converting an oil boiler to a heat pump
Balancing	Does the policy increase the use of limited resources which are essential to the net zero transition?	Power : additional pressures on the power system, particularly during peak consumption in winter Biomass : no direct impact
Consistency	Is the policy consistent with other policy instruments already in place ?	Pre-existing or planned measures encouraging the switch from oil boilers to heat pumps: • Market-based instruments: upfront subsidies for heat pumps, white certificates, fuel excise tax • Regulations: ban on the purchase of new oil boilers, ban on the rental of energy-inefficient homes
Driving effect	Will the policy actually drive the expected actions?	Risk of windfall effects: market conditions could lead households to invest without being subsidised. To deal with this, the subsidy could primarily target low-income households for whom the triggering effect of public spending would be higher, since they are more financially constrained.
indirect Effects	What are the other induced effects and are they desirable?	Risk of technological lock-in: the scheme may discourage a future connection to a district heating network in dense areas. Other indirect socioeconomic effects : distributive effects, reduction in energy poverty, reduction in pollution, summer thermal comfort, trade balance effects…

2. Macroeconomic effects of the net zero transition

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Analysis of the macroeconomic implications of the transition to carbon neutrality

Analysis framework & Modeled transmission channels

- **Two analyses developed** :

  France: Analysis of the economic effects of the transition to carbon neutrality, based on the Mésange model;

  EU and rest of the world: Analysis of the economic effects of the energy transition for different levels of action and international coordination, using the Oxford Economics model.
- Central hypothesis of an **orderly and coordinated transition** at the global level to limit the increase in the average temperature of the planet to well below 2°C compared to pre-industrial levels.
- Results on the effects of the **transition alone,** without taking into account the avoided damage linked to climate change. A perspective of the results is nevertheless proposed.
- International transition scenarios **do not model the productivity gains** that could be enabled by green R&D, economies of scale and learning, which are more important in a globally coordinated transition.

- At the macroeconomic level, **two transmission channels for the net zero transition** are modeled (see the conclusions of the report by Jean Pisani-Ferry and Selma Mahfouz):
  1. Increase in the relative cost of greenhouse gas (GHG) emissions;
  2. Triggering additional investments in decarbonization, net of carbon disinvestments.
- Based on the literature (NGFS, European Commission, OECD, IMF, etc.), a **transitory and moderate slowdown in economic growth is expected.** This slowdown must be seen in the light of the damage avoided.

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2.A. WHAT EFFECTS DOES THE TRANSITION TO CARBON NEUTRALITY HAVE ON FRENCH ACTIVITY?

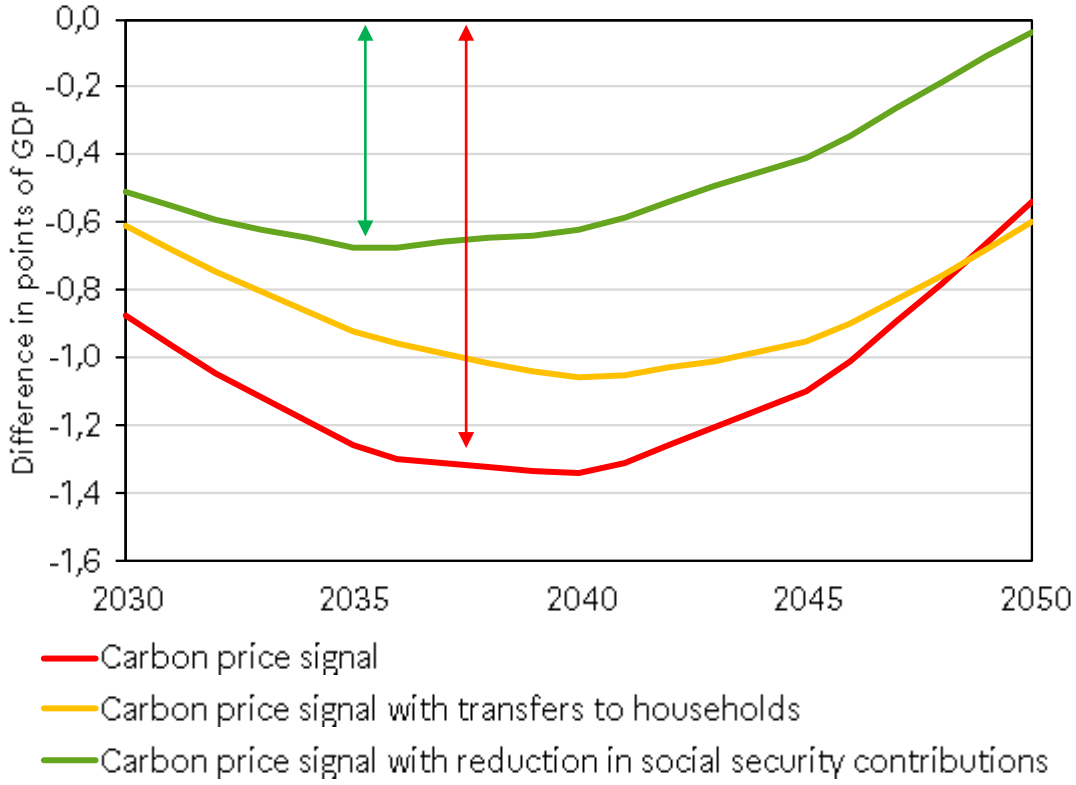
EVALUATION CARRIED OUT WITH THE MÉSANGE MODEL

1st channel: The increase in the relative cost of GHG emissions…

…would have a persistent negative impact on the activity

…which may be limited by the use of carbon revenues

Impact on French activity



Source: French Treasury calculations.

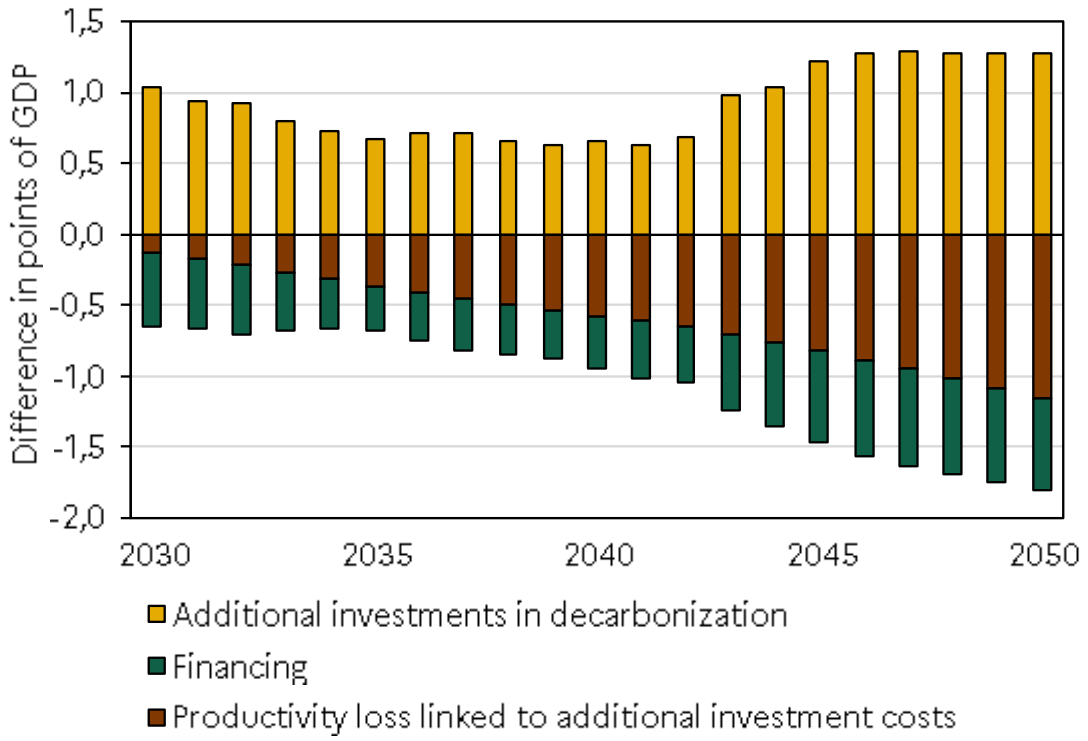
2nd channel: Additional investments in decarbonization…

… would have a positive impact on the activity

…which could be limited by financing needs…

…and by the loss of productivity linked to the additional cost of these investments compared to existing alternative technologies

Impact on French activity

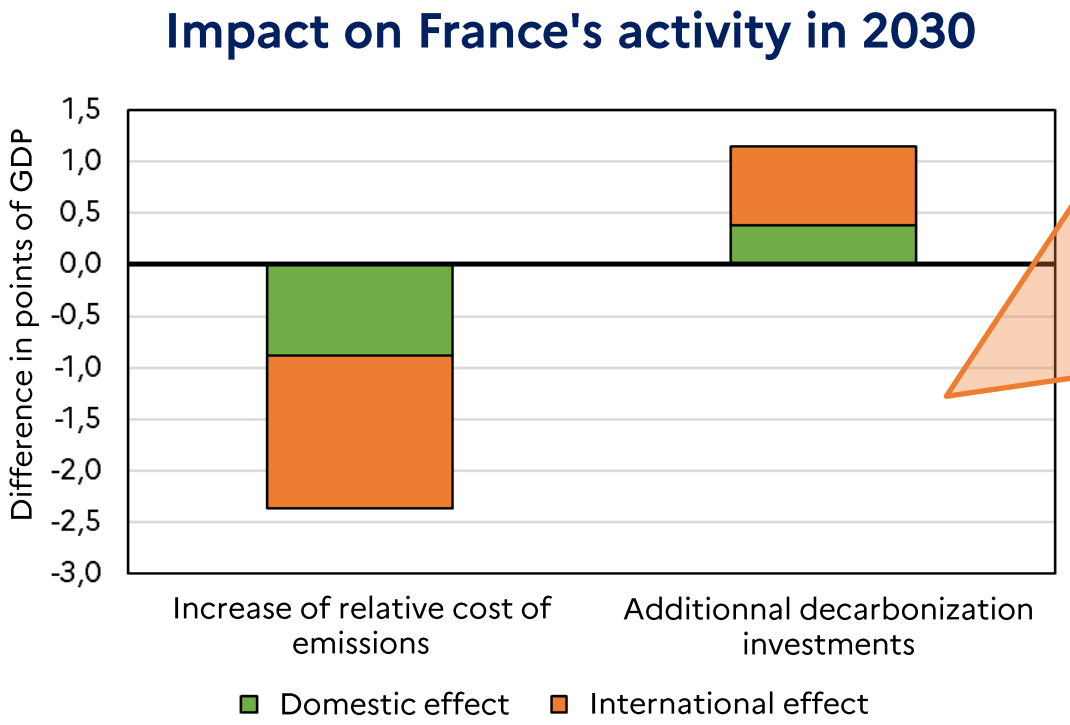


Source: French Treasury calculations.

Taking into account the international environment…

… amplifies the macroeconomic effects of the transition to carbon neutrality in France

according to the same two transmission channels as previously (carbon price and decarbonization investments)



France being an economy open to the rest of the world, the economic impacts of the transition in the rest of the world will also affect it via economic, commercial and financial interconnections.

Source: French Treasury calculations.

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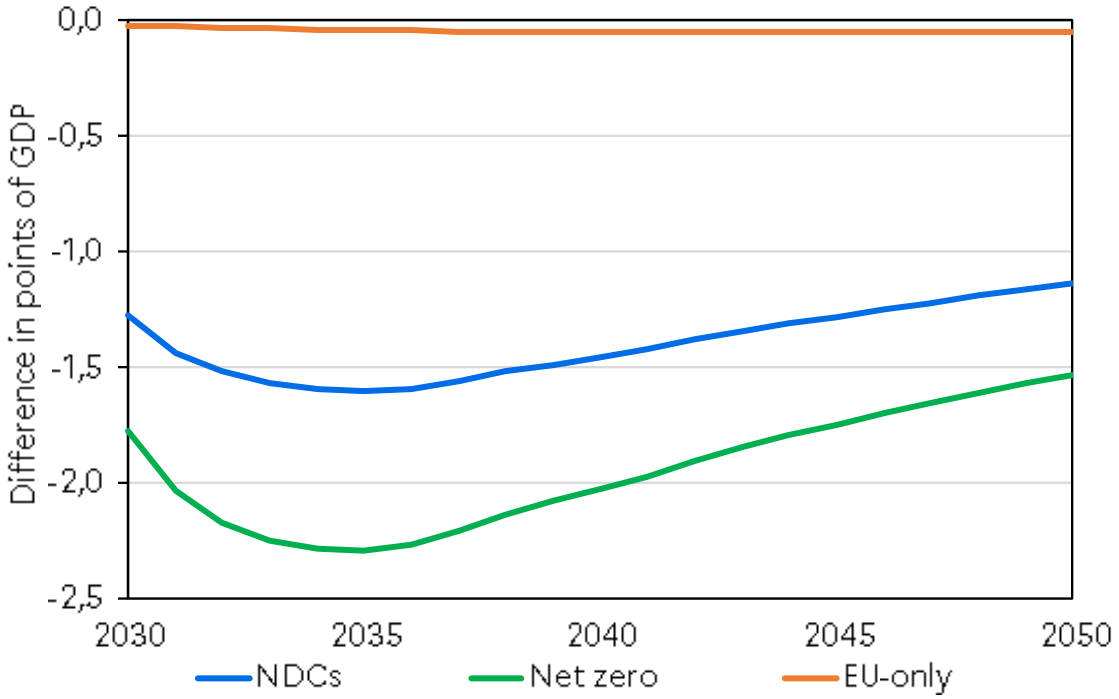
2.B. WHAT ARE THE CONSEQUENCES OF THE ENERGY TRANSITION IN THE EUROPEAN UNION AND IN THE WORLD DEPENDING ON THE LEVEL OF ACTION AND COORDINATION?

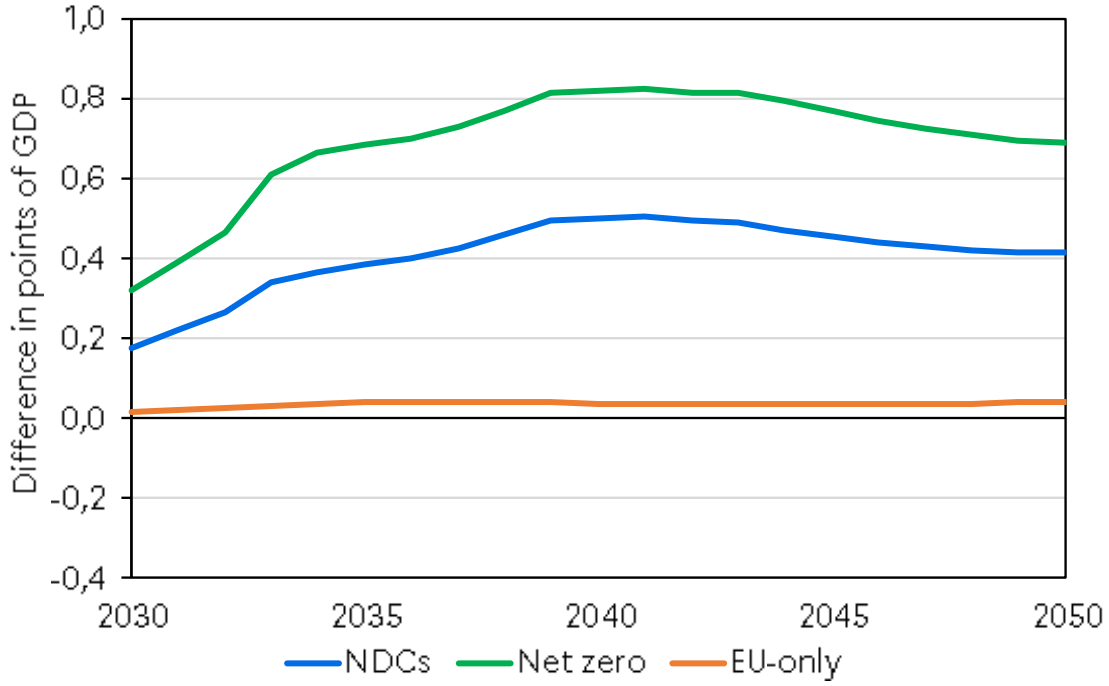
EVALUATION CARRIED OUT WITH THE OXFORD ECONOMICS MACRO-INTERNATIONAL MODEL USING DATA FROM THE INTERNATIONAL ENERGY AGENCY

The energy transition in the world would have a limited macroeconomic cost

Effect on global GDP of an increase in the price of GHG emissions for different transition scenarios, without recycling of revenues



Effect on global GDP of an investment shock financed by households for different transition scenarios



Source: IEA; French Treasury calculations. Scenarios: NZ = net zero at global level in 2050; NDC = emission reductions announced by countries at the global level; EU-Only: only the EU reaches net zero and the rest of the world follows current climate policies. All estimations are expressed in difference to a current policies scenario.

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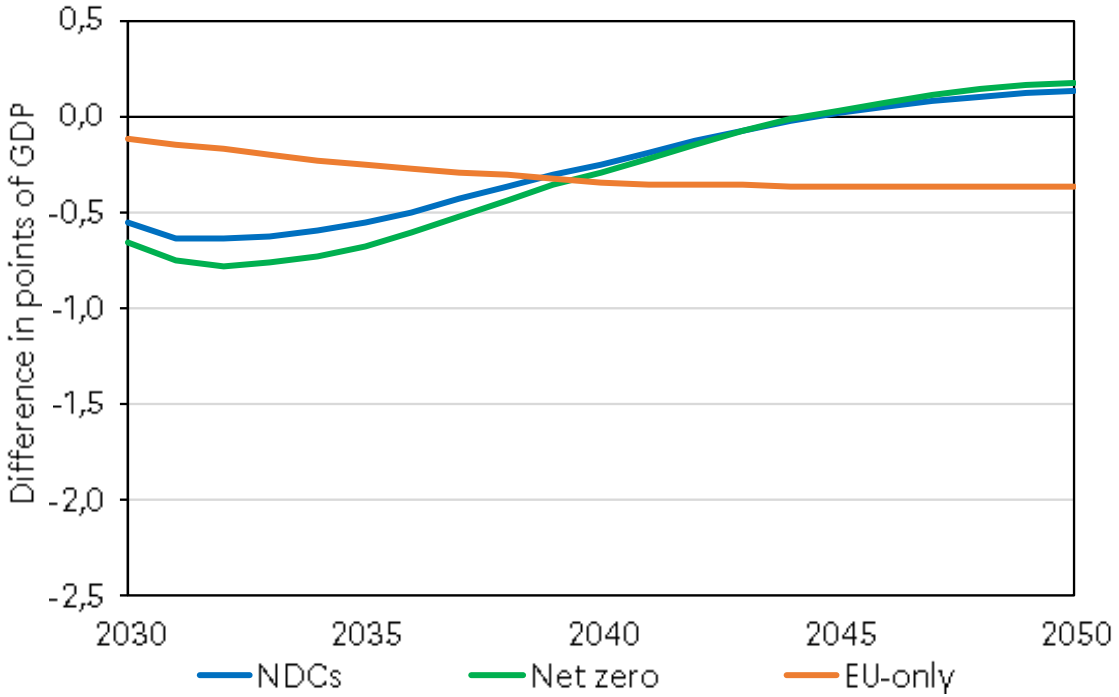
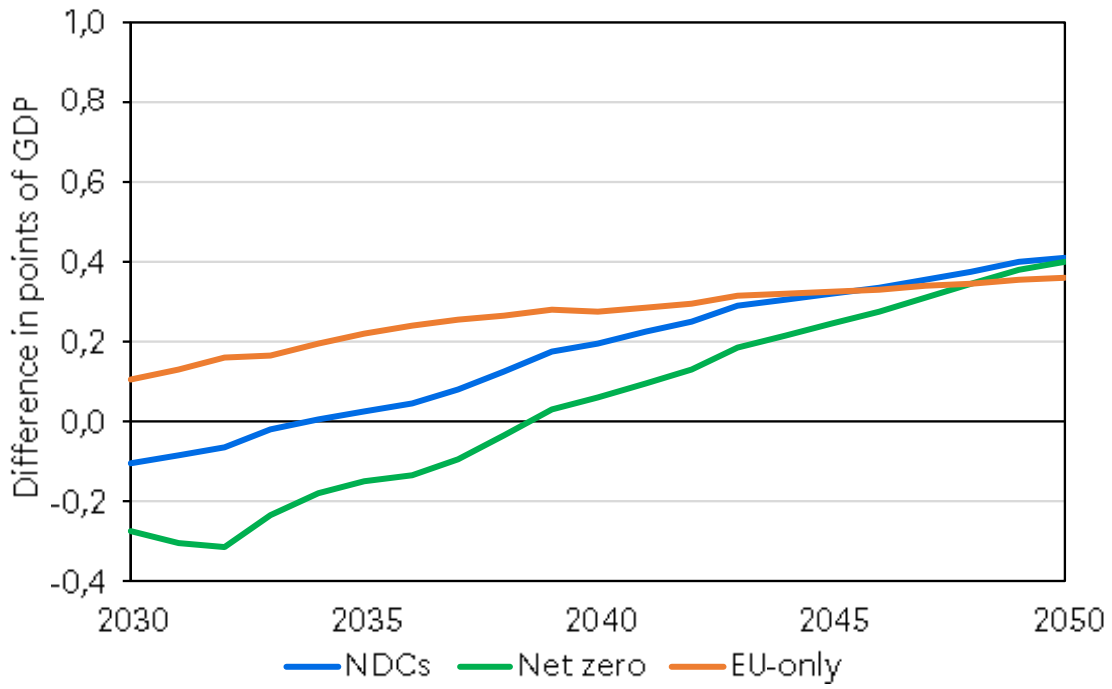
International coordination helps reduce the cost of the energy transition in Europe in the long term

Effect on the EU GDP of an increase in the price of GHG emissions for different transition scenarios, without recycling of revenues



Effect on the EU GDP of an investment shock financed by households for different transition scenarios



Source: IEA; French Treasury calculations. Scenarios: NZ = net zero at global level in 2050; NDC = emission reductions announced by countries at the global level; EU-Only: only the EU reaches net zero and the rest of the world follows current climate policies. All estimations are expressed in difference to a current policies scenario.

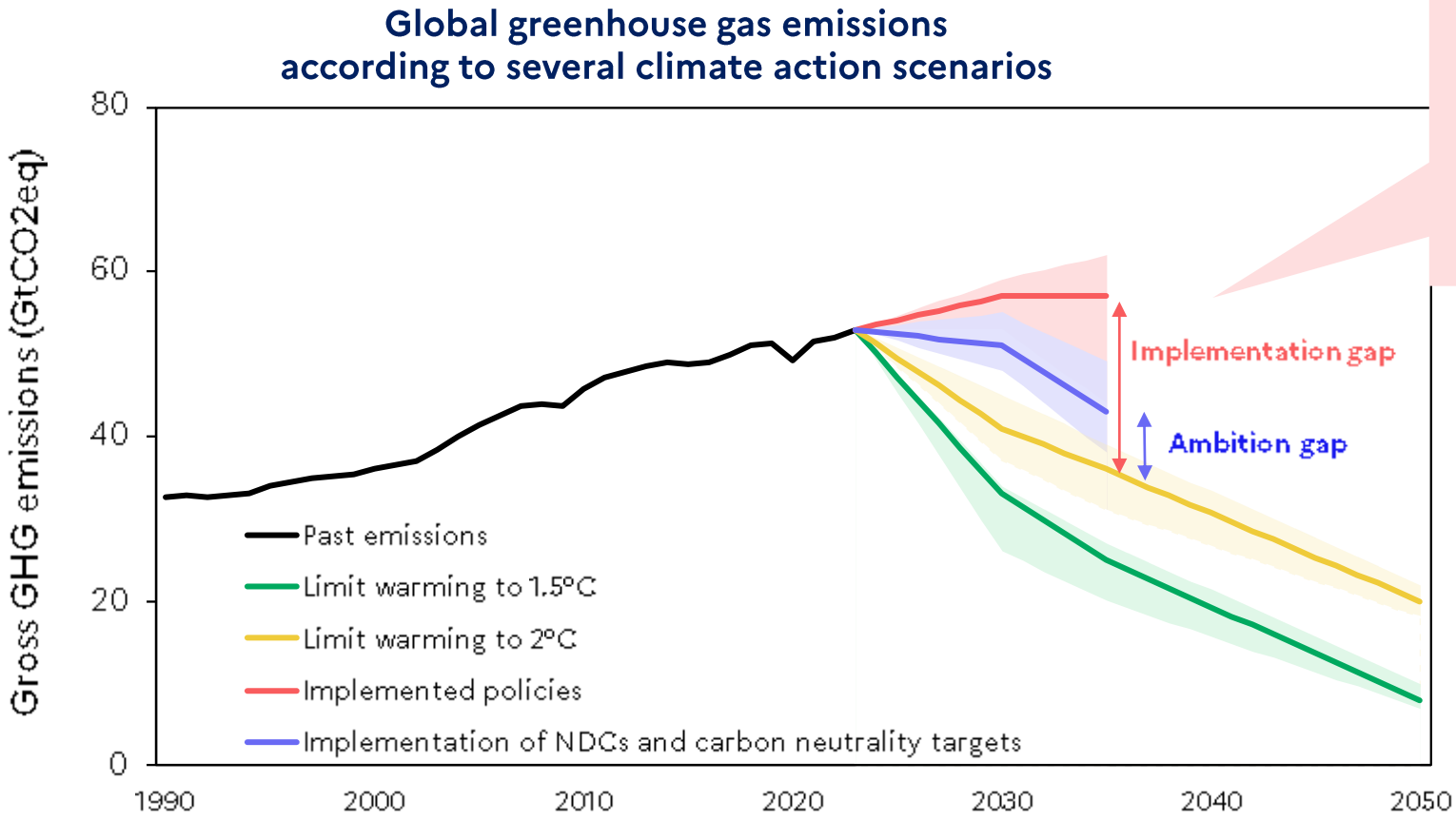
Summary of the results of these two analyses

Scenario	Region	Carbon price shock without use of carbon revenues		Carbon price shock with transfer to households/reduction in social security contributions		Investment shock, financed		Climate change damage avoided (by 2050) NGFS Source		
		2030	2050	2030	2050	2030	2050	5th	Median	95th
Transition to carbon neutrality	France (excluding international coverage)	-0.9	-0.5	-0.6/-0.5	-0.6/0.0	+0.4	-0.5	+5	+6	+7
Energy transition	EU	-0.7	+0.2	-0.2/-0.7	0.0/+0.2	-0.2	+0.4	-1	+6	+15
	World	-1.8	-1.5	-1.2/-1.8	-1.8/ -1.4	+0.4	+0.7	2	+9	+18

Sources: French Treasury calculations (for mitigation); NGFS v5 (for avoided damage).

3. The net zero transition must be considered in a global context

The net zero transition must be considered in a global context, because GHG emissions are a global negative externality

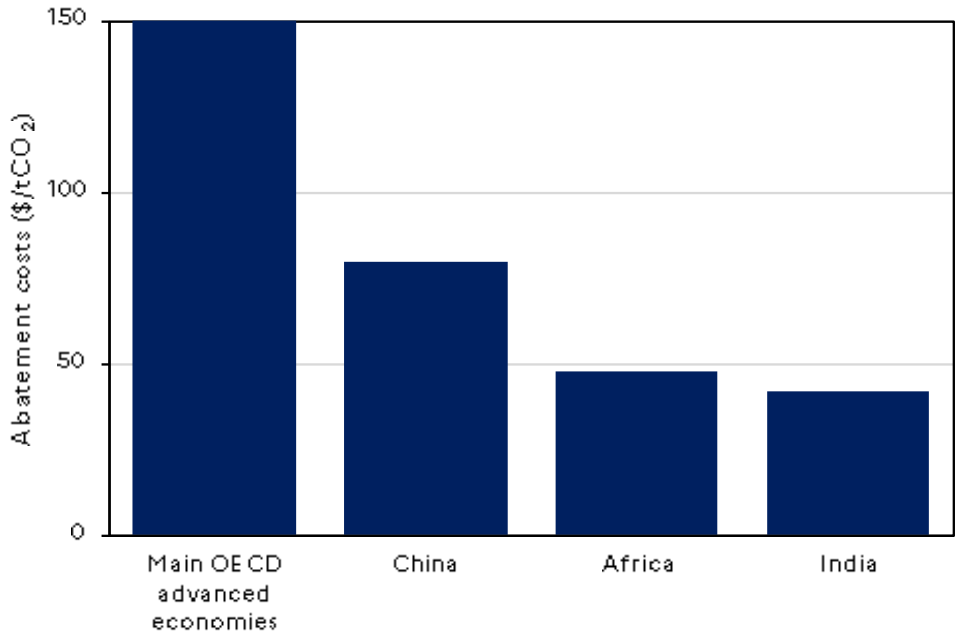


Current climate policies are insufficient to align with the decarbonization trajectory compatible with the Paris Agreement

Source : United Nations Environment Programme (2024), "Emissions Gap Report 2024 » / IMF.

The marginal cost of reducing emissions appears to be lower in developing economies than in developed ones; but all countries must be on a net zero trajectory

Marginal cost of reducing emissions in different countries

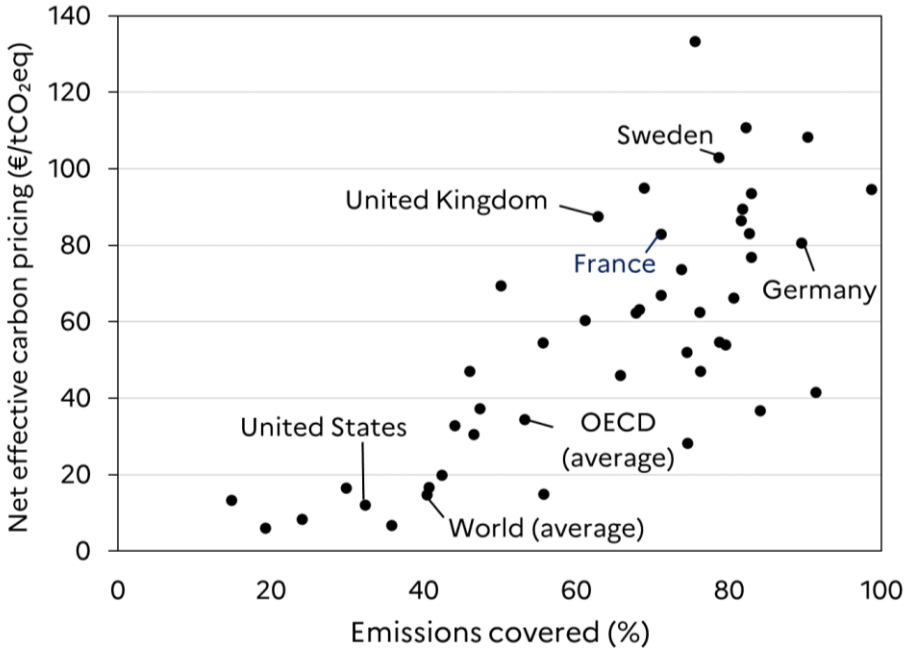


- The **marginal cost of reducing emissions appears to be lower in developing economies** than in advanced economies.
- **Climate finance**, to which France contributes, already makes it possible to finance low-cost emission reductions in developing countries.
- **The costs of complete decarbonization, expected by 2050 for most advanced economies, are highly uncertain**. They will depend on the availability of carbon sinks, the cost of negative emissions, and the amount of residual emissions.

Sources: IMF, CPAT model.

International coordination is essential to mitigate the costs of the transition and limit the risks of carbon leakage

Net effective carbon pricing in OECD countries, 2021



- **Coordination is essential because economies are integrated,** including through trade and capital flows, which impacts decarbonization efforts. Coordination helps limit carbon leakage and reduce the costs of decarbonization.
- **Carbon pricing is still heterogeneous across regions of the world** (see chart)**, which leads to risks of carbon leakage**. In the absence of a global carbon price, differentiated prices by country or geographical area coupled with the implementation, in the EU, of the carbon border adjustment mechanism are **relevant climate policy instruments.**

Source: OECD.

4. The challenges of the net zero transition for public finances

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Climate change and the net zero transition will have implications for public finances, which will depend on policies implemented

Climate change mitigation policies

- Additional public investments or decarbonisation subsidies
- Carbon tax revenue
- Reduction in fuel excise tax revenues

Physical effects of climate change

- Cost-sharing schemes with companies and households (*e.g.*, compensations for victims after extreme weather events)
- Damage to state-owned assets

Adaptation policies

- Public spending on reactive adaptation (*e.g.*, renovation of public buildings to deal with rising summer temperature) and preventive adaptation (*e.g.*, investing in infrastructure to prevent damage from natural disasters)

The policy mix will affect both the total costs of decarbonisation and the way they are shared. In particular, it will determine the extent to which public finances are affected by decarbonisation.

Direct effects

Primary balance

Overall effect on public expenditures and revenues

Indirect effects

Macroeconomic variables

Overall effect on macroeconomic variables (GDP, inflation, interest rates)

Public debt

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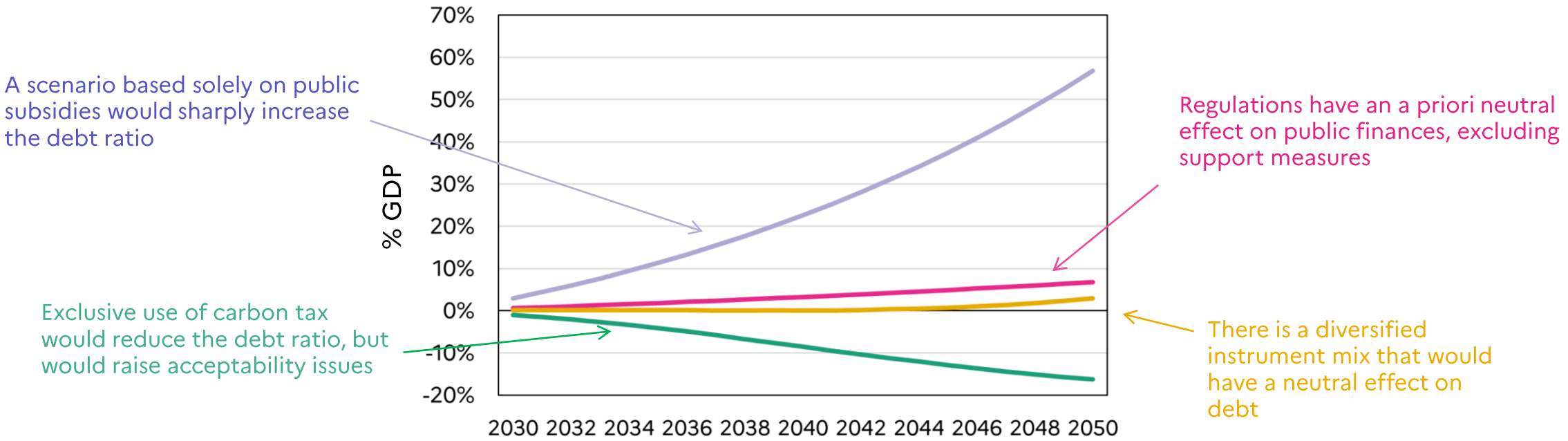
A transition led with a diversified combination of instruments, increasingly utilizing carbon pricing, could have a limited effect on public debt, despite the erosion of energy excise revenues

Illustrative scenarios of decarbonization instruments (carbon tax-led transition, subsidies, regulations or a combination of these instruments) and effects on the debt-to-GDP ratio compared to a business-as-usual scenario.

Evolution of the debt-to-GDP ratio relatively to the counterfactual scenario



Source: French Treasury calculations.
Notes: This illustrative modelling has several limitations, including the failure to take into account the differentiated macroeconomic effects of decarbonization instruments.

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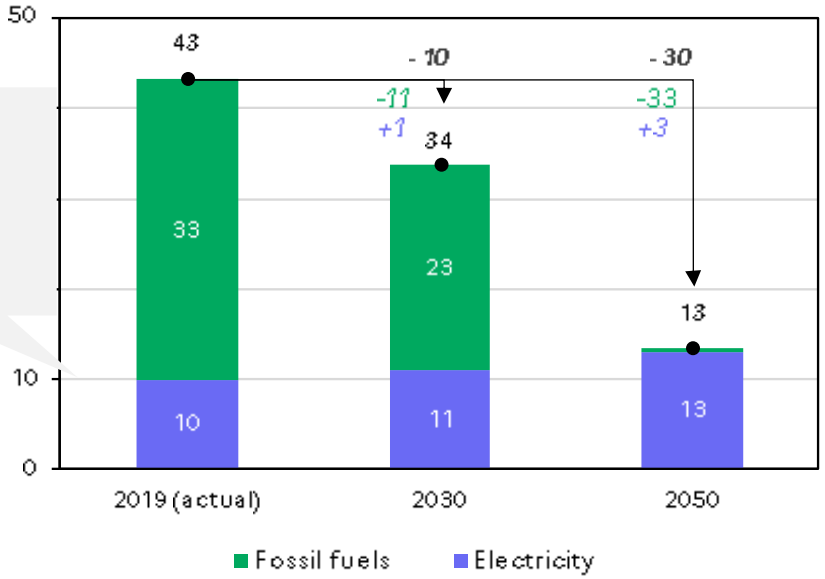
At unchanged tax rates, net excise tax revenues on energy would erode by around €10 billion in 2030 and €30 billion in 2050 in a scenario compatible with carbon neutrality.

The decarbonization of the economy implies a gradual reduction in energy excise revenues, in particular due to the electrification of uses, via a rate effect (electricity is currently less taxed than fossil fuels) and a base effect (energy efficiency gains)

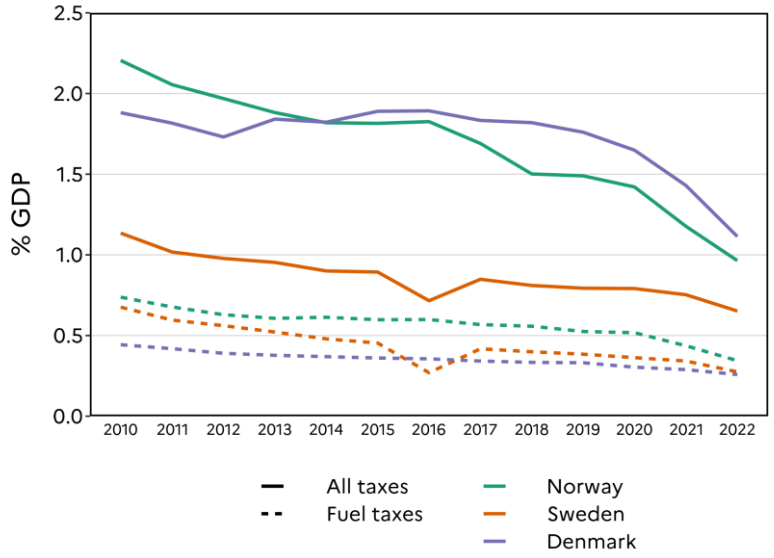
Update from 2023 interim report

Energy excise revenues in the AMS scenario of the preparatory work of the SNBC3 [1], at constant taxation (all sectors)



The electrification of road vehicles plays an important role in the loss of fossil fuel excise duties. Excise tax duties from road fuels amounted to 1.2% of the French GDP in 2020.

Evolution of tax revenues from road transport in Scandinavian countries



Scandinavian countries, where a large proportion of road vehicles are electrified, are facing a **loss of revenue from taxes on road fuels as well as other road taxes** (although more research is needed to establish whether the effect is causal)

Sources: DGEC for SNBC trajectories of consumption of petroleum products, natural gas and electricity; national data from Scandinavian countries; French Treasury calculations; European Commission (2022): " Taxation trends in the European Union"
Sources: Ministry of Ecological Transition for projected consumption of petroleum products, natural gas and electricity; national data from Scandinavian countries; French Treasury; European Commission (2022): " Taxation trends in the European Union"
Notes: energy consumption projections underlying the long-term national decarbonisation strategy are currently being reviewed. Only final metropolitan energy consumption is taken into account. Projections use 2019 net weighted average fuel excise tax rates;; These estimates do not take into account the reallocation of consumption and activity, which could also have effects on public revenue.

5. Private finance and decarbonization of the French economy

Ambitious climate policies, well-articulated with financial policies, are essential to mobilize the private sector in financing the transition

- The **mobilization of private finance** is essential for the success of the transition to carbon neutrality and the financing of decarbonization investment needs (SPAFTE).
- **Climate policy instruments** (pricing, subsidies, regulations) help mobilize private finance by improving the private profitability of low-carbon activities, which nevertheless remains today lower than that of brown activities in several economic sectors.
- **A lack of information** on the sustainability of activities, the risk of **greenwashing**, and other barriers increase the cost of financing low-carbon activities.
- The consideration of **transition risks** (e.g. devaluation of fossil fuel "stranded assets") by the financial sector still appears imperfect and limited.
- The **European and French framework for sustainable finance**, **extra-financial reporting by non-financial companies**, and **regulations** on financial activities, particularly banking and insurance, aim to improve information, transparency, and confidence in sustainable and transition assets.

Overview of sustainable finance instruments

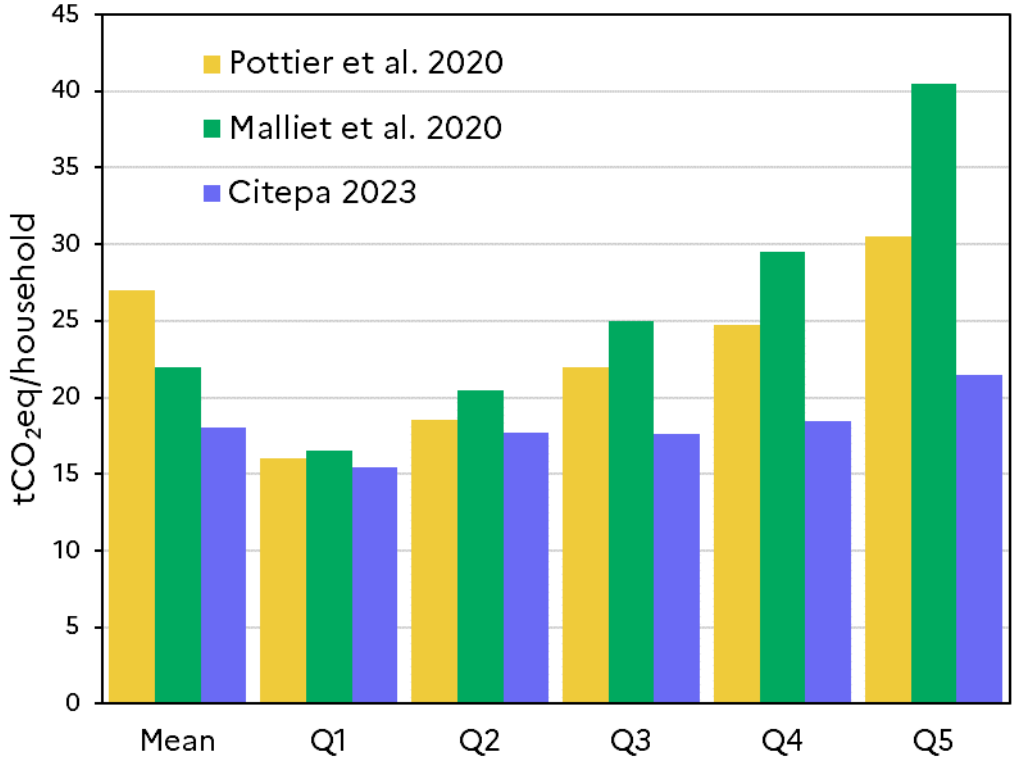
Objective	Instrument	Companies (all sectors)	Banks (in addition to cross-sectoral requirements)	Insurance (in addition to cross-sectoral requirements)
Information, transparency	Sustainable activities labels	Definition of the taxonomy of sustainable activities Defining labels according to common criteria: EU Paris-Aligned Benchmarks; EU Climate transition benchmark; EU Taxonomy-Aligning Benchmarks (TABs) Definition of national labels for savings products (including SRI and Greenfin)		
	Reporting of transition-enabled/aligned activities according to common standards	**Optional reporting** EU Paris-Aligned Benchmarks (EU PABs) EU Taxonomy-Aligning Benchmarks	**Mandatory reporting** Green Asset Ratio (GAR): share of the balance sheet exposed to activities meeting the taxonomy criteria. Book Taxonomy Alignment Ratio : completes the GAR for entities outside NFRD (Non Financial Reporting Directive) and CSRD.	
	Reporting of activities unfavorable to the transition	**Mandatory reporting,** CSRD, NFRD	**Mandatory reporting,** CRR3 .	
Risk assessment by supervisors	Risk assessment, stress tests		Climate stress tests, conducted both through bottom-up (by banking and insurance institutions) and top-down approach (ECB, Banque de France)	
Reducing transition risks	Transition plans	CS3D	CRR3, CRD6	Solvency 2
	Monitoring transition plans	CS3D	CRD6	In progress
	Reduction of systemic risks		CRD6	ORSA

Source: French Treasury.

6. Understand the differentiated impact of the transition on households to support them

The transition will have a differentiated impact on households depending on their characteristics (income, geographic location and others)

Carbon footprint of French households



- **The impact of the low-carbon transition on French households is heterogeneous.** It depends in particular on their carbon footprint and the possession of "brown capital" (emission-intensive cars, homes heated with fossil fuels).
- **The carbon footprint of French households increases with their income, but at a slower pace, making low-income households generally more vulnerable to the transition.**
  - Significant disparities within the same income decile are observed (notably related to the location of residence).
  - Methodological difficulties complicate the precise assessment of the carbon footprint and its variation with income.
- **The effects of the low-carbon transition crucially depend on the public policies that will be mobilized to implement the transition and support households:**
  - Carbon pricing would affect lower-income households more, in proportion to their income. However, targeted support measures can be introduced to assist lower-income households and improve the acceptability of the low-carbon transition.
  - Environmental and climate standards also have costs and distributive effects that need to be studied on a case-by-case basis.

Sources: Pottier et al (2020), Malliet et al (2020), Citepa (2023)

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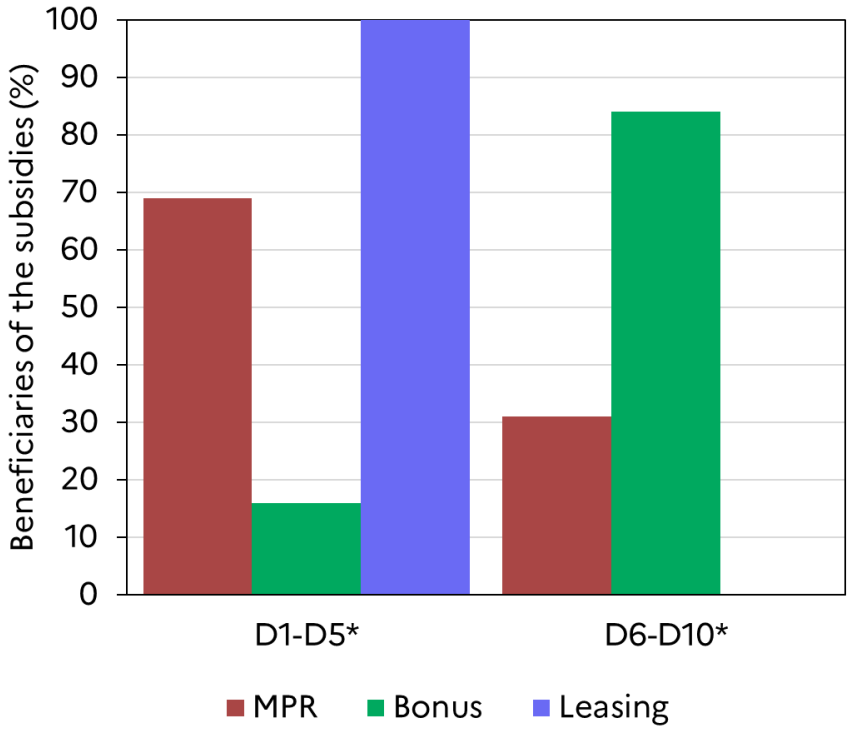
Transition subsidies support households, particularly low- and middle-income households, which represent a significant proportion of the beneficiaries of decarbonization subsidies

Distribution of aids according to household income



- **France has implemented subsidies to reduce the additional costs of low-carbon investments.** These include MaPrimeRénov energy renovation aids, the ecological bonus for purchasing electric vehicles and electric vehicle leasing.
- **These subsidies are increasingly targeted at low-income households :**
  - MaPrimeRénov, which supports households in their energy renovation projects, subsidizes more the households among the lowest 50% income bracket.
  - The amount of the ecological automobile bonus is increased for lower-income households and electric vehicle leasing helps support high mileage drivers among the 50% of the most modest households.
  - Overall, the share of households in this income bracket among the beneficiaries of these schemes has increased, and is expected to reach 35% in 2024.
- **Zero-interest loan schemes have also been deployed to address the financing constraints of households, particularly low-income ones, for making low-carbon investments** (energy renovation, electric vehicles).

Sources: (i) Bonus: ASP 2024. (ii) MPR: ANAH, First half of 2024. French Treasury calculations. The Very Modest and Modest profiles according to the ANAH categorization are grouped in D1-D5*.

Subsidies help reduce the payback period for household decarbonization actions

Payback period

	Purchase of an electric car for a high-mileage household in income deciles D6-D7	
	With subsidies	8 years old
	Without subsidies	13 years old
	Purchase of a heat pump for a household in income decile D5, initially heated with gas, in a 90m² house	
	With subsidies	8 years old
	Without subsidies	> 15 years

The duration of ownership after which operational savings exceed the additional initial purchase cost of the low-carbon investment (relatively to a fossil one – internal combustion car / gas boiler).

Source: French Treasury calculations. Main assumptions: Heat pump (€15k), gas boiler (€4k), electric car (€34k), thermal car (€20k).
Subsidies: scheme in effect until December 2024.

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An increase in carbon pricing by €60/tCO_2 would further reduce the payback period.

Payback period

			Reduction due to the carbon pricing increase
	Purchase of an electric car for a high-mileage household in income deciles D6-D7		
	With subsidies	8 years old	- 1 year
	Without subsidies	13 years old	
	Purchase of a heat pump for a household in income decile D5, initially heated with gas, in a 90m² house		
	With subsidies	8 years old	- 3 years
	Without subsidies	> 15 years	

Source: French Treasury calculations. Main assumptions: Heat pump (€15k), gas boiler (€4k), electric car (€34k), thermal car (€20k).
Subsidies: scheme in effect until December 2024.

7. The net zero transition will have significant impacts on jobs and skills

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Jobs can be considered brown or green depending on the activity of the company and the profession practiced

Principles of the approach adopted to classify jobs

Occupation \ Sector of activity	**Green activities (protect the environment or facilitate the transition)**	**Neutral activities**	**Brown activities (highly exposed to transition risk)**
Green professions (with a direct environmental purpose)	Core transition jobs (2.3% of salaried employment, e.g. architects and roofers in building thermal insulation)	Jobs that reduce the environmental footprint of a sector whose purpose is independent of the transition *(6.9% of salaried employment, e.g. engineers and technicians specializing in energy efficiency in low-emission industries)*	Jobs in sectors that may decline, but with similar opportunities in other sectors *(5.2% of salaried employment, e.g. support functions in a fossil industry)*
Greening professions (the evolution of their tasks and skills enables the transition)			
Neutral professions	« Strategic » jobs: they enable the transition but their tasks and skills remain unchanged *(2.3% of salaried employment, e.g. welders for the installation of renewable energy production systems)*	Jobs that are a priori little affected by the transition, but may participate in reallocations *(79.3% of salaried employment)*	
Brown professions (staff very concentrated in brown activities)	Jobs whose numbers are not initially threatened by the transition, but whose tasks, skills or working conditions will need to evolve to minimize their environmental impact *(1.0% of salaried employment, e.g. mechanics specializing in automobile maintenance-upkeep within a neutral activity)*		Jobs highly exposed to transition risk *(3.0% of salaried employment, e.g. a plane pilot)*

Source: All Employees administrative database for 2021, French national statistics Institute (Insee), French Treasury calculations.

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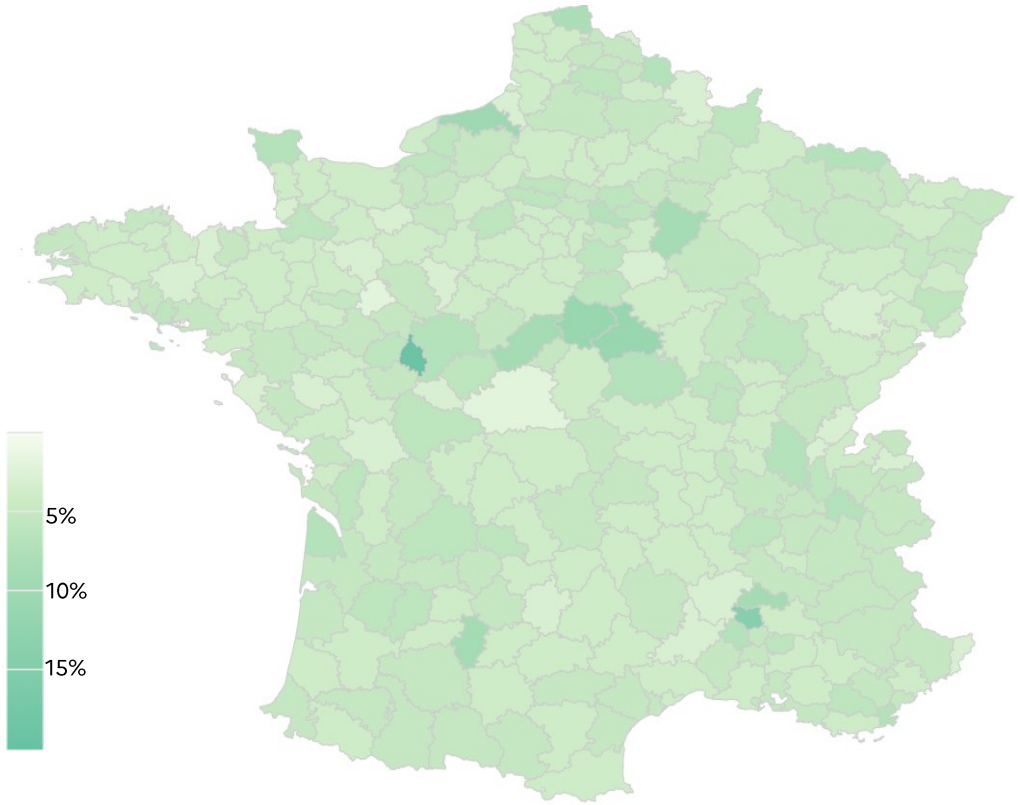
The number of green jobs, which already represent 12% of jobs, is set to grow with the low-carbon transition

Share of green activities in local salaried employment



- The structural transformation of the economy will lead to job reallocations, with fewer brown jobs and more green jobs. **The extent of the reallocations** is however very uncertain.
- In 2021, **12% of employees contributed to the ecological transition** .
- Climate policies are the main driver of green job creation.
- An estimation of ~300,000 green jobs were created between 2016 and 2021, at a rate twice that of the overall economy.
- The **attractiveness of green jobs** is essential for this trend to accelerate.

Source: All Employees administrative database for 2021, French national statistics Institute (Insee), French Treasury calculations.

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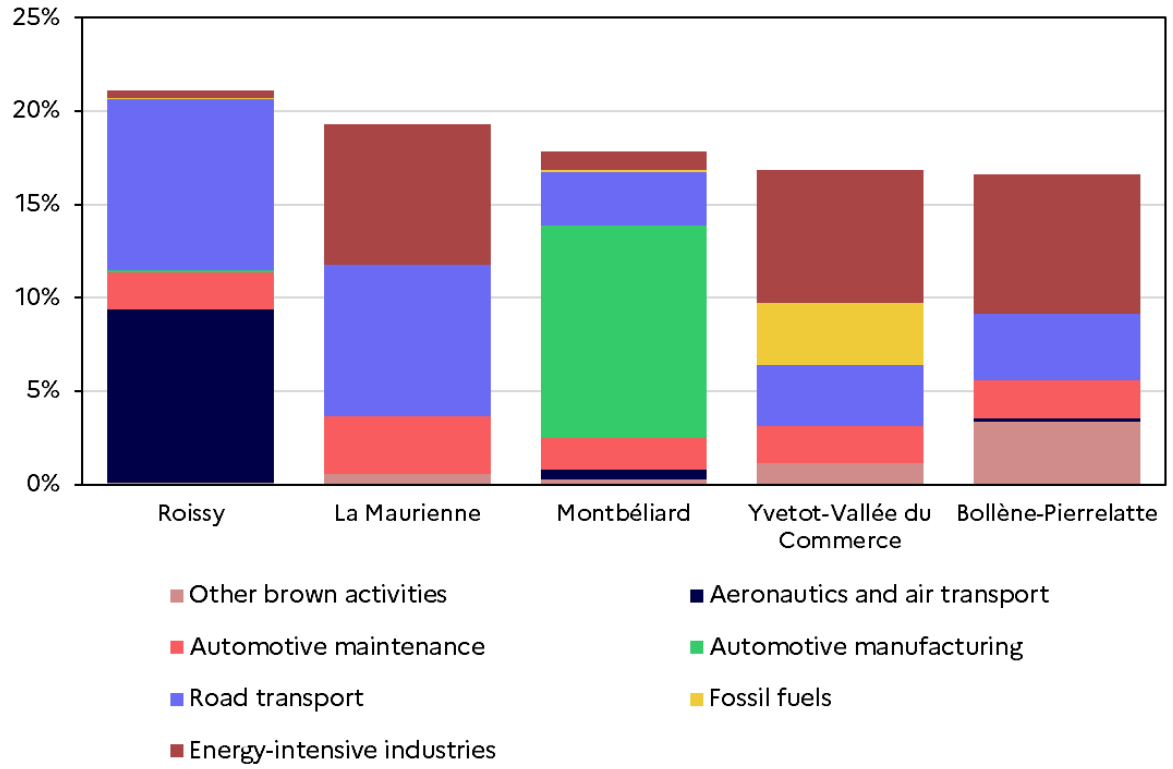
Brown jobs are geographically more concentrated than green jobs

Share of brown activities in employment and contributions by type of activity, for some examples of employment zones



- Emission-producing activities accounted for 8% of salaried employment, and **jobs most highly exposed to transition risk only 3% of employment**, but some emission-intensive activities are concentrated in certain employment areas.
- Transitions and retraining from brown jobs are facilitated by existing labour market policies.
- Brown activities, as well as associated jobs, can transform rather than disappear. In this sense, **support for the decarbonization of emission-intensive sectors exposed to international competition**, such as industry, **contributes to the transformation of jobs** .

Reading: nearly 20% of employees in the Maurienne area work in emissive activities, and in particular in certain industries with emissive processes (8 percentage points), then in road transport (8 pp) and automobile maintenance (3 pp). Source: All Employees administrative database for 2021, French national statistics Institute (Insee), French Treasury calculations.

8. The economic challenges of the net zero transition for French manufacturing

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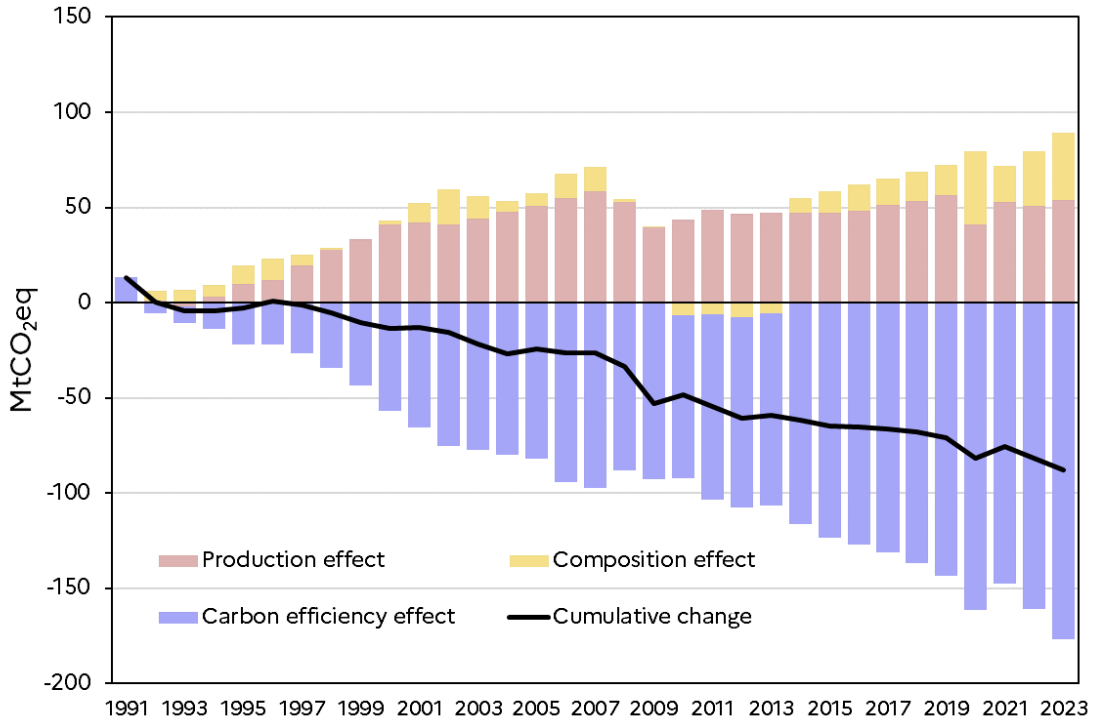
The French manufacturing industry has successfully decoupled its emissions from its production

Contributions to the cumulative reduction of greenhouse gases emissions in the manufacturing industry since 1990

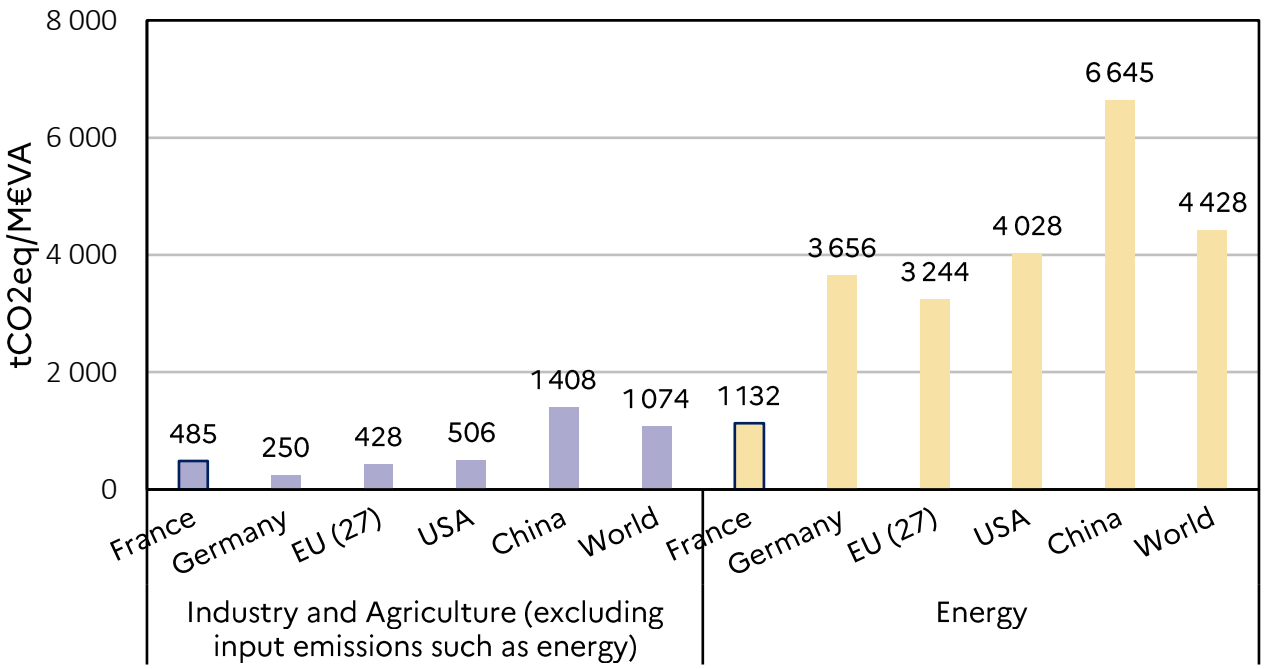


- **Between 1990 and 2022, ~~the~~ manufacturing ~~industry~~ is the sector of the French economy that has most reduced its direct emissions**, with a reduction of 51%, compared to 18% for other sectors and despite a 49% increase in value added over the period. The reduction in emissions has thus relied on investments to improve "carbon efficiency".
- **Deindustrialization has contributed to the reduction of greenhouse gas emissions in the manufacturing industry**, although the extent is difficult to quantify and depends on the measure of deindustrialization used.
- **Decarbonization efforts must continue** : in 2022, direct greenhouse gas emissions from industry still represented 18% of French territorial emissions. Emissions from this sector must still fall by around 37% by 2030, according to the draft of the 3rd French National Low-Carbon Strategy.

Source: French Treasury calculations based on INSEE data and the methodology described in French Treasury (2021) " Which industrial firms make decarbonization investments?", Working document 2021/3.

The carbon intensity of French manufacturing is overall better than that of the rest of the world, especially when indirect emissions related to electricity consumption are taken into account.

Comparison of the carbon intensity of production for different regions

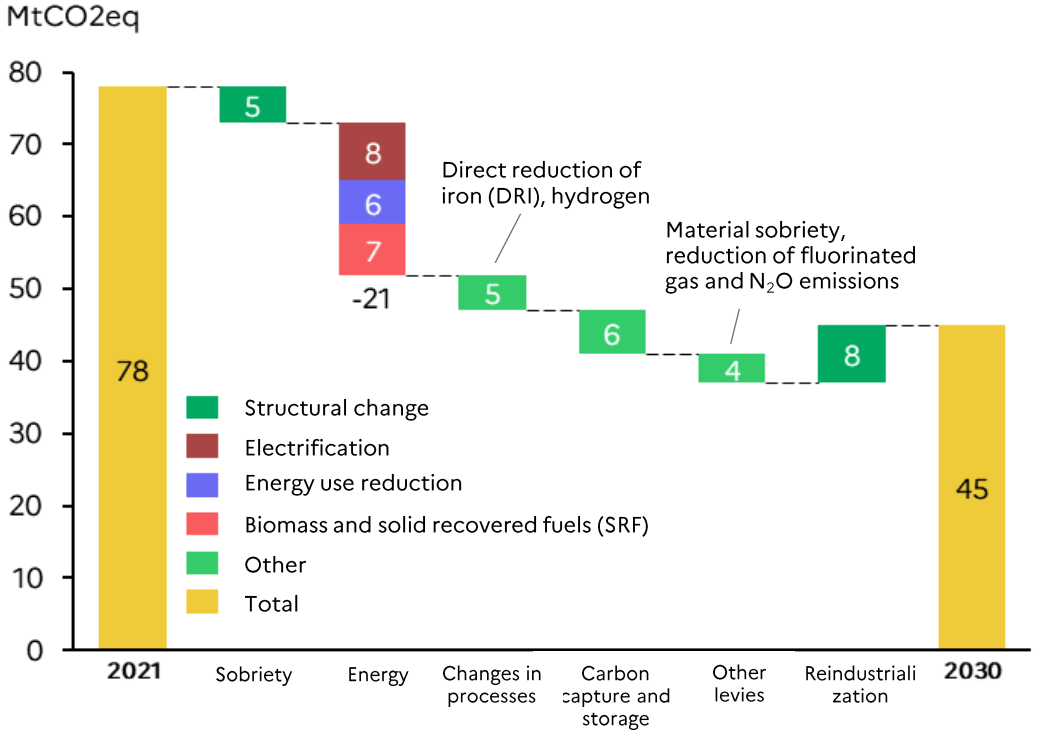


- **The carbon intensity of French manufacturing industry excluding electricity appears better than that of the rest of the world** (notably China) and rather in line with the European average.
- **Moreover, the total carbon intensity of France's manufacturing value added benefits from its low-carbon electricity.**
- **The climate performance of French manufacturing varies from one sector to another.**
  - French manufacturing appears at the **European frontier in terms of carbon intensity in several sectors** (e.g., agri-food industries or the repair and installation of machinery and equipment), while it seems relatively distant in others (such as the paper and cardboard industry, metallurgy or the automotive industry).
  - **Measurement difficulties** limit this comparison.

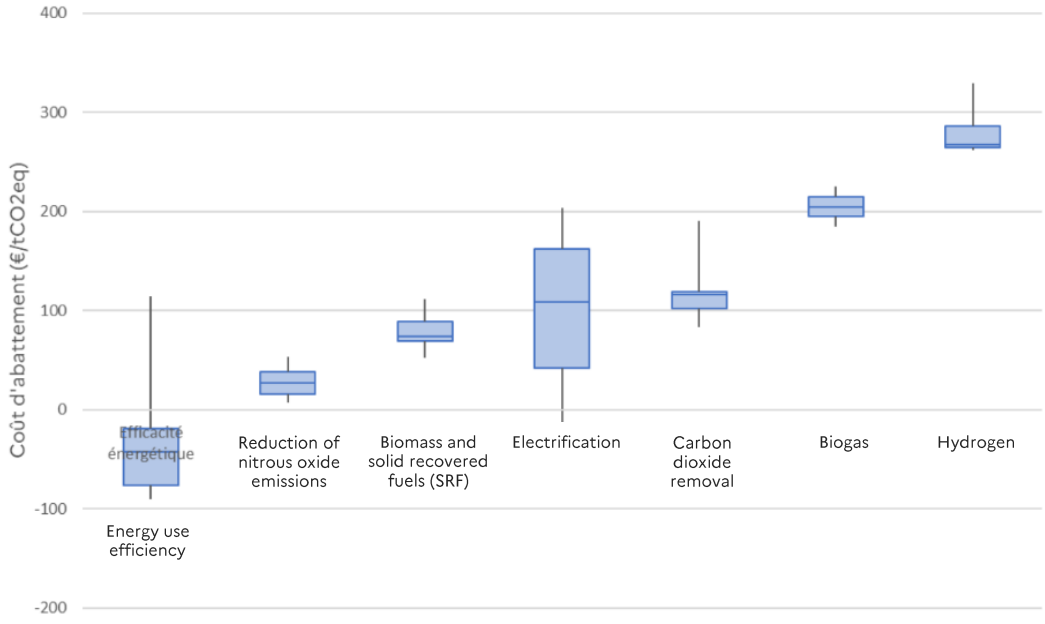
Sources: Eurostat, Bourgeois and Montornes "Producing in France rather than abroad, what are the consequences?", Insee analysis 2023; French Treasury calculations.

The continued decarbonization of the industry involves using various decarbonization levers with heterogeneous abatement costs

Several levers are considered by the National Low-Carbon Strategy to decarbonize manufacturing…



…These levers present heterogeneous abatement costs, as illustrated by the chemical sector



Sources: Draft of the 3rd National Low-Carbon Strategy (left graph); Report on the environmental impact of the State budget, 2023 (right graph)

Instruments have been deployed to address market failures hindering the decarbonisation of the industry

Several market failures and other obstacles stand in the way of decarbonization…	… Faced with instruments implemented by public authorities
Climate externalities of GHG emissions from manufacturing industries	European carbon market (EU ETS), taxation on fossil fuels
Carbon leakage risks in the case of unilateral pricing	Carbon Border Adjustment Mechanism (CBAM), subsidies for the decarbonization of exporting industries (e.g. France 2030, ecological transition contracts)
Knowledge externalities in low-carbon innovation	Low-carbon R&D subsidies (e.g. France 2030, Innovation Fund)
Path dependence in innovation	
Financing constraints for low-carbon investments	Loans and guarantees by public authorities (e.g. Green Industry Loan from Bpifrance)
Limited profitability horizon of business leaders	Extra-financial rating or green reporting (e.g. CSRD)

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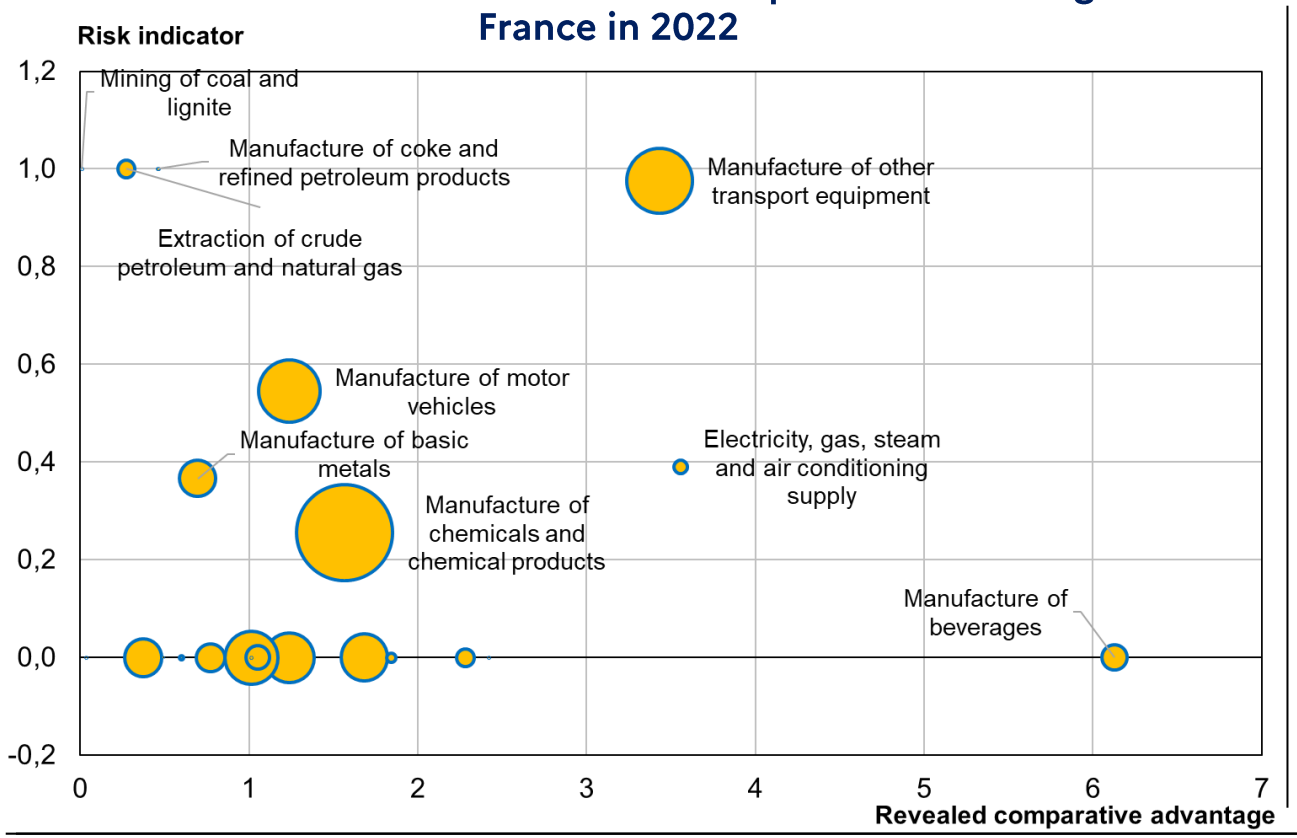
Some domestic productions oriented towards export are exposed to transition risks (automotive, aviation, chemicals)

Sectoral risk indicator and revealed comparative advantages in France in 2022



- **Transition risks** refer to all transformations (*e.g.*, demand reduction, technological transformation) to which companies, sectors and economies are exposed during the low carbon transition, and are identified by expert opinion (here, the JRC).
- **French exports are specialized in both products that are not very exposed to the risk of transition** (such as beverages or leather products) **and in products with higher exposure** (such as chemicals or thermal vehicles).
- **The United States and the United Kingdom are, on average, more exposed to this risk** (*e.g.* products from coking).

Sources : BACI, French Treasury calculations. Note: the size of the bubbles matches the sector's share in exports.

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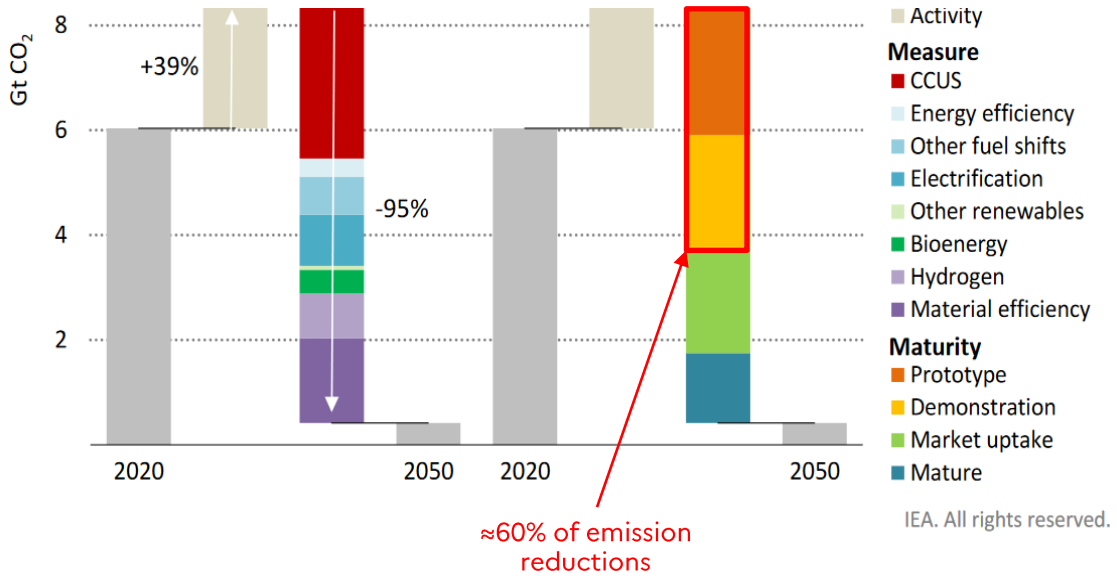
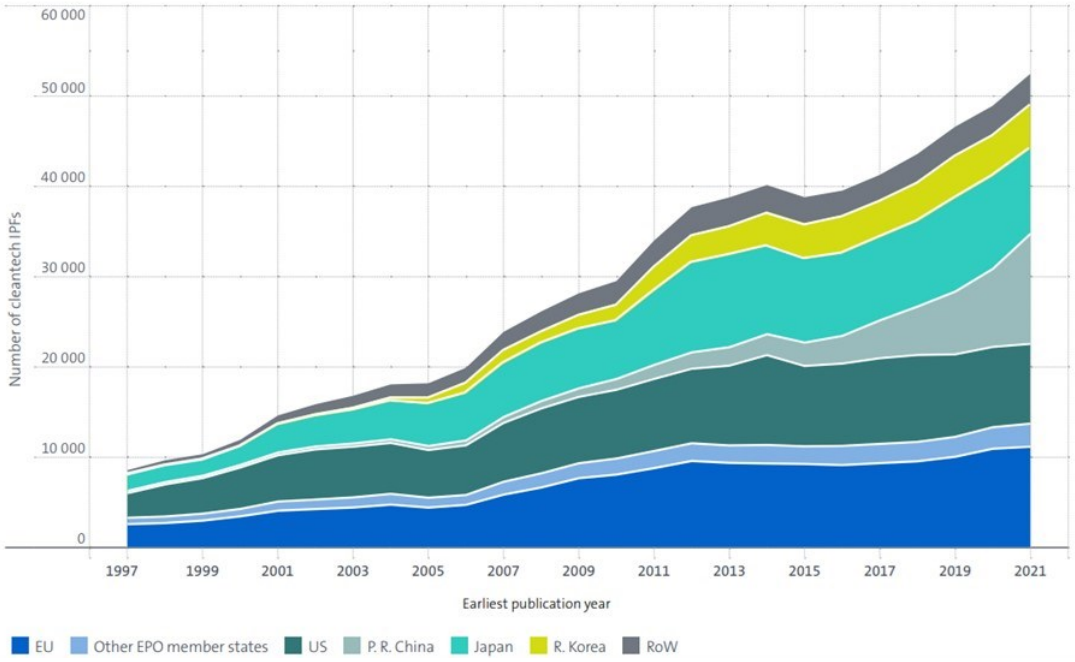
Low-carbon innovation is a key factor for the decarbonization of industry and the economy as a whole

The decarbonization of heavy industry will rely by 60% on the adoption of innovations that are still at a relatively immature stage…



Source: IEA, "Net Zero by 2050 – A Roadmap for the Global Energy Sector", 2021 .

…in this regard, the rise of patents in clean and sustainable technologies worldwide is favorable for decarbonization

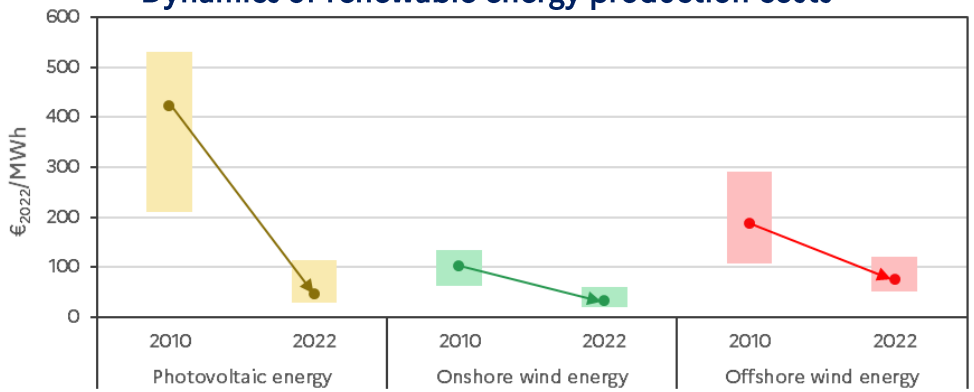


Source: European Investment Bank (2024), "Financing and commercialization of cleantech innovation".

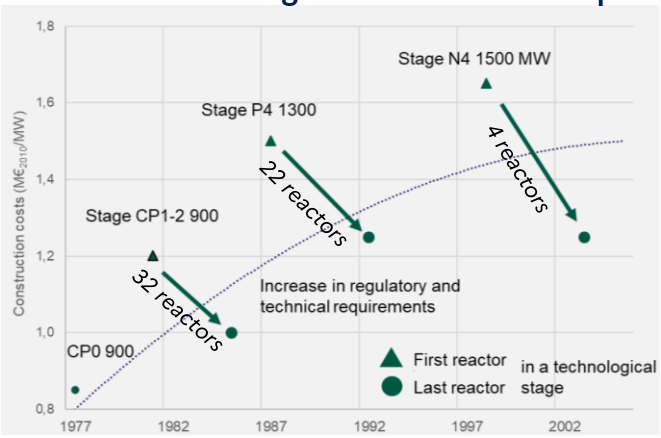
9. Decarbonization of the energy system

Electrification, a central pillar of decarbonization, requires the development of renewable energies and nuclear power; the latter in which France has a specialization in innovation

Dynamics of renewable energy production costs



Cost evolution observed between the first and the last reactor built in each technological series of nuclear power



- **Already low in carbon, French electricity production must significantly grow** in order to enable the decarbonization of other sectors through electrification, while a large part of the current production fleet will be decommissioned by 2050.
- Controlled electrification will reduce fossil fuel imports and thus **reduce France's exposure to price shocks on these energies** .
- **Each low-carbon energy production technology raises specific challenges for the transition.**
  - Renewable energies have a production cost that is falling sharply over the long term. However, they induce additional costs in transport networks and supply flexibility (batteries, low-carbon power plants) and face **local acceptability issues**.
  - The construction of new nuclear power plants represents a **major industrial challenge**, but it helps limit connection and network reinforcement costs. Their economic profitability will be sensitive to financing costs and the dynamics of construction costs. Modular nuclear reactors, on the other hand, are still an immature technology and therefore present risks related to their development and industrialization.

Access to low-cost, low-carbon electricity will be a key determinant of industrial competitiveness

Source	Variation in the cost of the complete electrical system per MWh produced, 2050 vs. 2019 in the central scenario
RTE, "Energy Pathways 2050" (2022) *Domestic consumption only (gains from external balance decrease the cost of the electricity system)*	+0-40%
RTE, "Energy Pathways 2050" (2022) *Variation of the external balance counted in production rather than in cost*	+5-60%
French Treasury update with new cost assumptions from RTE, "Projected supply estimates for 2035", (2024)	+15-70%
Criqui Commission, France Stratégie (2022)	+ 15% (compared to a counterfactual without further decarbonation actions)

Several instruments have been deployed to remove barriers to the decarbonization of the energy system.

	Market failure / Other barriers	… Faced with which the public authorities have put in place instruments to overcome them
	Several market failures and other obstacles stand in the way of decarbonization…	
	**Climate externalities** of GHG emissions from electricity production	European carbon market (EU ETS), taxation on fossil fuels
	**Carbon leakage risks** in the case of unilateral pricing, particularly for energy-intensive industries	Carbon Border Adjustment Mechanism (CBAM)
	**Other environmental externalities** (visual, noise, biodiversity, nuclear risk)	Regional planning, sustainable development, and territorial equality scheme, exclusion zones and local consultations for the installation of renewable energies, Nuclear Safety Authority, etc.
	**Knowledge externalities** in low-carbon innovation	Low-carbon R&D subsidies (e.g., France 2030, Innovation Fund), guaranteed purchase tariffs to promote *learning by doing*
	**Production-network coordination**	Regional Connection Schemes for Renewable Energy Networks (S3REnR)
	**Low diffusion of dynamic pricing**	Deployment of smart meters
	**High financing costs**	Contract for Difference (CfD)

10. The economic challenges of decarbonizing transport

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Various instruments have been deployed to remove the obstacles to the decarbonization of the different transport sectors

Market failure | Other brake

Several market failures and other obstacles stand in the way of decarbonization…

Underpricing of climate externalities of GHG emissions (positive negative) in certain transport sub-sectors

→ **Risks of carbon leakage,** in the case of unilateral pricing (e.g. air or freight transport)

Path dependency: may favor innovations in historical technologies (thermal vehicle) to the detriment of innovation in new technologies (electric vehicle)

Additional cost when purchasing an electric car

Household myopia in their vehicle purchasing behavior

Misjudgement of vehicle ancillary costs, unfavourable to electric vehicles

Imperfect substitutability between thermal and electric cars, for example in terms of autonomy and ease of refueling

… Faced with which the public authorities have put in place instruments to overcome them

Road transport	Air transport	Maritime
Pricing		
Excise duties on fossil fuels, ecological malus	ETS1 for intra-EU flights	ETS1 for intra-EU traffic and 50% of international traffic)
Grants		
TIRUERT, ecological bonus, leasing, conversion bonus, LCV ownership taxes, France 2030 subsidies, calls for projects for heavy vehicles	Sustainable Aviation Fuel Subsidies	
Regulations		
European CO2 emission performance standards for passenger cars and light commercial vehicles, European obligation to distribute sustainable fuels (RED3), obligation to green national fleets	ban on flights with alternative of less than 2h30, Refuel, CORSIA	Refuel
	Solidarity levy	
France 2030 Innovation Grants		
Ecological bonus		
Energy-CO2 label on new vehicles at national level, "InfoGES" regulation	"InfoGES" Regulation	
Deployment of charging stations, France 2030 innovation subsidies		

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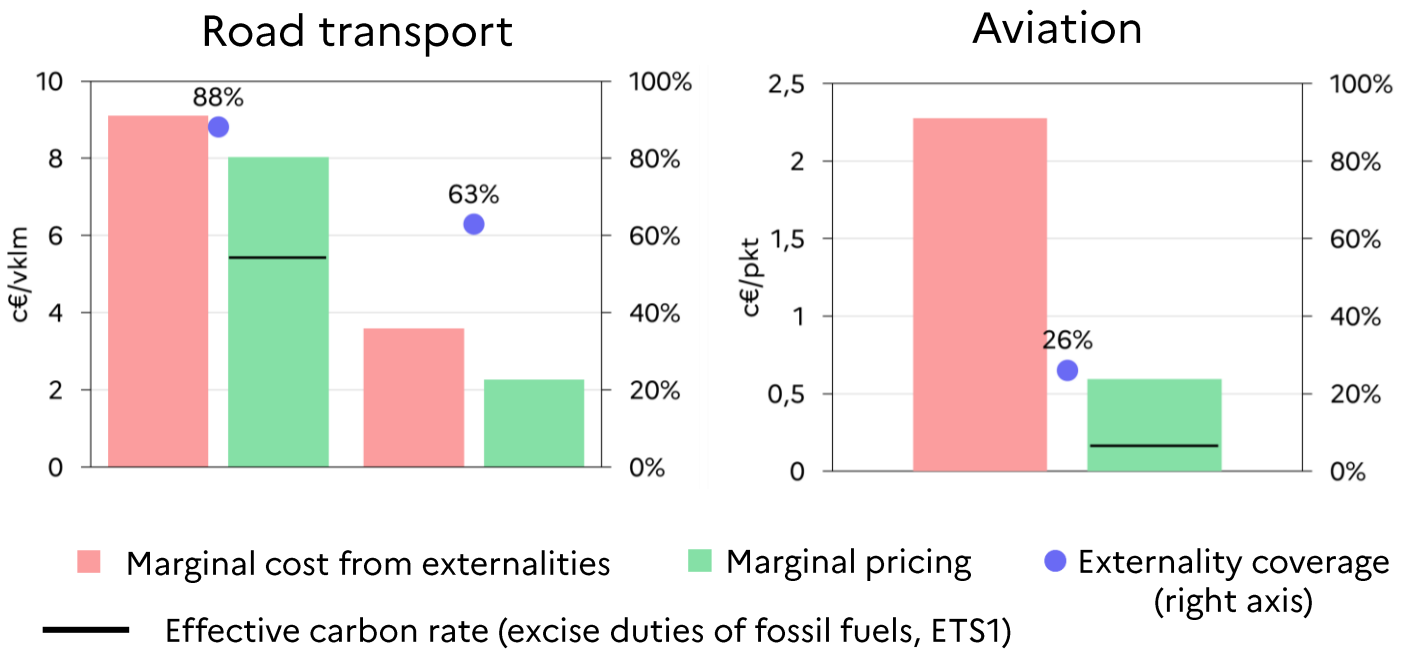
Carbon pricing is the most effective instrument for decarbonizing transport. It must be coordinated with the pricing of other externalities and be supplemented to control its distributive effects.

Current coverage of road and air transport externalities



- **The effective carbon pricing is high (180€/tCO2eq, source CGDD), but also covers the other externalities of the sector.** Transport externalities (CO2, local pollution, infrastructure wear and tear) are insufficiently covered by current taxation, relatively marginally for road transport, and more significantly for air transport.
- **Effective pricing is heterogeneous, from 0 (extra-European air travel) to €250/tCO2 (household fuels).** This is explained by the multiple instruments (ETS1, excise, etc.), partial coverage, and the existence of reduced rates. It is partly justified by exposure to international competition of certain sub-sectors.
- **Carbon pricing is the most cost-effective instrument, but its distributive effects call for the implementation of accompanying policies.**

Source: French Treasury calculations for the year 2020 for road transport; 2022 for air transport. vkm: vehiculer-kilometer traveled; pkt : passenger-kilometer-transported

Complementary measures can help to remove obstacles to electrification

Effect of a €1000 bonus on the market share of electric vehicles according to several studies

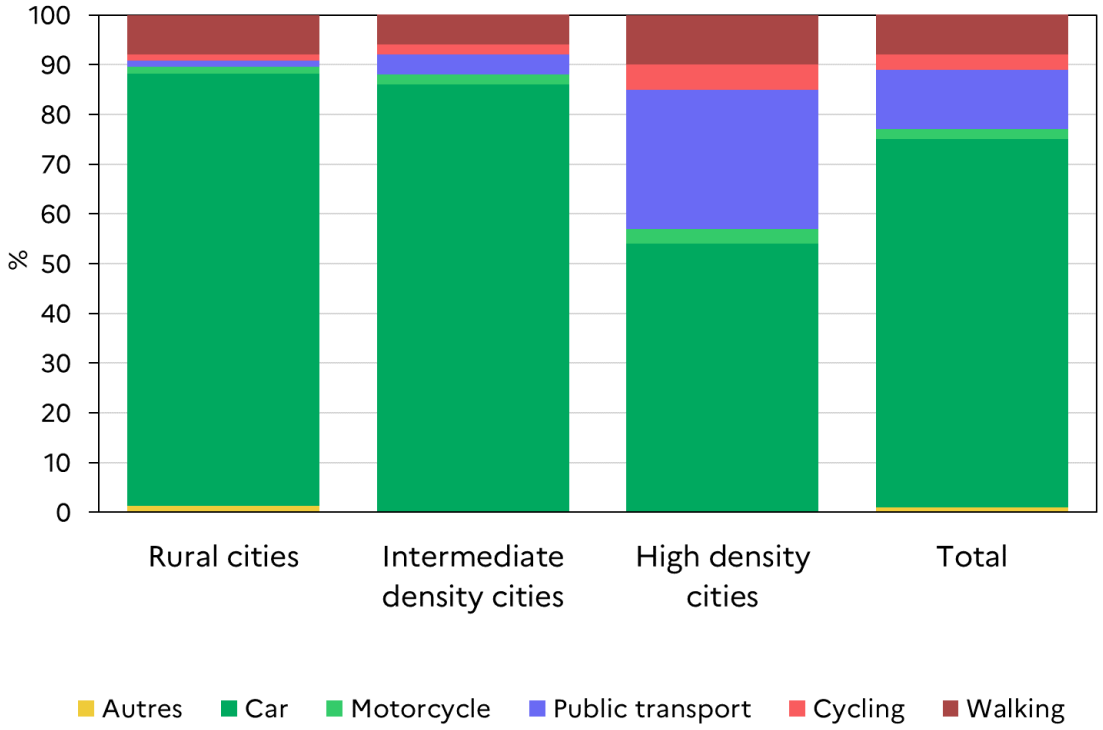
IPP	+ 2.5 pp
I4CE	+ 1.8 pp
IMF	+ 1.2 pp

- **Behavioural biases (preference for the present, imperfect assessment of costs, etc.) and the imperfect substitutability between electric and international combustion engine cars** justify supplementing carbon pricing with complementary measures.
- **Subsidies help increase the market share of electric cars** and play a supportive role **:**
  - An €1,000 increase in the bonus raises the market share of electric cars by 1.2 to 2.5 pp.
  - Targeting lower-income households helps limit potential windfall effects, which is the rationale behind the electric vehicle leasing scheme.
  - It will be possible to reduce aid in the long term, as observed in the most advanced countries in terms of electrification.
- **Fleet greening obligations, which remain poorly enforced,** have the potential to stimulate the second-hand market.
- **However, these instruments do not affect vehicle usage** and cannot replace carbon pricing.
- **Targeted innovation subsidies** can support immature technologies (e.g., France 2030)

Sources: IPP, 2024, « Evaluation of support measures for clean vehicles " ; I4CE, 2021, « Automobile bonus-malus : the necessary evaluation » ; IMF, 2024, « Balancing Environmental, Fiscal, and Welfare Impacts of Transportation Decarbonization in France ", 2024

Several levers are at the disposal of the public authorities to promote modal shift

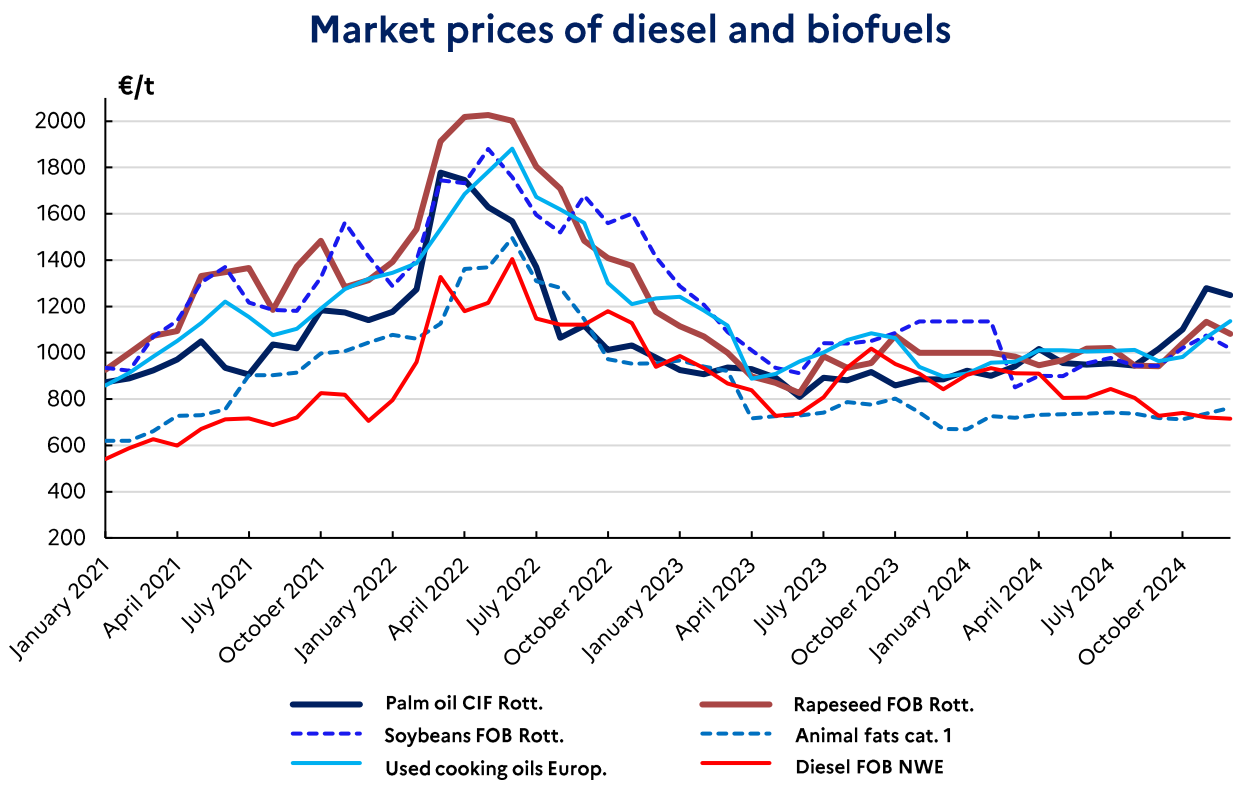
Mode of transport used for journeys to or from a regular place of work according to municipal population density in 2018



- **The modal shift towards more sustainable and active modes can be facilitated through land use planning.** Academic literature highlights a positive link between urban form, density and more environmentally and health-friendly mobility. Land use planning can further encourage active modes, which generate significant health co-benefits.
- **The socio-economic profitability of transport infrastructure, including the valuation of climate externalities, should be assessed on a case-by-case basis.** In some cases, the environmental and financial costs are not justified by the economic gains derived from the increase in demand and the reductions in emissions permitted.
- **Some public transport is already subsidised, and further fares reductions would only have a modest impact on emissions.**
- **Some policies may incentivize the use of a vehicle due to inadequate calibration.** In particular, the mileage allowance is overestimated, as is the assessment of expenses related to company vehicles.

Source: according to SDES (2024), based on EMP (2019)

Developing non-fossil fuels can help decarbonize aviation, but raises cost and supply constraints issues



- **Non-fossil fuels (biofuels and e-fuels) could help reduce emissions, particularly in aviation.**
- **They nevertheless raise several issues :**
  - Additional cost **:** moderate for biofuels, significant for e-fuels (x10). This additional cost could remain significant in the future, though there is significant uncertainty.
  - Supply constraints : **domestic supply for biofuels is limited requiring imports; the production of e-fuel can generate tensions on the electrical system** (20-40% of today's electricity production would be necessary to decarbonize half of current aviation consumption*)
- **These constraints highlight the need to control demand,** as provided for in the SNBC3 project.

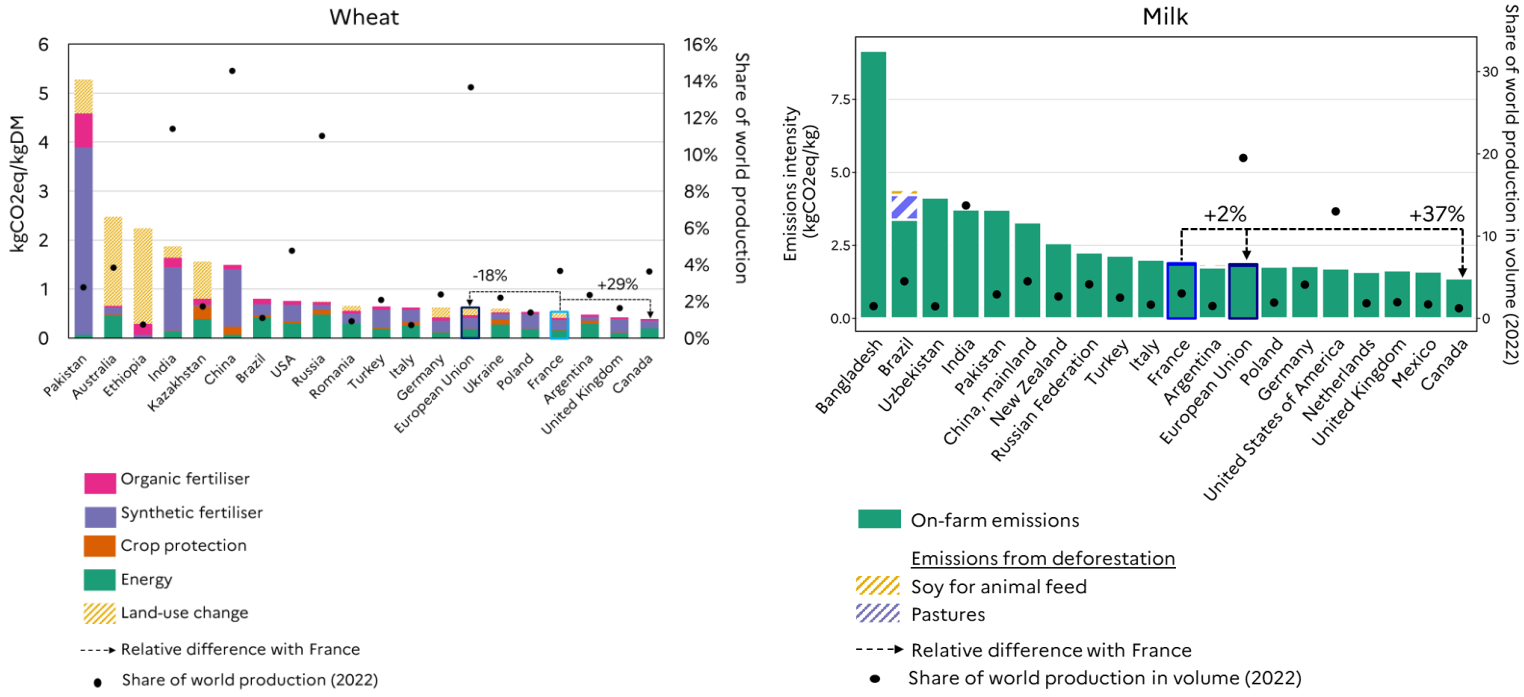
Source: La Dépêche – le petit meunier and SquareCo . *Domestic flights and 50% of international arrivals/departures

11. The economic challenges of decarbonizing agriculture

French agriculture already benefits from a relatively low emissions intensity compared to the world's major producers in crop production and certain types of livestock farming

International comparison of the emission intensity of wheat and raw milk

(productions with the highest value in 2023 among French plant and animal productions respectively)

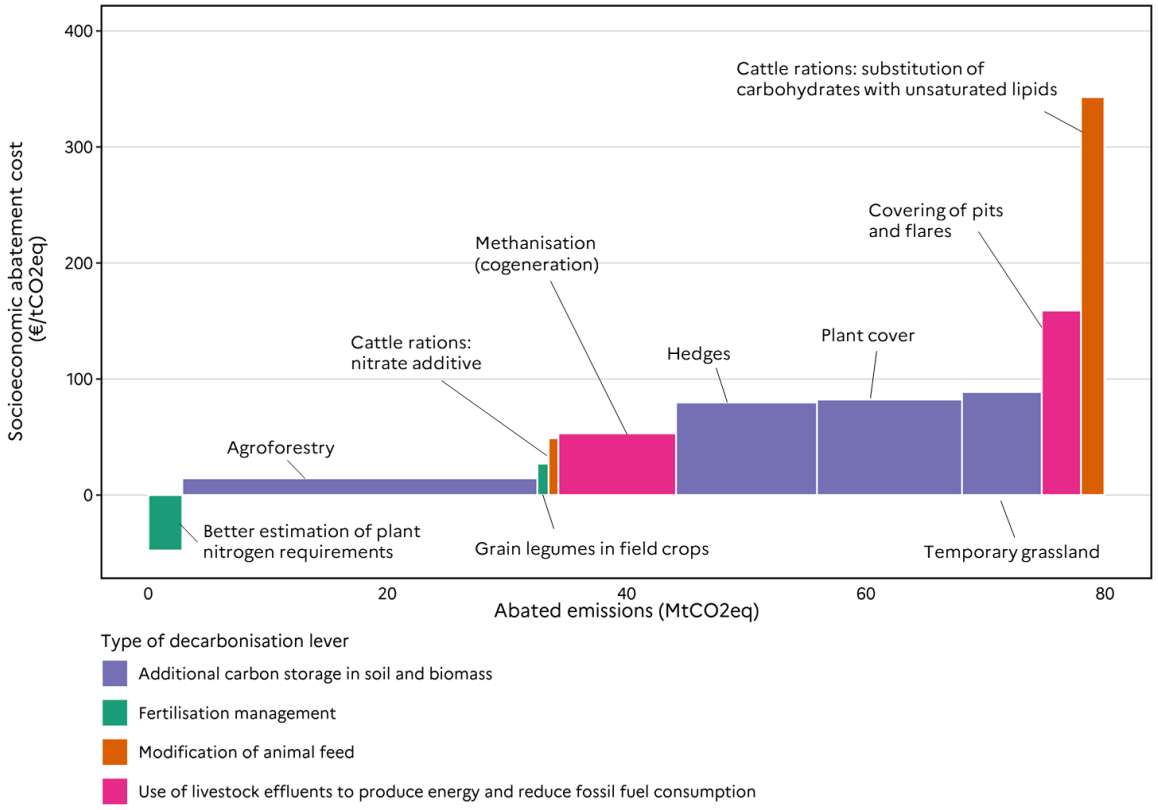


- According to FAO data for 2010, **France is one of the most efficient countries in terms of emissions for major crops (wheat and corn).** Its emissions intensity is lower than the European average (by -18 to -30%), thanks to greater efficiency in fertilizer use and energy consumption.
- However, **France ranks around the median for the main livestock products** (beef, milk, poultry), with an emissions intensity slightly above the EU average (from +2 to +19%) **except for pig farming where it is one of the most efficient producers.**

FAO LEAP and Gleam databases for emission intensities; FAOSTAT for production data.
Notes: Only emissions from upstream to the farm gate are considered. For each production, only the top 20 producers (by quantities produced) along with France and the European Union (EU) are presented. The EU emission intensity corresponds to the weighted of EU countries' emission intensities, based on their respective production levels. Production data correspond to the year 2022 (most recent available) while emission intensities reflect the year 2010. These data have several limitations. Indirect land-use changes, which refer to land-use changes in other regions triggered by crop cultivation, are not taken into account. In the case of livestock farming, only deforestation linked to the expansion of soybean crops and cattle grazing is taken into account in land-use changes, while for crops all land-use changes are taken into account. Direct emissions from agricultural soils are also not taken into account.

Several technical mitigation levers in agriculture are characterized by a low or moderate theoretical abatement cost

Abatement costs in agriculture in France



- In crop production, certain practices enable carbon storage in biomass and soil. In particular, the greatest potential for low-cost technical abatement comes from the **deployment of agroforestry (>30% of the total),** which allows carbon sequestration by integrating trees with agricultural crops and/or livestock farming.
- **In livestock farming, technical levers involve higher abatement costs** , with the exception of methanization. They mainly concern the recovery of livestock effluents and the modification of animal feed**.**
- **The deployment of these strategies face obstacles, leading to additional costs not taken into account in these estimates.**

Sources : France Stratégie and French Treasury, based on data from Ben Fradj and Bamière (2021) "Mitigating greenhouse gas emissions in the agricultural sector", Regional study for ADEME, Bamière et al. (2023) "Reduction in greenhouse gas emissions enabled by additional carbon storage on French agricultural land: marginal abatement cost curve"; France Stratégie processing ("carbon budget" calculation method).

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Several explicit decarbonisation instruments and other instruments contribute to removing the obstacles to the low-carbon transition in agriculture

Market failure | Other brake

Several market failures and other obstacles stand in the way of decarbonization…

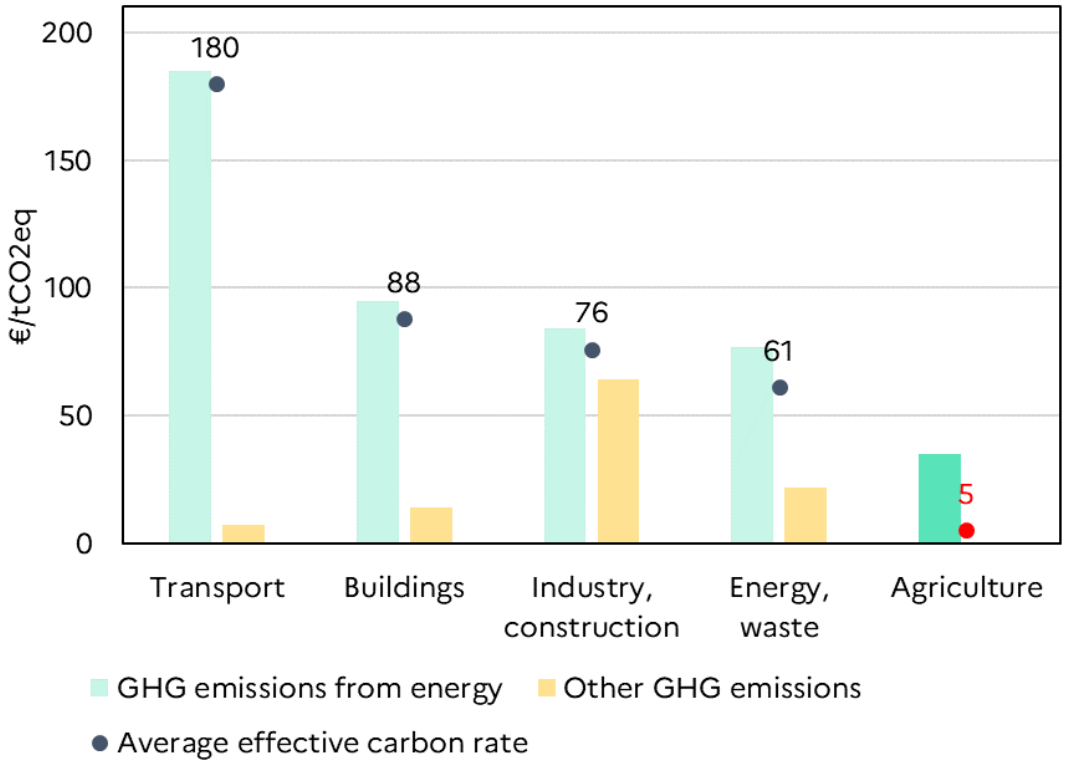
- **Underpricing of climate externalities of GHG emissions (positive and negative)** from farms. This can be addressed through effective pricing, but also through other instruments (subsidies, regulations)
  - **Risks of carbon leakage** in the case of unilateral pricing
- **Organizational lock-in:** low-carbon products and production methods struggle to be deployed in an agri-food system designed to maximize the competitiveness of conventional crops and practices
- **Asymmetric and incomplete information** on the climatic and health attributes of foods
- **Imperfect competition** : in some sectors, the market power of industrial processors and distributors exacerbates the economic difficulties of producers by reducing their revenues, thus reducing their capacity to absorb the additional costs of decarbonization
- **Economic difficulties of some farmers,** which limit their capacity to absorb the **additional cost of decarbonization** compared to conventional practices
- **Inertia of** GHG-emitting food practices
- **Food purchasing power of low-income households** weakened in the event of additional costs induced by decarbonization

… Faced with which the public authorities have put in place instruments to overcome them

Explicit decarbonization instruments	Other instruments
Pricing	
Effective carbon pricing only for energy consumption and at a reduced rate	
Grants	
Carbon credits (LBC) and other decarbonization subsidies (MAECs, national aid, etc.)	Other aid for the ecological transition with climate co-benefits: CAP eco-schemes, guaranteed loans for ecological agricultural projects (INAF)
Regulations	
Regulations on collective catering Egalim2/climate resilience law (vegetarian meals)	CAP conditionalities with climate co-benefits: BCAE, Nitrates directive
Given the low level of effective carbon pricing in agriculture, no explicit instruments deployed at this stage	Regulation on imported deforestation (constraint on imported emissions)
Financing of calls for projects to structure legume sectors (France Relance, PLF Protein Plan); guaranteed outlets in public catering with EGALIM2 regulations/climate resilience law	
The environmental display currently being deployed will contain a climate criterion	Nutritional recommendations and information campaigns; environmental labels (organic, HVE)
	EGALIM 1-2-3
	Agricultural income support measures of the Common Agricultural Policy (CAP)
Regulations on collective catering EGALIM/ climate resilience law (vegetarian meals)	Other regulations on collective catering (sustainability criteria); nutritional recommendations, information campaigns
	Food aid (food stamps); cross-cutting social benefits

Agriculture stands out for its very low pricing of GHG emissions compared to other sectors

Effective pricing of GHGs in 2023, by economic sector

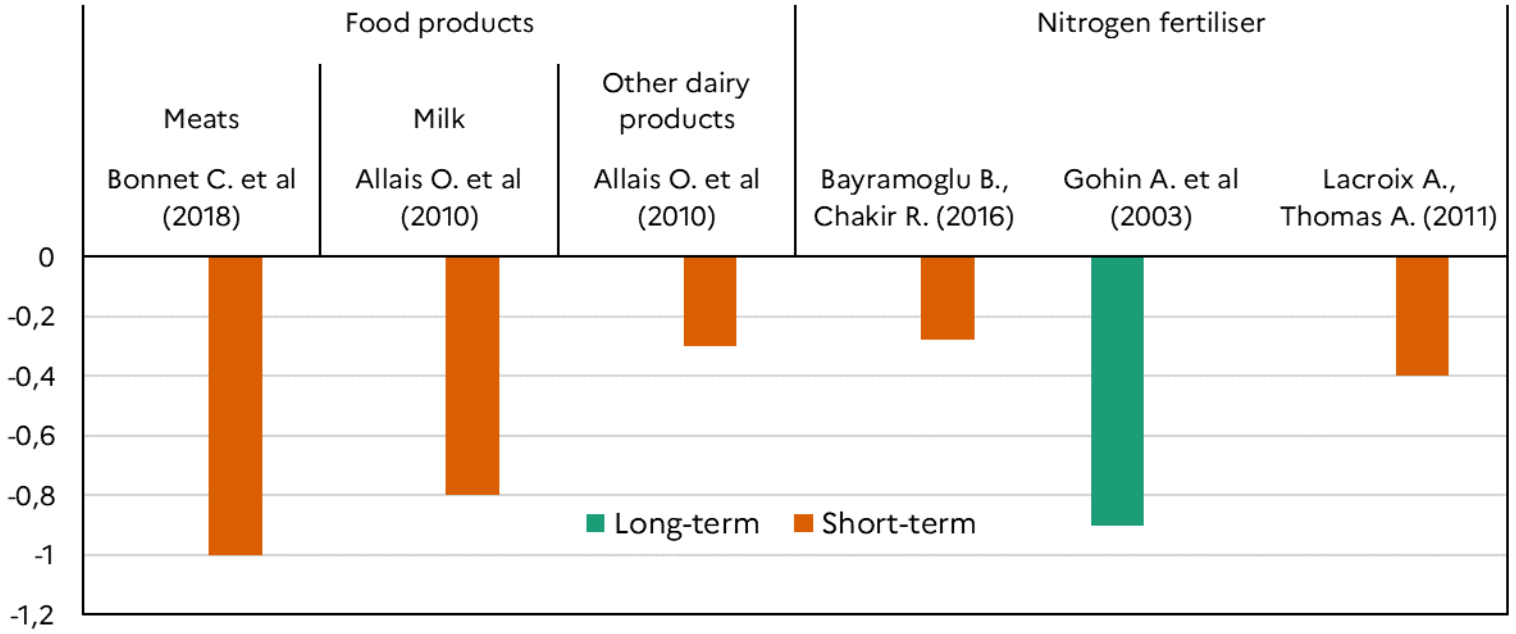


- **Low pricing of agricultural GHG emissions**, mainly due to the absence of pricing of non-energy emissions.
- A variety of s**ubsidy, regulatory, and informational measures have been implemented** to support the decarbonization of agriculture and food systems. However, most of these measures have either had a limited impact on emissions so far or have not yet been fully assessed.
- **The pricing of greenhouse gas emissions from agriculture is being considered in some countries (Denmark, Canada).** Other countries such as New Zealand have abandoned it after proposing it.

Source: CGGD (2024), Unequal pricing of greenhouse gas emissions across sectors , Théma Essentiel n° 34

However, the emissive consumption of the food system appears relatively elastic in the long term…

Own-price elasticity of consumption of food products of animal origin and consumption of nitrogen fertilizers in France



- **The price elasticity of fertilizer consumption appears moderate in the short term** (up to -0.4) **but could be significantly higher in the long term** and at an aggregate level (-0.9), due to production reallocations and market share gains by producers who use fertilizers more efficiently.

- **Consumption of high-emission food products is price elastic** (with a specific price elasticity close to 1). However, in the absence of comprehensive GHG emissions pricing, consumers do not naturally shift toward less emissive alternatives.

Source : DG Treasury . Notes: In the case of food products, short-term elasticity corresponds to the change in household food consumption following an increase in their price, without taking into account changes in dietary practices resulting from long-term exposure to higher prices. In the case of nitrogen fertilizers, short-term elasticity corresponds to the change in fertilizer consumption following an increase in the price of fertilizers for given production factors (e.g., allocation of crops, agricultural equipment). Long-term elasticity reflects the change in consumption after adjusting all production factors (e.g., adoption of crops requiring less fertilizer, acquisition of equipment to optimize nitrogen input).

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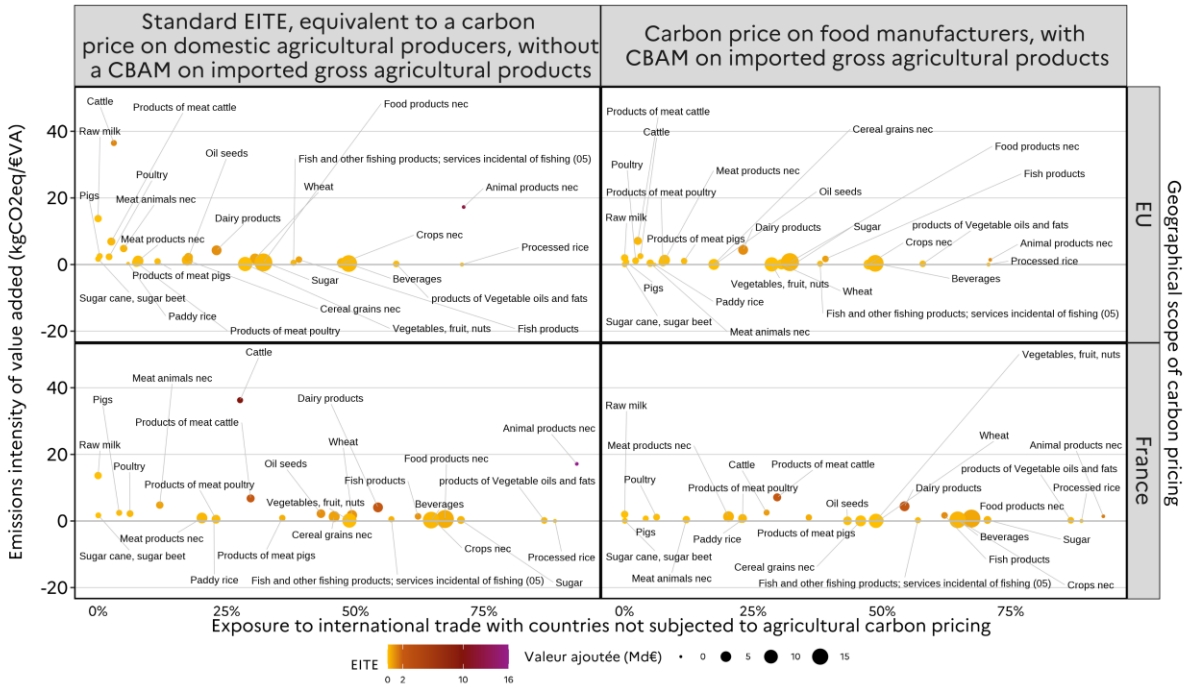
… Pricing agricultural GHG emissions would, however, entail risks for producers and consumers, particularly carbon leakage.

Carbon Leakage Risk Exposure Indicator ("EITE") for French agricultural sub-sectors



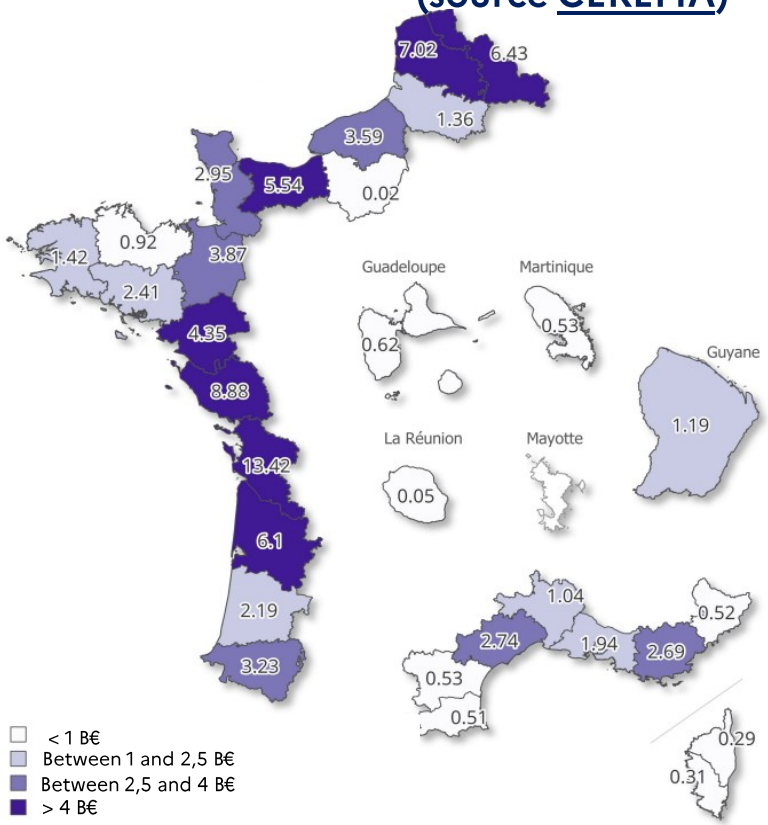
- **Pricing direct agricultural GHG emissions would induce a risk of carbon leakage** through the competitiveness channel in the case of a unilateral national or EU-wide initiative, in the absence of adjustment measures.
- **The risk of carbon leakage appears low for large-scale crops, while it appears high for certain livestock products such as beef.**
- **The point of application of agricultural emissions pricing via an ETS** (producers, processors or distributors) **would have a strong impact on carbon leakage** .
- **In the case of pricing applied to production rather than consumption, it would be essential to implement it at the EU level and complement it with adjustment measures to mitigate the risk of carbon leakage** (e.g. free allowances, CBAM, recycling of revenues to taxable entities), in the absence of international coordination **.**
- **Beyond carbon leakage, other risks are associated with carbon pricing in agriculture** : distributional effects, farmer/consumer acceptability, and administrative costs linked to measurement difficulties.

Sources : Exiobase v3.8.2 (2022 data) , French Treasury calculations
Notes : the " EITE " indicator corresponds to the product of exposure to international trade (on the x-axis) and emissions intensity (on the y-axis). The darker its color, the higher the value of the indicator. The international trade exposure score (x-axis) corresponds to the ratio of the sum of exports and imports to regions not affected by potentially more restrictive climate policies in agriculture (all countries excluding France in the first column, non-EU countries in the second column), by the sum of domestic production and imports (towards the same countries). Emissions intensity (y-axis) takes into account all emissions subject to the policy at the domestic level (France or EU depending on the scenarios).

12. The economic challenges of adapting to climate change

Adaptation to climate change will help limit residual damage

Market value of housing threatened by erosion in 2100 (source CEREMA)



Example of public action: To protect the population from the consequences of the retreat of the coastline, one of the key measures of the PNACC-3 aims to support local stakeholders in the definition and implementation of their coastline management strategy as well as the determination of a financing model for the restructuring of territories exposed to the coastal retreat

- Public action is essential to implement **adaptation actions and prevent "maladaptation",** thereby minimizing both adaptation costs and residual damages.
- An adaptation strategy first requires **setting acceptable residual risk levels for each sector and each hazard** and defining adaptation trajectories.
- In line with long-term objectives, three types of actions could be prioritized in the short term:
  - **Integrate adaptation into decisions** with long-term consequences for both public and private actors. The 3rd National Climate Change Adaptation Plan (PNACC-3) aligns with this approach, aiming to eliminate funding for unsuitable investments and ensure that all public policies are in line with the reference warming trajectory by 2030.
  - Trigger **no-regret actions** with short-term benefits regardless of climate change (e.g. natural disaster prevention)
  - Initiate adaptation actions whose benefits will show in the **long term** (e.g. securing land for renaturation projects)
- Regulatory tools and economic incentives have significant potential to encourage private adaptation, but they are still little used.
- The estimation of additional financing needs for adaptation is very uncertain, and depends on adaptation choices that are still to be defined.

13. The economic challenges of decarbonizing the private housing stock (see Interim Report 2023)

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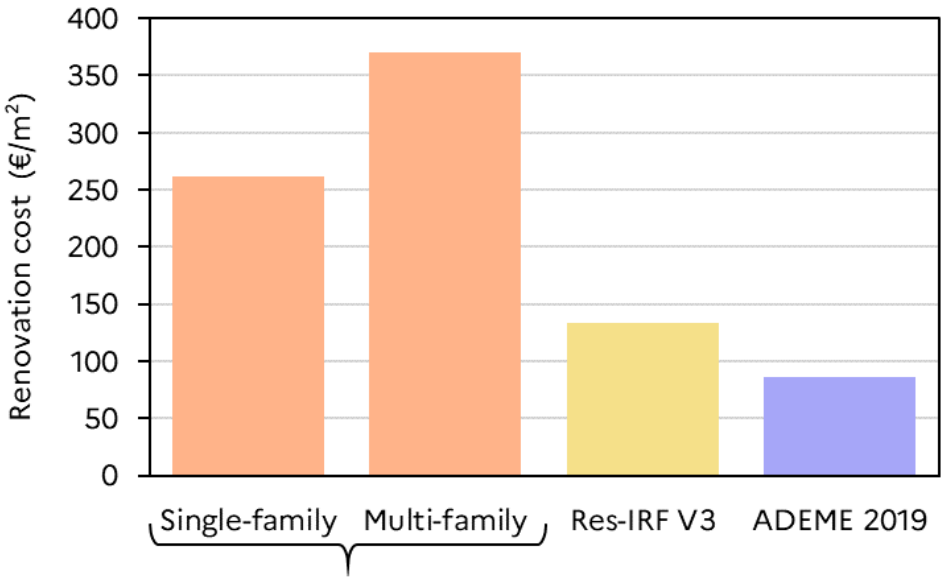
Decarbonising the private housing stock plays a key role in achieving carbon neutrality in France, must but it must overcome heterogeneous abatement costs which are on average higher than previously anticipated

Average costs of retrofits leading to an upgrade of 2 EPC classes for an energy-inefficient home



Data from retrofits subsidised through MaPrimeRénov' (MPRS/MPRC)

Thermal insulation is characterised by high abatement costs for homes with intermediate energy efficiency but can be cost-efficient for very energy-inefficient homes:

- **Renovation costs** tend to be higher than anticipated by most technoeconomic models
- Actual reductions in energy consumption and emissions from retrofits tend to be **lower than predicted** by energy efficiency modelling
- **Insulation work** seems mostly effective for improving the energy performance of **very energy-inefficient homes**

The initial priority should therefore be to insulate very energy-inefficient homes and promote heat decarbonisation for others (e.g., installing heat pumps and heat networks), while ensuring low-carbon energy generation can keep pace with demand

Sources : MPRS/MPRC 2022 data, ADEME 2019, French Treasury calculations

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Increases in energy prices reduce energy consumption by first promoting energy conservation practices and then triggering energy efficiency investments

+10% increase in energy prices

Short-term (1 year)

Energy conservation practices : *e.g.*, reducing home heating temperature

2 to 3.5% reduction in energy consumption

This may lead to aggravating fuel poverty for low-income households.
Targeted support measures are key

Long-term (>1 year)

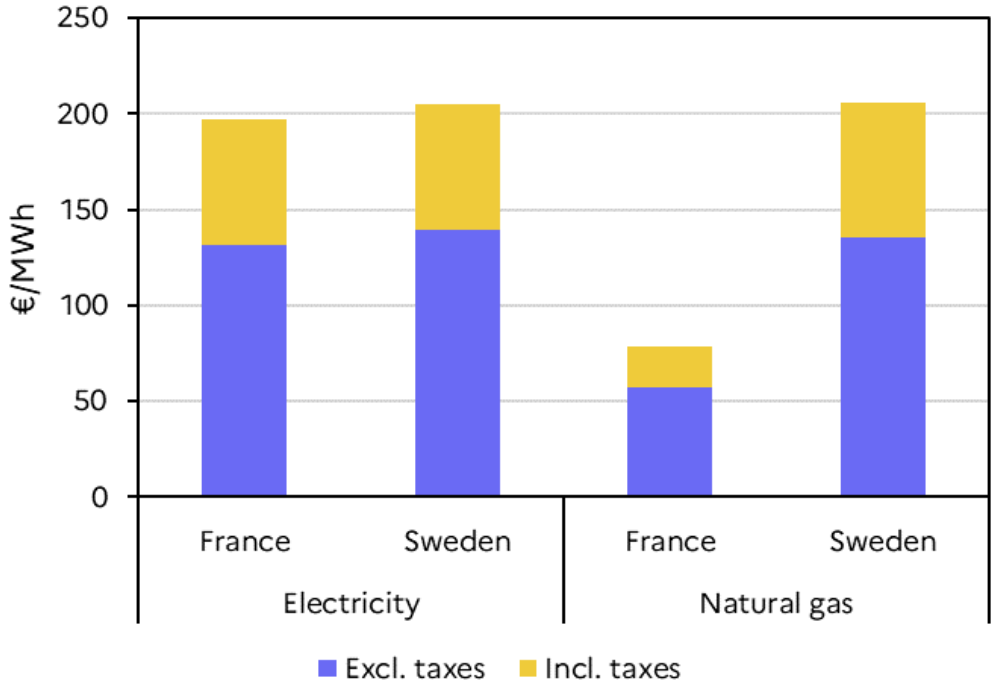
Investments in energy efficiency : change of heating system, insulation work

6% reduction in energy consumption

Sources : Labandeira et al. (2017); Douenne (2020); Berry (2019)

The Swedish example highlights the importance of a comprehensive policy mix to decarbonise the housing sector

Electricity and natural gas prices in France and Sweden for households in 2021



Sweden has succeeded in decarbonising its housing stock by relying on both market-based instruments and regulations:

- Sweden has the most low-carbon and among the least energy-intensive housing stock in Europe
- This performance can be attributed to the joint and early introduction of **market-based instruments** (*e.g.*, carbon tax from 1991; see attached graph) and **regulations** (*e.g.*, energy efficiency standards for new buildings as soon as 1960)
- Sweden has also relied substantially on **district heating** in urban areas

Sources : Eurostat, French Treasury calculations

The "green value" of homes helps make renovations profitable by embedding energy efficiency into home retail prices

Home purchase green value in France (2021)

- **Green value** = price difference observed between energy-efficient and energy-inefficient homes
- **The purchase green value improves the profitability of renovations**, mainly for houses (whose green value appears sufficient to make their renovation profitable, even without subsidies) and to a more limited extent for flats.
- **In the rental market, green values on rents are lower and insufficient** to make renovations profitable for landlords.
- **Public policies have an influence on green value,** in particular, measures leading to higher energy prices (*e.g.* carbon tax) and regulatory measures (*e.g.* ban on the rental of energy-inefficient homes)

Sources : French Ministry of Housing (DHUP)

Decarbonization of housing must overcome several market and behavioral failures and other barriers, to which instruments have been deployed

Several market and behavioral failures are hindering the decarbonization of housing…

Underpricing of climate externalities of energy consumption

Information asymmetries : owners vs. tenant, buyer, retrofit company, bank

Behavioral biases : inattention to energy prices, household myopia, non-rational expectations

Financing constraints

… Faced with which the public authorities have deployed a certain number of instruments (examples)

Carbon pricing: fuel excise duty (including a "carbon component")

Subsidies : MaPrimeRenov', white certificates

Bans : ban on the rental of strainers, ban on the installation of fuel oil boilers

Informational instruments : EPC, energy audits (mandatory in certain cases such as for multi-family dwellings), RGE label for certified renovation companies whose retrofits can beneift from renovation subsidies

Zero-rate loan for renovation work