

# The integration of transition risk drivers at a sectoral level

New perspectives for climate stress tests and other climate risk management tools

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The Institute for Climate Economics (**I4CE**) is a Paris-based think tank with expertise in economics and finance with the mission to support action against climate change. Through its applied research, the Institute contributes to the debate on climate-related policies. It also publishes research to support financial institutions, businesses and territories in the fight against climate change and that assists with the incorporation of climate issues into their activities and operations. I4CE is a registered non-profit organisation, founded by the French National Promotional Bank Caisse des Dépôts and the French Development Agency.



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# Technical summary

The incorporation of climate risks into stress testing by financial institutions is still in an exploratory stage. Under the initiative of the NGFS, several central banks and supervisors have begun to conduct their first climate stress testing exercises. The goal of these exercises is to make banks more aware of climate risks and to develop new methodologies for the analysis of climate-related risks, rather than to increase capital requirements, as may be the case in the context of conventional stress tests. In June 2020, the NGFS developed a first guide to climate scenario analysis, that can serve as a basis for conducting the first climate stress tests. This analytical guide was taken up in France by ACPR and Banque de France in the context of their pilot climate exercise, the results of which were published in 2021.

## An opportunity to enhance the first climate scenario analysis framework developed by the NGFS through a sectoral approach

This report is part of a research project aimed at providing new thinking on the climate scenario analysis work conducted by the NGFS. The goal of this work is thus to identify ways to refine the scenarios and to enhance their relevance, without making the exercise more complex. The findings of the analysis would then be used to determine whether there is a need for more in-depth methodological research on the climate scenarios. This is an intermediate report, and is part of a broader research project to analyse the sectoral risks associated with climate change.

In its first guide to climate scenario analysis, the NGFS chose to focus in its reference scenarios on two types of transition risk drivers (public policy measures, captured by an emissions price, and technology availability, especially carbon capture technologies), which are not differentiated by sector. The additional elements provided by the Banque de France/ACPR exercise have partially filled this gap, by enabling a sectoral analysis, which is nevertheless insufficient to capture changes within the sectors. Although an aggregated approach is typical in the context of conventional stress testing, the complexity of climate issues means that this analytical framework could generate results that are significantly different from those of a more comprehensive analysis of transition risk drivers.

In order to verify these exploratory analyses, two sectoral case studies have been conducted, one focusing on the private residential property sector and the other on the cement industry in France.

These two sectors were chosen because of the level of challenges they face in a context of transition. For the property sector, another decisive selection criterion was its weight in bank portfolios in France. The choice of the cement sector was influenced by the availability of a detailed

Sectoral Transition Plan, prepared by ADEME<sup>1</sup> in the context of the Finance ClimAct project. These sectoral transition plans (other sectors will be covered in the next few years) detail decarbonisation scenarios aimed at achieving the objectives set by the French National Low-Carbon Strategy for the sector, as well as the challenges and opportunities for the sector. They are therefore an ideal basis for this type of exercise.

## An intra-sectoral analysis helps to better identify all transition risk drivers and their potential interactions

There are many transition risk drivers, which differ according to the sector and can overlap

The two case studies have shown that transition risks stem from highly varied risk drivers and impact chains, and differ according to the economic sector. A detailed analysis of these two sectors and of their specific transition issues has identified several transition risk drivers for each sector, through the development of transition scenarios that are intentionally adverse (figure 1).

For each of the two sectors, the different risk drivers identified could increase the vulnerability of actors, and thereby increase the financial risks for financial institutions.

The analysis of these risk drivers has demonstrated the plausibility of their overlapping. If they emerge simultaneously, the effects of these risk drivers could be multiplied, thereby increasing the final risks. For the cement sector, for example, a significant increase in the emissions price combined with an innovation shock in green cement technologies could weaken companies in the sector that have not invested or are unable to invest in these new technologies.

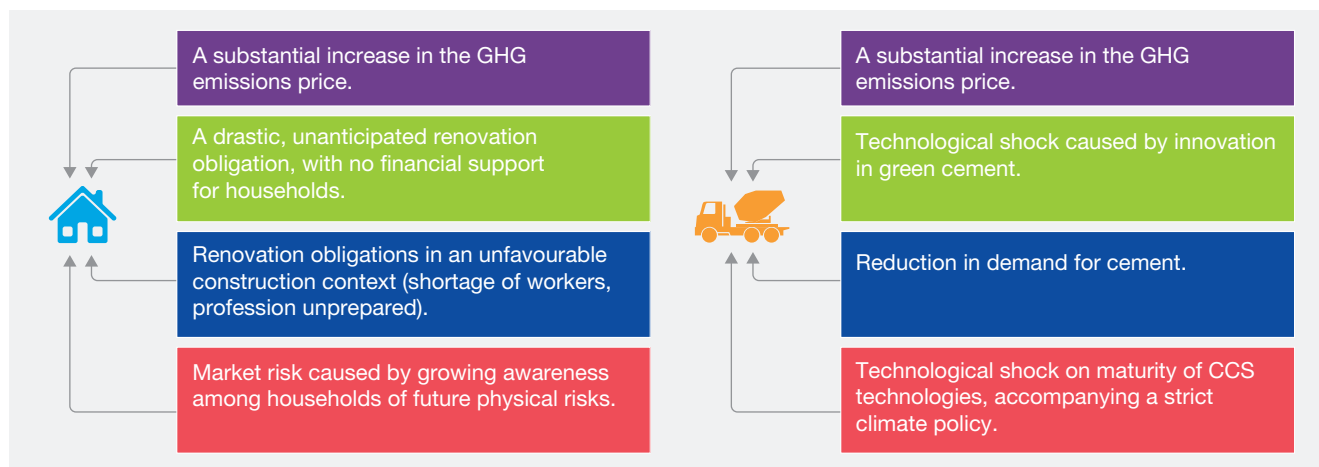
## Not all actors within a given sector have the same capacity to deal with transition risks

The case studies have also shown that the risk drivers emerge in different ways within a given sector and that different key indicators can be used to better determine the vulnerability of economic actors (households and companies) to the various risks.

For example, for the property sector, the energy performance level of buildings is one of the key indicators used to better identify the potentially vulnerable counterparties with regard to a risk driver caused by an increase in the emissions price or a renovation obligation. However, a detailed geo-localisation of the property is required to assess a market risk driver linked to a change in demand from households due to growing awareness of future physical risks.

<sup>1</sup> For more information: <https://finance-climact.eu/news/sectoral-transition-plans/>

FIGURE 1: THE DIFFERENT RISK DRIVERS IDENTIFIED BY SECTOR FOR THE TWO CASE STUDIES



Source: I4CE

An intra-sectoral analysis thus makes it possible to assess the vulnerability of the different economic actors to the different risk drivers. This research is also essential to determine the extent to which the overlapping of these risk drivers could multiply the impacts, since the number of counterparties potentially concerned increases (e.g. houses with low energy performance and houses in specific geographical areas).

**The intra-sectoral analysis of transition risk drivers would improve risk management tools**

**The improvement of climate stress test scenarios through a quantification of the orders of magnitude for the different risk drivers**

Although a sectoral analysis has shown that the risk drivers can differ according to the sector, it is important to next ascertain whether the risk drivers identified for each economic sector and taken individually could generate higher financial risks than those already covered by the NGFS analytical framework. If this is not the case, then the risk drivers covered by the NGFS analysis could be sufficient to cover all of the risks specific to each sector.

However, the overlapping of these risk drivers could worsen the results. A quantification of these risk drivers could be appropriate in order to confirm this assumption. It would help to determine the orders of magnitude for each risk driver. This quantification could be done using the different indicators of the vulnerability of economic actors (companies, households) to the risk drivers previously identified.

**In addition to stress tests, analyses of risk drivers would improve other risk management tools**

The research could also potentially provide valuable insights to improve the transition risk management tools used by financial institutions. Indeed, this analysis would enable an in-depth understanding of transition risks at the sub-sectoral levels and could therefore be of interest not only for the community of climate stress test experts, but also for the risk management teams within financial institutions, as well as for service providers seeking to optimise their risk analysis tools for the management of climate-related transition risks.

# Introduction

## 1. Since 2015, a growing awareness of climate-related risks in the financial sector

On 29 September 2015, the Governor of the Bank of England, Mark Carney, made a historic speech, warning for the first time of the risks of climate change for financial stability. Climate shocks could affect the whole world, with major risks of asset depreciation and impacts on economic stability. He theorised the “tragedy of the horizon”, highlighting the disparity between the medium- and long-term emergence of costs generated by climate change and the short-term decisions made by investors.

Incorporating climate risks into financial management practices is no easy task. The intrinsic characteristics of climate risks, being uncertain, unprecedented and long-term, are difficult to reconcile with the conventional risk management processes used by financial institutions, which are typically based on loss probabilities obtained from historical defaults. The availability of data is also a major issue in the development of climate risk analysis.

Accordingly, and in order to address these issues, in 2017 eight central banks and bank supervisors created the Network for Greening the Financial System (NGFS). Today, 90 central banks and supervisors from all over the world are members of the network. The goal of the NGFS is to contribute to developing climate-related risk management in the financial sector and to mobilise the financial institutions to support the transition to a sustainable economy. In this context, the NGFS recommends that financial institutions use tools and methods enabling them to assess climate-related financial risks, such as climate stress tests

## 2. Climate stress tests: a new tool to incorporate climate risks into the financial sector

Stress tests are risk management tools used by supervisors and financial institutions. They are aimed at measuring the sensitivity of financial institutions in relation to scenarios simulating extreme but plausible macroeconomic and financial conditions. When conducted at the initiative of supervisors, the results of these exercises can determine the capital requirements needed by financial institutions to deal with these different shocks. Stress tests emerged in the late 1990s further to the Asian financial crisis and developed rapidly after the 2008 financial crisis.

Use of this type of exercise to measure the impact of climate risks on financial institutions is still new, but several supervision authorities have begun to work on or have already conducted this type of exercise, such as De Nederlandsche Bank (Vermeulen *and al.*, 2018), the Bank of England (Bank of England, 2019), or Banque de France and ACPR (ACPR, 2021). For the time being, the goal of these different exercises is not to impose an additional capital requirement on financial institutions, or to require them to develop internal risk management models, but rather to make them aware of the different climate-related risks and to develop methodologies to incorporate these risks into the financial sector. This is a very specific exercise, because while a traditional stress test assesses the effect of macroeconomic shocks in the short term (two to three years), the effects of climate change and the transition emerge in the long term and the timing and exact manner of their materialisation is uncertain.

There are three successive levels of materialisation and transmission of risk within the financial system (Jacquetin, 2021).

The first level is the trigger of the risk, here climate risk, including physical and transition risks.

The physical risks are the financial impacts resulting from the effects of climate change. These risks can be linked to extreme events (heatwaves, flooding, forest fires, storms, etc.), or can be chronic (changes in average temperatures, sea level rise, etc.).

Transition risks are the financial impacts resulting from the transition to a low-carbon economy. These risks can be linked to the introduction of climate policies such as carbon taxation, to technological changes such as the development of renewable energies or carbon capture technologies, to market evolution caused by changes in consumer behaviour or product availability, or they can be reputational (TCFD, 2017).

The second level of risk materialisation corresponds to the transmission of these climate risks into economic effects, that can be associated with shocks to macroeconomic parameters (inflation, unemployment rate, etc.), but also include transmission channels at a finer level (for example, damage to physical capital).

The third level of risk materialisation corresponds to the impact of these different shocks into financial risks for financial institutions through different risk categories (credit risk, market risk, operational risk, etc.).

The forward-looking nature of climate-related risks and the inherent uncertainty about future events make it difficult to analyse climate risks using standard modelling processes. In order to address this problem, in 2020 the NGFS proposed a first analytical framework for scenario analysis of climate risks aimed at central banks and supervisors.

### 3. A guide to climate scenario analysis developed by the NGFS

This first guide to climate scenario analysis, developed by the NGFS, is intended to be integrated into the different risk management tools used by the central banks and supervisors, and can serve as a basis for conducting the first climate stress tests.

The guide to scenario analysis developed by the NGFS proposes four families of scenarios, based on whether

climate targets are met and on the transition pathway involved (orderly or disorderly). This set of scenarios includes a certain number of transition risks, physical risks and macroeconomic variables. These scenarios draw primarily on the mitigation and adaptation pathways defined by the IPCC. To build the different scenarios, several assumptions have been made on future greenhouse gas emissions, the socio-economic context, climate policy, technology and consumer preferences.

#### BOX N°1: THE NGFS SCENARIO FAMILIES AND THEIR REPRESENTATIVE SCENARIOS

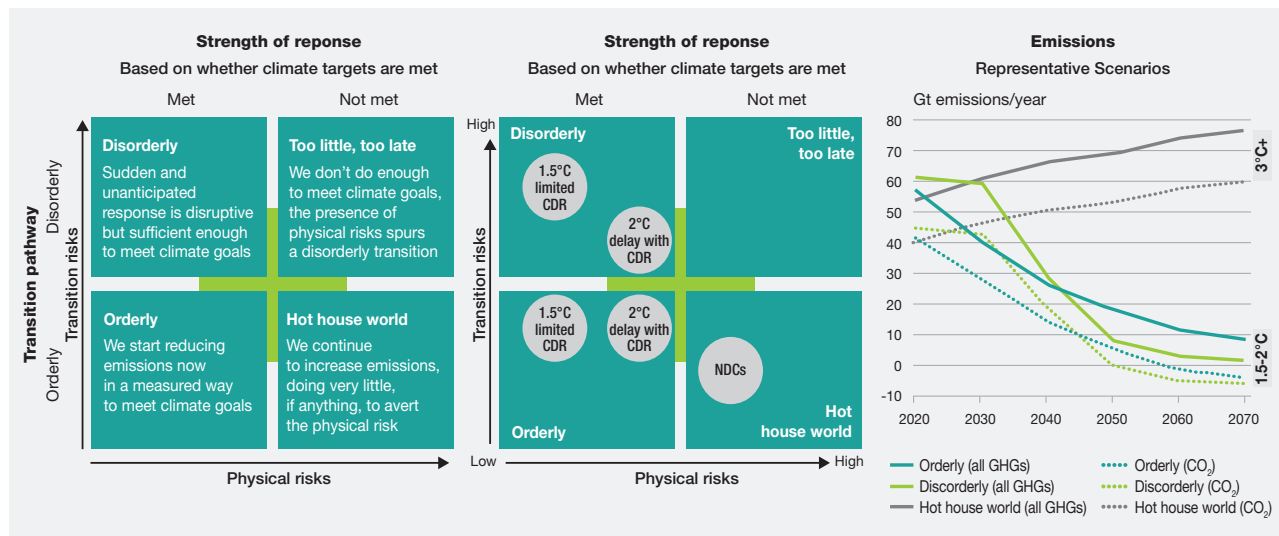
The “orderly” transition scenarios correspond to the implementation of a rapid, ambitious and anticipated transition that is sufficient to meet climate goals. These scenarios result in low physical and transition risks.

The “disorderly” transition scenarios correspond to the implementation of a late, disruptive, sudden or unanticipated transition, but which is also sufficient to meet climate goals. These scenarios result in low physical risks but high transition risks.

The “hot house world” scenarios correspond to scenarios in which no transition measures are taken to limit global warming, resulting in continued growth in greenhouse gas emissions and high physical risks.

The final scenario family, “too little too late”, presenting both high physical risks and high transition risks, has not been included in the NGFS analysis.

FIGURE 2: THE NGFS CLIMATE SCENARIOS AND ASSOCIATED EMISSIONS PATHWAYS



Source: NGFS, Guide to climate scenario analysis for central banks and supervisors, 2020

For the three scenario families described above, the NGFS has proposed three representative scenarios and several alternative scenarios.

The representative scenario for an orderly transition assumes the immediate introduction of an optimal emissions price that increases gradually until 2050, as well as the full availability of carbon capture technologies.

The representative scenario for a disorderly transition assumes the introduction of an emissions price from 2030, which increases more rapidly in order to offset the delay. This scenario assumes limited availability of carbon capture technologies.

Other alternative disorderly transition scenarios have also been selected, assuming, for example, the introduction of earlier and more disruptive emissions taxation policies, and with no availability of carbon capture technologies.

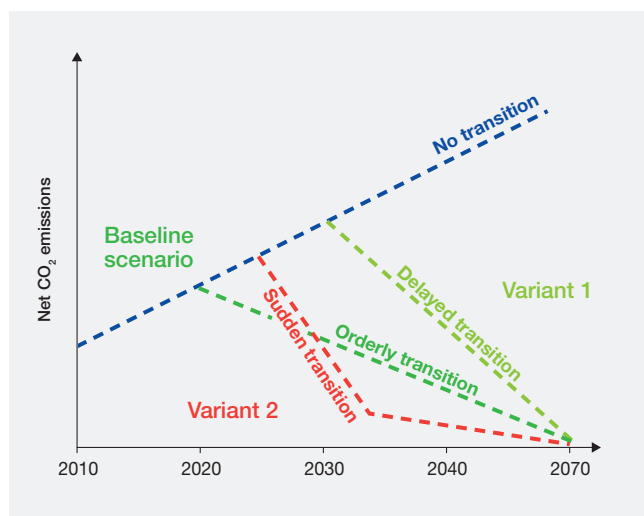
Finally, the representative scenario for a “hot house world” assumes that only current policies are implemented.

## 4. A first pilot exercise conducted by ACPR based on the NGFS analytical framework and including a sectoral dimension

In 2020, ACPR undertook its first pilot climate exercise in order to assess the vulnerability of the French financial sector (banks and insurance companies) to climate-related risks. The exercise was conducted in a bottom-up approach, with ACPR submitting the different scenarios to the banks and insurance companies participating in the exercise to enable them to conduct their own qualitative and quantitative analysis of the impact of these scenarios on their portfolios. ACPR then aggregated these individual results.

ACPR developed an analytical framework with Banque de France teams (Allen *and al.*, 2020), based on the work of the NGFS, in order to propose more detailed scenarios for the financial institutions. These scenarios combine policy, technology and socio-economic assumptions. The reference scenario chosen by ACPR is an orderly transition scenario, assuming a significant increase in the emissions price from 2020, which is both announced and anticipated. Two other scenarios are disorderly transition scenarios that are adverse to the first scenario. The first variant describes a late policy response, with the introduction of a carbon price in 2030, exactly aligned with the NGFS reference scenario. The second variant, which is more adverse than the scenarios proposed by the NGFS, describes a sudden, unanticipated transition scenario, with the introduction of a carbon price from 2025, accompanied by negative productivity shocks in relation to the reference scenario, due to the immaturity of renewable energy production technologies. The final scenario, used to determine the physical risks, describes the continuation of existing policies, and thus a pathway with no transition.

**FIGURE 3: SCHEMATIC REPRESENTATION OF TRANSITION SCENARIOS INCLUDED IN THE ACPR PILOT EXERCISE**



Source: ACPR and al., *Climate-Related Scenarios for Financial Stability Assessment: an application to France, Working papers, 2020*

The pilot exercise developed by ACPR has several specificities. The exercise is conducted over a 30-year period, until 2050, with exposures in four geographical areas (France, rest of the EU, United States, and rest of the world). It has a sectoral dimension, including 55 sectors of activity, in order to increase the granularity of the analysis and to measure the sensitivity of certain sectors to the different scenarios. The analytical framework also proposes a balance sheet that is static until 2025, then dynamic until 2050, in order to enable the financial institutions to adjust their portfolios according to the different transition dynamics at work.

## 5. The objective of this report: contributing to the development of the methodological framework for climate stress tests

This report is part of the Finance ClimAct project, and is aimed at providing new thinking on the climate scenario analysis work conducted by the NGFS. The goal of this work is to find ways to refine the scenarios in order to enhance their relevance, without making the exercise more complex. The findings of the analysis would then be used to determine whether there is a need for more in-depth methodological research on the climate scenarios. This is an intermediate report, and is part of a broader research project to analyse the sectoral risks associated with climate change.

The aim of the Finance ClimAct project is to contribute to the implementation of the French National Low-Carbon Strategy and the European Union Sustainable Finance Action Plan. In particular, the project will develop tools, methodologies and new knowledge to enable the financial institutions and supervisors to incorporate climate change into their financial management and decision-making processes. To this end, the project works to build the capacity of these actors to conduct climate stress tests, by producing guidelines, tools and appropriate metrics, thereby helping them to better understand the financial risks associated with climate change.

Although the NGFS analytical framework lays the groundwork for a first climate risks analysis methodology for financial institutions, it could result in a partial analysis of transition risks. Indeed, the NGFS has chosen to focus in its first edition reference scenarios on two transition risk drivers (public policy measures, captured by an emissions price and technology availability, especially carbon capture technologies). Although they rely on a complex modelling of sector transformations, in particular in the energy sector, the NGFS scenarios, do not offer a granular analysis by sector. and does not propose any granular analysis within a given sector. The additional elements provided by the Banque de France/ACPR exercise have partially filled this gap, by enabling a sectoral analysis, which is nevertheless insufficient to capture changes within the sectors. While an aggregated approach is consistent with a more classical



approach to stress testing, the complexity of climate issues means that this analytical framework could generate results that are significantly different from those of a more comprehensive analysis of transition risk drivers.

This report therefore undertakes a first exploration through two sectoral case studies to demonstrate the extent to which the analysis of the intra-sectoral dimension could provide new and significant information.

## 6. The initial assumptions: multiple transition risk drivers differentiated by sector and by economic actor

The existing analytical framework for climate stress tests can be enhanced in several ways. Different assumptions can support this process. The first assumption is based on the fact that there are many different potential sources of transition risk and that these can differ according to the sector. These risks can be due to the introduction of regulations imposing a high carbon price, but also to many other types of regulations, to rapid and disruptive technological shocks, or to market risks such as changes in demand from economic actors. Furthermore, the combination of these different risks could generate significant financial risks. Current risk analyses could then give a very partial view of the risks and could therefore underestimate them.

The second assumption is based on the fact that not all of the actors within a given sector have the same levers to deal with the transition risk drivers thus identified. They do not necessarily all have the same ability to adapt, to transfer or avoid risk, or to absorb financial shocks. Risk analyses that do not take account of these factors specific to different actors could potentially identify risks that will not materialise or that do not affect financial actors, or, on the contrary, could potentially overlook certain risks specific to some of the actors in the sector.

The current analytical framework proposed by the NGFS focuses mainly on transition risks based on the introduction of climate policies captured by trajectories leading to an increase in the emissions price, and on the availability of certain technologies, especially carbon capture technologies. It does not include any scenario assumptions that are differentiated according to the sector, and the analysis does not enable differentiation between the impact of different shocks within a given sector. The analytical framework proposed by the NGFS could therefore give only an incomplete view of the transition risks that could affect the financial institutions.

## 7. A methodological approach based on the development of two sectoral case studies: residential property and cement

This report adopts a sectoral approach to test these different initial assumptions. Two sectors have been selected for the purposes of the study: the cement sector and the private residential property sector. These sectors were chosen because of the level of challenges they face in a context of transition, because the literature is abundant on the subject and, for the property sector, because of its weight in bank portfolios.

The research conducted for this report was based on the literature and on discussions with sector experts from ADEME, in order to obtain technical information on the different sectors. For the property sector, this research was compared with the more financial views of Banque de France experts, in order to identify transition scenarios that could represent financial risks. These scenarios are intentionally designed to stress bank balance sheets under different transition risks. They are by no means projections and indicate neither the desirable nor the probable outcomes. They cannot be used to judge the merits of the transition.

Although the methodological analysis in this report is based on the example of France, with its specificities, it can also apply to a broader context and to other climate stress test exercises conducted by financial regulators and supervisors throughout the world.

The report will build on the methodology proposed by Vailles *and al.* (2020) for implementing a scenario analysis of transition-related issues. For each of the case studies, the first part will define the objectives, the issues and the scope of the study. The second part will explore the key issues of the low-carbon transition for the sector studied. The third part will identify the uncertain future changes that could be problematic in the framework of this transition, but also the opportunities. Finally, the last part will determine the different transition risk drivers that are relevant to each of the sectors, establish the risk transmission dynamics and identify the data required in order to quantify scenarios that model these risk drivers.

# Part 1. Case study on the private residential property sector

## Part 1.1. Choice of the scope of the property sector and the extent of exposure to transition risks

### 1.1.1. Mortgage loans to households: high exposure of French banks to transition issues

Property and buildings are central to the issues of the transition to a low-carbon economy and adaptation to climate change. Indeed, the residential sector accounts for 11% of national emissions in France (CITEPA, 2020) and Europe (IAE, 2020). Although the greenhouse gas emissions generated by the sector have been declining since the 1990s (-1.0% per year), France is lagging behind on its emissions reduction targets, exceeding the indicative annual shares of the carbon budget for 2015-2018, thereby putting the country at risk of failing to meet the European emissions reduction targets for 2030.

The French banks are particularly exposed to these different transition issues through their high exposure to the property sector. Indeed, total mortgage loans (excluding the public sector) account for 26% of the amount of loans outstanding for French banks, and 21% are mortgage loans to households (Banque de France, 2020)<sup>2</sup> (figure 4). Ultimately, the transition risks for the sector could therefore also represent risks for banks.

In view of the weight of mortgage loans to households in bank portfolios, and for a purpose of data granularity, the scope of this analysis will focus on the private residential property sector.

### 1.1.2. Exploration of the characteristics of households and dwellings conditions risk

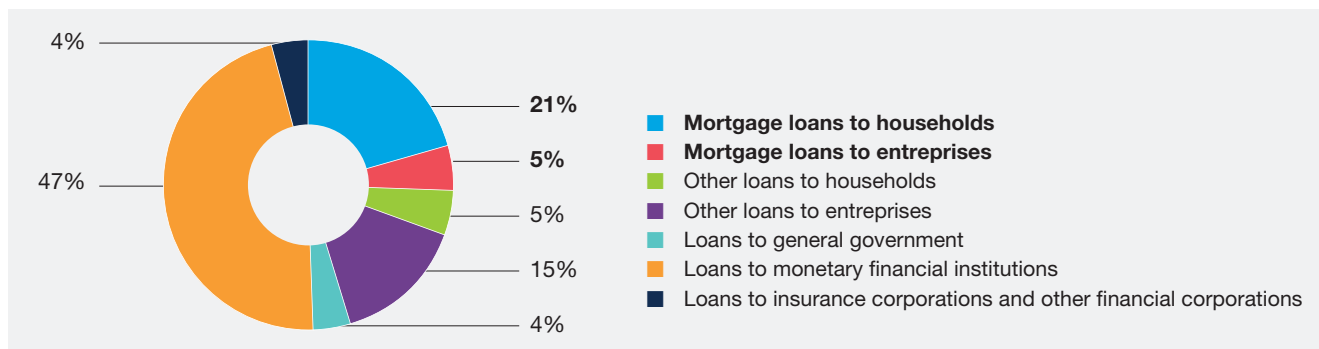
The goal of this study is to identify the characteristics and possible evolution of the residential property sector in view of the issues of the low-carbon transition and climate change, in order to identify the transition risk drivers for the sector. These transition risks can be caused by the introduction of a regulation to reduce the impact of the sector on climate change, for example, or by changes in household behaviour.

The scenarios modelling these different risk drivers can have consequences for bank balance sheets, through different risk categories (credit risk, market risk). Since the scope of this report focuses specifically on the private residential property sector, the transition risks for this sector emerge for banks through the mortgage loans taken out by households in order to finance the purchase of their residential properties. The dwellings concerned by this analysis are therefore those exchanged on the property market and financed by a bank loan. The households studied are homeowners or landlords.

Transition scenarios can involve different household debt and property price dynamics, which imply different levels of risk for credit institutions. Banks can be exposed to credit risk, through financial insolvency of households, which can be compounded by a loss of property value.

Exploration of the characteristics of households and properties covered by mortgage loans is therefore key to determining the areas of risk in a context of transition.

FIGURE 4: DISTRIBUTION OF ALL OUTSTANDING LOANS PROVIDED BY FRENCH BANKS TO FRENCH RESIDENTS IN 2020



Source: I4CE, according to Banque de France data, 2020

2 It should be noted that these results may differ between banks, which do not all have the same exposure to the property sector.

**1.1.3. The building occupancy phase is key to exploring household exposure to transition risks**

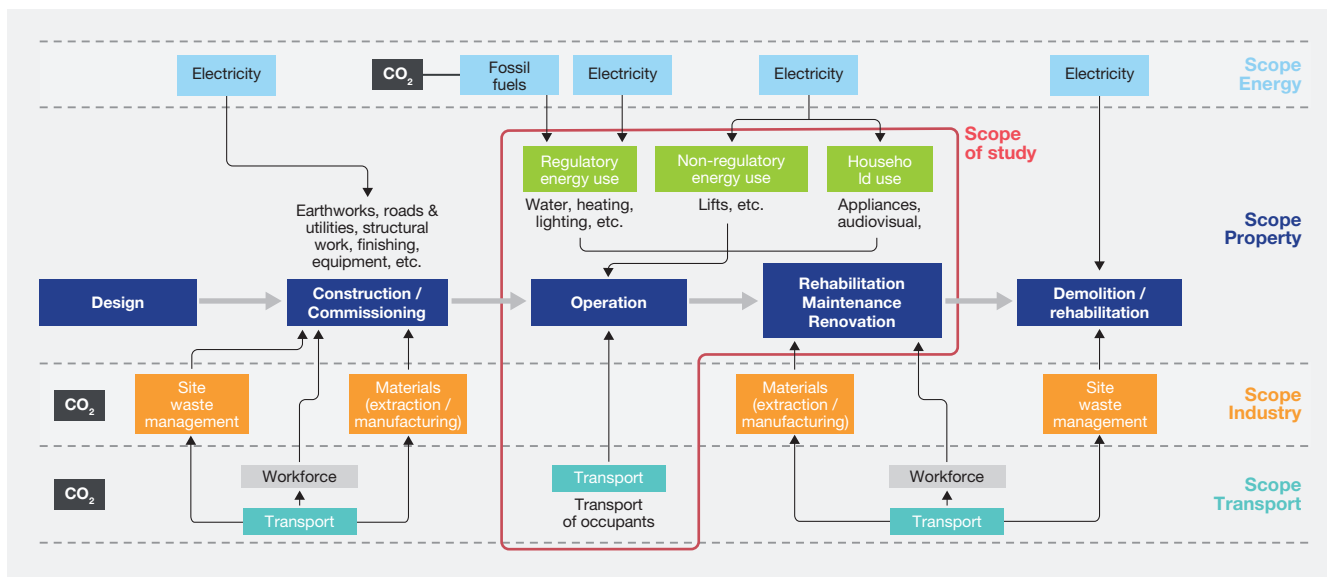
The life cycle of a dwelling is comprised of several phases (ADEME *and al.*, 2011): (i) the design and construction of the building (structural work, finishing work and equipment), (ii) its use (operation, servicing/maintenance), and finally (iii) its demolition or rehabilitation (figure 5).

The scope of the study focuses mainly on the phase of building occupancy by the household. Indeed, the issues of

the low-carbon transition that can impact households, and therefore their capacity to repay a loan, are mainly associated with this phase. The costs associated with transport for the occupants of the building are also taken into account in the analysis, as they are primarily linked to the location of the dwelling.

The phases linked to the construction of the building and its demolition are not, however, included in the scope of the analysis, since the transition issues associated with these phases mainly impact manufacturers and building companies.

**FIGURE 5: LIFE CYCLE OF A BUILDING**



Source: I4CE, from Ademe *and al.*, Bilan Carbone © appliqué aux bâtiments, 2011

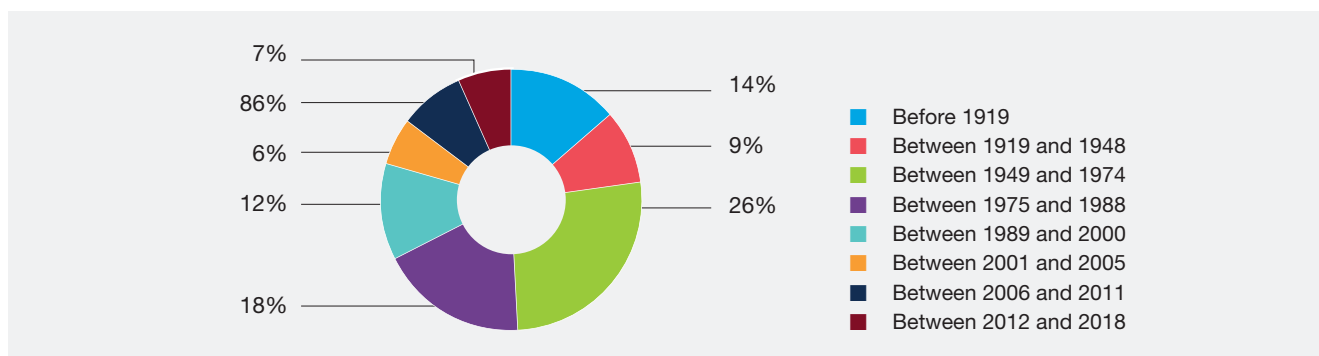
## Part 1.2. Key characteristics of the residential property sector in France faced with the transition to a low-carbon economy

### 1.2.1. The private housing stock in France is marked by existing stock

As of 1 January 2018, France had 36.3 million housing units, including 29.7 million primary residences, 3.5 million second homes and 3 million vacant dwellings. In total, 57% of primary residences were one-family dwellings, compared to 43% multi-family dwellings (INSEE, 2018). Almost half of all

primary residences were built prior to 1975 (figure 6), in other words before the first thermal regulation was introduced (CGDD, 2020). Since the beginning of the 1980s, the housing stock in France has grown by an average of 1.1% per year (between approximately 300 000 and 400 000 housing units per year) (INSEE, 2018). This context means energy retrofits are all the more important in the framework of the transition to a low-carbon economy and the French objective of bringing the housing stock up to the low-energy level or equivalent by 2050 (SNBC, 2020). This could encourage regulations to have a greater focus on renovation than on construction with a view to improving the energetical performance of the housing stock.

FIGURE 6: STRUCTURE OF THE STOCK OF PRIMARY RESIDENCES BY CONSTRUCTION PERIOD AS OF 1 JANUARY 2018



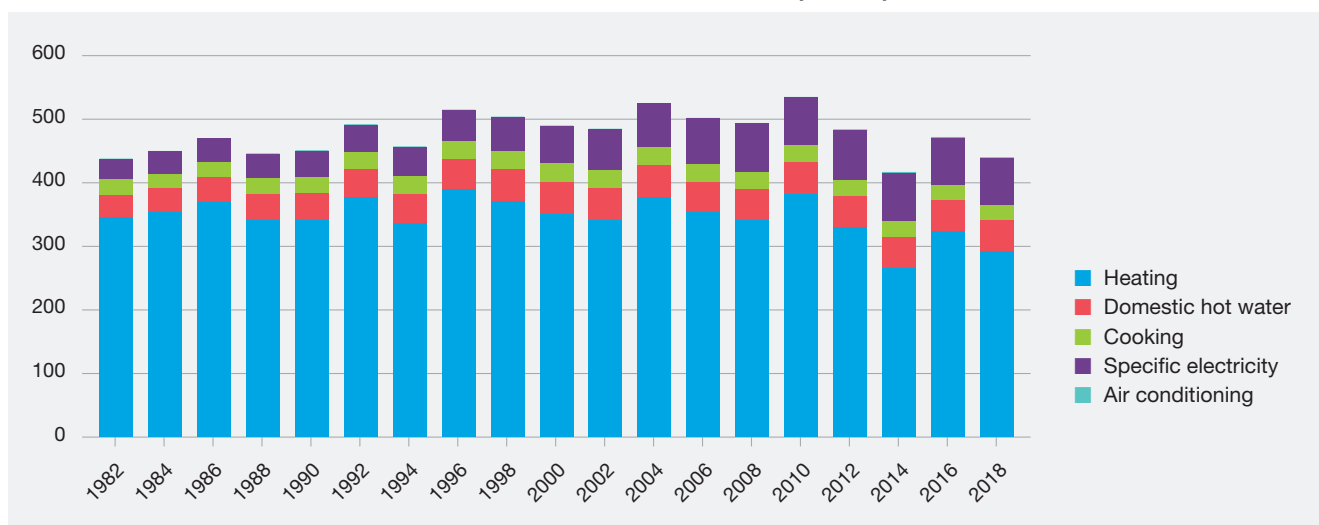
Source: I4CE, from CGDD, *Le parc de logements par classe de consommation énergétique*, 2020.

### 1.2.2. Households consume fossil fuels through their heating needs

Energy consumption of residential buildings stood at 439 TWh in 2018 (CEREN, 2019). The main energy consumption item in homes was heating (66% of total consumption), followed

by specific electricity (excluding heating, domestic hot water and cooking) (17%), domestic hot water (11%) and cooking (5%). There has been an overall decrease in energy consumption in residential buildings over the last decade (around -2% per year on average), mainly due to a slight reduction in consumption of heating (figure 7).

FIGURE 7: EVOLUTION OF ENERGY CONSUMPTION IN HOUSING BY USE (IN TWH)

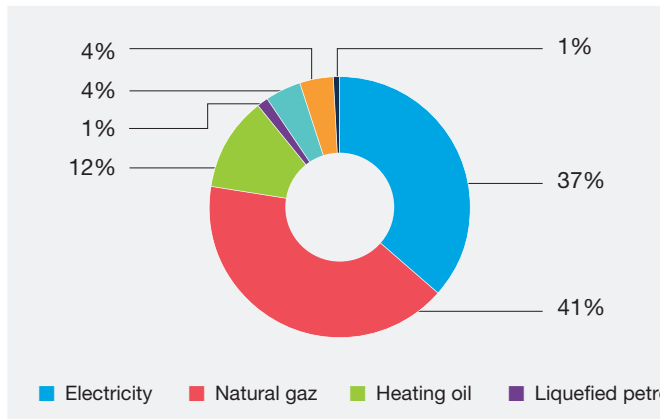


Source: I4CE, from Ceren, *Energy consumption of the residential sector in 2018*, 2019

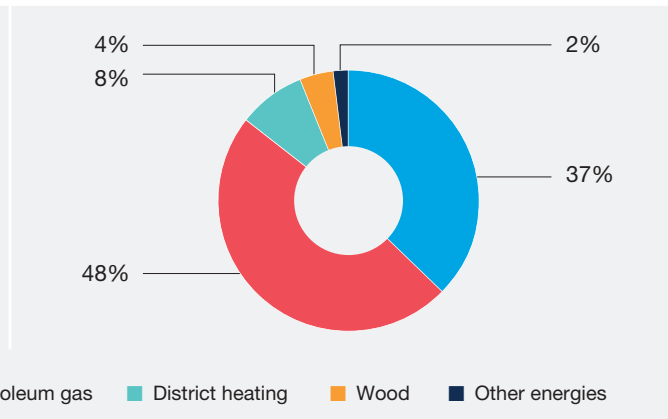
Natural gas remains the main source of heating in primary residences (41% in 2018), followed by electricity (37%). The electricity produced in France is largely carbon-free<sup>3</sup> (RTE, 2020), still more than half of all primary residences in France uses fossil-based energy for heating (figure 8).

Fossil fuels are still the predominant source of energy for heating in new buildings, with natural gas accounting for around 48% of main energy sources in 2018. It should be noted, however, that heating oil and liquefied petroleum gas have almost disappeared from the main energy sources used in new buildings (figure 9) (CEREN, 2018).

**FIGURE 8: ENERGY SOURCE FOR HEATING IN PRIMARY RESIDENCES IN 2018**



**FIGURE 9: MAIN ENERGY SOURCE FOR HEATING IN NEW BUILDINGS IN 2018**

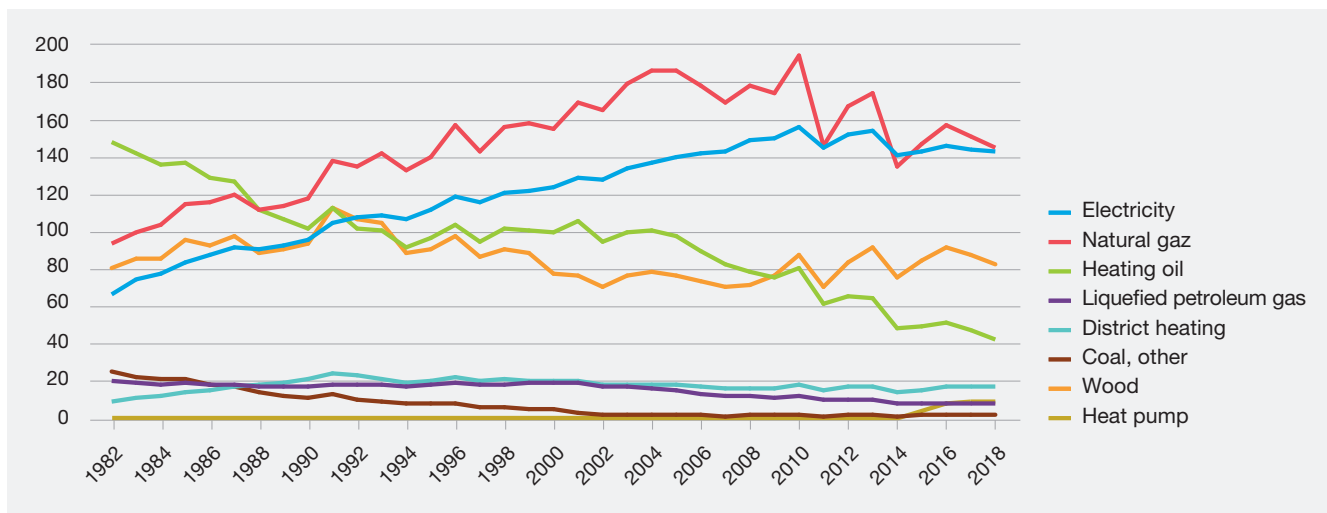


Source: I4CE, from Ceren, Energy consumption of the residential sector in 2018, 2019

The consumption of heating oil in housing has decreased substantially since the early 1980s (-3% per year), as has that of coal (-5% per year) and LPG (-2% per year), in favour of electricity (+2% per year) and natural gas (+2% per year). Heat pumps still only account for a small percentage of the energy mix (2% of the total) (figure 10).

This predominant consumption of fossil fuels in housing in France, as well as the dependence on automobiles, mean a certain number of households may be vulnerable to the risk of transition to a low-carbon economy, especially an increase in the carbon tax.

**FIGURE 10: EVOLUTION OF ENERGY CONSUMPTION OF HOUSING ACCORDING TO THE ENERGY MIX (IN TWH)**



Source: I4CE, from Ceren, Energy consumption of the residential sector in 2018, 2019

3 As of 2020, 67% of this electricity was generated by nuclear power and 23% by renewable sources (RTE, 2020).

**PART 1. CASE STUDY ON THE PRIVATE RESIDENTIAL PROPERTY SECTOR**

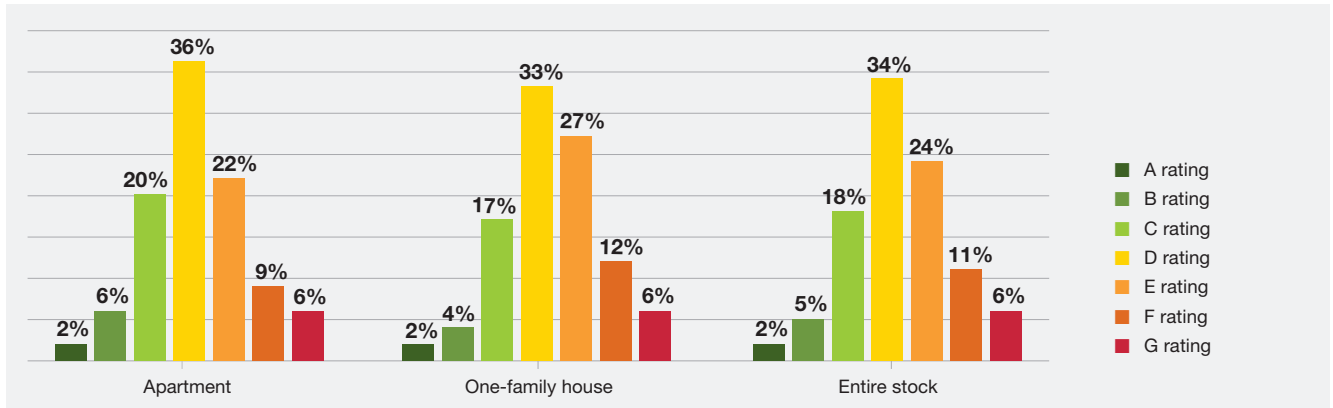
*Part 1.2. Key characteristics of the residential property sector in France faced with the transition to a low-carbon economy*

**1.2.3. A private housing stock with many poorly insulated homes**

According to the study published by the data and statistics department of the French Ministry for the Ecological Transition

(2020), as of 1 January 2018, 1.9 million primary residences, or 6.6% of the stock, were energy efficient (energy performance rating A or B), while 4.8 million, or 16.6% of the stock, were thermal sieves (energy performance rating F or G) (figure 11).

**FIGURE 11: DISTRIBUTION OF DWELLINGS ACCORDING TO THEIR ENERGY RATING**

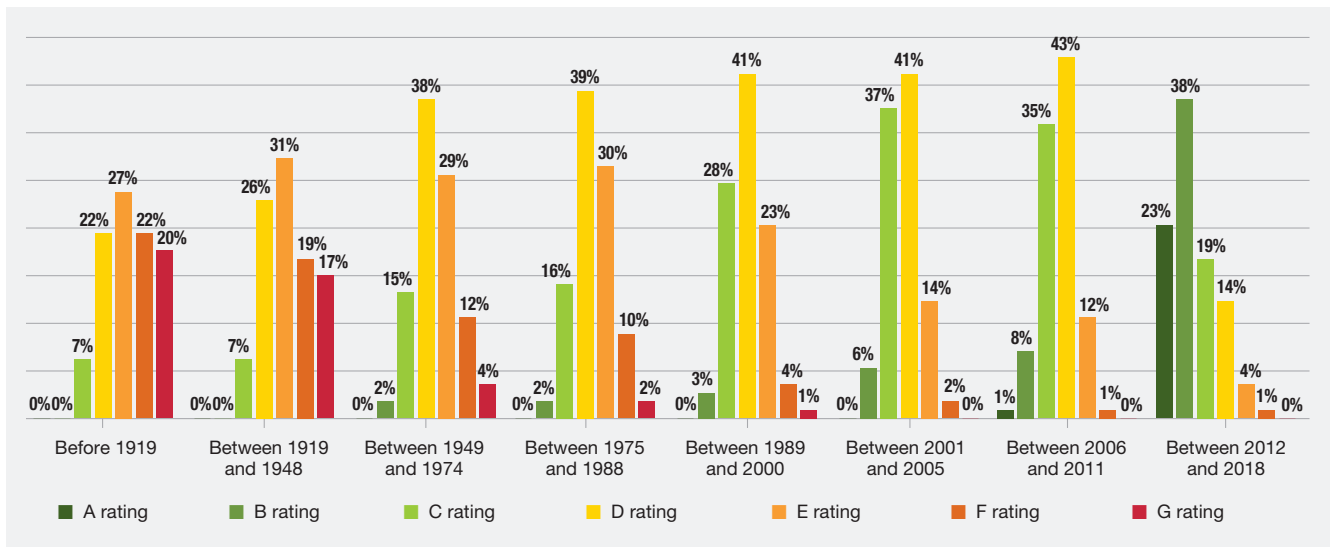


Source: I4CE, from CGDD, *Le parc de logements par classe de consommation énergétique, 2020*

The study also shows that the older a dwelling is, the lower its energy performance will be. Around 40% of dwellings built prior to 1948 are very inefficient, compared to only 1% or 2% of dwellings built since the 2000s. The thermal regulation

of 2012 has had a major impact on the energy performance of new buildings, since more than 60% of dwellings built after 2012 are very efficient (figure 12).

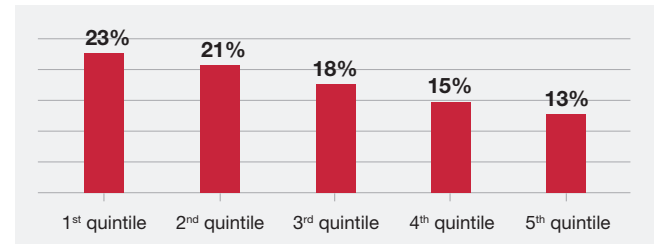
**FIGURE 12: DISTRIBUTION OF DWELLINGS BY YEAR OF CONSTRUCTION ACCORDING TO THEIR ENERGY RATING**



Source: I4CE, from CGDD, *Le parc de logements par classe de consommation énergétique, 2020*

Finally, a more detailed analysis of the distribution of dwellings according to the income of owner-occupiers shows that almost a quarter of low-income homeowners have an inefficient home (figure 13), which makes them more vulnerable to transition risks. The combination of these two factors presents a risk in the context of stricter regulations with a view to making the housing stock carbon-neutral by 2050.

**FIGURE 13: PROPORTION OF INEFFICIENT DWELLINGS ACCORDING TO THE INCOME OF OWNER-OCCUPIERS**



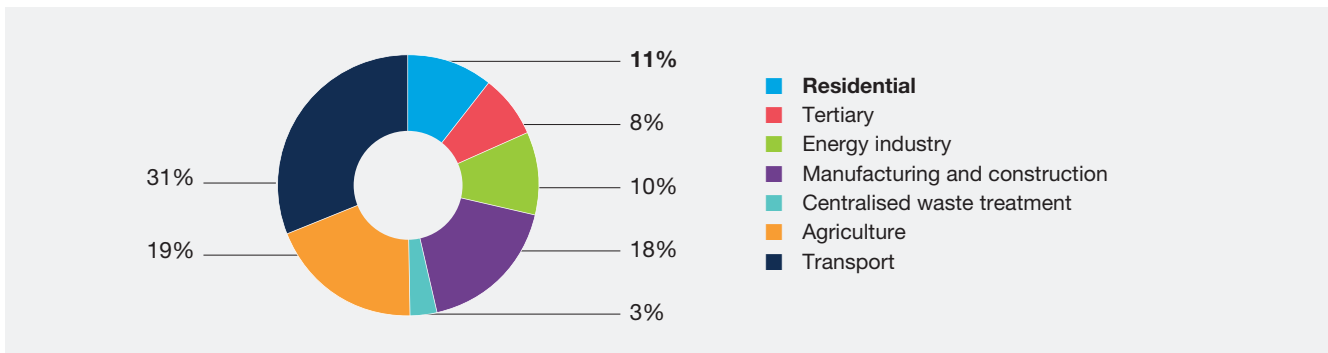
Source: I4CE, from CGDD, *Le parc de logements par classe de consommation énergétique, 2020*

**1.2.4. The pace of decarbonisation is insufficient in the residential sector**

Greenhouse gas emissions from the residential building sector stood at 48 MtCO<sub>2</sub>eq in 2018, or 11% of total national emissions (CITEPA, 2020). These emissions, as measured by CITEPA, are generated by the domestic activities of households (the “use” phase of the life-cycle), and more specifically by the combustion of fossil fuels in the use of heating appliances.

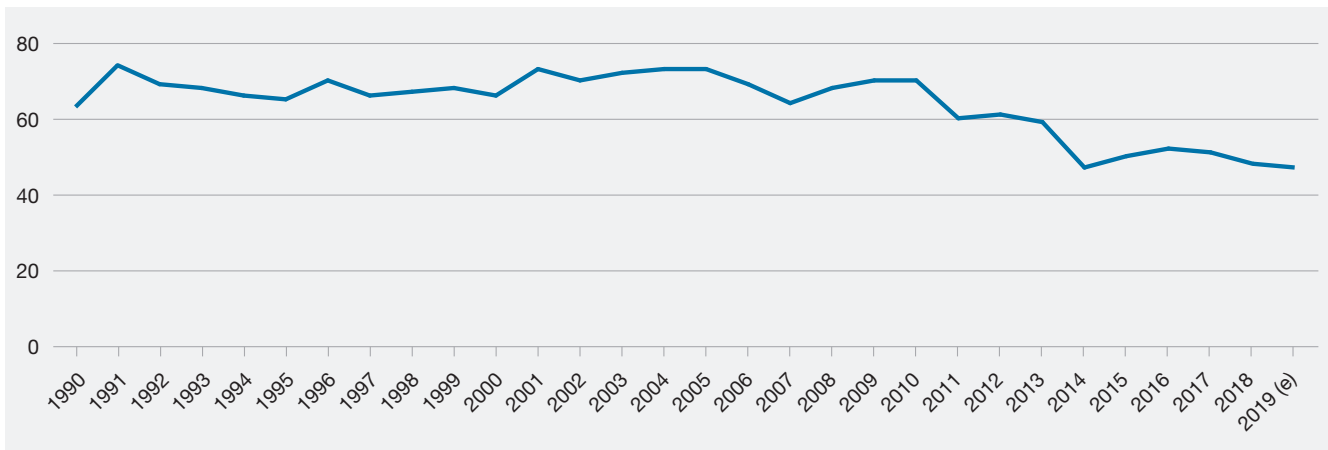
There has been an overall reduction in these emissions since 1990 (-1% per year). This reduction is mainly explained by changes in the types of fuel used. In France, heating oil has been gradually replaced by electric heating and gas heating, which have lower greenhouse gas emissions (see part 1.2.2). However, the reduction in greenhouse gas emissions from housing in the last few decades is not yet enough to achieve the reduction target of at least 49% by 2030 relative to 2015 (SNBC, 2020). These emissions make the occupants of housing sensitive to the risks of the transition to a low-carbon economy, especially an increase in the carbon tax.

**FIGURE 14: DISTRIBUTION OF GHG EMISSIONS IN FRANCE IN 2018**



Source: I4CE, from CITEPA, SECTEN report, 2020

**FIGURE 15: EVOLUTION OF GHG EMISSIONS FROM THE RESIDENTIAL SECTOR IN FRANCE (IN MT CO<sub>2</sub>EQ)**



Source: I4CE, from CITEPA, SECTEN report, 2020

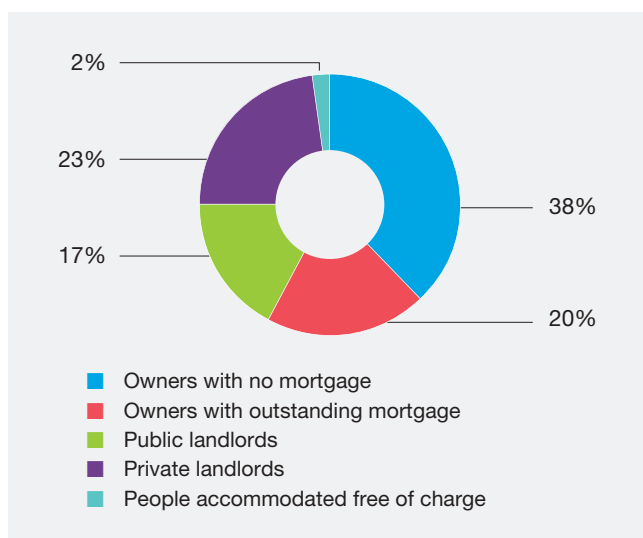
## PART 1. CASE STUDY ON THE PRIVATE RESIDENTIAL PROPERTY SECTOR

Part 1.2. Key characteristics of the residential property sector in France faced with the transition to a low-carbon economy

### 1.2.5. Property investments largely financed by bank loans for purchases but not for renovation

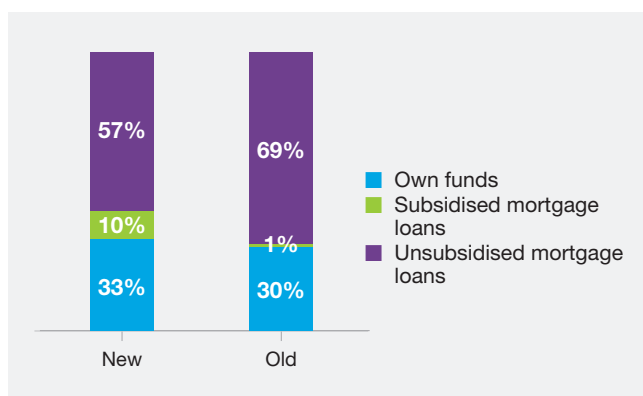
As of 1 July 2019, 58% of households in France were owners of their primary residence, and 35% of owner-occupiers had an outstanding mortgage loan (figure 16). The average proportion financed by bank loan for the acquisition of a home is around 70% of the total investment (CGDD, 2020) (figure 17). Household indebtedness for property purchases could be an aggravating factor of risk in the context of transition scenarios that cause a decrease in income.

**FIGURE 16: DISTRIBUTION OF PRIMARY RESIDENCES IN FRANCE ACCORDING TO OCCUPATION STATUS ON 1 JANUARY 2020**



Source: INSEE, CGDD, annual estimation of the housing stock in France on 1 January 2020.

**FIGURE 17: FINANCING OF PROPERTY ACQUISITIONS FOR BUYERS ON 1 JULY 2019**



Source: I4CE, from CGDD, *Compte du logement 2019, 2020*

In order to undertake energy renovations, households are more likely to finance their investments with their own savings rather than with a bank loan. According to the TREMI survey (ADEME *and al.*, 2018), 32% of households questioned took out a bank loan to finance their renovation projects. The predominant use of own funds to finance renovation is largely explained by the fact that such work is mostly done in stages, and the different bank loans available today are ill-suited to the large sums required (see part 1.3.2) and depend on the characteristics of borrowers.

### 1.2.6. The surroundings of the dwelling: a selection criterion for households

Demand for housing in France is largely driven by population growth, changes in ways of cohabiting (the number of household members) and the location of property (according to different areas with or without high demand).

For a household, the choice of housing and the price its members are willing to pay depend on different aspects, such as the comfort of the property, its size, its characteristics and its location. Although all of these criteria are important in the choices made by households, and implicitly in the determination of prices, the location takes precedence.

The choice of location is mainly driven by the accessibility of jobs and services, the environment and the social quality of the neighbourhood. Over the last 30 years, there has been a growing tendency to move further away from city centres, with a marked preference for one-family houses (peri-urbanisation), especially for low-income households, which increasingly purchase houses further away from centres (INSEE, 2017).

However, changes in household behaviour have been observed in recent years. Population concentration and densification have significantly increased in several large cities, which can be explained by the concentration of activities in these areas with a view to productivity gains, or by an increase in the environmental costs of automobile transportation, resulting in a decline in the construction of one-family houses in favour of multi-family dwellings (INSEE, 2017).

Property values are thus closely linked to the location of the property. Changes in lifestyles (especially ways of cohabiting), in the distribution of activities across the territory, or in the housing environment could also affect demand for housing in the future, making some households vulnerable if demand for the type of dwelling they own decreases in the coming decades.



## Part 1.3. Uncertain changes in the residential property sector could present transition risks

### 1.3.1. The climate policy agenda could affect households with inefficient dwellings that use fossil fuels

#### 1.3.1.1. Carbon taxation imposed on households through their consumption of energy products

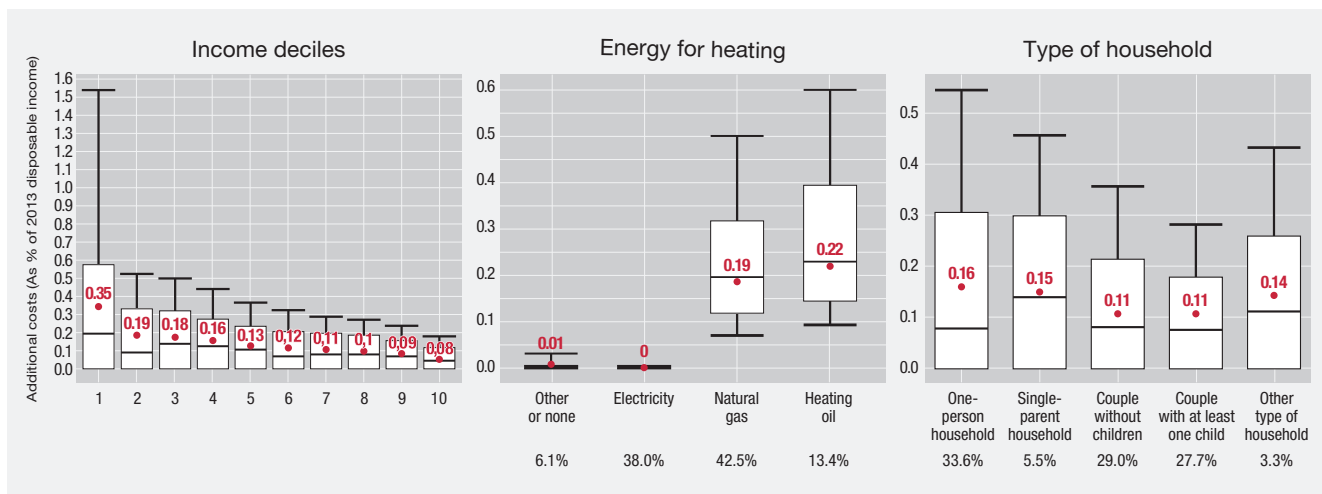
Carbon taxation was established in France in 2014 through the implementation of a carbon component, introduced into the calculation of domestic consumption taxes and proportional to the CO<sub>2</sub> content of energy products. It increased from 7 euros per tonne of CO<sub>2</sub> in 2014 to 44.6 euros per tonne of CO<sub>2</sub> in 2018. Without the “yellow vests” crisis, it would have risen to 55 euros per tonne of CO<sub>2</sub> in 2019, to reach 86.2 euros per tonne of CO<sub>2</sub> in 2022 (PLF, 2018)<sup>4</sup>.

An increase in the carbon tax can affect households through their energy bills, especially linked to their consumption of heating, and to the fuel they use for their journeys.

The Prometheus model, developed by CGDD (2016), analysed the impact of the carbon component on household energy bills linked to their dwelling, and identified different criteria that could potentially reduce or increase this impact (figure 18):

- Household disposable income: the additional cost linked to the introduction of the carbon component has a greater impact on the energy bills of the lowest income households (0.35% of their disposable income) than on those of the highest income households (0.06% of their disposable income);
- The type of energy used for heating: the additional cost is greater for households that use heating oil (0.22% of disposable income) and gas (0.19% of disposable income) than for those that use electricity (0%);
- The number of household members: the additional cost is greater for single-parent or one-person households (0.15% - 0.16% of disposable income) than for couples without children or with at least one child (0.10% - 0.11% of disposable income);
- The geographical location of the dwelling, with average living space being greater in rural areas.

**FIGURE 18: ADDITIONAL COST OF THE INTRODUCTION OF THE CARBON COMPONENT FOR HOUSEHOLD HOUSING ENERGY BILLS IN 2016 (AS % OF DISPOSABLE INCOME)**



Source: CGDD, Prometheus model, 2016

An increase in the carbon tax could thus have different consequences for the budgets of households, depending on their specific characteristics. Such an increase could have a greater financial impact on the lowest income households.

#### 1.3.1.2. Policies on renovation obligation of inefficient dwellings could undermine the capacity of households to use their property

The renovation obligation of housing is one of the key points of France’s climate objectives. Indeed, if France is to meet its climate commitments, a massive retrofitting programme

for the sector, combining both energy efficiency of heating systems and insulation of homes, but also energy system decarbonisation, is crucial. In its National Low-Carbon Strategy (SNBC), France plans to bring the housing stock up to BBC<sup>5</sup> (low-energy building) level by 2050, with a target of 500 000 to 700 000 renovations per year.

The Climate and Resilience bill<sup>6</sup>, drawn from the proposals of the French Citizens’ Climate Convention, provides for renovation obligation of dwellings in the G class from 2025, in the F class from 2028, and in the E class from 2034, failing

4 French National Assembly 2017 – Budget bill for 2018.

5 BBC-Effinergie® label (low-energy building) by decree of 29 September 2009 (80 kWhpe/m<sup>2</sup>/year).

6 French National Assembly, 2021 – Bill n°3875 on combating climate change and strengthening resilience to its effects.

which they will be considered as substandard and will therefore be impossible to rent.

Renovation obligation was one of the central points of the Citizens' Convention on Climate (2020), which initially planned to oblige owner-occupiers and landlords to carry out global renovation of their property in order to achieve an A or B energy performance rating (or C for certain dwellings that would be unable to achieve a BBC level). In particular, the Convention proposed making whole-building renovation obligation prior to property transfer (sale, legacy, transmission), and progressively imposing a ban on the letting of inefficient housing.

Renovation obligation may also cover the replacement of heating appliances. The Ecological Defence Council of 27 July 2020 provided for the phase-out of oil- and coal-fired boilers by 2030, with a ban from 2022 on the installation or replacement of new boilers of these types.

### **1.3.2. Numerous obstacles to energy renovation can exacerbate the financial situation of households in the context of the transition**

#### **1.3.2.1. Global, high-performance renovation are complex to implement yet essential to achieve energy performance objectives in buildings**

Energy renovations need to be rolled out on a huge scale in order to achieve the SNBC objectives of bringing the housing stock up to the BBC level by 2050. Yet the majority of renovations today fall short of these objectives. Indeed, according to the TREMI survey (ADEME *and al.*, 2018), for the 1.3 million households questioned, only 25% of the work completed had resulted in the dwellings (one-family houses) changing energy efficiency rating, and only 5% had made a major impact on energy performance (moving up two levels or more).

The low level of performance achieved by this work is largely explained by the fact that most housing renovations are currently done "step-by-step" (one or two components in general). These practices do not typically involve any coherent, systemic planning.

Very few renovations aimed at achieving a BBC level or equivalent have been undertaken. To date, only 3 780 global renovations to BBC level or equivalent have been conducted, and several hundred "step-by-step" BBC renovation have been started but not finished (ADEME *and al.*, 2021).

A high-performance renovation (achieving a BBC level or equivalent), whether conducted in one or several steps, should comply with certain parameters (ADEME *and al.*, 2021). In particular, it requires a holistic plan of the different stages involved and should anticipate how the interfaces between projects will be managed.

Today, these interfaces between projects in one-family houses are often handled by different professionals, explaining this tendency to undertake "step-by-step" renovations. Most craft companies can rarely cover all the different trades needed for a high-performance

renovation, especially as the profession is struggling with a shortage of skilled workers. According to the négaWatt association (2019), the number of skilled manual workers available in France is not sufficient to meet all BBC retrofit requirements, and today most tradespeople prefer step-by-step renovations, which are less complex and often more profitable.

Bringing the housing stock up to the BBC level by 2050 will therefore be impossible without a holistic approach to renovation and efforts to coordinate the different trades. The difficulty of ensuring that a renovation achieves a high-performance level may be a source of risk for households, especially in the context of stricter mitigation policies (carbon tax, renovation obligation).

#### **1.3.2.2. Support schemes and incentives for renovation are varied but ill-suited to financing global renovation**

In order to enable households to carry out these works, a certain number of support schemes and incentives have been set up, including MaPrimeRénov', which resulted from the merger on 1 January 2020 of the CITE (tax credit for the energy transition) and the Habiter Mieux Agilité programme by ANAH (Agence Nationale de Rénovation et de l'Habitat - French national renovation and housing agency), which provides grants for renovation. These grants can be combined with other types of public support, such as energy saving certificates (CEE), or other public support programmes set up by ANAH. Financial incentive schemes have also been created, such as the EcoPTZ, an interest-free eco-loan available to all households to finance renovation of old housing.

However, these schemes introduced by the state are unsuitable and insufficient to enable households to conduct high-performance renovations. The renovations needed to bring the housing stock up to the BBC level by 2050 require investments, which are for the time being largely borne by households.

According to an EnerTech report submitted to ADEME (2016), the average cost of a BBC renovation for a one-family house ranges from 30 000 to 70 000 euros excluding taxes. In its report entitled "Renovating better: Lessons from Europe", the French High Council on Climate highlights the unsuitability of the aid schemes and incentives set up by the state to enable households to finance their renovation without any personal contribution. Indeed, combined MaPrimeRénov and CEE support ranges from 11 000 to 15 000 euros for the lowest income households, and the EcoPTZ ranges from an average of 13 342 euros to a maximum of 30 000 euros, which may be insufficient to cover the remaining amount for households, especially those in the lowest income group.

The maximum term of 15 years for the EcoPTZ is also unsuitable, since the energy savings made do not offset the high monthly payments for the loan. In addition, the EcoPTZ is not necessarily accessible to all households, some of which may be refused a loan by the bank if it decides they are not creditworthy. The "Habiter mieux" eco-loans put in

place for households benefiting from the ANAH “Habiter mieux” programme to overcome this difficulty remain inconsequential, with only three such loans granted as of 2019.

Consequently, without major changes to support schemes and incentives, the remaining amount could be an obstacle to households wishing to conduct global, high-performance renovation, and could put them in financial difficulty if they were obliged to undertake such work.

### 1.3.2.3. A certain lack of guidance on renovation for households that do not necessarily see the need to undertake such work

Carrying out renovation of dwellings is complex and may be a source of anxiety for households, especially given that almost half of them think that renovating their homes is unnecessary (OpinionWay, 2017). The complexity and duration of work can be an obstacle to renovations for households, especially if they see little or no need for them.

These feelings are often accentuated by the fact that households may feel they lack guidance on how to conduct renovations. Again, according to the TREMI survey (ADEME and al., 2018), 29% of households say they lacked such guidance during renovation work, especially administrative and financial guidance on the financial support available and the preparation of applications for this support, technical guidance on the work required and especially the materials to be used, and finally guidance on project management.

This feeling of a lack of guidance is reinforced for households living in jointly owned property, which face numerous administrative, technical and informational obstacles that hamper the launch of major renovations in multi-family dwellings (HCC, 2020).

The lack of guidance for households on how to complete this work makes them more vulnerable to potentially inefficient renovations.

## 1.3.3. Failing to adapt the housing stock to climate change could affect household behaviour in terms of demand for housing

### 1.3.3.1. Dwellings that will be increasingly affected by physical risks

Climate change could mean many buildings become exposed to certain vulnerabilities. These vulnerabilities can be one-off, linked to extreme weather events such as hurricanes, cyclones or floods, but they can also be chronic, such as sea level rise or prolonged heat waves. The frequency of climate hazards could increase over the 21<sup>st</sup> century. Consequently, certain areas that are currently relatively unaffected by the risks of climate hazards are likely to be more and more impacted in the coming decades. Six in ten people in France could be concerned (CGDD, 2020).

### 1.3.3.2. Growing awareness of climate risks among households

Today, global warming is increasingly in the headlines, and is central to the public debate. Households are gradually beginning to understand the future dynamics of the risks of climate change, but accurate information on the subject is still poorly understood.

According to the barometer of social representations of climate change produced by ADEME in 2020, French people say the environment is the second most important issue France is facing, and for 33% of them, global warming is the number one environmental concern. A survey conducted by Harris Interactive ENEDIS in 2018 shows that although 60% of French people are concerned about the risks of climate hazards that could occur near their homes, 54% of them say they are poorly informed about these risks.

### 1.3.3.3. Anticipation of physical risks could affect the dynamics of demand in the residential sector

In a report on the impact of global warming on the property market in Florida, the consulting firm McKinsey (2020) highlights the effect of consumer behaviour on property prices. The devaluation of property in Florida is not due only to current exposure to climate risks; the prospect of future climate hazards could influence future buyers. According to the consultants, as future buyers start to recognise future risks, and determine the price of such risks, property values could adjust well before the damage linked to climate hazards actually occurs. For example, the value of properties adjacent to flood risk areas could fall as future buyers begin to be concerned about the potential risks in those areas. For these different reasons, McKinsey estimates that dwellings situated in flood risk areas in Florida will lose between 15 and 35% of their value by 2050.

The prospect of the non-insurability of property or the increase in insurance premiums for property in high-risk areas could also be a source of concern for households seeking to purchase a dwelling. In California, further to the numerous wildfires that hit the State in 2018, almost 350 000 Californians have lost their housing insurance (The Conversation, 2019).

The prospect of physical risks could thus generate market risks linked to changes in household demand for property considered to be poorly adapted to present or future climate change.


## Part 1.4. Identification of relevant risk drivers for the residential property sector

Based on the key issues and major uncertainties identified in the first two chapters in a context of low-carbon transition and climate change, the goal of this part is to outline several plausible transition risk drivers in this sector, and to determine their parameters as well as the data necessary for the quantification of scenarios that incorporate these risk drivers. These risk drivers are intentionally designed to stress bank balance sheets under different transition risks. One of the risk drivers identified is included in the scenarios used in the context of the pilot exercise conducted by ACPR.

The different risk drivers proposed below are designed for the needs of financial stability. They consist in a selection of risks that generate *disorderly*<sup>7</sup> transition scenarios and that are aimed at testing the resistance of financial institutions and the financial system to shocks. They are therefore hypothetical and intentionally adverse; they are by no means projections and indicate neither the desirable nor the probable outcomes. They cannot be used to judge the merits of the transition.

### 1.4.1. A risk driver concerning an increase in the carbon price, aligned with the NGFS recommendations

TABLE 1: A RISK DRIVER CONCERNING AN INCREASE IN THE CARBON PRICE FOR THE RESIDENTIAL PROPERTY SECTOR

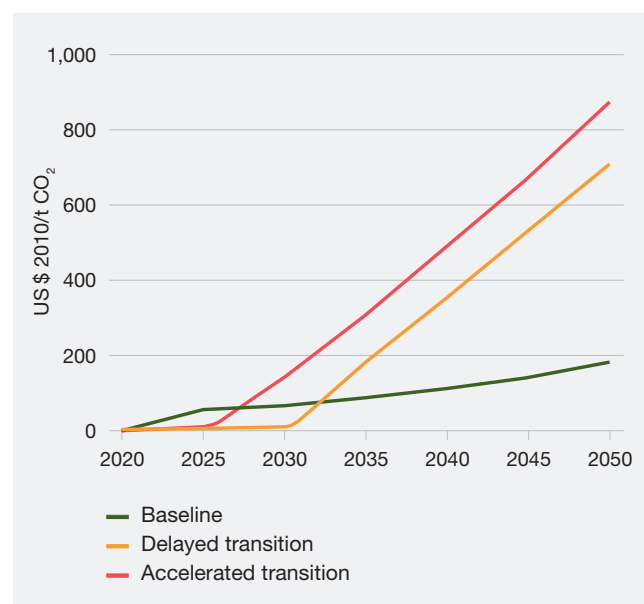
 <b>An increase in the carbon price</b>	
<b>Transition risk</b>	Regulatory risk.
<b>Risk driver</b>	<ul style="list-style-type: none"> <li>• A significant, rapid and unanticipated increase in the emissions price.</li> </ul>
<b>Households at risk</b>	<ul style="list-style-type: none"> <li>• Households using fossil fuels for heating, especially if living in inefficient dwellings;</li> <li>• Low-income owner-occupiers;</li> <li>• Aggravating factor: long work commutes by car (long distance to public transport).</li> </ul>
<b>Risk incurred</b>	<ul style="list-style-type: none"> <li>• An increase in energy bills (heating + fuel for cars) could result in a risk of non-payment of energy bills, which could in turn result in default on mortgage payments by households;</li> <li>• Risk of loss of property value;</li> <li>• Macroeconomic risks for business activity and unemployment.</li> </ul>

In the context of its pilot exercise, ACPR built on the NGFS recommendations to select its transition scenarios. These scenarios include risk drivers based on assumptions of an increase in the emissions price and in productivity, introduced with different timescales according to the different scenarios (orderly transition, sudden transition, delayed transition) (figure 19). The increase in the emissions price results in an increase in different taxes, determined according to the greenhouse gas emissions from each sector of activity<sup>8</sup>.

This exercise will analyse only risk drivers that result in disorderly transition scenarios, imposing drastic or sudden changes in emissions prices to achieve the French commitments, without any particular redistributive effect or any organisation of the transition. The delay in achieving the French commitments, and thus the necessary implementation of particularly strong public measures, could translate into abrupt changes in behaviour among economic actors, with recessionary effects on the macroeconomy and financial risks. These scenarios based on a disorderly increase in the emissions price represent a transition risk for households through their energy consumption, for both domestic heating and travel, resulting in a reduction in their purchasing power.

In the context of the ACPR pilot exercise, the projection of losses for households was conducted by the institutions based on macroeconomic and financial assumptions corresponding to the scenarios selected, but was not included in a detailed analysis of credit risk for households (ACPR and al., 2020).

FIGURE 19: EMISSIONS PRICE TRAJECTORIES ACCORDING TO THE THREE TRANSITION SCENARIOS PROPOSED BY ACPR



Source: ACPR and al., Scenarios and main assumptions of the ACPR pilot climate exercise, 2020

<sup>7</sup> See definition in the introduction.

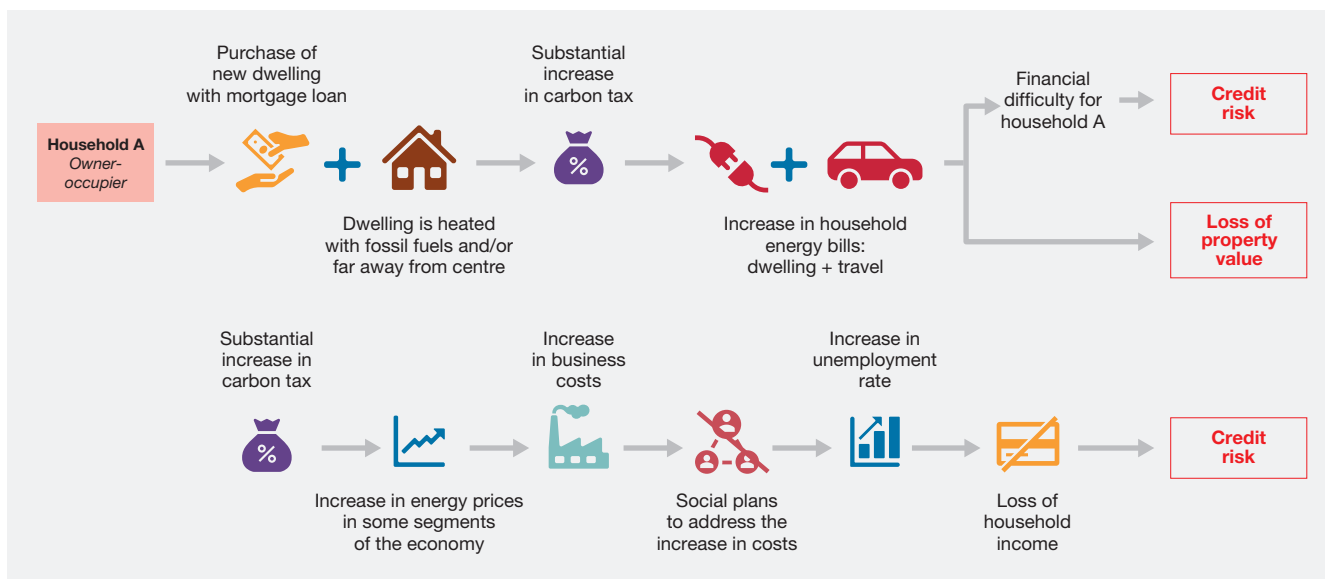
<sup>8</sup> The Banque de France/ACPR work is based on a sectoral division including 55 sectors of activity.

Consequently, given the weight of energy in a household budget today (9% of disposable income, including 3% for the dwelling) (CGDD, 2020) and the high proportion of fossil fuels in heating energy (see part 1.2.2), a substantial increase in the carbon component, if not accompanied by appropriate redistributive measures, could rapidly become a heavy burden in household energy bills (see annex 1).

It is important to take account of the broader effects of carbon taxation on the overall budget of households, especially on their travel and mobility capacities, which could have

an amplifying effect not only on debt, but also on property values. If, in France, households are liable for their property debt based on the historical cost of their dwelling, a loss of property value could affect the finances of households if they find themselves obliged to sell their property for different reasons. It is also important to consider the plausible but more adverse assumptions that an increase in the emissions price could have on the macroeconomy, in particular on energy prices and their consequences for business activity and unemployment (figure 20).

FIGURE 20: EXAMPLE OF DISORDERLY TRANSMISSION OF A CARBON PRICING POLICY



Source: I4CE

In contrast, the implementation of a carbon tax in the context of an orderly transition could have beneficial effects on the macroeconomy. According to a report by ADEME (Callonnec *and al.*, 2019), if the increase in the carbon tax translates into a full redistribution of the revenue generated, household income could increase by 0.7% through job creation (especially in the construction sector and services), real wage increases (under the effect of a drop in the unemployment rate), and declining energy consumption.


In order to accurately estimate the number of households concerned, as well as the increase in the risk of default on mortgage payments and the impacts on property markets for this risk driver, the following combined data need to be estimated for the entire scope of study:

- The type of dwelling (one-family house, multi-family dwelling);
- The status of the occupants (owner-occupiers, landlords, tenants);

- The number of household members;
- The size of the dwelling, or at least its geographical location (at least: rural versus urban, and the region);
- The type of heating;
- The level of energy consumption of the dwelling or its energy performance;
- The level of disposable income for owner households, their level of debt, and their average budget.

### 1.4.2. A risk driver concerning a radical, unanticipated renovation obligation

**TABLE 2: A RISK DRIVER CONCERNING A DISORDERLY RENOVATION OBLIGATION FOR THE RESIDENTIAL PROPERTY SECTOR**

 <b>A radical, unanticipated renovation obligation</b>	
<b>Transition</b>	Regulatory risk.
<b>Risk driver</b>	<ul style="list-style-type: none"> <li>• Mandatory improvement <b>to level A or B</b>;</li> <li>• <b>New standards</b> invalidating previous renovation or recent buildings;</li> <li>• <b>Insufficient/unsuitable financial support</b> to enable households to conduct renovation to a BBC level;</li> <li>• <b>Ban on letting, selling or transferring</b> the dwelling concerned.</li> </ul>
<b>Households at risk</b>	<ul style="list-style-type: none"> <li>• Owner-occupiers and landlords <b>whose dwellings are targeted by the regulation.</b></li> </ul>
<b>Risk incurred</b>	<ul style="list-style-type: none"> <li>• <b>Inability to pay for whole-building retrofits</b> results in households being <b>unable to let, sell or transfer dwellings</b>, which may lead to a <b>loss of income</b>.</li> <li>• Loss of income may result in a <b>risk of default</b> for households.</li> <li>• Risk of <b>loss of property value</b>.</li> </ul>

A sudden increase in carbon taxation policies is not the only public policy that could generate a transition risk in the residential property sector. Another risk driver, this time concerning the introduction of a renovation obligation for dwellings, could also be possible.

A “disorderly” renovation obligation would concern an obligation implemented in a sudden, unanticipated way for households, with mandatory upgrading of household renovation to a high energy performance level, for example level A or B of the EPC (Energy Performance Certificate). New performance standards would invalidate previous retrofits or recent buildings. Financial support would be insufficient and/or unsuitable to enable households to conduct renovation to achieve a BBC level for their dwelling. This renovation obligation would result in a ban on letting, selling or transferring any dwelling that does not comply with the new standards. An increase in the property tax could also be possible.

An “adverse” renovation obligation could put a certain number of households in financial difficulty. This risk driver would first affect any household with a dwelling concerned by the new standards that wishes to sell or let its property. As indicated in **part 1.2.3**, almost 94% of dwellings could be concerned by this new regulation.

Since the current estimated cost of high-performance renovation is high (see **part 1.3.2**), this risk driver thus concerns all households that do not have sufficient own funds to finance the work not covered by support.

This risk driver, if accompanied by adverse economic conditions, could lead to over-indebtedness for households that need to borrow in order to finance their renovation. Indeed, while it is reasonable to assume that the terms on which loans are granted for renovations take account of the initial solvency of the household, adverse economic conditions (an increase in the carbon tax or the property tax, a loss of income, etc.) could exacerbate the financial situation of a household that has already incurred debt.

This risk driver could also result in selling at a loss if the household is obliged to sell its property without being able to pay for renovation work. The sale of the property, whose value would fall by at least the cost of the work required, would not cover repayment of the mortgage loan taken out for its purchase.

Finally, this factor could result in a considerable loss of income for landlords, who would no longer be able to let their property if they were unable to pay for renovation work.

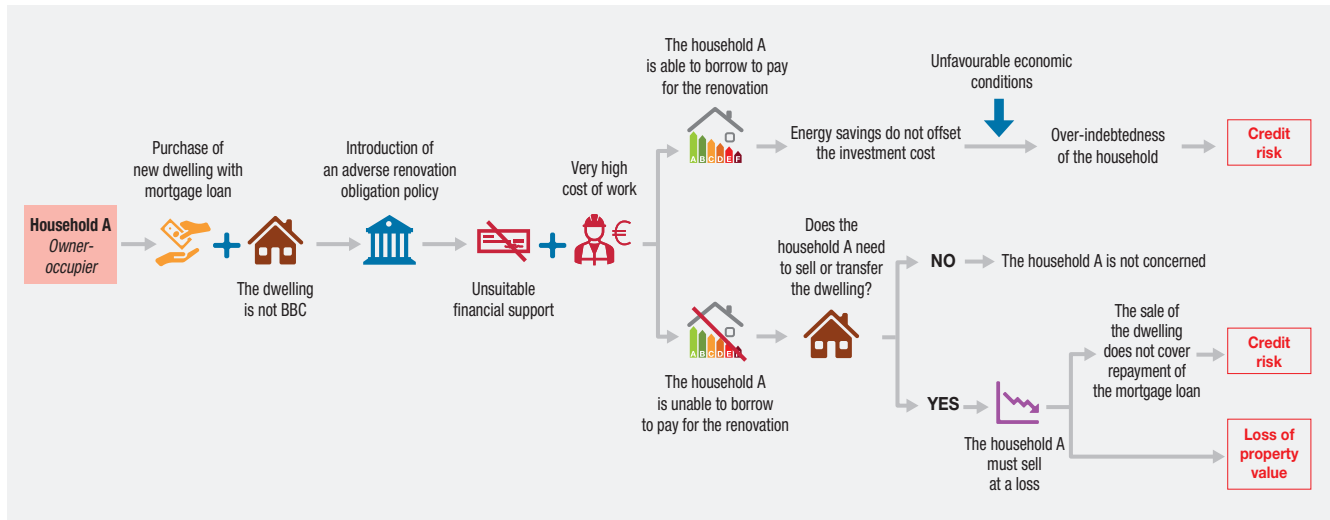
These problems could all result in credit risks for households (**figure 21** and **figure 22**).

This adverse transition contrasts with an “orderly” transition, in which the renovation obligation is announced, progressive and anticipated by households, which could benefit from support or financing options suited to their renovation works. An orderly transition could have positive macroeconomic effects, and the number of renovations required could result in job creation (HCC, 2020).

The indicators needed for the quantification of a scenario based on an adverse renovation obligation are as follows:

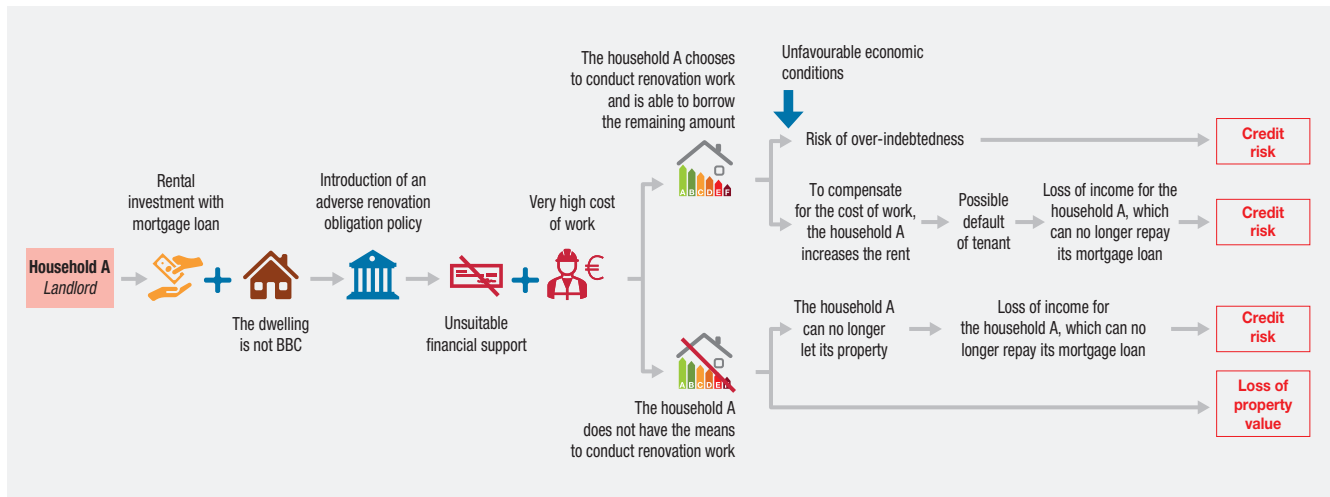
- The type of dwelling (one-family house, multi-family dwelling);
- The status of the occupants (owner-occupiers, landlords, tenants);
- The size of the dwelling, or at least its geographical location (at least: rural versus urban, and the region);
- The energy performance level of the dwelling;
- The level of disposable income for owner households, their level of debt, and their average budget;
- The average cost per m<sup>2</sup> of work required to reach a BBC level according to the type of dwelling.

FIGURE 21: EXAMPLE OF RISK TRANSMISSION FOR A “DISORDERLY” RENOVATION OBLIGATION FOR OWNER-OCCUPIED HOUSEHOLDS



Source: I4CE

FIGURE 22: EXAMPLE OF RISK TRANSMISSION FOR A “DISORDERLY” RENOVATION OBLIGATION FOR LANDLORDS



Source: I4CE

### 1.4.3. A risk driver concerning a renovation obligation in an unfavourable construction context

**TABLE 3: A RISK DRIVER CONCERNING A DISORDERLY RENOVATION OBLIGATION FOLLOWED BY A TECHNOLOGICAL RISK FOR THE RESIDENTIAL PROPERTY SECTOR**

A renovation obligation in an unfavourable construction context	
<b>Transition risk</b>	Regulatory risk + technological risk.
<b>Risk driver</b>	<ul style="list-style-type: none"> <li>Renovation obligation introduced;</li> <li><b>Shortage of skilled manual workers</b> capable of conducting/supervising high-performance renovation;</li> <li><b>Difficulty in carrying out overall renovations</b> can lead to several defective renovations;</li> <li><b>Profession is unprepared</b> to conduct overall renovation;</li> <li><b>Lack of guidance</b> for households on how to conduct renovation work.</li> </ul>
<b>Households at risk</b>	<ul style="list-style-type: none"> <li>Owner-occupiers and landlords whose dwellings are targeted by the regulation.</li> </ul>
<b>Risk incurred</b>	<ul style="list-style-type: none"> <li>Being unable to achieve a BBC level, households would no longer be allowed to sell or let their property, even though they had invested for this purpose.</li> </ul>

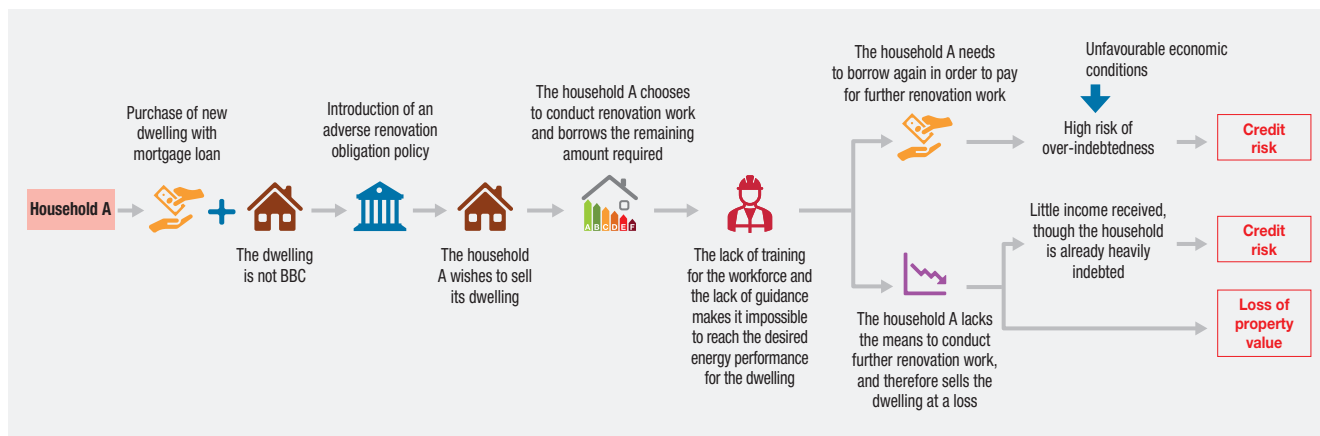
A third risk driver concerning an adverse renovation obligation could be possible, this time with the regulatory risk being accompanied by a technological risk.

A certain number of technical obstacles linked to the complexity of global, high-performance renovation were identified in part 1.3.2. The difficulty of conducting this type of renovation, the unpreparedness of the profession, and the lack of guidance for households on how to go about the work, could add additional difficulties for households that want or need to conduct renovation of their dwellings.

Most housing renovations are currently done “step-by-step”. If these step-by-step renovations are not conducted in an optimal manner, it will be impossible to reach an energy performance level without generating high additional costs. Here, the investment made would be “stranded”, in other words the associated asset would be devalued due to these new regulatory and technical constraints, making it obsolete well before it is fully amortised.

The risk would be that households would incur significant costs for renovations without being able to achieve a BBC level. The renovation would not comply with the requirement, and households that were unable to achieve a BBC level for their property would no longer be allowed to sell it or let it, even though they had invested for this purpose. Here, the technological risk would exacerbate the effects of the regulatory risk (figure 23).

**FIGURE 23: EXAMPLE OF RISK TRANSMISSION FOR A “DISORDERLY” RENOVATION OBLIGATION IN A CONTEXT OF DIFFICULTY ACHIEVING HIGH-PERFORMANCE RENOVATION**



Source: IACE

The indicators needed for the quantification of a scenario modelling this risk driver are as follows:

- The type of dwelling (one-family house, multi-family dwelling);
- The status of the occupants (owner-occupiers, landlords, tenants);
- The size of the dwelling, or at least its geographical location (at least: rural versus urban, and the region);

- The energy performance level of the dwelling;
- The level of disposable income for owner households, their level of debt, and their average budget;
- The cost of the different renovation projects;
- A map of low-performance renovation pathways.



### 1.4.4. A risk driver concerning the anticipation of physical risks and market risks

**TABLE 4: A RISK DRIVER CONCERNING THE ANTICIPATION OF PHYSICAL RISKS FOR DWELLINGS FOR THE RESIDENTIAL PROPERTY SECTOR**

Anticipation of physical risks and market risks	
<b>Transition risk</b>	Market risk.
<b>Risk driver</b>	<ul style="list-style-type: none"> <li>Change of behaviour of individuals due to growing awareness of future climate physical risks;</li> <li>For instance: <b>coastal areas</b>, where property prices are currently high, <b>could be abandoned because of the prospect of rising sea levels</b>;</li> <li><b>Risk is not currently reflected in property prices.</b></li> </ul>
<b>Households at risk</b>	<ul style="list-style-type: none"> <li>Households owning <b>property located in a future risk area.</b></li> </ul>
<b>Risk incurred</b>	<ul style="list-style-type: none"> <li><b>Risk of a loss of property value</b>, or even impossibility of reselling the property.</li> </ul>

Transition risks, as defined by the TCFD (2017), can also concern market risks. In the case of the residential property sector, as previously seen, these market risks can be associated with a change in demand caused by growing awareness of the physical risks of climate change (see part 1.3.3). Indeed, while dwellings are currently

concerned by a certain number of physical risks, these risks could increase significantly in the next few decades because of climate change.

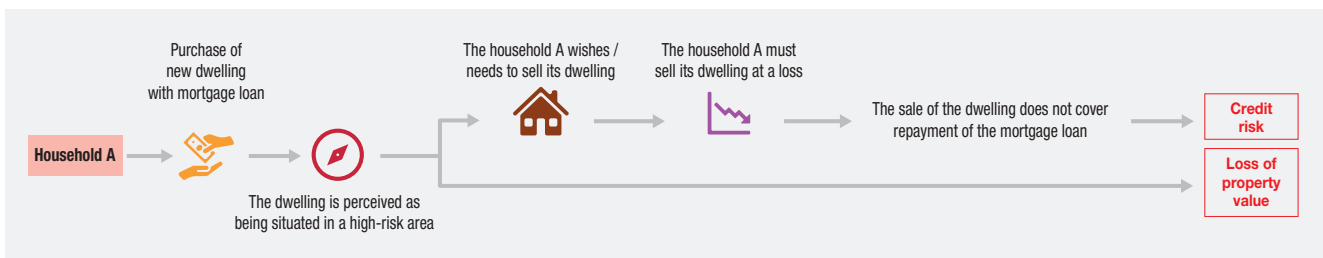
Failure to adapt cities and buildings to climate change or to factors of geographical obsolescence, for example in a coastal area threatened by sea level rise, property in a winter sports resort, thermal comfort in the hot season in the context of an increase in the frequency of heat waves, as well as growing awareness of these risks, could all lead households to change their behaviour, thereby altering the dynamics of demand. As seen in part 1.3.3, the prospect of future risks can result in a loss of value for some property.

Information concerning the future physical risks that could be caused by climate change is not currently provided during property sales, when only the current risks are specified. Today, most of these future risks are not reflected in property prices (see annex 2) and are generally given little attention in sector analyses.

Although the financial institutions are beginning to analyse future risks, the behaviour of individuals with regard to these risks is no less important. The risks associated with a change of individual behaviour could occur well before the future risk emerges.

The risk for households that have purchased property in future risk areas would be that this property could be substantially devalued as buyers become more aware of the future risks facing it. High uncertainty about this risk driver surrounds the timing of this change of behaviour in the population. Here, the location of the property can have a major impact on its risk of devaluation (figure 24).

**FIGURE 24: EXAMPLE OF RISK TRANSMISSION FOR A CHANGE IN DEMAND**



Source: I4CE

Behavioural studies could be conducted in order to explore the impact of climate change and awareness of future physical risks on household behaviour.

In order to determine the proportion of the housing stock that is at risk, certain data needs to be clarified and the following combined data must be obtained:

- The different types of household behaviour with regard to the risks for property;
- The type of dwelling;
- The status of the occupants;
- The geographical location of the dwelling;

- The type of risk to which it is exposed and projections of risk evolution;
- An estimation of the valuation/devaluation of this property;
- The income bracket of the occupants.

## **Part 1.5. Conclusion of the case study**

The residential property sector presents many challenges in a context of low-carbon transition and climate change. The energy performance of the French housing stock is still too low and is evolving slowly, making renovation a crucial issue for the coming decades. Global warming and its consequences could also lead households to change behaviour with regard to their demand for housing. These important issues could generate transition risks.

The transition risk drivers selected by the NGFS concerning an increase in the carbon price are relevant drivers for the sector in France, but they are not the only ones. Other types of regulations could be possible, such as a sudden, unanticipated renovation obligation, without financial support for households. A third technological risk driver could be added to the renovation obligation, which would exacerbate the results. Indeed, a shortage of skilled manual

workers and a lack of technical guidance for households could result in low-performance renovations and would not enable households to achieve the desired results. A fourth risk driver, concerning changes in household behaviour with regard to demand for housing, due to growing awareness of future climate risks, could also be possible.

It should also be noted that all of these risk drivers concerning different transition risks can overlap. Overlapping of these risk drivers could increase the risk for households.

Each of these risk drivers can be a source of risk for households, through the risk of default due to over-indebtedness or to a loss of disposable income, a loss of property value, or broader macroeconomic risks. Since banks have high exposure to the property sector, these risk drivers could be sources of financial risk for them.

A quantification of the scenarios concerning these risk drivers, as well as a quantification of these risks for banking institutions, would be the next stage in determining the impact of these risk drivers on bank portfolios.

# Part 2. Case study on the cement industry

## Part 2.1. Definition of the scope of the study and the extent of exposure to transition risks

**Note:** This study is largely based on the research conducted by ADEME as part of its Sectoral Transition Plan (STP) for the

cement sector, detailing decarbonisation strategies aimed at achieving the French 2050 carbon neutrality objectives for the sector (see box n°2), as well as on discussions with their sector experts. The final version of the STP<sup>9</sup> for cement is expected to be published in 2021.

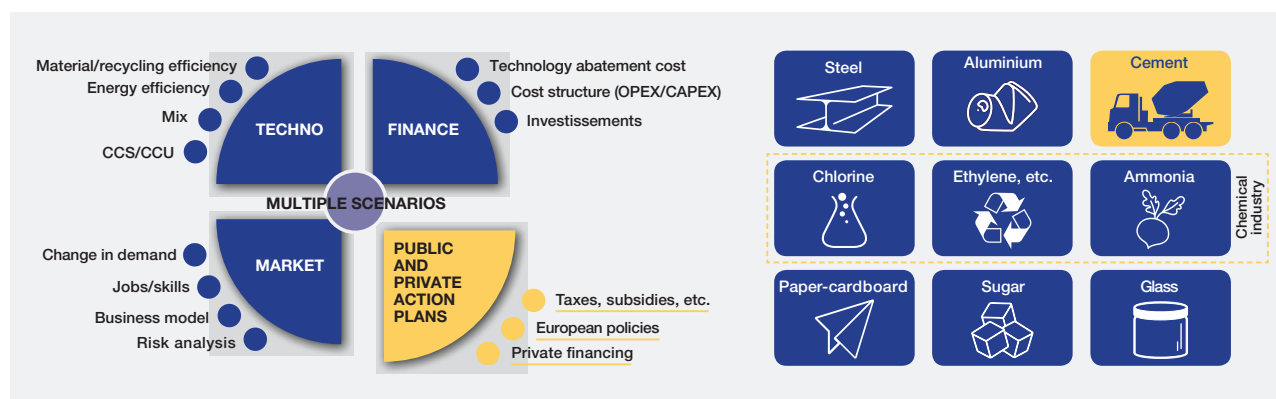
### BOX N°2: ADEME SECTORAL TRANSITION PLANS FOR INDUSTRY

As part of the Finance ClimAct project, ADEME co-produces the Sectoral Transition Plans<sup>10</sup> with actors from the energy-intensive industries, which account for two thirds of GHG emissions from industry in France.

**Goal: to promote investment in the transition of French heavy industry in order to aim for decarbonation by 2050, taking into account the specificities of each sector**

The Sectoral Transition Plan (STP) aims to develop tools to support the forward-looking dialogue in nine industrial sectors, in consultation with sector stakeholders (manufacturers and federations). Conducted over a 12-month period, an STP builds decarbonisation scenarios aimed at achieving the French energy and climate objectives for 2050 (-81% emissions relative to 2015 for industry), quantifies the impacts on production costs, assesses climate investment needs, and analyses changes in employment. Finally, the Sectoral Transition Plan proposes public and private actions to create the socio-economic conditions for the decarbonisation of the sector.

### THE 360° VISION TO INFORM THE TRANSITION TO CARBON NEUTRALITY IN NINE SECTORS



### 2.1.1. The cement sector, a sector with major decarbonisation challenges

The cement sector presents major low-carbon transition challenges due to its high energy-intensity and greenhouse gas emissions. It is thus one of the industrial sectors directly concerned by the French greenhouse gas emissions

reduction objectives for the industrial sector. The SNBC aims for a 35% reduction in emissions from the sector by 2030 relative to 2015, and an 81% reduction by 2050. The cement industry accounts for 3% of French CO<sub>2</sub> emissions and 15% of CO<sub>2</sub> emissions from the manufacturing and construction industry (Infociments, 2020 and CITEPA, 2020).

9 First economic results of the Sectoral Transition Plan for the French cement industry: <https://finance-climact.eu/news/decarbonizing-the-cement-industry/>

10 Find out more: <https://finance-climact.eu/news/sectoral-transition-plans/>

## PART 2. CASE STUDY ON THE CEMENT INDUSTRY

### Part 2.1. Definition of the scope of the study and the extent of exposure to transition risks

The goal of this study is to identify the characteristics and possible evolution of the cement industry in view of the issues of the low-carbon transition, in order to identify different transition risk drivers for the cement sector.

#### 2.1.2. The cement sector is exposed to transition issues all along its value chain

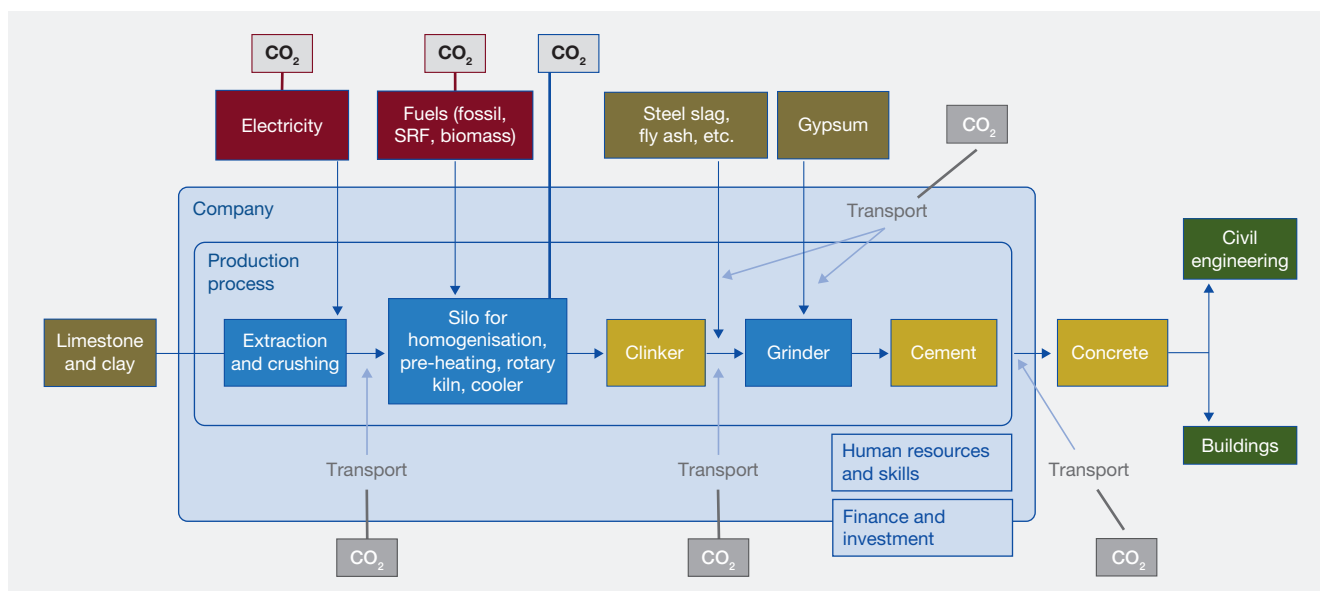
The cement sector is exposed to the issues of the low-carbon transition all along its value chain, from the manufacturing of clinker<sup>11</sup>, the main component of cement, to cement sales, which are strongly driven by the construction sector.

Cement is a hydraulic binder mainly used in the production of concrete. The value chain for the cement production process goes from the extraction of raw materials to the sale of cement in its final form (figure 25).

Clinker production is very carbon-intensive (see part 2.2.5), making the sector sensitive to the changes of the transition. The clinker-to-cement ratio varies according to the different types of cement. The cement most commonly used today in France and Europe is Portland cement – 80% of all cement in France (infociments, 2020) –, which contains between 65% and 95% clinker (infociments, 2018). France has 41 cement plants, 26 of which produce clinker. The other plants manufacture cement using clinker directly transported to the site (Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021).

Sales of concrete, and therefore implicitly of cement, are mainly driven by construction, whether for buildings or for civil engineering. The evolution of the construction sector in the context of the transition will also be an important issue for the sector in the future.

FIGURE 25: MAP OF KEY ELEMENTS OF THE CEMENT AND CONCRETE PRODUCTION PROCESS



Source: IACE, from Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021

#### 2.1.3. Exploration of the characteristics of the sector and the issues of the transition conditions risk

The different transition issues to which the cement sector is exposed can generate transition risks for the sector. These transition risks can be generated by the introduction of a regulation aimed at mitigating the effects of climate change, such as measures to strengthen the EU ETS system, by technological shocks or by a reduction in demand.

These risks can have consequences for bank balance sheets, through different types of risk, whether credit risk through bank loans by companies in the sector, or market risk, through the value of sector assets held by banks (stocks, bonds, etc.).

Transition risks can generate different debt dynamics for companies, substantial loss of income or a significant increase in production costs. These risk dynamics may vary from one company to another.

Studying the characteristics of the sector and of companies is therefore key to determining the risk areas in a context of transition.

11 Cement is made from clinker, the result of heating a mixture of limestone and clay to very high temperatures (see annex 3).

## Part 2.2. The characteristics of the cement industry faced with the transition to a low-carbon economy

### 2.2.1. A capital-intensive industry with long investment cycles that prevent cement companies from adapting in the short term

The cement industry is very capital-intensive with high investment costs, obliging it to invest in the long term. Most of the equipment used by this industry has a useful life of between 20 and 50 years. The fixed costs of setting up a cement plant in France are between 100 and 200 million euros (Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021). This capital intensity explains the concentration of the sector between just a few large companies within the European Union (Material Economics, 2019). In France, five companies account for around 95% of total cement production (INSEE, 2018).

Consequently, a cement company that has recently invested in new equipment will be less able to rapidly make new low-carbon investments if it has not already planned to do so. These characteristics make it difficult for cement companies to adapt their plants in the short term.

### 2.2.2. The overall performance of French plants is average in relation to current performance standards, although plant renewal has been observed in recent years

Although plant performance indicators are difficult to obtain, the overall performance of French plants is rather average in relation to current performance standards.

Most French cement plants are old (they were built 80 years ago on average, and none of them are less than 30 years old), but there is not necessarily a clear linkage between the current performance of a plant and its year of construction, since most of them have had constant maintenance and improvement work. There has nevertheless been a renewal of cement production capacities since the 2010s, since the average obsolescence ratio (net fixed assets/gross fixed assets) in the sector in France rose from 32% in 2009 to 69% in 2019 (INSEE, 2019).

The thermal energy efficiency of cement production processes is also a relevant indicator of performance, but data on French cement plants can be difficult to obtain. According to internal estimates by ADEME, the thermal energy intensity of French plants is between 3.5 and 4 GJ per tonne of clinker. By way of comparison, the standards for the best available technology (BAT) are currently close to 3 GJ per tonne of clinker. This average performance of thermal energy efficiency in production processes in French cement plants could make them sensitive to transition risks, especially an increase in energy prices.

### 2.2.3. The high cost of transporting cement contributes to a strong regional presence

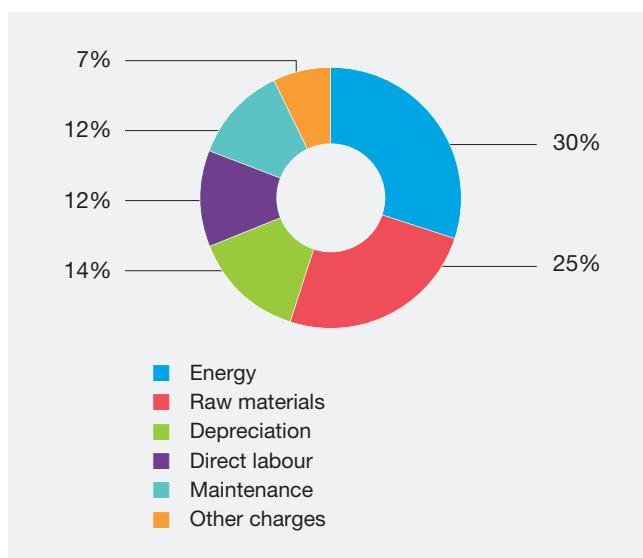
The high cost of transporting cement means cement companies are obliged to set up their production plants close to raw material sources and to supply a mainly local market. Indeed, the low weight-to-value ratio makes long distance transportation of cement unprofitable. Transporting cement costs around 10 to 15 euros per 100 km, for a selling price of between 60 and 80 euros per tonne (Material Economics, 2019). Around 95% of cement produced is consumed in the country of production, and on average within 200 to 300 km of the place of production. Beyond this distance, the cost of transportation is too high to be profitable (Cembureau, 2021). This reduces the possibilities for exporting cement in case of a fall in demand in the country of production.

Clinker imports remain marginal today, although there has been an increase in imports from developing countries in the last few years. Net imports of clinker only account for around 5% of all clinker used in France (infociments, 2020). However, since 2015, imports of clinker have begun from North Africa and the Middle East. In just three years, Turkey, Morocco, Saudi Arabia and Algeria have captured around 14% of the import market, and imports have increased overall (ADEME internal calculations based on customs data). The recent increase in these imports can be explained by the lower cost of producing clinker in those countries. Some manufacturers have consequently chosen to set up grinding plants in port areas and to import clinker in order to limit their fixed costs and their sensitivity to carbon prices (Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021). Clinker imports from the emerging countries could reduce the competitiveness of French and European clinker in the context of an increase in carbon prices.

### 2.2.4. An industry in which the intensive use of thermal energy makes up a significant proportion of operating costs

The cement sector is classed as an energy-intensive industrial sector because of the high share of energy in its production costs (Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021). The cement production process is very energy intensive, with the production of one tonne of clinker consuming around 3.7 GJ of energy (Material Economics, 2019). In order to start the clinkering process, kilns need to be heated to a very high temperature (1 500°C). The thermal energy required to reach these temperatures accounts for 90% of the energy needs of cement plants. Energy-related costs account for around 30% of all operating costs (figure 26). This high share of energy in operating costs makes companies in the sector sensitive to an increase in energy prices.

**FIGURE 26: DETAIL OF PRODUCTION COSTS FOR A CEMENT PLANT**



Source: Pipame and al., 2016

### 2.2.5. Greenhouse gas emissions are mostly from the production process and are difficult to cut

Within the perimeter of a cement plant, two thirds of the greenhouse gas emissions generated by the cement sector are released during the cement manufacturing process, and more specifically during the clinkering process, while the remaining emissions are due to the fossil fuels used to heat the kiln (SFIC, 2015).

The emissions resulting from the clinkering process are due to the calcination of limestone, when carbon dioxide is released at very high temperatures, leaving calcium oxide, one of the main components of cement. The cement production process releases around 0.525 tonnes of CO<sub>2</sub> per tonne of clinker (ADEME, 2019). The emissions resulting from the other stages of production are marginal. These emissions cannot be reduced by changing the fuel used or

by implementing energy efficiency measures (see part 2.3.1) (Material Economics, 2019).

For the purposes of the clinkering process, the energy used to heat the kiln to the necessary temperature of 1 500°C cannot currently be provided by electricity, but only by thermal energy, especially from fossil fuels.

In 2016, the emissions associated with the production of one tonne of cement were around 656 kg of CO<sub>2</sub>, with an average clinker-to-cement ratio of 78% (infociments, 2020).

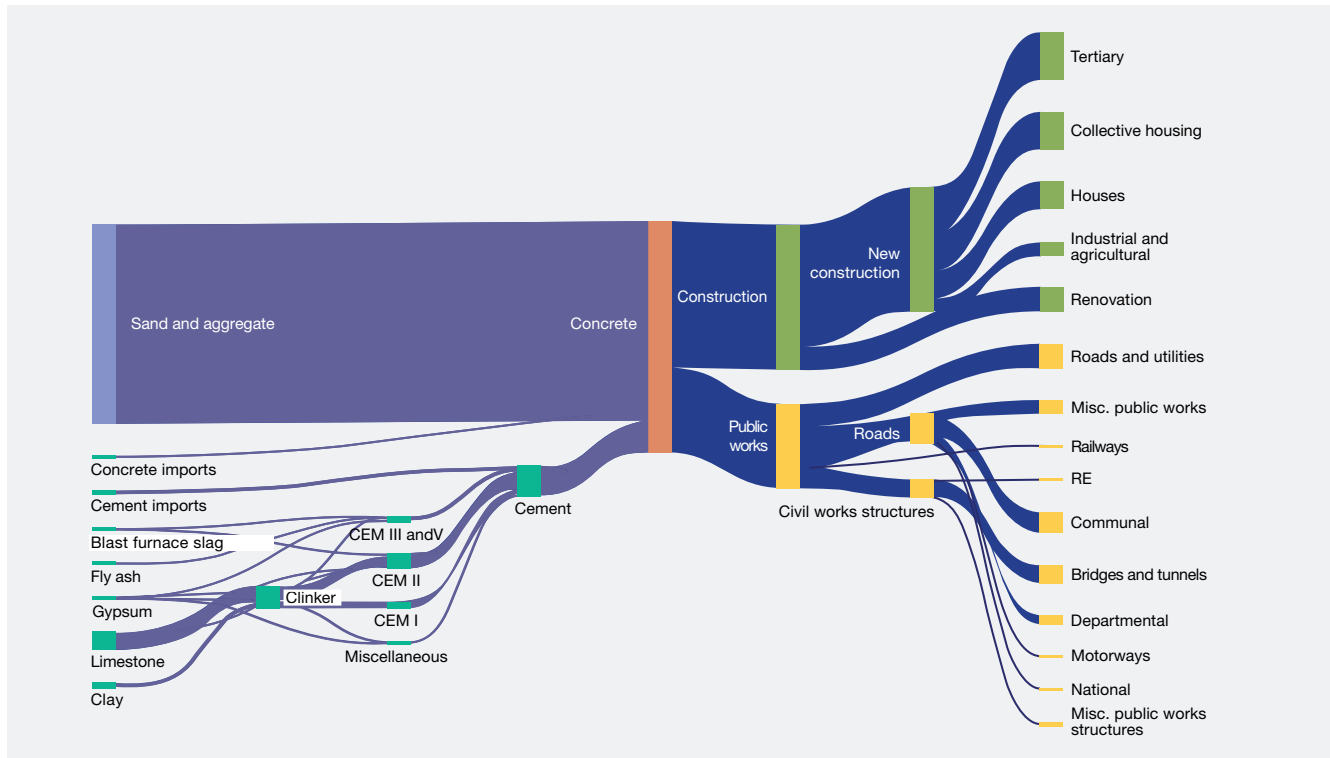
### 2.2.6. Demand is highly dependent on demand for concrete, driven by the construction of new housing, which has been declining since 2008

Cement is one of the main components of concrete, one of the most widely used building materials in Europe. In 2015, the European Union consumed more than a billion tonnes of concrete. Steel comes far behind in second place, at 66 million tonnes consumed in the same year (Material Economics, 2019).

In France, demand for concrete is mainly driven by two types of markets. Two thirds of demand are from the building sector. The remaining third comes from civil engineering, and especially the construction and maintenance of roads and networks (figure 27). The results of the modelling process using the ADEME PEPITO model (2020) on the elasticity of demand for clinker in France confirm that new construction of one-family and multi-family dwellings, as well as regional and local road maintenance works, are the most important drivers of demand for cement. This distribution is fairly similar across the rest of Europe (Material Economics, 2019).

Demand for cement has been declining in France since 2008, especially because of the economic and financial crisis, which has seriously affected the building sector (Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021), although a pickup in activity has been observed since 2016.

FIGURE 27: OUTLETS FOR THE CEMENT INDUSTRY IN FRANCE IN 2014



Source: Ademe, Sectoral Transition Plan for the French Cement Industry, first technical-economic results, 2021

## Part 2.3. The evolution of the cement sector in a context of low-carbon transition: between risks and opportunities

### 2.3.1. Solutions for sector decarbonisation are at different levels of maturity and are heavily reliant on the availability of raw materials

As previously seen, the decarbonisation of the cement sector requires both the decarbonisation of emissions linked

to the type of energy used and the reduction of emissions directly generated by the cement production process. There are different options to reduce these two types of emissions (table 5). Most of these solutions are currently being developed, have different levels of maturity and are heavily reliant on the availability of the raw materials needed for their deployment. These solutions have several levers: a reduction in the use of thermal energy, a reduction in the clinker-to-cement ratio, and an increase in the use of carbon capture and storage (CCS) technologies.

TABLE 5: SUMMARY OF MOST COMMON LEVERS FOR DECARBONISATION (NON-EXHAUSTIVE)

Decarbonisation technologies/levers	Emissions reductions	Investment cost	Maturity of technology	Dependence on raw materials
Dry process with precalciner	Moderate	From 100 to 200 m€	Available	Access to dry raw materials
Replacement of fossil fuels by alternative fuels	Moderate	From 2.5 to 7.5 m€	Available	Dependent on SRF and biomass (competition with other industries) Importance of biomass content in SRF
Use of blast furnace slag	High	From 5 to 10 m€	Available	Dependent on the production of blast furnace steel in France and abroad
Use of fly ash	Moderate	From 8 to 12 m€	Available	Dependent on power generation from coal-fired power stations
Use of natural pozzolans	Moderate	From 8 to 12 m€	Available	Dependent on local geological conditions
Use of calcined clay	Moderate	From 8 to 12 m€	Available but not fully developed	Good availability of raw materials
High belite cement	Low	Up to 12 m€	Available but not fully developed in Europe	Good availability of raw materials

TABLE 5: SUMMARY OF MOST COMMON LEVERS FOR DECARBONISATION (NON-EXHAUSTIVE) *continued*

Decarbonisation technologies/levers	Emissions reductions	Investment cost	Maturity of technology	Dependence on raw materials
Oxyfuel CCS	High	From 300 to 380 m€	R&D phase	Carbon storage will depend on local geology, social acceptability conditions, infrastructure deployment
Post-combustion CCS (MEA solvent)	High	From 100 to 300 m€	R&D and testing phase	Carbon storage will depend on local geology, social acceptability conditions, infrastructure deployment
Post-combustion CCS (calcium looping)	High	Around 200 m€	Preliminary development stage	Carbon storage will depend on local geology, social acceptability conditions, infrastructure deployment

Source: ECRA 2017, Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021, Material Economics 2019

### 2.3.1.1. Decarbonisation levers through the reduction of energy-related emissions

The first lever for reducing the use of thermal energy in cement production is improving the energy efficiency of plants. The introduction of dry processes with precalciner in clinker production plants is considered to be one of the best technology solutions currently available to increase the energy efficiency of the production process. It can reduce energy consumption to 3.15 GJ per tonne of clinker (compared to an average of 3.7 GJ today). However, such changes have high costs: the investment cost of installing a dry process with precalciner could be from 100 to 200 million euros (Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021).

The second lever for reducing thermal energy use is the replacement of the fossil fuels needed to meet the energy requirements of cement plants. The alternative fuels include solid recovered fuel<sup>12</sup> (SRF), other waste (waste oils, solvents, wood waste, agricultural waste, etc.), and biomass.

The proportion of possible alternative fuels in the energy mix of a cement plant strongly depends on the equipment installed. A maximum substitution of 90% is technically possible at present if a precalciner is installed (Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021). However, the effect on greenhouse gas emissions reductions may be limited if the fossil carbon content of waste is high. For example, in the case of SRF, around 50% of the waste is derived from fossil sources, with the rest being biomass-based (e.g. the proportion of natural rubber in car tyres).

Substantial investments could be required to enable high substitution rates, amounting to between 2.5 and 7.5 million euros per plant (Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021). Given that alternative fuels are mainly derived from waste, cement producers could be able to obtain them at low cost.

### 2.3.1.2. Alternatives to Portland cement: solutions to replace the use of clinker

The first lever to enable a reduction in the emissions directly associated with the cement production process is to reduce the percentage of clinker in cement by using alternatives. Given that most of the CO<sub>2</sub> emissions from the cement manufacturing process are released during the production of clinker, reducing the clinker-to-cement ratio could be a critical solution for the decarbonisation of the sector.

Several clinker substitutes already exist, including supplementary cementitious materials such as limestone, fly ash, blast furnace slag or pozzolans. These substitutes simply need to be crushed and do not require heating to very high temperatures. They currently represent 26% of all cement produced in Europe. Since the 1980s, they have enabled a 20% to 30% reduction in CO<sub>2</sub> emissions from the cement sector in the European Union (Material Economics, 2019).

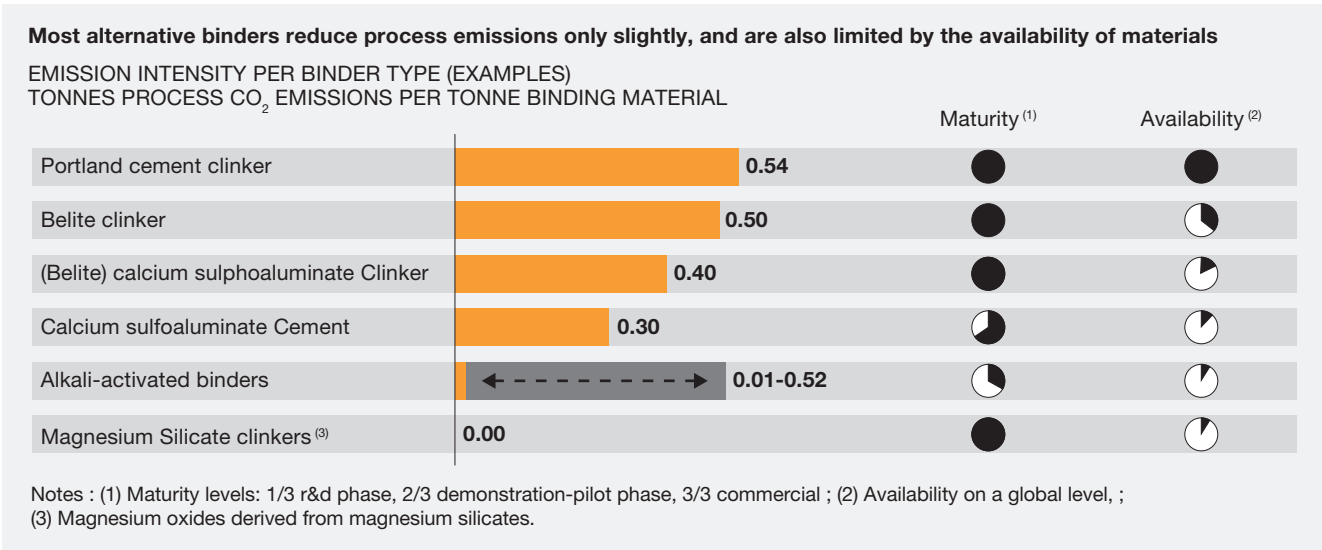
However, these substitutes are heavily reliant on the availability of raw materials. For example, pozzolans are derived from volcanic ash and, in Europe, are found mainly in Italy and Greece. Moreover, some of these substitutes have limited potential in the context of a low-carbon transition, such as fly ash, which is a coal combustion product, or blast furnace slag, which come from steel production (Material Economics, 2019). The development of installations that can reduce the percentage of clinker in cement production for a cement plant will largely depend on its access to these different raw materials.

Different types of alternative binders are in the research and development phase in order to replace ordinary Portland cement. The goal is thus to reduce the proportion of limestone in the initial mix, since its calcination is the largest source of CO<sub>2</sub>. However, given that cement is consumed in large quantities, it is essential that the alternative raw materials remain as accessible and low-cost as limestone and clay to ensure they are affordable in all countries. Most binders with the lowest CO<sub>2</sub> emissions are also those for which research is in the earliest stages, or for which the raw materials are the most difficult to obtain (figure 28) (Material Economics, 2019). Once again, access to raw materials could be critical to enable cement plants to develop these new types of cement.

<sup>12</sup> SRF is solid fuel derived from non-hazardous waste with sufficient calorific power to be of interest for recovery by combustion.



FIGURE 28: ALTERNATIVE BINDERS AND THEIR CHARACTERISTICS



Source: Industrial Transformation 2050, Pathways to Net-Zero Emissions from EU Heavy Industry, Material Economics, 2019

Finally, recycled concrete fines could also be used to replace clinker in cement manufacturing as a substitute for limestone and clay, which release large quantities of CO<sub>2</sub> during calcination. In addition, fines are crushed at medium rather than very high temperatures; emissions from the energy used to heat kilns could thus also be reduced (Material Economics, 2019). However, the use of recycled concrete fines to replace clinker is still in the exploratory phase; studies have not yet determined whether its use would affect cement properties, and its profitability has not yet been established.

**2.3.1.3. Use of CCS technologies to capture emissions from the cement production process**

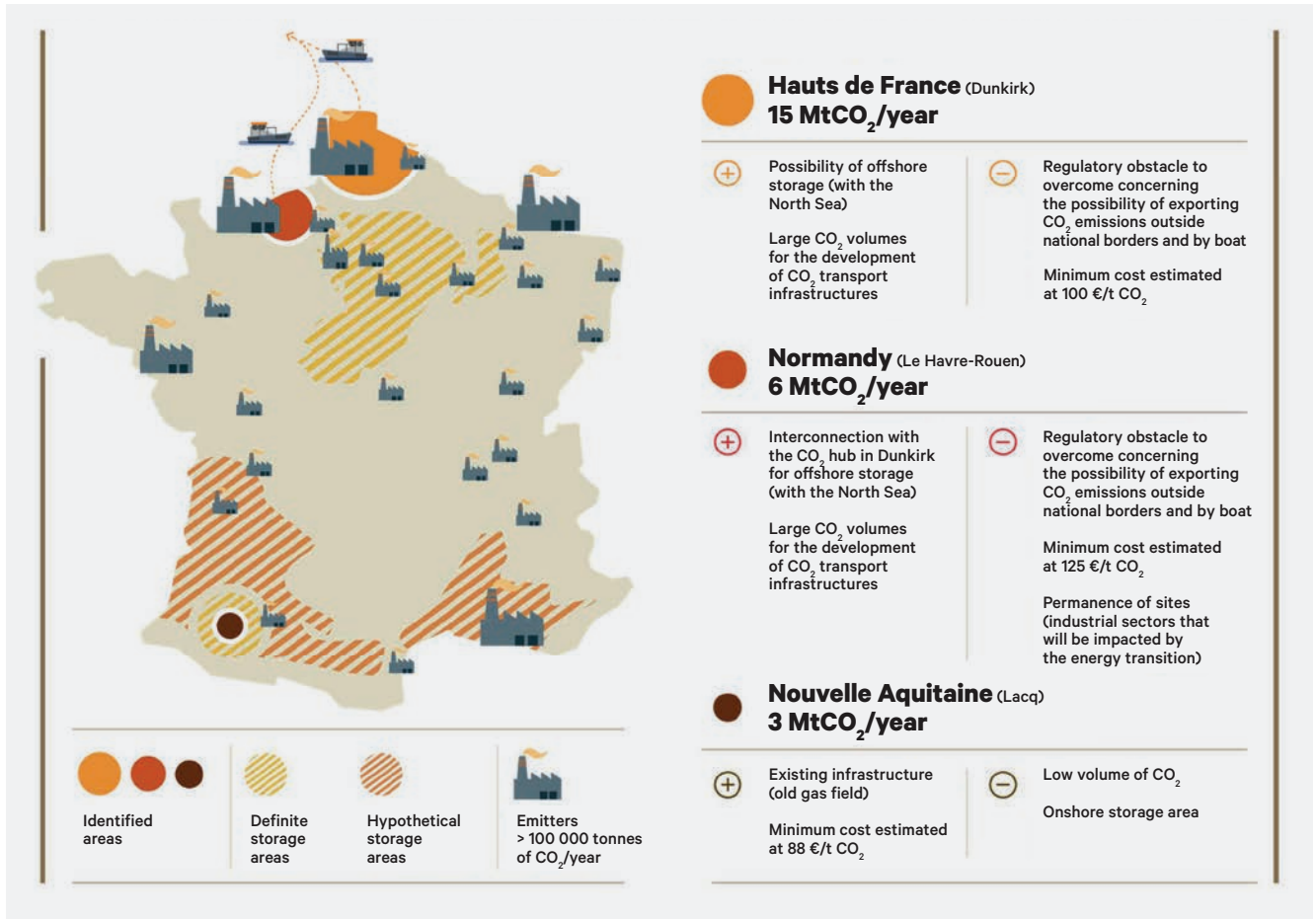
CCS technologies could be a solution to reduce the CO<sub>2</sub> emissions generated by cement production. There are several categories of CCS: pre-combustion processes, post-combustion processes and oxy-combustion. Several CCS trials have been conducted for the cement sector. According to sector experts, oxy-combustion is the most promising technology for future development, and could capture up to 95% of CO<sub>2</sub> emissions (Material Economics, 2019).

However, the development of CCS technologies poses a number of obstacles. Indeed, there are few potential storage areas in France. Given the cost of transportation, only sites close to ports or onshore storage areas could be eligible for the development of these technologies. In France, two onshore storage areas have been identified in the Paris Basin and in the Nouvelle Aquitaine region (ADEME, 2020). Most French cement plants are not located near to these storage areas (figure 29 and figure 30).

**PART 2. CASE STUDY ON THE CEMENT INDUSTRY**

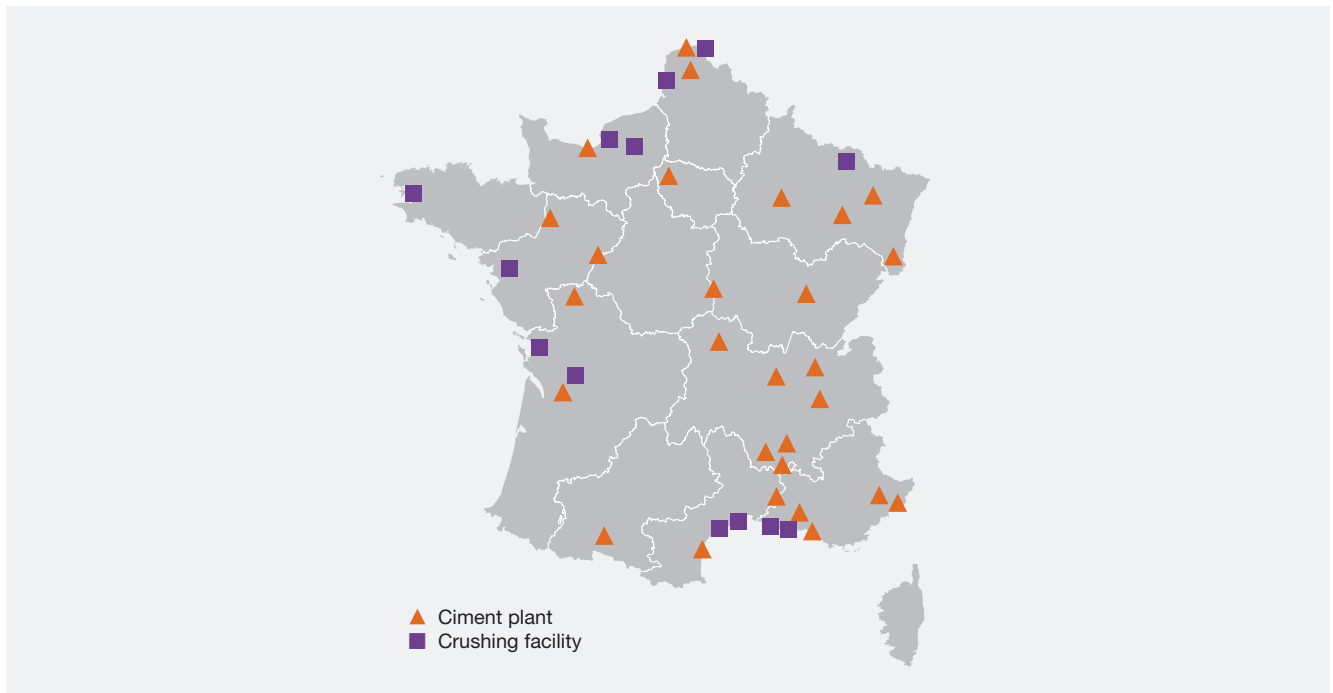
Part 2.3. The evolution of the cement sector in a context of low-carbon transition: between risks and opportunities

**FIGURE 29: POTENTIAL FOR THE IMPLEMENTATION OF CCS IN FRANCE (ALL INDUSTRIES COMBINED)**



Source : ADEME, *Le captage et stockage géologique de CO<sub>2</sub> (CSC) en France : un potentiel limité pour réduire les émissions industrielles*, 2020

**FIGURE 30: DISTRIBUTION OF CEMENT PLANTS AND CRUSHING FACILITIES IN FRANCE (MEMBERS OF SFIC)**

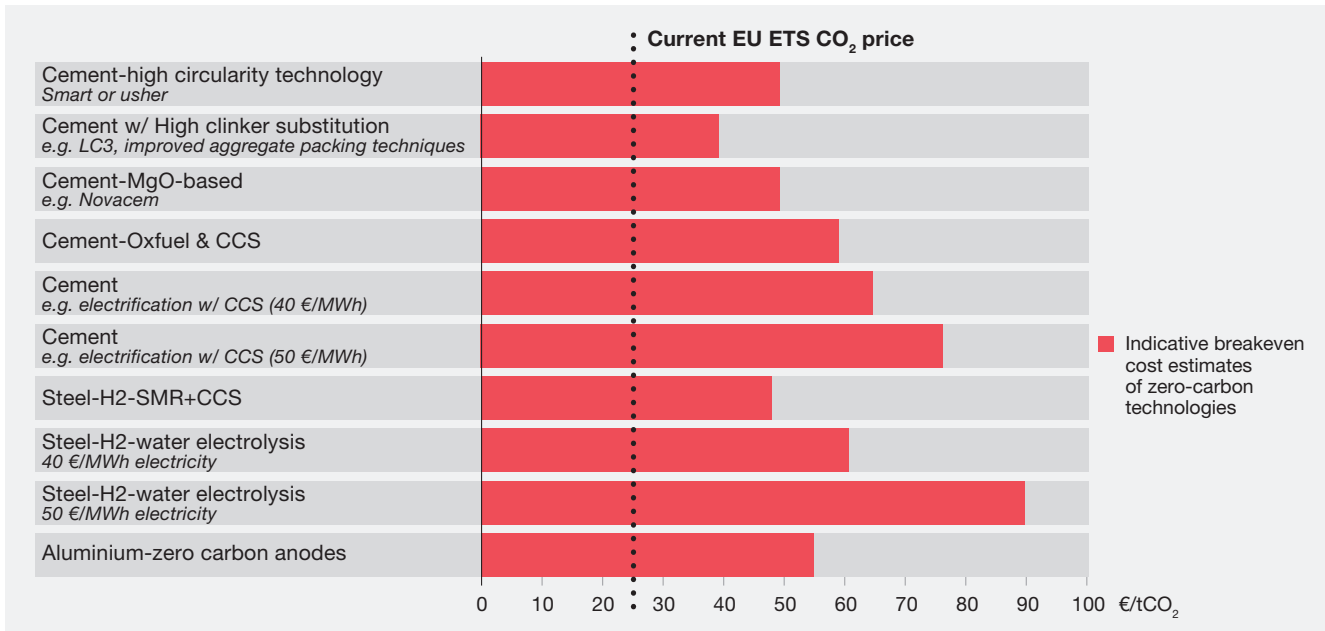


Source: Infociments, *chiffres clés 2019, 2020*

The cost of CO<sub>2</sub> capture can also be high (between 40 and 80 euros per tonne of CO<sub>2</sub>) (IEAGHG, 2018). IDDRI (2019) calculated that the break-even point for the development of CSS technologies for cement could be reached with a

carbon price of between 60 and 80 euros per tonne of CO<sub>2</sub> (figure 31). The deployment of these technologies is therefore still highly uncertain.

**FIGURE 31: ESTIMATE OF MINIMUM CARBON PRICE ENABLING DEPLOYMENT OF LOW-CARBON TECHNOLOGIES FOR CEMENT, STEEL AND ALUMINIUM IN 2019**



N.B. : This graphic is simply illustrative and not intended to be an exhaustive list of technologies, not to reflect precise breakeven cost conditions at all specific site locations.

Source: IDDRI, *Decarbonising basic materials in Europe: How Carbon Contracts-for-Difference could help bring breakthrough technologies to market*, 2019

### 2.3.2. Existing policies for sector decarbonisation provide little incentive, but more stringent measures could be introduced in the coming years

#### 2.3.2.1. So far, the EU ETS system has contributed little to sector decarbonisation

The production of clinker and cement is covered by the EU ETS, the European Union Emissions Trading System, which sets a cap on greenhouse gas emissions (GHGs) from power generation and energy-intensive industries. The EU ETS cap is reduced every year: over the period 2013-2020, this cap was reduced by 38 million allowances annually, which enabled a 35% cut in the emissions covered between 2005 and 2019 (European Commission, 2020).

Like other industries, cement companies receive some of their allowances for free. The share of free allowances is higher for cement production because it is considered to be at significant risk of carbon leakage. The quantity of allowances received is calculated according to historical activity levels and carbon intensity benchmarks. During phase 3 (2013-2020), the benchmark for grey cement clinker was 0.766 allowances per tonne of clinker (EU, 2018).

So far, the EU ETS has not really provided an incentive to decarbonise the cement sector. Before crossing the symbolic threshold of 50 euros per tonne of CO<sub>2</sub>eq in May 2021, the price of emissions allowances was capped at 20-25 euros per tonne since 2018 (Sandbag, 2021), which was not sufficient for the deployment of low-carbon solutions in the cement sector. Indeed, this sector as a whole has a surplus of free allowances equivalent to around 2.5 years of emissions. This can be explained first of all by the fact that allowance allocations are based on the historical activity levels determined at the beginning of each phase and are only adjusted if production falls by more than 50%. The emissions allowances for cement companies for phase 3 of the EU ETS were determined before 2013, and were subsequently adjusted very little, despite the reduction in activity in the sector. Furthermore, the volume of free allowances received by companies in the sector is disproportionate to their exposure to the risk of carbon leakage. Indeed, the sector meets the minimal carbon cost intensity criterion, but not the trade intensity criterion, as provided for in the EU ETS rules (Sandbag, 2016).

From 2021 onwards, the EU ETS rules will change. The cap will be reduced more rapidly, by 48 million allowances per year, in order to achieve a 43% cut in emissions by 2030 relative to 2005. Free allocation will continue according to the same general principle for the most exposed sectors, but some parameters will change: the benchmarks have been

recalculated based on data concerning carbon intensity improvements, and activity levels will be updated. The new benchmark for the grey clinker sector is 0.693 (European Commission, 2021). The new allocation rules will also be more dynamic: allocation will reflect changes in activity from a threshold of 15%.

The Market Stability Reserve (MSR) entered into operation in January 2019 to regulate the surplus of allowances, but its current parameters will not be sufficient to absorb a new surplus (Vailles *and al.*, 2020), while the historical surplus still amounted to 1.4 billion allowances in 2019 (European Commission, 2020).

### **2.3.2.2. An end to free allowances and the establishment of a carbon border adjustment mechanism announced**

In the context of the Green Deal, in June 2021 the European Commission will propose a European Union carbon border adjustment mechanism (CBAM). The goal of this mechanism will be to price emissions associated with goods imported from outside the EU at the same level as goods from within the EU (Trésor Eco, 2021). The objective of this mechanism would be to ensure European industries stay competitive compared to foreign industries with lower environmental performance, thereby making it possible to increase the carbon price on the European market without creating unfair competition with companies that are not subject to the same level of taxation. It is thus more of a tool to control transition risks.

The text should also provide for a rapid end to the allocation of free allowances for several sectors, probably including cement. Indeed, in view of its characteristics (high carbon intensity, little international trade), cement is very often considered in proposals on the implementation of the carbon border adjustment mechanism (CEDD, 2019).

### **2.3.2.3. A possible increase in the carbon price could affect cement companies in the medium-term**

Other changes to the EU ETS are possible in the medium-term. First, a revision of the MSR is planned for 2021. Strengthening the MSR could contribute to increasing prices beyond current levels. In line with the Green Deal, in December 2020 the European Union endorsed the objective of carbon neutrality by 2050, with the goal of reducing its emissions to at least 55% below 1990 levels by 2030. This increase in the target for 2030 will mean reducing the EU ETS cap more rapidly, which could contribute to strengthening the EU ETS price signal.

### **2.3.3. A downward trend in demand could undermine actors in the sector**

Changes linked to the low-carbon transition in the cement sector, whether the multiple regulatory incentives, changes in practices or behaviours, or technological innovations, could all affect demand for cement in the coming decades.

#### **2.3.3.1. A decline in demand in the building sector would affect demand for concrete and therefore demand for cement**

It is possible that there could be a decline in demand in the building sector in the coming decades, which would directly affect demand for concrete, and therefore demand for cement. For example, the SNBC (2020) projects a reduction of almost 40% in the construction of new housing by 2050.

Urban planning policies could potentially bring about a significant decline in the construction of new buildings, especially one-family houses. These policies could seek to revitalise city centres by focusing more on multi-family dwellings, could place greater emphasis on housing renovation and could make building permits more difficult to obtain. Planning policies could also implement strategies to optimise the existing stock so as to limit the number of empty buildings and the acquisition of second homes.

A fall in demand from public works could also be expected, especially due to decisions to halt the construction of motorways and national roads in favour of rail transport development.

All of these factors could bring about a reduction in demand of more than 50% (Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021).

#### **2.3.3.2. Replacing concrete with other building materials, such as wood, could also reduce demand for cement**

Replacing concrete with low-carbon materials, such as wood, could be possible in the building sector, thereby causing a decrease in demand for cement. Indeed, emissions per square metre of wood construction materials are far lower than for those made of concrete. Wood itself can be a source of CO<sub>2</sub> storage in long-term use. The potential of wood is relatively high for the construction of one-family houses, whereas it accounts for less than 10% of the housing stock today. However, the availability of this resource could be an obstacle to construction in the coming years (Material Economics, 2019).

#### **2.3.3.3. Less need for cement in concrete would also reduce demand for cement**

Although cement is one of the main components of concrete, numerous studies and practical experiments show that it is now possible to make concrete of the same quality with a far lower cement content. This reduction in the amount of cement in concrete could be down to the fact that cement is currently overused in concrete, which is often over-specified in relation to the real requirements of the work for which it is used. It is then possible to modify concrete production while maintaining the same level of resistance with a lower cement content. Some studies indicate that this proportion could even be halved without affecting the resistance of concrete. However, investments would be needed to enable the use of these new techniques and to make changes to production processes (Material Economics, 2019). Different obstacles must be overcome to generate a significant reduction in demand for cement for use in concrete.

## Part 2.4. Identification of relevant transition risk drivers for the cement industry in France

Based on the key issues identified in the first two chapters in a context of low-carbon transition, the goal of this part is to identify several plausible transition risk drivers in this sector, and to determine their parameters as well as the data necessary for the quantification of scenarios that incorporate these risk drivers. These risk drivers are intentionally designed to stress bank balance sheets under different transition risks.

In the framework of this analysis, four relevant risk drivers have been identified with regard to the low-carbon transition. One of the risk drivers identified is included in the scenarios used in the context of the pilot exercise conducted by ACPR.

Although ACPR and the NGFS have selected risk drivers mainly concerning risks associated with the implementation of public policies, other aspects of the transition can also represent a risk for the companies in the sector, including technological and market aspects.


The different risk drivers proposed below are designed for the needs of financial stability. They consist in a selection of *disorderly*<sup>13</sup> transition risk aimed at testing the resistance of financial institutions and the financial system to shocks. They are therefore hypothetical and intentionally adverse; they are by no means projections and indicate neither the desirable nor the probable outcomes. They cannot be used to judge the merits of the transition.

### 2.4.1. A risk driver concerning an increase in the carbon price, deriving from the NGFS recommendations

In the context of its pilot exercise, ACPR built on the NGFS recommendations to select its transition scenarios. These scenarios include risk drivers based on assumptions of an increase in the emissions price and in productivity, introduced with different timescales according to the different scenarios (orderly transition, sudden transition, delayed transition).

For the cement sector, an increase in the carbon price in France and in Europe would require a significant tightening of the EU ETS rules. This tightening would result in an increase in the price of allowances (especially through a revision of the MSR in 2021 and an increase in the emissions cap reduction rate). A carbon border adjustment mechanism (CBAM) may or may not be introduced at the European level. The establishment of a CBAM would be a risk mitigator faced with the increase in the carbon price, although it does not rule out all types of risk (figure 32). The end of free allowances for companies in the sector could also be possible. An increase in carbon prices would apply not only to emissions from the use of fossil fuels, but also to emissions directly associated with the clinker production process.

TABLE 6: A RISK DRIVER CONCERNING AN INCREASE IN THE CARBON PRICE FOR THE CEMENT SECTOR

 An increase in the carbon price	
Transition risk	Regulatory risk.
Risk driver	<b>Significant tightening of the EU ETS rules:</b> <ul style="list-style-type: none"> <li>• Increase in the price of allowances;</li> <li>• Carbon border adjustment mechanism (activated or not);</li> <li>• End of free allowances in the sector.</li> </ul>
Risk incurred	<ul style="list-style-type: none"> <li>• Significant increase in operating costs;</li> <li>• Reduction in demand for cement;</li> <li>• Loss of asset value;</li> <li>• Over-indebtedness.</li> </ul>
Key indicators to be determined	<ul style="list-style-type: none"> <li>• Sensitivity of costs to the increase in the price of allowances;</li> <li>• Possibility for a company to import clinker;</li> <li>• Distance from places where cement is used.</li> </ul>

Faced with an increase in energy prices, several possibilities are available to cement companies. Since the production of clinker is the main source of emissions from cement, companies could decide – assuming the carbon inclusion mechanism is not introduced – to import more clinker from outside the European Union. This is possible if the company is able to reduce its existing production of clinker in order to import it, but could mean that clinker production facilities are decommissioned before reaching the end of their life cycle. Companies that do not produce clinker could be at an advantage, since they have greater flexibility.

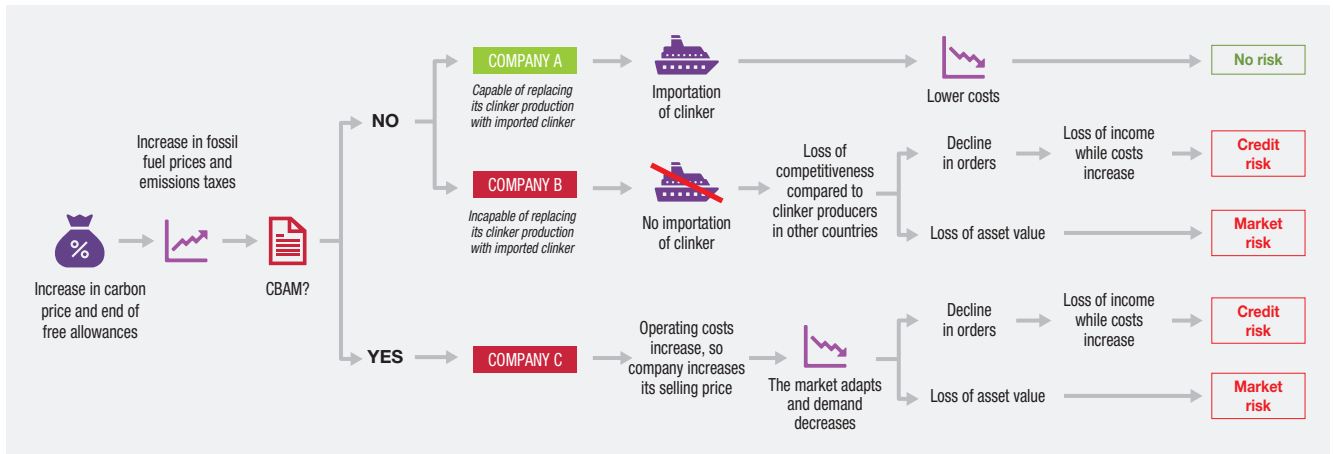
If the increase in the carbon price is important, existing technologies may not be sufficient to enable companies to truly reduce the cost of their emissions. It is also possible that the market could adapt to an increase in the price of cement, leading to a reduction in demand. This could be caused by a fall in demand for buildings, which become too expensive for consumers, or by greater use of more competitive materials, such as wood (figure 32).

<sup>13</sup> See definition in the introduction.

**PART 2. CASE STUDY ON THE CEMENT INDUSTRY**

*Part 2.4. Identification of relevant transition risk drivers for the cement industry in France*

**FIGURE 32: EXAMPLE OF DISORDERLY TRANSMISSION OF A POLICY TO INCREASE CARBON COSTS**



Source: IACE

Several indicators could be used to determine the capacity of companies to withstand an increase in carbon costs. It is first necessary to calculate the sensitivity of costs to an increase in the ETS allowance price, in order to determine the threshold from which a plant becomes unprofitable according to the types of technologies installed. The price elasticity of demand, used to measure the sensitivity of demand in relation to an increase in the price of cement, will also help to quantify this risk driver. The capacity of a company to import clinker from abroad could be another relevant indicator, as well as the position of its facilities in the investment cycle. Finally, the places where cement is used may also be important. Indeed, the further they are from the cement plant, the higher the cost of transportation will be.

**2.4.2. A risk driver concerning innovation shocks in green cement**

**TABLE 7: A RISK DRIVER CONCERNING AN INNOVATION SHOCK IN GREEN CEMENT FOR THE CEMENT SECTOR**

Innovation shocks in green cement	
<b>Transition risk</b>	Technological risk.
<b>Risk driver</b>	<ul style="list-style-type: none"> <li>Development of <b>innovations</b> to reduce greenhouse gas emissions from the sector:                             <ul style="list-style-type: none"> <li>- New alternatives to clinker;</li> <li>- New binders;</li> <li>- Use of recycled concrete.</li> </ul> </li> <li>The development of these new innovations would drive the creation of <b>new labels and green criteria</b>, especially in public procurement.</li> </ul>
<b>Risk incurred</b>	<ul style="list-style-type: none"> <li>A decline in orders leading to a loss of income;</li> <li>Over-indebtedness;</li> <li>A loss of asset value.</li> </ul>
<b>Key indicators to be determined</b>	<ul style="list-style-type: none"> <li>Financial capacity of a company to invest in low-carbon technologies;</li> <li>Estimated abatement cost of technologies used and their impact on the production cost;</li> <li>Innovation capacity of a company and R&amp;D expenditure incurred;</li> <li>Access to alternative raw materials.</li> </ul>

As seen in part 2.3.1, numerous innovations are possible in the cement sector. These innovations, whether they enable a reduction in fossil fuel consumption in the sector, or a reduction in emissions from the production process (through the introduction of new alternatives to clinker, new binders or the use of recycled concrete), would all reduce emissions from the sector. Most of these innovations have not yet reached maturity, but could do so in the next few years. Other innovations could also emerge.

To support the transition to a low-carbon economy, new labels could be created for cement with lower CO<sub>2</sub> emissions. Green criteria could also be developed, especially in public

procurement. The emergence of these new technologies could represent a risk for actors in the sector that have not innovated or are unable to do so.

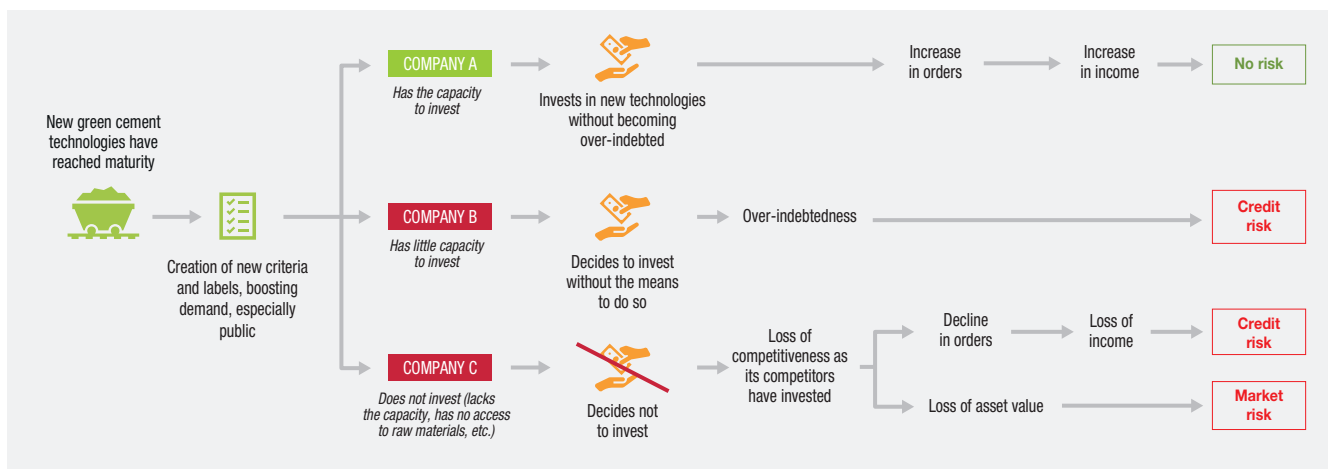
Indeed, these innovations would require considerable investment within production lines, or even the full conversion of industrial sites. Given the long investment cycles, reinvesting in new technologies before existing equipment is fully amortised could be unprofitable for some cement plants.

The capacity of actors in the sector to withstand these technological shocks will thus depend on their ability to develop new products and to invest in new facilities to

meet new demand for green cement. Access to certain raw materials, including cement replacements such as pozzolans, or other minerals used to develop new binders, could also be decisive.

A company whose existing structure and installations prevent it from investing in a sufficiently profitable way in new green cement production technologies, in relation to its national or foreign competitors, could then find itself in difficulty. Such companies could choose not to invest, but would risk losing orders and therefore income, or could choose to invest, at the risk of becoming over-indebted (figure 33).

FIGURE 33: EXAMPLE OF TRANSMISSION OF RISK CAUSED BY INNOVATION SHOCKS IN GREEN CEMENT



Source: I4CE


In the context of an orderly transition, the public support that could be provided for the development of low-carbon technologies for financial companies would help to mitigate these technological shocks.

In order to determine which companies are at risk, a more in-depth analysis of the financial structure of French cement companies is needed, along with details on the type of installations they have in order to determine which cement

plants would be able to bear new investment burdens and which would not. Investment in R&D and the innovation capacities of companies would also be elements to take into account. The estimated abatement cost of technologies used and their impact on the production cost would be another indicator to be estimated. Finally, access to raw materials for cement plants to enable them to use these new technologies is also an important indicator.

### 2.4.3. A risk driver concerning a reduction in demand

**TABLE 8: A RISK DRIVER CONCERNING A REDUCTION IN DEMAND FOR THE CEMENT SECTOR**

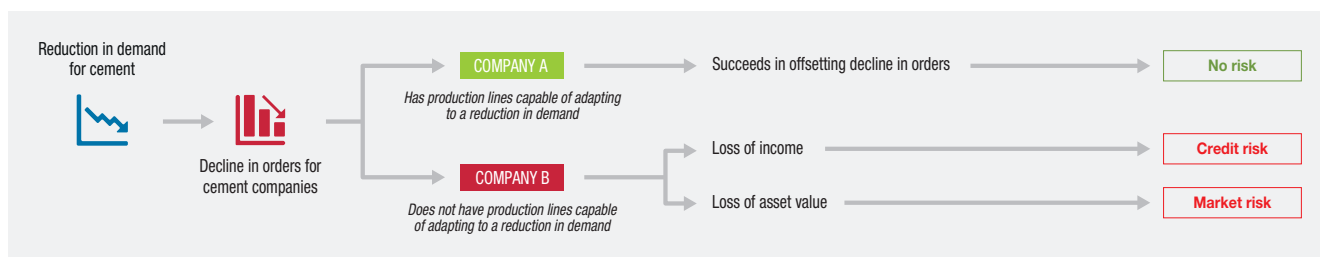
 <b>Reduction in demand</b>	
<b>Transition risk</b>	Market risk.
<b>Risk driver</b>	<p><b>Reduction in demand:</b></p> <ul style="list-style-type: none"> <li>Caused by a <b>reduction in new buildings</b> due to urban planning policies;</li> <li>Caused by a <b>reduction in demand for concrete</b>, replaced by low-carbon building materials, such as wood;</li> <li>Caused by a reduction in demand for cement for use in concrete production.</li> </ul>
<b>Risk incurred</b>	<ul style="list-style-type: none"> <li>Companies could be obliged to <b>reduce their selling prices in order to stay competitive, resulting</b> in a loss of turnover;</li> <li>Loss of asset value.</li> </ul>
<b>Key indicators to be determined</b>	<ul style="list-style-type: none"> <li>Profitability of a cement company's production process and capacity to withstand a reduction in demand;</li> <li>Minimum production capacity by type of plant to ensure a plant is profitable;</li> <li>Share of production under contract in the coming years for a cement plant;</li> <li>Level of integration of the company within the sector (cement, concrete);</li> <li>Type of cement produced (for housing, tertiary buildings, infrastructure).</li> </ul>

As indicated in part 2.3.3, several factors can cause a significant reduction in demand for cement in the context of a transition. This reduction in demand could stem from new urban planning policies leading to a reduction in new buildings. The development of new labels and regulations on the carbon intensity of buildings could encourage the use of wood or other low-carbon materials in construction and thereby reduce demand for concrete. Finally, changes in practices and in European regulations could significantly reduce the cement content of concrete, with markets evolving towards concrete with lower CO<sub>2</sub> emissions.

The combination of these different factors causing a reduction in demand for cement could present a significant risk for cement companies in France and Europe, especially if the reduction in demand is rapid and unanticipated. ADEME has modelled an extreme demand shock scenario (the “low-tech sobriety shock” scenario) that could reduce the French market for cement by more than 50% (Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021).

A reduction in demand could oblige companies to reduce their selling prices for cement in order to stay competitive. Given that the life cycle of installations is relatively long, it could be difficult for industries to rapidly reinvest in sites that are better adapted to lower demand. The level of resistance of actors will thus depend on their capacity to reduce their cement production and to adapt to declining demand (figure 34).

**FIGURE 34: EXAMPLE OF TRANSMISSION OF RISK CAUSED BY A REDUCTION IN DEMAND**



Source: IACE


In order to identify which companies could be at risk, it is necessary to establish for each cement plant the level of profitability of its production process, its past investments and its future investment needs, in order to determine whether it is capable of bearing (i) a reduction in demand, and (ii) new investments for better adapted plants. To do so, it is also necessary to determine the minimum production capacity to ensure a plant is profitable. The share of production under contract in the coming years for a cement plant could also be an indicator of sensitivity to a reduction in demand. The level of integration of the company within the sector is another important indicator, since a company present along the whole chain of the sector (cement,

concrete) would only be impacted by a reduction in demand for concrete, whereas a company present only in the cement sector could be affected by a reduction in demand for both cement and concrete. Finally, the type of cement produced by a plant could also be an indicator, depending on the cause of the reduction in demand (construction of new housing, or construction of tertiary buildings or infrastructure).



2.4.4. A risk driver concerning an innovation shock in carbon capture and storage technologies

TABLE 9: A RISK DRIVER CONCERNING AN INNOVATION SHOCK IN CCS TECHNOLOGIES FOR THE CEMENT SECTOR

 <b>Innovation shock in carbon capture and storage technologies</b>	
<b>Transition risk</b>	Technological risk.
<b>Risk driver</b>	<ul style="list-style-type: none"> <li>Cement companies decide to <b>focus on CCS technologies to decarbonise</b> their cement production.</li> <li>Technological shock viable only in <b>the context of a scenario with increasing carbon costs</b> or introduction of stricter environmental standards.</li> </ul>
<b>Risk incurred</b>	<ul style="list-style-type: none"> <li><b>Loss of competitiveness</b> in relation to other cement companies located close to storage sites;</li> <li>Loss of asset value;</li> <li>Over-indebtedness.</li> </ul>
<b>Key indicators to be determined</b>	<ul style="list-style-type: none"> <li>Capacity of a cement company to invest in CCS technologies;</li> <li>Distance from a storage site;</li> <li>Quantity of additional energy to be used for carbon capture;</li> <li>Presence of carbon transport infrastructures.</li> </ul>

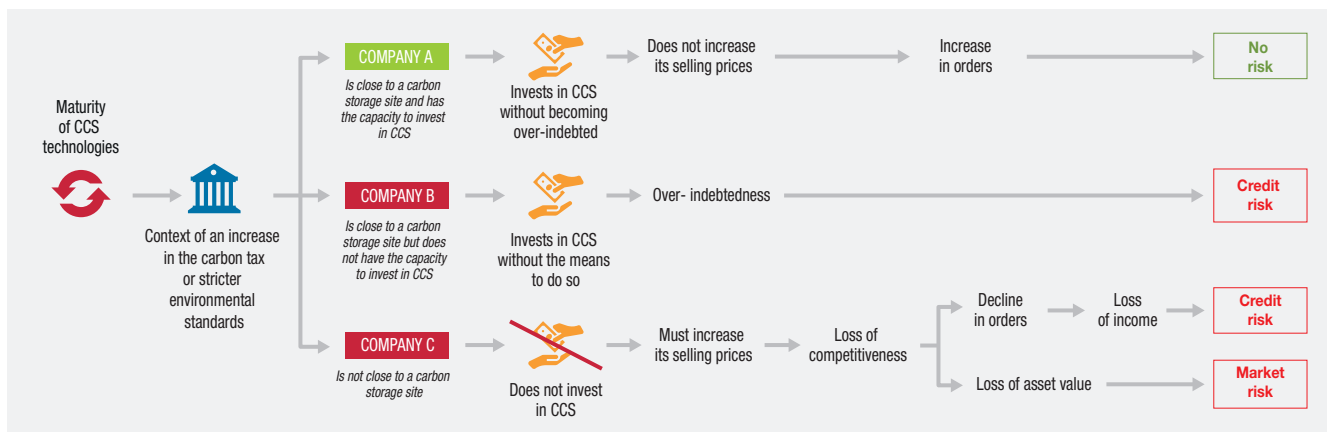
Cement companies could plan in the future to focus on CCS technologies to decarbonise their cement production. Given the investment required by these technologies, their use would only be feasible in the context of a scenario with increasing carbon costs or stricter environmental standards.

Although the use of CCS technologies is often considered as a mitigating factor for transition risks, it can also be a source of risk for some companies that are unable to use these technologies while other competitor companies are able to do so.

Indeed, cement companies may come up against the availability of storage sites, of which there are few in France (see part 2.3.1). Storage possibilities depend on the local geology. In France, ADEME has identified two main onshore storage areas, in the Paris Basin and in the Nouvelle Aquitaine region (see figure 29). The development of offshore storage in the Mediterranean, as well as in the English Channel, could also be possible. If there is no network to evacuate the CO<sub>2</sub> captured, then operating near a CO<sub>2</sub> storage site is crucial to ensure the CCS technology is profitable.

At the European level, where storage sites could be unequally distributed, a company that does not use CCS technologies could rapidly become less competitive than other actors situated close to storage sites. A company located close to a storage site or to CO<sub>2</sub> transport infrastructures could decide to invest in CCS technologies, but the investment would be such that it could find itself over-indebted (figure 35). The resistance of actors in the sector to the shock will therefore depend on their access to these technologies and on their capacity to invest in these new technologies without becoming over-indebted.

FIGURE 35: EXAMPLE OF TRANSMISSION OF RISK CAUSED BY AN INNOVATION SHOCK IN CCS TECHNOLOGIES



Source: I4CE

In order to measure the key indicators used to determine the viability of CCS deployment for a company, it is first necessary to determine the distance of the company from a storage site, the quantity of additional energy to be used for carbon capture, the presence of carbon transport infrastructures, and the capacity of the company to invest in these new technologies.

## **Part 2.5. Conclusion of the case study**

The cement sector presents many low-carbon transition issues. Technological solutions exist or are being developed in order to reduce emissions from the sector, but the vast majority of these solutions have very high investment costs and may depend on the availability of raw materials.

Although the NGFS and ACPR have mainly chosen transition risk drivers concerning an increase in the emissions price<sup>14</sup>, other transition risks exist for the cement sector. These may stem from technological shocks concerning solutions to decarbonise the sector (low-carbon cement, or the use of CCS). These solutions might not be available to all companies, because of their initial financial structure, as well as their location and their access to the raw materials needed to develop or use these technologies. A significant reduction in demand in the sector could also be possible, due to new urban planning policies or to changes in the construction materials used. All of these risk drivers can overlap, and this overlapping may exacerbate the risks for cement companies.

These transition risks can result in financial risks (credit risk, market risk) for financial institutions through different risk transmission channels.

Not all of the companies in the sector will react in the same way to these different shocks, depending on their specific characteristics (capacity to invest in new low-carbon technologies, innovation strategy, access to certain raw materials, etc.). The level of risk will also depend on the level of public support for innovation, as well as on mechanisms to protect against environmental dumping by certain producer countries with less stringent environmental standards. Certain key indicators will need to be determined for each company by risk driver in order to assess their level of vulnerability to these different risks. A more granular analysis within a given sector is therefore needed in order to determine the financial risks that can be incurred by the cement sector faced with the issues of the transition.

A quantification of the scenarios concerning these risk drivers, as well as a quantification of these risks for banking institutions, would be the next stage in determining the impact of these risk drivers on bank portfolios.

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<sup>14</sup> Assumptions on the availability of carbon capture technologies have been considered in the NGFS and ACPR scenarios more as an opportunity for economic actors than as a risk driver.

# General conclusion

This report tests two assumptions associated with the analytical framework for climate scenarios developed by the NGFS, with the goal of refining the scenarios proposed. To do so, the report develops a sectoral approach and seeks to identify, through two case studies (the cement sector and the private residential property sector), key issues and factors that could define the evolution of these sectors in a context of transition.

## There are many transition risk drivers, which differ according to the sector and can overlap

The first assumption is based on the fact that there are many potential sources of transition risks and that these may differ according to the sector. However, the NGFS representative scenarios mainly cover two risk drivers (the emissions price and the availability of technologies, especially carbon capture technologies) and could therefore underestimate the plausible risks.

For the two sectoral case studies, the identification of disorderly transitions for each sector shows that there are in fact several plausible risk drivers.

Indeed, for the residential property sector, the risk drivers can stem from an increase in the greenhouse gas emissions price, but also from a policy imposing a renovation obligation for housing that is introduced in an abrupt, unanticipated way, without financial support for households, preventing them from financially disposing of their property. These policies could be exacerbated by an unfavourable construction context, marked by a shortage of skilled manual workers, with a lack of training in global renovation, making it difficult to achieve the high-performance renovation required by the regulation. Finally, a market shock caused by growing awareness among households of the future physical risks to housing in a context of climate change could modify the dynamics of demand for property.

Similarly, the cement sector presents different risk drivers. These factors can stem from an increase in the emissions price, through a tightening of the EU ETS, but also from technological shocks, whether due to green cement innovations or to the maturity of carbon capture technologies. A reduction in demand for cement could also be possible, due to declining demand for new buildings or an increase in the use of alternative building materials.

For each of the two sectors, the different risk drivers identified could increase the vulnerability of actors, and thereby increase the financial risks for financial institutions.

The analysis of these factors has also demonstrated the possibility of their overlapping, which could increase total risk levels.

## Not all actors within a given sector have the same capacity to deal with transition risks

The second assumption is based on the fact that not all actors within a given sector have the same capacity to deal with transition risks. However, the analytical framework proposed by the NGFS, like the one developed by ACPR, does not propose any granular analysis within a given sector. In this analytical framework, all actors within a given sector are assumed to react in the same way to a transition shock, taking no account of their specificities or their transition strategies.

The case studies confirm this assumption and identify the key indicators that can be used to more accurately determine the vulnerability of economic actors (households or companies) to the different risks. Several observations can be made.

First, not all economic actors are vulnerable in the same way. The levels of vulnerability for each risk driver differ according to the actors within a given sector, and the different factors do not necessarily affect the different economic actors with the same intensity.

For example, for the property sector, the energy performance level of buildings is one of the key indicators used to better identify the potentially vulnerable counterparties with regard to a risk driver caused by an increase in the emissions price or a renovation obligation. However, a detailed geo-localisation of the property is required to assess a market risk driver linked to a change in demand from households due to growing awareness of future physical risks.

An intra-sectoral analysis thus makes it possible to assess the vulnerability of the different economic actors to the different risk drivers. This research is also essential to determine the extent to which the overlapping of these risk drivers could multiply the impacts, since the number of counterparties potentially concerned increases (e.g. houses with low energy performance and houses in specific geographical areas).

## Avenues for research to improve climate stress tests, as well as for the other risk management tools

Although a sectoral analysis has shown that the risk drivers can differ according to the sector, it is important to first ascertain whether the risk drivers identified for each economic sector and taken individually could generate higher financial risks than those already covered by the NGFS analytical framework. If this is not the case, then the risk drivers covered by the NGFS analysis could be sufficient to cover all of the risks specific to each sector.

## GENERAL CONCLUSION

However, the overlapping of these risk drivers could exacerbate the results. A quantification of these risk drivers could be appropriate. It would help to determine the orders of magnitude for each risk driver. This quantification could be done using the different indicators of the vulnerability of economic actors (companies, households) to the risk drivers previously identified.

However, the objective is still to find a satisfactory compromise between the complexity of the process and the relevance of the results. One avenue worth exploring would be to analyse whether financial institutions could work with a limited number of risk drivers, and to use the results thus provided by the institutions to calculate a global risk covering more risk drivers. This global risk could be determined based on assumptions regarding the relative weight of the risk drivers and their potential for overlapping.

The preliminary research needed to establish the calculation assumptions could also provide valuable insights to improve the transition risk management tools used by financial institutions. The sectoral case studies have shown that for day-to-day risk management, an in-depth understanding at the sub-sectoral level is essential in order to identify the transition risks associated with a financial portfolio. Extending these analyses to other sectors may be of interest not only for the community of climate stress test experts, but also for service providers and financial institutions seeking to optimise their internal management of climate-related transition risks.

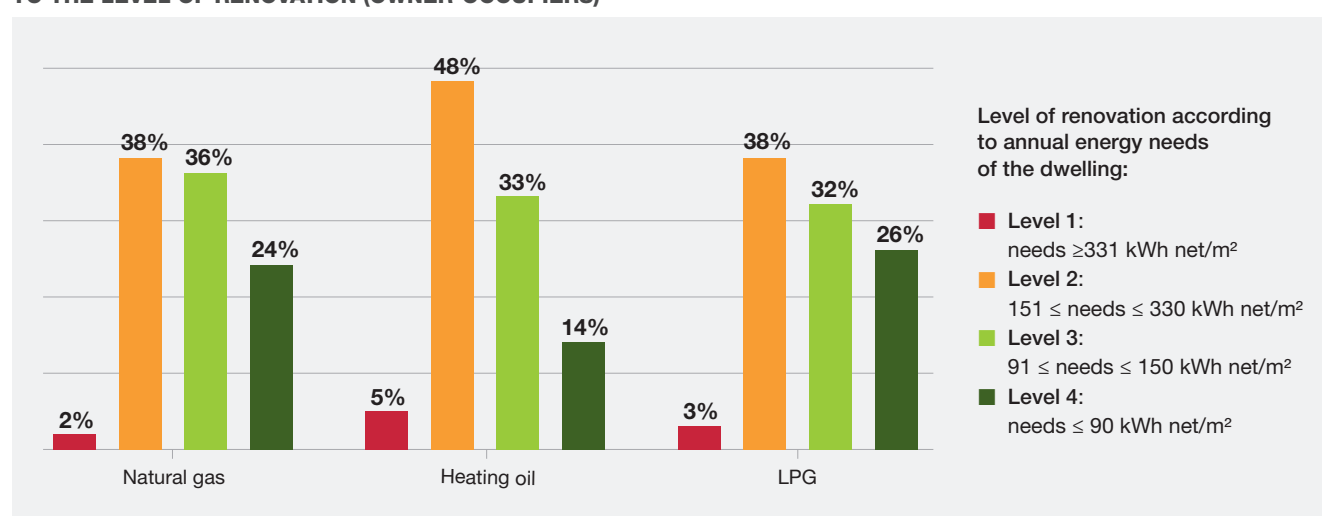
# Annexes

## Annex 1: Estimation of the effects of an increase in the carbon price on the housing budget of households

The ENERTER® 2015 Energies Demain database provides a view of the housing stock by type of heating, level of energy consumption, level of renovation, status of occupant (tenant or owner) and level of household income.

For households that use fossil fuels for heating and that own their home, between 2% and 5% of them live in a dwelling equivalent to an F or G level, and between 38% and 48% of them live in a dwelling equivalent to a D or E level (figure 36).

**FIGURE 36: DISTRIBUTION OF PRIVATE HOUSING STOCK BY TYPE OF ENERGY FOR HEATING ACCORDING TO THE LEVEL OF RENOVATION (OWNER-OCCUPIERS)**



Source: I4CE, from ENERTER® 2015 Energies demain

Based on the average household consumption levels in 2015 and on emissions factors by type of heating taken from the ADEME carbon database (2020), it is possible to calculate the potential average burden of the carbon tax linked to housing energy consumption according to the carbon price increase assumptions under the different ACPR scenarios and according to the level of renovation (see above). The

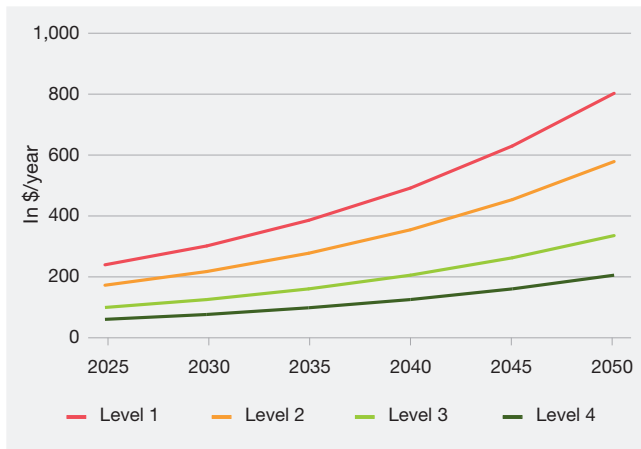
results show that the lower the level of renovation, the higher the burden. For a household heated by gas, it could be as much as 800 dollars/year by 2050<sup>15</sup> in the context of an orderly transition (figure 37), and 4 000 dollars/year in the context of a sudden transition (figure 38). It should be noted that no assumption has been made on changes in consumption.

<sup>15</sup> Based on assumptions concerning changes in the carbon price expressed in dollars for each transition scenario, communicated by ACPR in the context of its pilot exercise.

**ANNEXES**

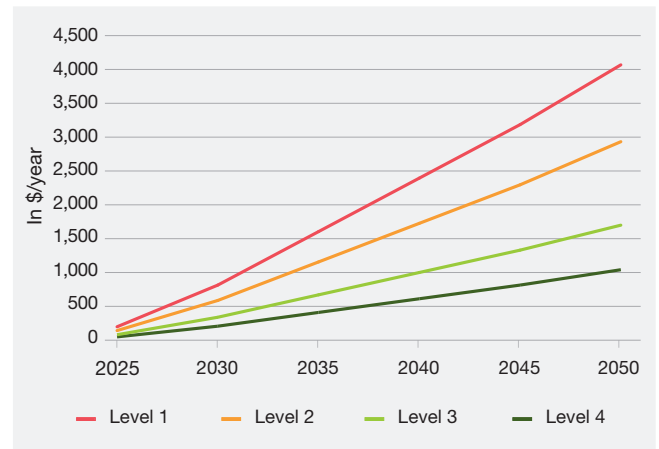
Annexe n°2 : Decorrelation of property values and risks of coastal flooding

**FIGURE 37: EVOLUTION OF THE AVERAGE CARBON TAX BURDEN IN DOLLARS/YEAR FOR A HOUSEHOLD HEATED WITH GAS ACCORDING TO THE LEVEL OF RENOVATION (ORDERLY TRANSITION)**



Source: IACE, from ENERTER© 2015 Energies demain and ADEME carbon database

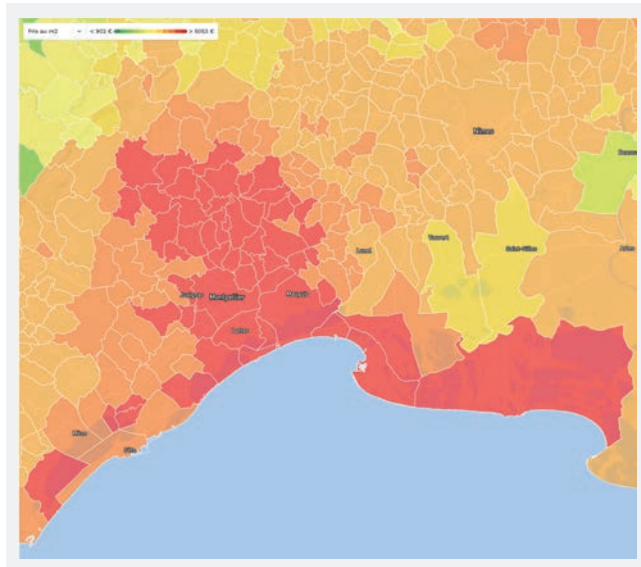
**FIGURE 38: EVOLUTION OF THE AVERAGE CARBON TAX BURDEN IN DOLLARS/YEAR FOR A HOUSEHOLD HEATED WITH GAS ACCORDING TO THE LEVEL OF RENOVATION (SUDDEN TRANSITION)**



## Annex 2: Decorrelation of property values and risks of coastal flooding

At present, the market value of property situated in coastal areas does not yet reflect the risk of coastal flooding. For example, the region around Montpellier is an attractive one, where property prices are higher closer to the coast. The average price of a house in towns such as Palavas-les-Flots and La Grande-Motte can be as much as 6 500 euros per m<sup>2</sup>, or 2.4 times the average for the Hérault department and almost twice the average price per m<sup>2</sup> for houses sold in Montpellier, which is 10 km from the sea. Globally, a map of prices per m<sup>2</sup> for the region shows that the further a property is from the sea, the lower its price per m<sup>2</sup> (figure 39).

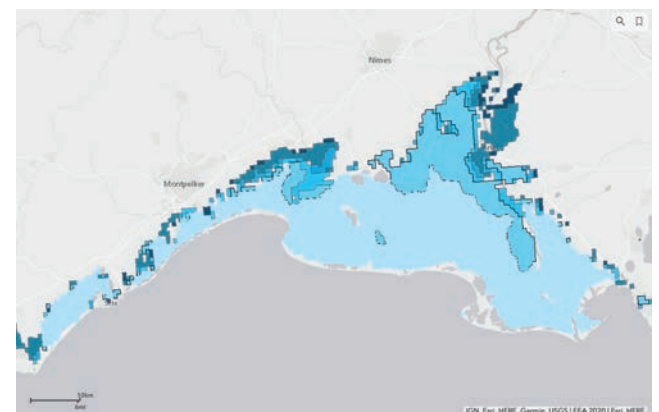
**FIGURE 39: PRICE OF PROPERTY PER M<sup>2</sup> IN THE MONTPELLIER REGION**



Source: meilleursagents.com

The map produced by the European Environment Agency identifying low-lying coastal areas that could be concerned by sea level rise, as well as the population that could be affected (figure 40), shows that a part of this coastal zone is less than 1 m above sea level and could be permanently flooded by the end of the century. The map also shows that almost 45 000 people currently live in this area.

**FIGURE 40: ESTIMATION OF FLOOD RISK AREAS AND POPULATIONS LIVING IN THESE AREAS IN THE MONTPELLIER REGION**



Source: European environment agency, from CReSIS and eurostat

There is thus a total decorrelation between the future climate risk of coastal flooding and the price per m<sup>2</sup> of dwellings in this coastal zone, which is higher than elsewhere, a sign that this risk is still not taken into account in the value of property in this area. The Montpellier region is not the only one facing this risk, which concerns a large part of the French coastline.

## Annex 3: The key elements of the cement and concrete production process

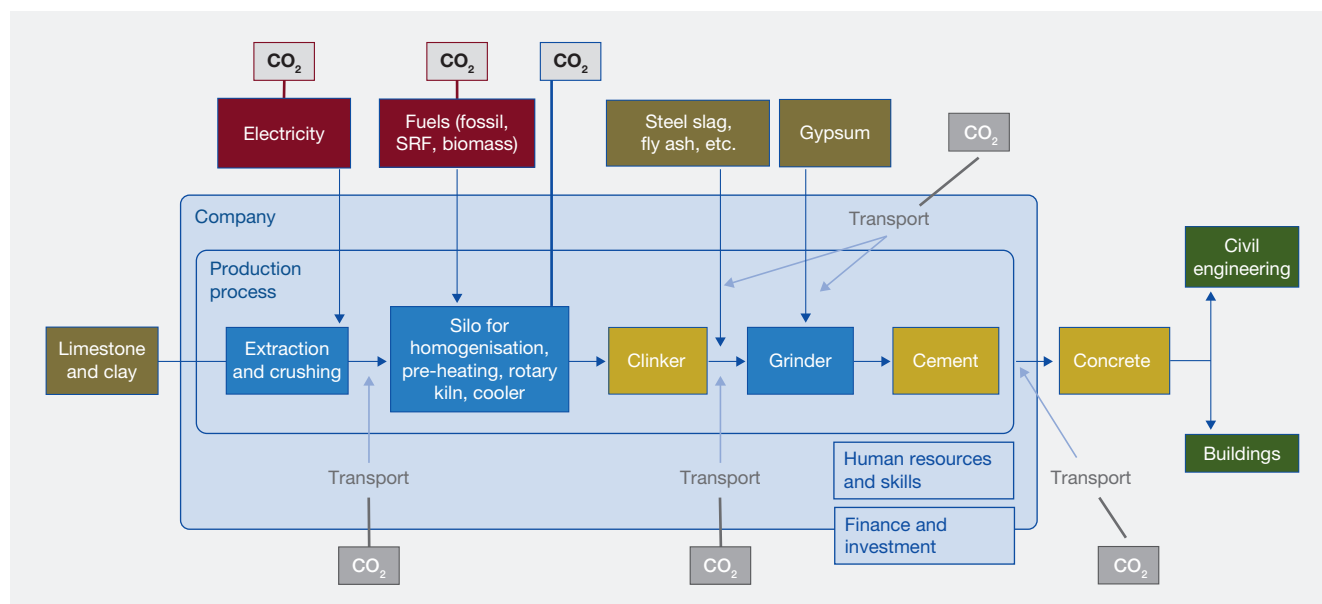
Cement is a hydraulic binder mainly used in the production of concrete. The value chain for the cement production process goes from the extraction of raw materials to the sale of cement in its final form (figure 41).

The biggest stage in the cement production process is the manufacturing of clinker, the main component of cement, using clay ( $\text{SiO}_2\text{-Al}_2\text{O}_3$ ) and limestone ( $\text{CaCO}_3$ ). These elements are extracted from quarries then crushed to a very fine mixture, known as “raw meal”. This raw meal is then preheated, before being heated to a very high temperature in a kiln ( $1\,500^\circ\text{C}$ ), which initiates the physical-chemical

process of “clinkering”. At high temperatures the powder is decarbonated, converting  $\text{CaCO}_3$  into  $\text{CaO}$  and  $\text{CO}_2$ , and thereby releasing  $\text{CO}_2$  (Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021).

Clinker can be produced by dry process or by wet process. The choice of process was traditionally determined by the state of the raw materials available, dry or wet, although it is now possible to convert a dry process plant into a wet process plant. Wet process production is far more energy-intensive than dry process production, with energy consumption being about 40% higher (Madloul *and al.*, 2011).

FIGURE 41: MAP OF KEY ELEMENTS OF THE CEMENT AND CONCRETE PRODUCTION PROCESS



Source: I4CE, from Sectoral Transition Plan for the French Cement Industry, summary and final report, ADEME, 2021

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### ABOUT FINANCE CLIMACT

The Finance ClimAct project contributes to the implementation of France's National Low Carbon Strategy and the European Union's Sustainable Finance Action Plan. It aims to develop new tools, methods and knowledge enabling (1) retail investors to integrate environmental targets into their investment choices, and (2) financial institutions and their supervisors to integrate climate issues into their decision-making processes and align financial flows with energy/climate objectives.

The consortium, coordinated by ADEME, also includes the French Ministry for the Ecological Transition, the Autorité des Marchés Financiers (AMF), the Autorité de Contrôle Prudentiel et de Résolution (ACPR), 2° Investing Initiative, Institute for Climate Economics, Finance for Tomorrow and GreenFlex.

Finance ClimAct is an unprecedented programme with a total budget of €18 million and funding of €10 million from the European Commission.

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