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Real estate and climate transition risk

A financial stability perspective

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1 Corresponding author. We thank DNB colleagues and experts from PBL Netherlands Environmental Assessment Agency and IIO – Institute for Real Estate Economics for useful discussions about this project. Clemens Bonner, Maurice Bun and Joris van Toor provided useful feedback on the draft of this Study. We also thank colleagues at DNB Statistics and Jack Bekooij for help with data and statistical support. Any remaining errors are our own.

Content

1 Introduction

Real estate plays an important role in debates on the transition to a carbon-neutral economy. Based on detailed real-estate data and climate scenario analysis, this study analyzes climate transition risks in real estate and their impact on Dutch financial institutions. First, for a substantial part of the real estate exposure, transition risk may already materialize before 2030. Second, a significant share of homeowners may face financing constraints, which would increase credit risks. Third, stricter standards may impair asset values, which would mean significant financial losses for investors. Such climate financial risks underline the importance of an orderly and, therefore, timely transition to carbon neutrality.

1.1 Climate change and financial risks

Climate change is increasingly seen as a potential source of financial instability. The instability could come from physical risks (i.e. more extreme weather) or transition risk (i.e. sudden shocks to policy or technology). Insurers could be directly exposed to substantial claims from physical risks, such as more frequent and severe storms, floods and droughts. Shocks to climate policy or energy technology could prompt a reassessment of asset values, giving rise to large losses for financial institutions potentially leading to an economic downturn. Mark Carney (2015) was one of the first to draw attention to climate financial risks. The Network for Greening the Financial System (NGFS, 2019) has emphasized that climate change could have much larger impacts than other sources of structural change affecting the financial system, necessitating the integration of climate-related risks in financial stability monitoring. Bolton et al. (2020) suggest that climate change could be the cause of the next systemic financial crisis.[1]

1 This study focuses on transition risks. In a companion paper, Caloia and Jansen (2021) consider the links between floods (a physical risk that is highly relevant for the Netherlands) and financial stability.

Financial risks depend on the transition path. The impact of climate financial risks will be smaller under timely and orderly transition paths. In 2015, almost 200 countries signed the Paris Agreement during the COP21 conference[2], thus pledging to keep the rise of global temperatures to well below 2°C. Various jurisdictions have since worked on the steps necessary to fulfil this pledge. For instance, the European Union (EU) has been working on legislation to reduce greenhouse gas emission by, at least, 55% by 2030. The long-term vision is to reach climate-neutrality in the EU by 2050. Despite this type of progress, much remains to be done, while a need for urgency remains. The most recent report of the Intergovernmental Panel on Climate Change (IPCC, 2021) gives strong indications that extreme weather is occurring more frequently. This would imply that efforts to organize the energy transition should only be further intensified, which could more readily lead to large and unexpected shocks.

In light of the uncertainty, this study uses climate scenario analysis to analyze possible vulnerabilities. Many central banks and supervisors are starting to rely on climate scenario analysis and climate stress testing. Though still under development, these tools offer useful analytical frameworks for exploring this new type of financial risk. EU authorities alone have completed or are in the process of conducting or planning 18 climate exercises (ECB/ESRB, 2021). One example is the bottom-up climate stress test that the European Central Bank (ECB) will conduct for systemically-important banks in 2022.[3] The Bank of England recently launched a climate stress test for banks and insurers, with results expected in early 2022. The European supervisory authority for pension

2 The *Conference of the Parties* (COP) is the governing body of the United Nations Climate Change Convention. See also https://unfccc.int/process/bodies/supreme-bodies/conference-of-the-parties-cop.
3 For information on the methodology of that stress test, see also 'ECB 2021 SSM stress test'.

funds and insurers (EIOPA) is also working on climate considerations around stress testing.[4]

1.2 A real estate perspective on transition risk

This study focuses on climate transition risk in real estate. Real estate exposures represent more than a quarter of the combined balance sheet total of Dutch banks, insurers and pension funds (Caloia et al., 2021). In addition, real estate plays a prominent role in discussions on the energy transition. By focusing on real estate, we add a further perspective to our previous climate work (Vermeulen et al. 2018).

Dutch financial institutions have significant exposures towards real estate. The combined real estate exposures of Dutch banks, pension funds and insurers amount to almost EUR 1,400 billion. For the banking sector, loans secured on real estate make up 38% of the balance sheet. For Dutch insurers the exposures to real estate amount to 17% of total assets. For pension funds the figure is 15%. While banks' real estate exposures mainly consist of mortgage loans and commercial real estate (CRE) loans, insurers and pension funds also have substantial real estate investments. Chapter 2 provides more details on these exposures.

The construction as well as the use of real estate lead to considerable greenhouse gas (GHG) emissions, making it key in discussions on the energy transition. In 2020 the built environment accounted for 13% of greenhouse gas emissions in the Netherlands (CBS, 2020); worldwide the figure was almost 30%. Both the Paris Agreement and the National

4 Examples of academic contributions on climate financial risks are Battiston et al. (2017), Jung et al. (2021), Faiella et al. (2021) and Vermeulen et al. (2021).

Climate Agreement state that greenhouse gas emissions from buildings must be reduced to zero by 2050. In addition, ambitious targets have also been set for 2030. As part of the Green Deal, the European Commission proposed plans in July 2021 to target a 55% cut in greenhouse gas emissions by 2030 compared to 1990 levels. To do so, the EU aims for a reduction in buildings' greenhouse gas emissions by 60%, their energy consumption by 14% and the energy consumption of heating and cooling by 18%.[5] In addition, the aim is to at least double renovation rates in the next ten years. Currently only 1% of buildings undergo energy efficient renovation every year. In order to achieve these targets, large investments will be required to improve the sustainability of buildings.

The transition to a carbon-neutral built environment could have a significant impact on property values. To meet standards or reduce carbon emissions, buildings may need costly adjustments to improve energy efficiency or switch to an alternative heating system. Such adjustments could lead to financial losses for financial institutions due to potential write-downs of loans and investments towards these assets. These risks could become especially problematic if the transition is disorderly. Higher energy efficiency standards will affect property values, if energy inefficient properties will face lower demand, or may no longer be rented out. For example, office buildings in the Netherlands must have an *energy performance certificate* (EPC) of at least C by 2023 (see also Box 1).

5 See the European Commission (2020) A renovation wave for Europe - greening our buildings, creating jobs, improving lives.

Box 1 Details on Dutch context

The Dutch Climate Agreement outlines ambitious targets to decarbonize the building sector in the coming decades. The Netherlands is committed to reduce the greenhouse gas emissions by 49% by 2030 and 95% by 2050 compared to 1990. This implies a major transformation for the entire building stock of about 7.7 million houses and about one million other buildings by 2050. A large part of the commitment to reduce the GHG emissions is to make all buildings natural-gas free by 2050, with an intermediate target of 1.5 million houses by 2030. Currently approximately 95% of buildings in the Netherlands are heated by natural gas. The implementation will mainly be the responsibility of local authorities. Achieving the intermediate target should lead to 2.4 mt of emission reductions in the residential sector. For the non-residential sector measures are proposed, mostly consisting of new efficiency standards, which should contribute another one mt of reductions by 2030.

Recent studies have highlighted the possibly strong impact of transition risks on real estate. Schütze (2020) examines transition risks in residential mortgages for Germany. The paper finds that expected credit losses can be substantially higher for a carbon-intensive portfolio compared to a "green" portfolio. Compared to a baseline, expected losses for a carbon-intensive portfolio could increase by as much as 256% in a scenario with stricter energy standards and a higher carbon price. An analysis by the National Bank of Belgium (2020) suggests that an abrupt introduction of a minimum energy performance standard can lead to material credit losses in the residential housing sector. Ferentinos et al. (2021) assess transition risks in the UK housing market in the context of the implementation of the Minimum Energy Efficiency Standard (MEES). They find that prices of properties affected by this policy (i.e. those with label F or G) decreased by about GBP 5000 to GBP 9000.

1.3 Our approach

This study examines to what extent the real estate exposures of the Dutch financial sector are vulnerable to transition risks. We provide a deep-dive into real estate exposures of Dutch banks, insurers and pension funds. We assess these transition risks by combining granular data on real estate assets and the underlying properties with scenarios for climate policies and carbon prices. We use supervisory and administrative data, together with building-level data on transition costs.

In a first deep-dive analysis, we assess transition risks in domestic exposures using the estimated costs to make existing buildings carbon neutral. For domestic real estate exposures, we have detailed information on building characteristics (from Kadaster, The Dutch Land Registry and Mapping Agency) and retrofitting costs (from the PBL Netherlands Environmental Assessment Agency). Using this information, we start by determining which real estate exposures are 'at risk' between now and 2030 under different policy scenarios. We define a building to be 'at risk' if it does not meet energy efficiency or carbon emission standards. Next, we compute the investments that are needed to make buildings zero-emission. We will refer to these investments in the rest of this Study as *retrofitting costs.* For residential mortgages, we also assess whether homeowners are able to finance these investments. Lastly, we analyze how this may affect the value and risk of real estate exposures of financial institutions. This effect can be either direct, through the value of real estate investments, or indirect, by affecting the collateral value of real estate loans and the financial position of borrowers.

In a second analysis, we assess risks in international exposures by computing the value of excess carbon emissions. For foreign real estate, we have less information on retrofitting costs, and the range of policy options across countries is very large. Therefore, we use a different methodology to quantify transition risks. First, we compare the carbon emissions of buildings to a country- and sector-specific decarbonization pathway that is implied by the emission reduction target under a 2°C and for a 1.5°C scenario, respectively. To do so, we use the Carbon Risk Real Estate Monitor (CRREM).[6] This tool is developed to conduct a carbon risk assessment for the global real estate industry. Properties that are not aligned with the decarbonization pathway are subject to transition risks. Subsequently, we estimate the potential impact on the value of these properties by means of the value of the excessive carbon emission and gauge the likely impact on the exposures of the financial institutions. We do this both for a 2°C and for a 1.5°C scenario.

1.4 Main findings and implications

Based on a number of quantitative analyses, this study highlights two potentially sizable vulnerabilities. First, we find that a large part of the real estate exposure of Dutch financial institutions is at risk, meaning that the energy transition will have an impact on the value and riskiness of these exposures. For more than 40% of the exposures, this risk could materialize already before 2030. Second, a significant share of Dutch homeowners may face difficulties in financing retrofitting costs. Our calculations suggest that, in a high-cost scenario, 50% of Dutch homeowners would currently not be able to pay the required invest-

6 CRREM provides a tool for quantifying and managing “stranding” risks and accelerating decarbonization of commercial real estate properties in the EU. The tool has been expanded to cover residential properties and properties outside the EU. See Appendix B for details on this approach.

ment from their own funds. In addition, around 20% of homeowners would be credit constrained and may not be able to finance the required investment. In addition, by computing the potential costs of inaction, we show that a substantial part of the value of real estate investments is at stake in the energy transition. Although a complete quantification of the transition risk in real estate is not yet feasible, our results do suggest that the impact is potentially large.

An orderly and, therefore, timely transition minimizes the likelihood that these vulnerabilities would materialize. Clarity on policy is one important factor in minimizing transition risks. Transition risks may already be significant in the shorter term if it is not made clear soon which sustainability requirements will apply to various types of real estate. In the meantime, it is important to conduct a timely discussion on possible ways to mitigate these climate financial risks. At this stage it is important that financial institutions already take account of certain pockets of risk relating to geographic locations or transition paths in their own risk management.

There is also a need for better information on energy-related characteristics. We find that climate-relevant information on foreign real estate is less complete compared to that for domestic exposures. This finding holds for information on location as well as energy characteristics. It is important for financial institutions as well as central banks and financial supervisors to improve data quality and availability, in order to fully integrate climate considerations into their risk assessments.

2 Mapping real estate exposures

This chapter describes the real estate exposures of Dutch financial institutions. This description is based on a combination of various granular data sources and a specific data request to financial institutions. We describe domestic as well as international exposures. The focus is on those characteristics that are most relevant from the perspective of climate transition risk, such as energy intensity and real estate type. We also point out issues on data availability and quality.

2.1 Overview of exposures

To assess climate risks in real estate exposures, we collected granular data from different sources. Detailed information on the characteristics of real estate exposures is often lacking in regulatory reporting. This is especially true when it comes to information that is needed to assess climate-related risks, namely data on location and energy characteristics of the properties. We combine regulatory, administrative and survey data to construct a unique dataset with data on buildings, the related financial assets and the households who own the majority of these buildings. In addition, we use data from a specific request among Dutch insurers and pension funds (Box 2). Based on these data sources, we provide a system-wide overview of real estate exposures, both domestic and international.[7]

7 See also Appendix A for further background on the data.

Box 2 Data request among pension funds and insurers

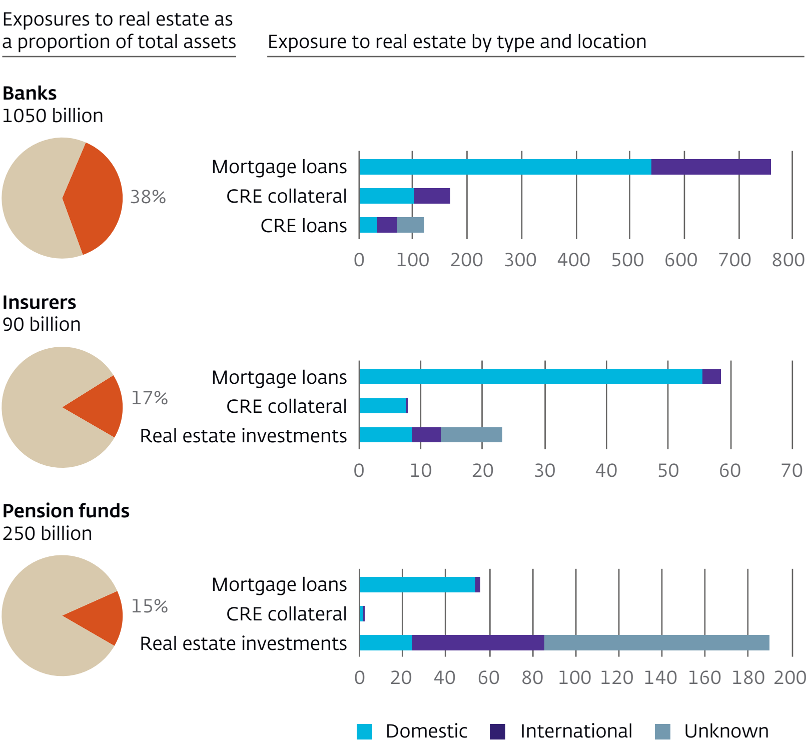
In March 2021 we collected information on the real estate exposures of twenty pension funds and six insurers through a data request. These institutions account for 84% and 95% of the total real estate investments of the Dutch pension funds and insurance sectors, respectively. The scope of the request included all direct and indirect real estate investments. Institutions were asked to report detailed information on the location and energy consumption characteristics of their exposures, both at the level of financial assets, such as real estate funds, and at the level of individual real estate properties. In total, the twenty pension funds and six insurers provided granular information on 77% (EUR 100 billion) and 63% (EUR 13.6 billion) of their real estate investments, respectively.

Real estate plays an important role on the balance sheet of Dutch financial institutions. Overall, real estate exposures account for almost EUR 1,400 billion, thus representing more than a quarter of the combined balance sheet total of Dutch banks, insurers and pension funds. Figure 2.1 shows details for banks, insurers and pension funds. In the banking sector, loans secured on real estate make up 38% of the balance sheet. These include residential mortgages (27%), commercial real estate (4%) and corporate loans secured on real estate (6%). Insurers and pension funds also have substantial portfolios of residential mortgages and are major investors in commercial real estate. These real estate investments mainly concern foreign real estate. In the case of insurers, the exposures to real estate amount to 17% of total assets. For pension funds the figure is 15%.

We have been able to collect the relevant information for a sizeable share of exposures, but significant data gaps remain. Figure 2.2 provides an overview of the coverage of the energy efficiency information

Figure 2.1 Real estate exposures of the Dutch financial sector

EUR billions



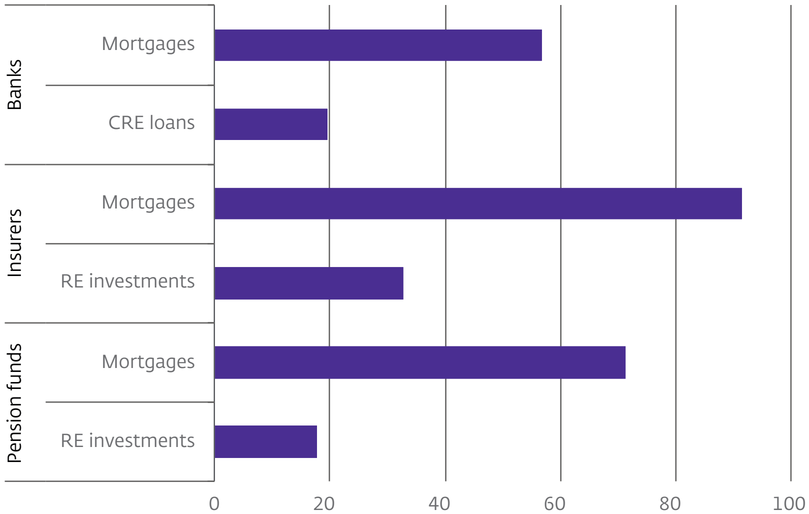
Source: DNB.

Notes: CRE collateral: loans secured on commercial real estate. CRE loans: financing of commercial real estate. Real estate investments: investments in buildings, securitisations and real estate funds and companies.
The exposures for which the location of the real estate is 'unknown' concern almost exclusively foreign real estate funds.

that we use in this study. We have energy information for most of the residential mortgages, but for CRE loans and real estate investments, the coverage is only 20 to 30%. Because of the limited coverage, we cannot provide an overall assessment of transition risk in the real estate exposures of the financial sector. Instead, we focus on specific analyses of segments of the portfolio for which we have sufficient data to do a meaningful analysis. The limited data coverage also underlines the importance of further improvements in the availability of climate-relevant information.

Figure 2.2 Coverage of data on energy efficiency

Percentages



Source: DNB.

Note: percentage of exposures for which information on energy label, energy intensity or greenhouse gas intensity is available in our dataset.

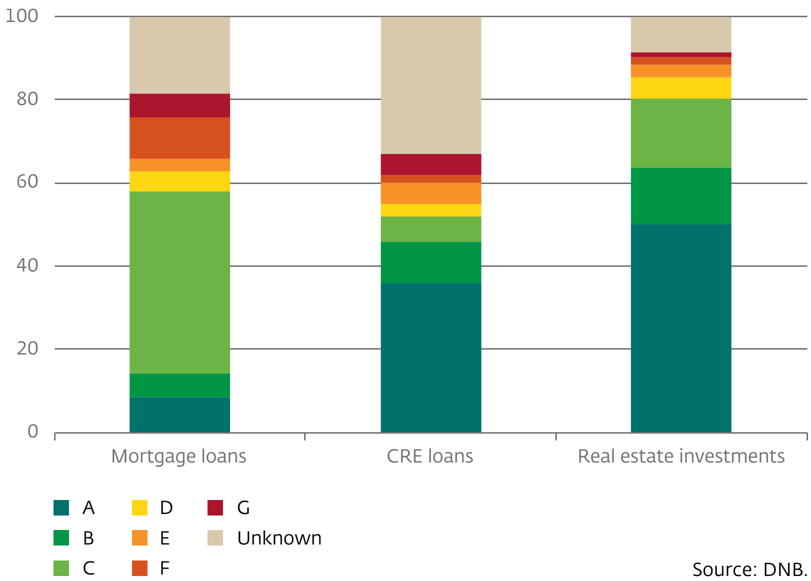
Financial institutions have more information on domestic exposures than on international exposures. Insurers and pension funds provided us with energy label information for almost 90% of their Dutch real estate exposures. Banks provided detailed information for 65% of their CRE loans in the Netherlands. In addition, for domestic exposures, detailed information on building characteristics can be obtained from other sources. In some cases, we were able to link this information at a granular level to exposures of financial institutions. For foreign exposures, we had to rely on the information provided by financial institutions. Based on our data collection, we find that on average insurers and pension funds have information on the relevant energy characteristics of only one-third of their foreign real estate exposures. We also find that there are large differences in the extent to which institutions have this information.

2.2 Domestic exposures

For domestic exposures, energy labels differ substantially across types of real estate. Figure 2.3 shows a breakdown for three types of real estate exposures by energy label. One notable feature is that the underlying properties for residential mortgages have significantly lower rated energy labels than CRE loan collaterals or real estate investments. This could be the result of owners of commercial real estate properties being more willing or able to invest in energy efficiency than homeowners, or facing more binding regulations. A second notable feature is the share of exposures for which no information is available. The share of missing observations ranges from 20% (for mortgages) to 35% (for CRE loans). Even though the share of missing observations is much lower than for foreign exposures, this is still a significant data gap. It is important that financial institutions make further progress on collecting this type of information.

Figure 2.3 Domestic real estate exposures by energy label

Percentages



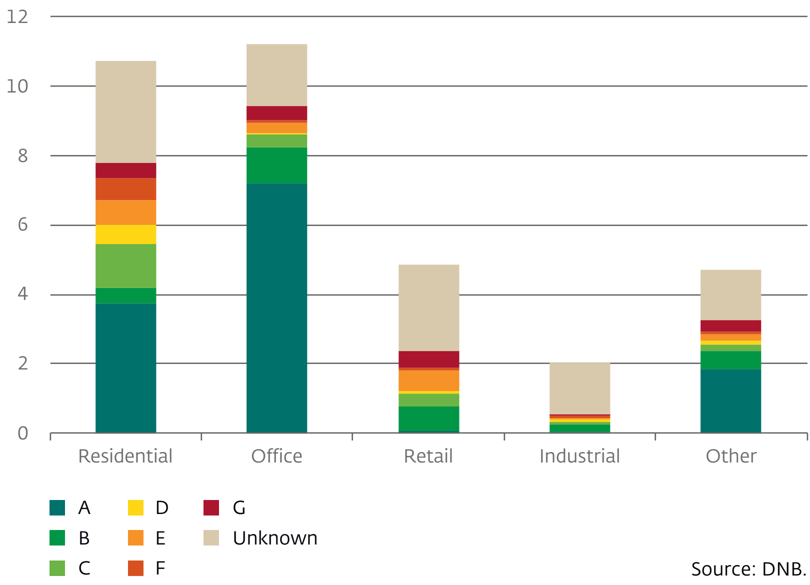
Source: DNB.

Note: Figures are based on institutions' supervisory reporting, supplemented with data from Statistics Netherlands and PBL.

Transition risk is likely to differ between types of real estate. This is suggested by a breakdown of energy labels across different type of real estate exposures. Figures 2.4 and 2.5 show such breakdowns, respectively for CRE loans and the real estate investments of insurers and pension funds. Both figures show that the distribution of energy labels differs substantially across real estate types. Rental houses ('residential') and office buildings seem to have relatively good energy labels, whereas information regarding energy labels is lacking for most of the industrial buildings. Differences in transition risk may also stem from differences in transition strategies and the available technological options. For relatively homogenous building types, such as rental houses and offices, the route to zero emission is likely to be clearer than for industrial buildings, which is a very heterogenous category. This could make it more difficult to assess transition risks for the latter category.

Figure 2.4 CRE loans and energy labels

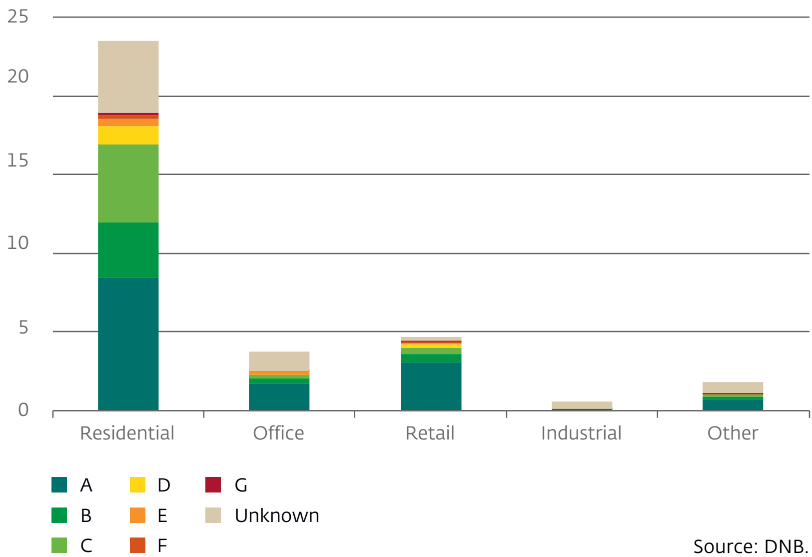
EUR Billions



Source: DNB.

Figure 2.5 Real estate investments and energy labels

EUR Billions



Source: DNB.

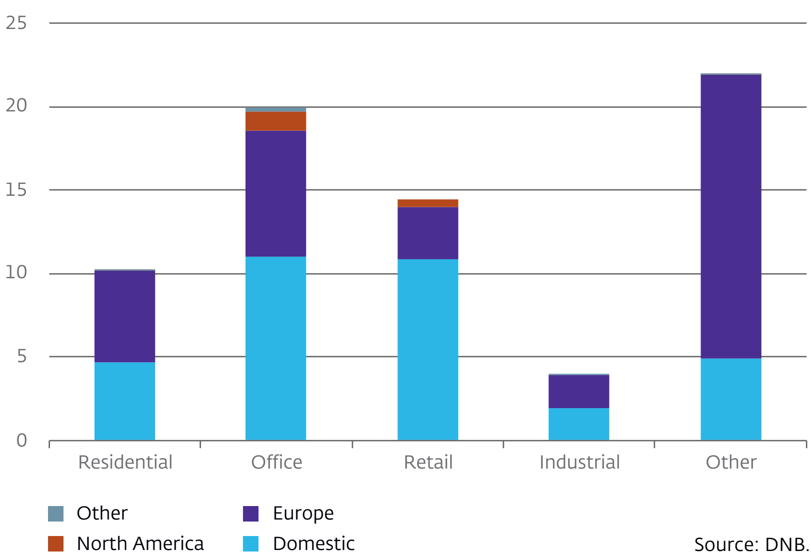
2.3 International exposures

For international exposures, making a broad, system-wide assessment of transition risk turns out to be especially challenging. To begin with, obtaining the relevant granular information is more difficult. Different metrics and standards are used to measure the energy characteristics of buildings. This presumably would already complicate a comparison across the real estate portfolio for an individual institution, let alone for the sector as a whole. Financial institutions also appear to have better access to building level information from domestic fund managers than from international ones. Another complicating factor is that different countries or regions may face different challenges in the energy transition of their built environment, depending on factors such as climate and existing heating systems. As a result, climate policies for buildings may differ substantially between countries and regions. These factors complicate the assessment of transition risk in international real estate exposures, as we will show in Chapter 4. With these caveats in mind, we now turn to a description of patterns in the data.

There is heterogeneity in types of exposures across geographical regions. Figures 2.6 to 2.8 present breakdowns for CRE loan collaterals, real estate investments of insurers and those of pension funds,

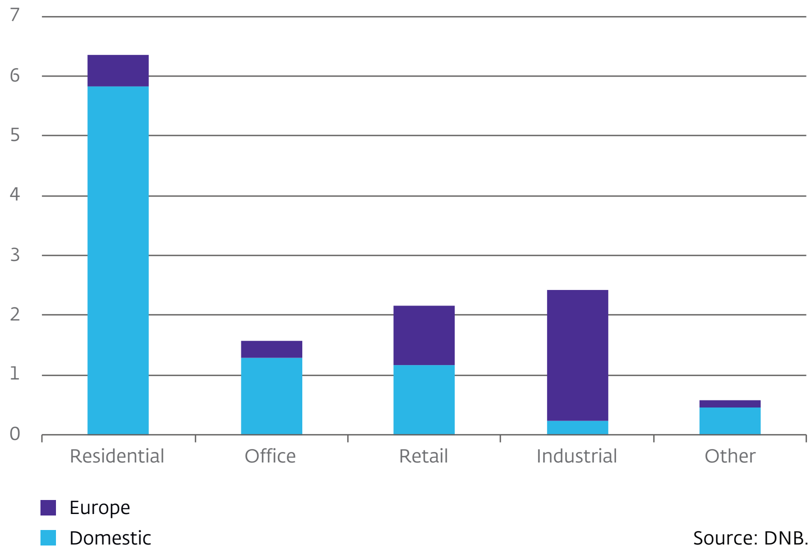
Figure 2.6 Breakdown of CRE loans by continent and RE type

EUR billions



Source: DNB.

Figure 2.7 Breakdown of RE investments for insurers
EUR billions

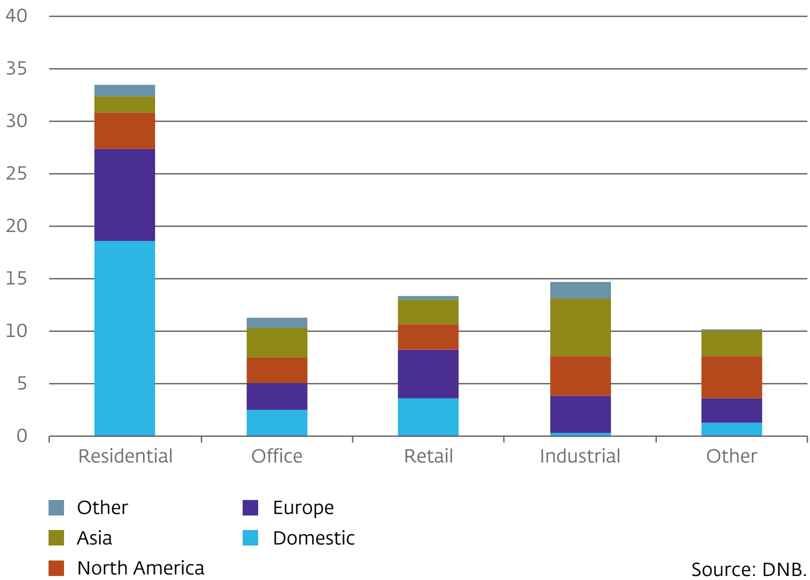


Source: DNB.

respectively, across various regions. CRE loan collaterals and the real estate investments of insurers are almost completely located in Europe (Figure 2.6 and 2.7). The investments of pension funds are more geographically dispersed, with substantial exposures to North America and Asia. Whereas exposures to domestic industrial buildings are typically small, these buildings make up the biggest part of international exposures for insurers and pension funds. The opposite holds for investments in residential buildings, which make up a large part of domestic exposure, but are less prevalent in international exposures.

Figure 2.8 Breakdown of RE investments for pension funds

EUR billions



Source: DNB.

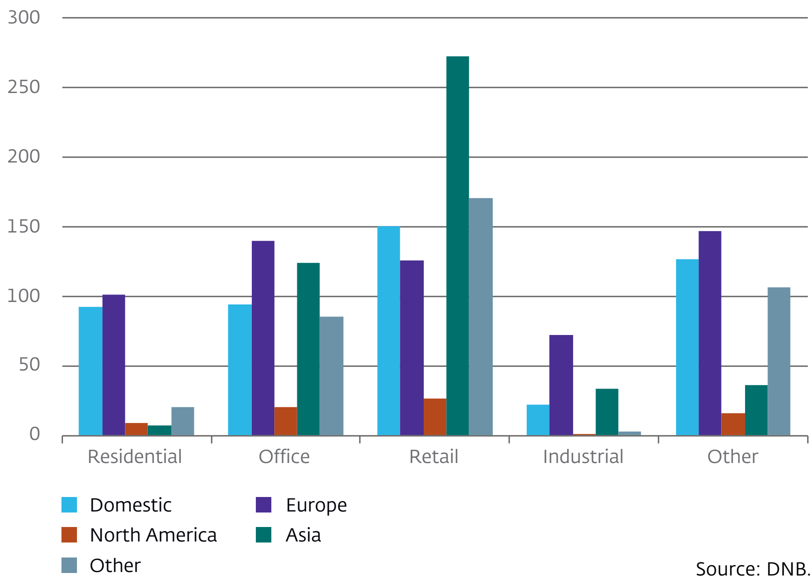
Insurers and pension funds report large differences in energy characteristics across real estate types and geographies. Figure 2.9 shows the median energy intensity of the properties in which insurers and pension funds have invested. The differences between regions are large, and appear to be larger than what can be explained by known differences in the average energy intensity across regions and real estate types.[8] While this may to some extent be the result of institutional investors selecting relatively energy efficient buildings, the limited

8 For example, according to the 2018 CRREM data, the average energy intensity of office buildings in the US is 245.4 kwh/m²/year, compared to 265.9 kwh/m2/year in the Netherlands and 259.5 kwh/m²/year in Singapore.

coverage of the energy-related information and data quality issues are likely to play a role here as well. In any case, the data suggest that energy characteristics differ substantially between regions and real estate types. This underlines the importance of improving the availability and quality of the data to be able to assess transition risks.

Figure 2.9 Energy intensity of RE investments by continent and real estate type

Median in Kwh/m²/year



Source: DNB.

3 The domestic perspective

This chapter assesses the transition risk of domestic real estate exposures. We quantify this risk using retrofitting costs of the underlying properties. First, we determine which exposures are 'at risk' between now and 2030, meaning that the related properties will need to be retrofitted to meet energy efficiency or carbon emissions standards. Then, we compute the investments that are needed to make a building zero-emission, where we account for various building characteristics. Third, we discuss how this may affect the value and risks of real estate exposures of financial institutions, mainly by assessing whether homeowners can undertake the required investments.

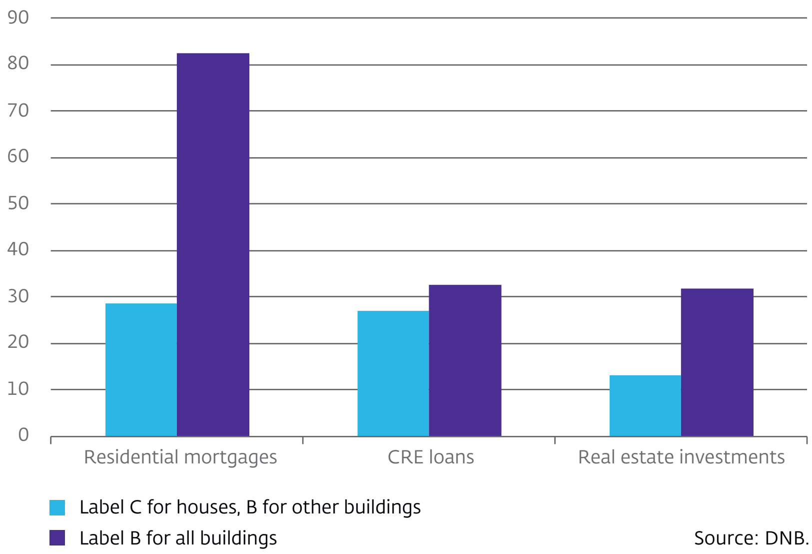
3.1 Exposures at risk

The amount of exposures 'at risk' between now and 2030 depends on the climate policies that will be implemented. Although overall emission reduction targets for buildings have been set for 2050 and 2030, it remains unclear how this will be achieved. For example, it is not clear how the energy efficiency minimum standard for office buildings (currently energy label C in 2023) will evolve over time. For other types of buildings, it is not even clear whether energy efficiency minimum standards will be set at all. It is also not clear what will be the impact of the introduction of an emission trading scheme for the built environment, as proposed by the European Commission. But even if the details of the policies are uncertain, it is clear that stricter energy efficiency standards are an indispensable part of the transition to a carbon-neutral built environment.

Between now and 2030, 30% to 75% of all real estate exposures could be at risk due to more stringent energy efficiency standards. We estimate the exposures at risk in two scenarios. In the first scenario, we assume that in 2030 the (explicit or implicit) minimum standard for energy efficiency for all houses (owner-occupied as well as rental) is label C, whereas it is label B for all other buildings. In this scenario, almost 30% of the exposures are related to buildings that would need to be retrofitted. In a second, more ambitious scenario, the minimum standard for energy efficiency of all buildings in 2030 is set at label B. This standard would imply that a large part of the existing housing stock (of which around 50% currently has label C) needs to be retrofitted

Figure 3.1 Real estate exposures at risk between now and 2030

Percentages



Source: DNB.

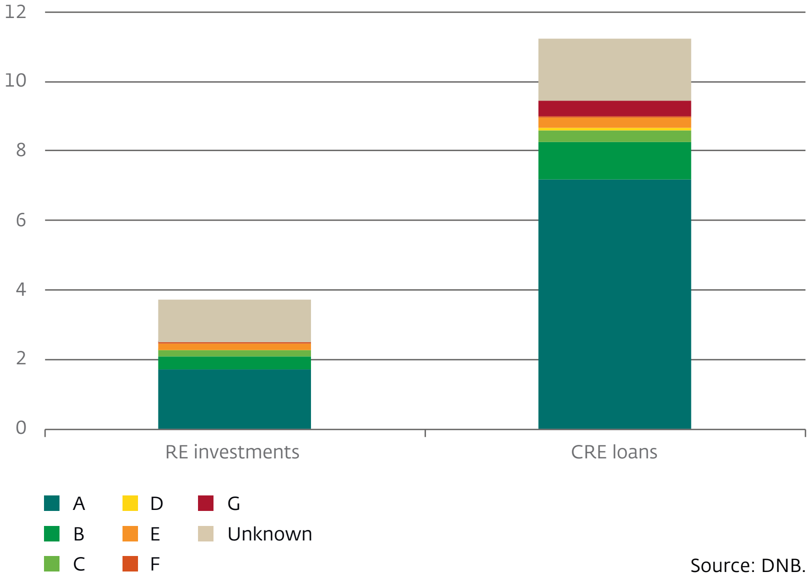
between now and 2030. In this scenario, the share of real estate exposures at risk increases to over 75%. Figure 3.1 shows how the percentage of 'at risk' exposures would vary across the two scenarios and types of exposure.

The amount of domestic exposures at risk depends heavily on the energy efficiency standards for houses. In general, binding minimum label requirements work well for buildings that are rented out, such as offices and rental houses, but may be less suitable for (existing) owner-occupied houses. If the requirement is not met, renting out a building can be prohibited, whereas the possibilities for similar measures with regard to living in one's own home are more limited. But it also seems unlikely that the housing stock will become carbon neutral without any form of explicit or implicit standards being put in place or developing over time. Moreover, to ensure that between now and 2030 a substantial part of the housing stock will be made carbon neutral, such standards may have to be implemented relatively quickly. Explicit standards could for example take the form of conditions that are imposed when a house changes owner, whereas financing conditions or consumer preferences could also lead to implicit standards.

Financial institutions still have exposures to office buildings which do not meet the label C minimum standard. Banks have an exposure of EUR 11bn to CRE-loans with office buildings as collateral. Figure 3.2 shows the distribution of these exposures across energy labels. 75% of these office buildings already have an energy label of at least C, which is the official minimum standard as of 2023. Insurers and pension funds have invested almost EUR 4bn in Dutch office buildings, of which 60% already meets the minimum standard. Even though the share of exposures to office buildings with lower-rated energy labels is small, energy characteristics are still unknown for a significant part of the exposures (16% for banks and almost one third for insurers and pension funds). With the binding minimum standard becoming effective in 2023, institutions need to step up their efforts to collect this information in order to make a proper risk assessment and take the necessary measures.

Figure 3.2 Exposures to office buildings by energy label

EUR billions



Source: DNB.

3.2 Investments in retrofitting

Substantial investments are required to ensure the built environment is carbon neutral by 2050. Part of these investments are building-specific and will have to be made by the owner of the building. This holds for investments in the efficiency of the building shell and in heating systems for individual buildings (e.g. heat pumps). Investments can also take the form of investments in collective heating systems or infrastructure. In this case, the building owner typically does not make the investment, but pays a fee to connect to the system or infrastructure. Given our focus on the real estate exposures of financial institutions, we only consider the investments that are building-specific and will therefore likely have to be made by the building owner.

We estimate the required investment for each building as a function of building characteristics and the zero-emission heating technology that is used. Our calculations use data from the Startanalyse by the PBL. The Startanalyse contains estimates of the (national) costs of making all buildings in the Netherlands zero emission, and it compares the costs of several technical options to achieve this.[9] The PBL dataset contains both the total system costs of the transition specified to its components as well as the costs for the building owner. The costs are determined at a granular level. Costs that are linked to an individual building are determined at the building level, as a function of building characteristics such as current energy label, building year, floor size, and building type. Costs that are related to collective investments are determined at the level of neighborhoods, taking into account the local

9 The Startanalyse was developed in 2020 by PBL to provide local governments with information on the costs of different strategies to make neighborhoods zero carbon ('Wijkaanpak').

availability of existing infrastructure and heat sources. From this analysis, we use the building-specific investments costs[10] and assume that these costs are borne entirely by the owner of the building.

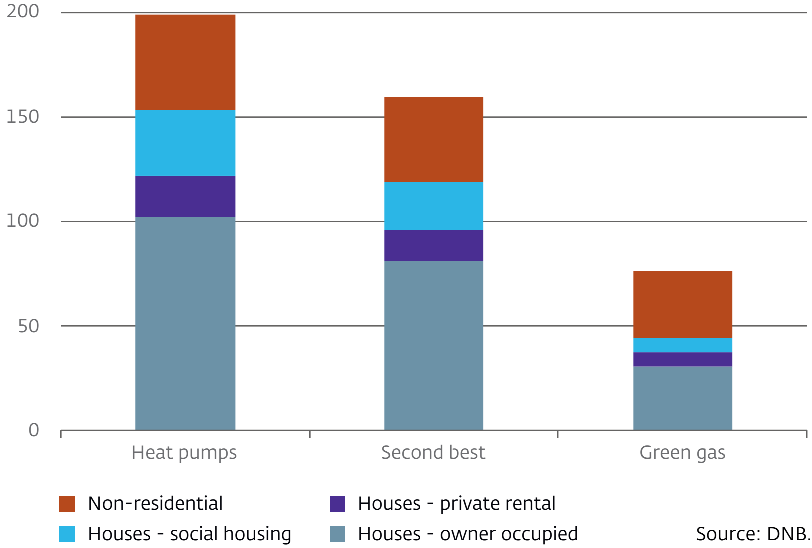
To make all buildings in the Netherlands zero-emission, building owners will need to invest between EUR 75 and 200 billion (see figure 3.3). The lowest investments by building owners are needed in a scenario where almost all buildings are heated through green gas. In this scenario ('green gas'), drastic improvements in energy efficiency of buildings are not needed and most building owners do not have to invest in installations. Also from the perspective of municipalities, this would in almost all cases be the lowest cost option. However, this can only be realized if green gas becomes available at a very large scale. This is currently not the case, and it is uncertain whether this is feasible.[11] The highest investments are needed in a scenario where collective approaches are absent, and all buildings have to rely on individual electric heating systems ('heat pumps'). This requires high energy efficiency of buildings and substantial investment in installations.[12] We also look at a scenario without green gas where municipalities successfully implement, from the available technologies, the heating system with the lowest total costs ('second best'). In this case, 45% of the buildings will rely on individual electrical heating systems. The remainder will use (collective) heat networks in various forms.[13]

10 In the Startanalyse, this is divided into investments in insulation and installations.
11 According to PBL, green gas is unlikely to become available in sufficient quantity before 2030.
12 The investments in electricity networks, which are also necessary in this scenario, are not included in our analysis.
13 Appendix B has further details on the scenarios and the calculations of the required investments.

Around 50% of the total required investment is needed to retrofit owner-occupied houses. The required investment differs substantially between house types. For instance, retrofitting a detached house would require an average investment of around EUR 34,000 in the 'heat pumps' scenario, whereas the owners of multi-family apartments would only need to spend around EUR 14,500 on average (figure 3.4). Moreover, for some house types, the differences between the scenarios are smaller than for others. For example, for detached houses, the difference between the 'heat pumps' scenario and the 'second best' scenario is relatively small. In most cases, for neighborhoods with many detached houses, individual heat pumps are in fact the second-best option. Because of differences in building characteristics, the average retrofitting costs are higher for owner-occupied houses (EUR 24,000) than for rental houses (EUR 16,000).

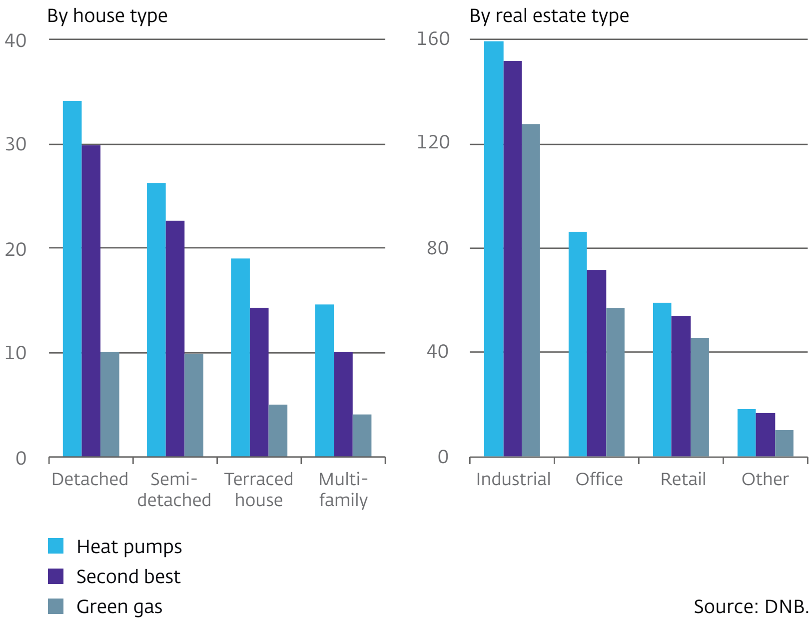
Figure 3.3 Required retrofitting investments by building owners

EUR billions



Source: DNB.

Figure 3.4 Average investment amounts for houses and non-residential buildings
EUR thousand



Source: DNB.

3.3 Implications for financial risks

The required investment can affect the value of institutions' real estate exposures in two ways. Ultimately, we are interested in the impact of the energy transition on the balance sheet of financial institutions. This effect can be either direct, through the value of real estate investments, or indirect, by affecting the collateral value of real estate loans and the financial position of borrowers.

The direct impact of retrofitting on the value of real estate will depend on a range of factors. If a building does not meet energy efficiency or emission standards, it will generate a lower rental income and become less valuable. To avoid this loss, building owners have to make sure that their properties meet energy efficiency and emission standards. From this perspective, the investment in retrofitting is actually a cost, which should be considered in the valuation of the property. However, an investment in retrofitting also has benefits, such as lower energy or CO_2 costs, which has a positive impact on the value of the property. The ultimate impact on the value of the property depends, among other factors, on future energy and carbon prices, which in turn are affected by the level of ambition of climate policies. Moreover, the building owner may not be able to reap the entire benefit from lower energy costs, as part of the benefit may go to the tenant.[14]

14 This may be especially relevant for retrofitting of rental houses, which often have regulated rents.

By affecting the collateral value and the financial position of the borrower, the required investments in retrofitting also affect the risk of mortgages and CRE loans. If the building owner does not make the required investments, the value of the collateral is likely to drop. On the other hand, building owners may end up with substantially smaller financial buffers after making the required investments in retrofitting. Both channels may increase the credit risk of the loan. For a lender, it is therefore important to know the willingness and ability of the building owner to invest in retrofitting.

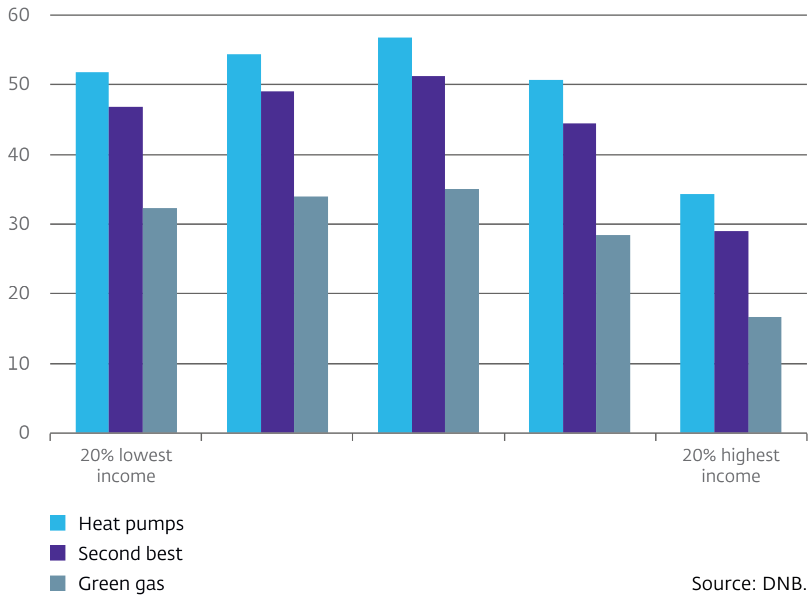
This indirect channel may be especially relevant for residential mortgages. Homeowners are more likely to face financing constraints than (professional) investors in commercial real estate. Moreover, homeowners may be reluctant or unwilling to invest in retrofitting, as they may find it too costly or too much effort. We assess the relevance of this risk channel by linking the required investment by homeowners to their financial position. We use administrative data from CBS on household wealth and income to determine the ability of homeowners to finance the required investment.

In the 'heat pumps' scenario, 50% of homeowners cannot pay the required investment from their own funds. In the 'green gas' scenario, this share would drop to almost 30%. This suggests that in any scenario, a substantial share of homeowners will have to use other sources of financing to retrofit their house. Figure 3.5 shows that only for the highest income group the share of homeowners with insufficient own funds is substantially smaller than average.[15]

15 In figures 3.5 and 3.6, we calculate income quantiles based on the income of homeowners instead of all households.

Figure 3.5 Share of homeowners with insufficient own funds

Percentages of all homeowners, by income quantile

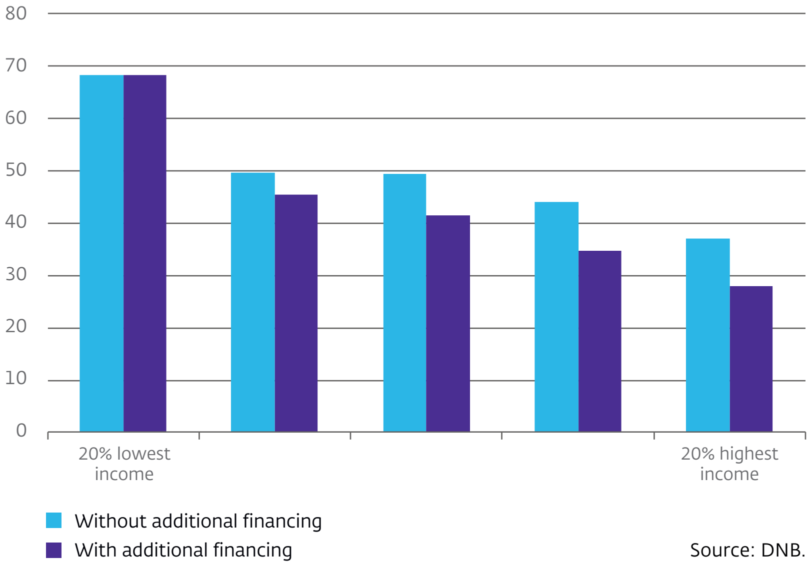


Source: DNB.

More than 20% of homeowners would be credit-constrained and may not be able to make the required investment. In the 'heat pumps' scenario, two million homeowners would – in addition to their own funds - have to borrow on average EUR 20,000 to make their house carbon neutral. Almost half of them cannot borrow the required amount, as they would exceed the loan to value (LTV) and/or loan to income (LTI) limits for mortgage credit. We also take into account the fact that mortgage lenders are allowed to grant additional financing to homeowners if they invest in retrofitting.[16] In these cases, mortgage amounts can exceed the maximum financing capacity established by the LTV and LTI limits. The availability of additional financing reduces the share of credit constrained borrowers somewhat, but it remains substantial. Especially homeowners in the lowest income quantile typically remain credit constrained (figure 3.6).

Figure 3.6 Share of homeowners that need to borrow, but are credit constrained

Percentages of homeowners with insufficient own funds, by income quantile



Source: DNB.

16 When they plan to make investments in retrofitting, homeowners can borrow up to 106% LTV and an additional EUR 9,000 on top of the maximum implied by the LTI limit.

Such a share of credit-constrained homeowners would have an impact on credit risk. Homeowners who are credit constrained may choose not to make their house carbon neutral, which could have a negative impact on the value of the collateral. Or, if a homeowner has to use all his savings and borrow up to his financing limit, he will be more vulnerable to negative shocks. In both cases, the risk of the loan increases. As part of their risk management, mortgage lenders should therefore collect information on the ability and willingness of borrowers to invest in retrofitting their house.

A widespread reliance on borrowing to finance the required investments could also lead to a more general increase in credit risk. Homeowners – credit constrained or not - may choose to finance a substantial part of the investment using credit. In case of massive recourse to debt-financing, banks may face increasing credit risk as the additional debt affects the risk characteristics of their exposures, such as the Loan-to-Income (LTI) and the Loan-to-Value (LTV) of mortgage loans. According to our calculations, the additional borrowing for undertaking the required investment would increase LTIs and LTVs of homeowners by an average 8% in the high cost scenario. These could lead to pockets of vulnerabilities, such as an increasing share of homeowners with very high LTVs or LTIs. In Box 3, we analyse the potential impact on credit risk parameters.

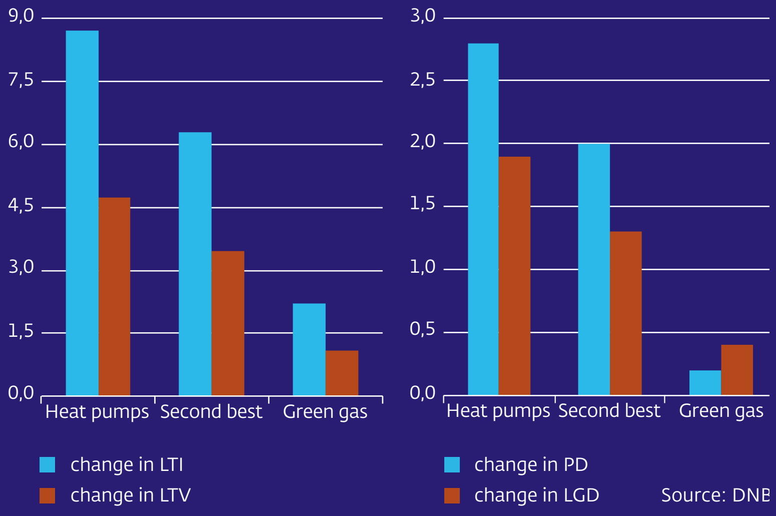
Box 3 The energy transition and the risk characteristics of residential mortgages

This box estimates how the energy transition can affect the risk characteristics of residential mortgages. Given the uncertainty surrounding the energy transition, this exercise is based on three assumptions. First, in line with the previous analysis we assume that investments are made if sufficient funds are available, either via savings or additional borrowing, and using own funds is the preferred financing option. Based on these assumptions, these investments would lead to an additional borrowing in the heat pumps scenario of at least EUR 40 bln. Second, we abstract from the timing of the energy transition and assume all decisions are made at present. This implies that risks would immediately materialize, while in reality they are more likely to increase gradually as more ambitious requirements are introduced. Third, we assume that all real estate properties that are not retrofitted will be 'stranded' (relatively to retrofitted ones) and the drop in collateral value equals the retrofitting investment amount.

LTIs and LTVs are modeled based on the estimated change in the loan amounts (L), collateral values (V) and incomes (I). The energy transition affects homeowners in different ways. First, additional borrowing by unconstrained homeowners increases their LTIs and LTVs due to the higher outstanding loan amounts (L). Second, constrained homeowners who defer retrofit investments also see an increase in their LTV, due to the drop in the value of their property (V). Third, homeowners who undertake retrofit investments also see immediate gains in disposable incomes (I) due to lower energy bills. We model this as a decrease in the LTI. This implies that homeowners who finance the retrofit investment from their own funds face an overall improvement in the risk characteristics. The impact from the changes in LTV and LTI on the Probability of Default (PD) of mortgages is estimated via historical correlations between changes in LTVs and LTIs and changes in the default status of borrowers.

Figure 3.7 The impact on the risk characteristics of mortgages

Percentage points



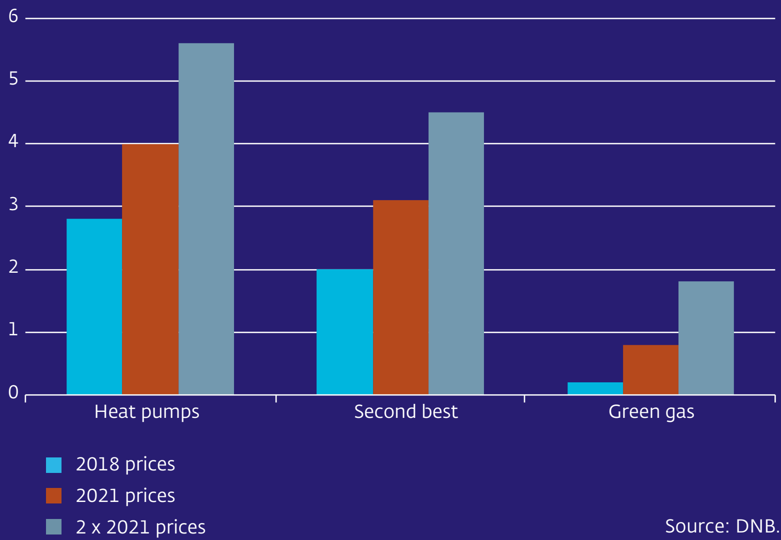
Source: DNB

In the 'heat pumps' scenario, the risk characteristics would deteriorate on average, leading to an increase in the expected loss for financial institutions. Figure 3.7 shows the average impact on the risk characteristics of mortgages, in the three transition scenarios. In the most costly scenario for homeowners (heat pumps) the average LTI and LTV would increase by 8.7 and 4.7 percentage points, respectively. This translates into an increase in the estimated PD and LGD of bank portfolios by 2.8% and 1.9%, respectively. This increases the expected loss for lenders, by an amount approximately equal to the product of the resulting PDs and LGDs. While the average impact seems small, it hides substantial heterogeneity and potential pockets of risk. Whereas the average PD declines by around 1% for homeowners with sufficient own funds, PD and LGD increase for credit constrained homeowners, who do not invest in retrofitting, but also for homeowners who do retrofit, but need substantial additional borrowing. For these homeowners, the average PDs and LGDs increase by 7% and 3%, respectively.

Future increases in energy prices would lead to an increase in transition risk for borrowers and lenders. If retrofit investments are not made or postponed, energy consumption would remain the same but energy costs could increase because of likely higher energy prices. Using data on the natural gas consumption of households, we run a sensitivity analysis showing how changes in gas prices could impact the risk characteristics. Focusing on the implications for the PD, figure 3.9 shows the result of alternative calculations with higher gas prices. In particular, the results based on 2018 prices (EUR 0,0834/KhW) are compared with those obtained using 2021 prices (EUR 0,1798/KhW) and a scenario with gas prices doubling with respect to the 2021 level.

Higher energy prices make retrofit investments more profitable, but hit credit constrained borrowers. We model the increase in the gas price as a negative disposable income shock for credit constrained borrowers. As the gas price increases, the immediate gain from undertaking retrofit investments increases. But as credit constrained homeowners are not able to retrofit, their disposable income decreases, increasing the LTI. Higher LTI lead to an increase in the probability of default. We find that for the 2021 price level, the impact on the average PD is almost 4% in the heat pump scenario, whereas it increases to 5.6% in the case of a further doubling of the gas price (see Figure 3.8). Again, the results are characterized by substantial heterogeneity between different types of homeowners.

Figure 3.8 Increase in Probability of Default, under various (gas) price scenarios
Percentage points

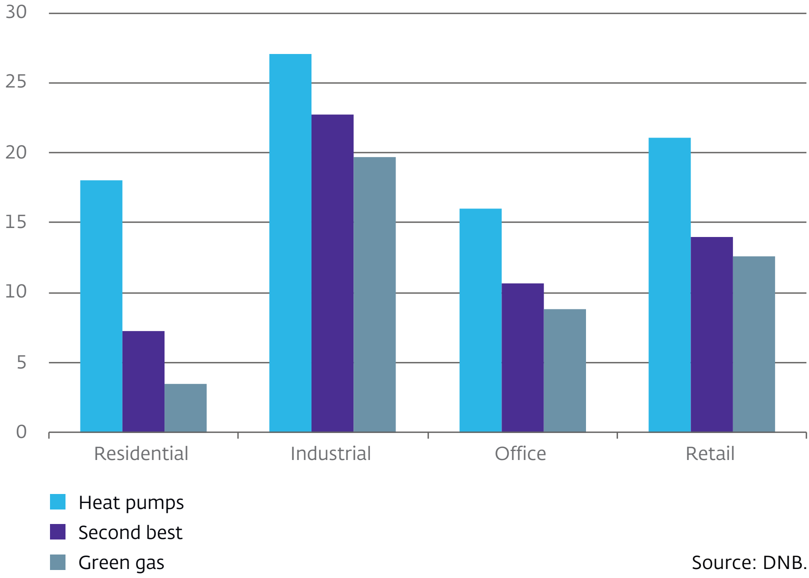


Source: DNB.

High required investments may also increase the credit risk of CRE-loans. Even though real estate companies will typically have more financing options than individual homeowners, this does not necessarily mean that they are willing and able to make the required investments. Owners may choose not to make the building carbon neutral, for example, if the required investment is too large in comparison with the value of the building. To assess this risk, we compute the required investment as a percentage of the current property value for all domestic buildings that serve as collateral for the CRE-loans of Dutch banks. In the high cost scenario, the required investment represents more than 10% of the property value, on average. For almost one fifth of all buildings, the relative investment is above 15%. We observe some differences between real estate types, with the relative investments being highest for industrial real estate (figure 3.9).[17]

Figure 3.9 Required investments for CRE loans

Share of properties with investment amount >15% of protection value



Source: DNB.

17 Transition risk could also have a negative impact on the value of these properties if the demand for these type of buildings typically comes from relatively carbon intensive companies.

46 **Although our analysis is stylized, the main findings seem relatively robust to changes in the underlying assumptions.** The 'heat pumps' scenario assumes that no collective heating systems are implemented, which can be seen as a worst-case scenario. On the other hand, the assumption in the 'second best' scenario that municipalities are able to implement the second best strategy is relatively optimistic. Moreover, even in this scenario individual heatmaps will have to be used in many cases (45% of all buildings, 52% of owner-occupied houses), suggesting that many building owners would face relatively high costs. In addition, whereas the availability of green gas could reduce transition costs substantially, from a risk perspective, counting on 'green gas' is not prudent. Finally, our calculations are relatively optimistic on the willingness of homeowners to use their savings to pay the retrofit costs.

4 The international perspective

This chapter assesses transition risks of international real estate, focusing on the exposures of Dutch pension funds and insurers. First, we assess the exposures at risk by analyzing whether the energy intensity of the buildings is in line with the targets that are implied by the Paris agreement. Next, we gauge the value impact by estimating the excess carbon emissions of properties, for cases where carbon pricing would be more stringent. Lastly, we discuss risk implications for financial institutions.

4.1 Decarbonization pathways

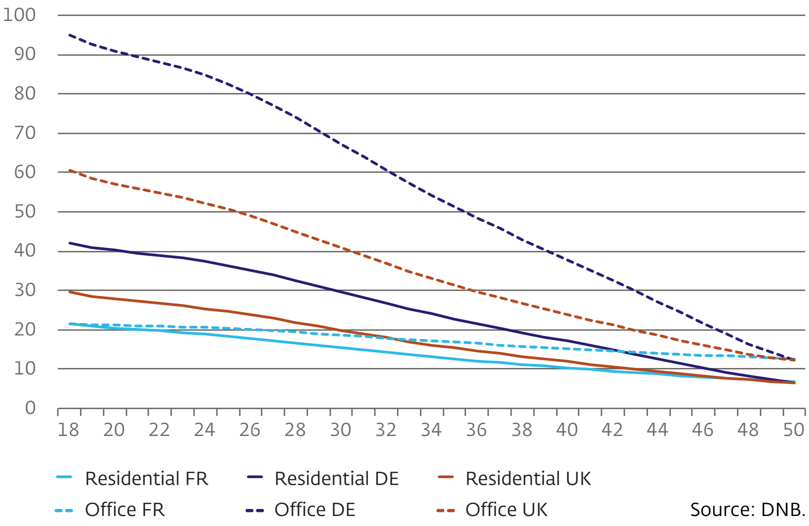
Alignment with 1.5°C or 2°C warming scenarios would require a drastic reduction of emissions related to the global building stock. According to estimates by CRREM (see Appendix C), the carbon-intensity of the building sector will globally have to decline from the current value of around 52 $kgCO_2e/m^2$/year to below 10 $kgCO_2e/m^2$/year by 2050 in order to be in line with the 2°C or a more ambitious 1.5°C global carbon budget. This is the policy goal endorsed by many national governments, which was strengthened at the COP26 conference in Glasgow. Such decarbonization pathways can be regarded as a proxy of how future policy restrictions will need to evolve to ensure compliance with international commitments. For this study, we use such pathways as scenarios against which we can assess transition risks for international exposures of financial institutions.

Decarbonization pathways vary considerably across countries and property types. This variation comes from two factors: current differences in carbon emission intensity depending on energy use intensity and energy mix and the magnitude of policy shifts required to ensure Paris-alignment. Figure 4.1 illustrates some of this variation for a 2°C scenario.[18] The figure shows country/property-type decarbonization

18 For 1.5 °C scenarios, the reduction paths would be more stringent. Figure available upon request.

Figure 4.1 Variation in decarbonization pathways

in $kgCO_2/m^2/year$



Source: DNB.

Note: for 2°C scenario according to CRREM.

pathways for residential properties and offices in three EU countries, namely UK, Germany and France.[19] We focus on these three EU countries, as our dataset indicates large exposures there for Dutch pension funds and insurers. Germany has the largest carbon reduction requirements, followed by the UK. France stands out with a less steep pathway due to its reliance on nuclear power to produce energy. Carbon emission intensity also varies by property type, with office among the most energy intensive sectors and residential among the least intensive sectors.

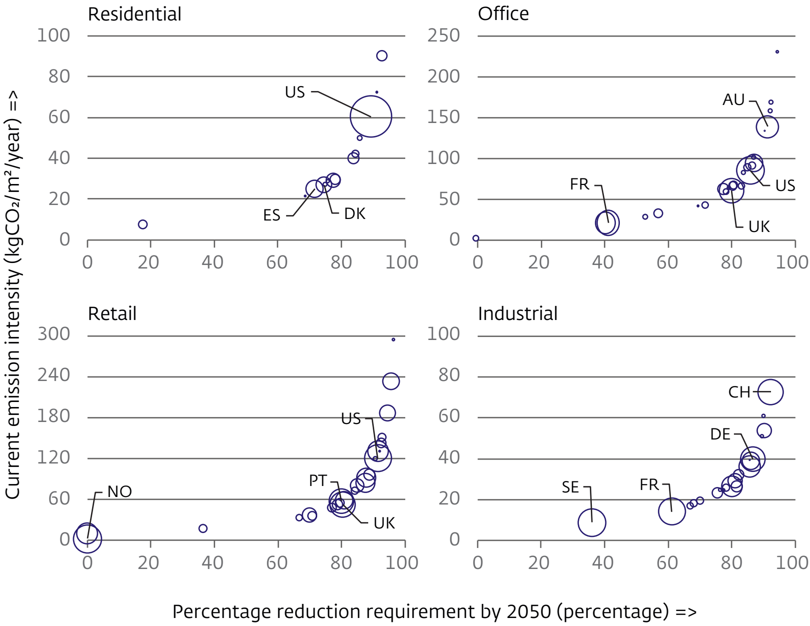
19 The CRREM tool also derives corresponding country/property-type energy use intensity pathways, taking into account the differences in energy mix across countries. Due to data reporting issues on carbon intensity at the building-level, our main analysis in sections 4.2 and 4.3 will focus on energy use intensity

4.2 Exposures at risk

Dutch financial institutions have significant exposures towards countries with more stringent emission reduction targets. We first calculate the emission reduction requirements by 2050 under a 2°C scenario for residential, office, retail and industrial properties, respectively, using the CRREM decarbonization pathways. There is a wide geographical dispersion in current emission intensity (y-axis) and required emission reduction (x-axis) for different types of properties. Figure 4.2 shows this dispersion as well as the distribution of the exposures across countries. Real estate properties located in countries with more stringent reduction targets are subject to transition risks. Exposures to US residential and commercial properties, Australian offices and the European retail and industrial properties are particularly vulnerable. For instance, the top left panel indicates a large exposure to US residential real estate, for which there would be a reduction requirement of more than 80%.

Between now and 2030, 35-45% of international real state exposures will not be Paris-proof without significant retrofitting. Our approach here is to compare the current energy use intensity of a property to the country/property-type specific pathway for 1.5°C or 2°C scenario's, respectively. The current energy use intensity is reported in the specialized data collection for Dutch pension funds and insurers. Due to limited reporting of this information, our analysis covers EUR 12.6bn international real estate in 30 countries, roughly 11% of the total exposure reported. When the intensity is higher than the level implied by the decarbonization pathway, the asset is considered to be at risk. In a 2°C scenario, approximately 35% of the exposures are likely to be at risk in the next decade (Figure 4.3, left bar). Looking further ahead, an

Figure 4.2 Exposure and emission reduction targets



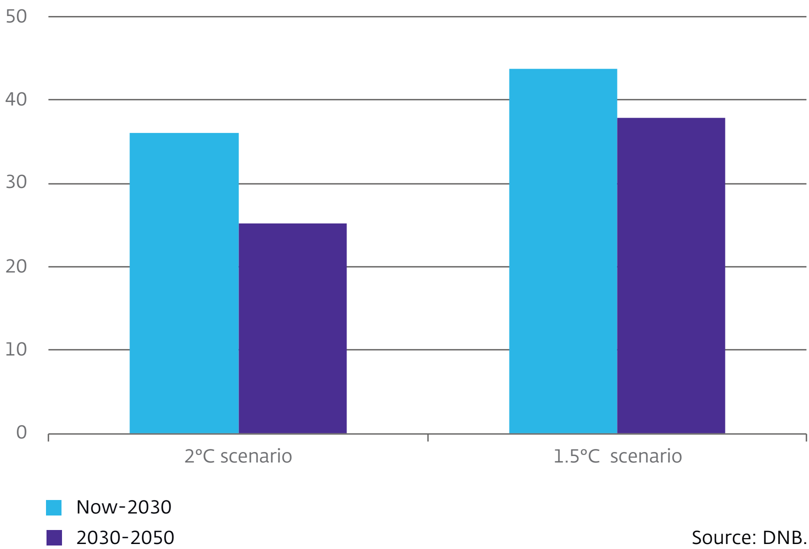
Source: DNB.

Note: For 2°C scenario according to CRREM. The size of the circle represents the size of the exposure.

additional 25% of exposures could become at risk between 2030 and 2050 (Figure 4.3, right bar). The share of exposures 'at risk' is significantly higher in a 1.5°C scenario. Under those, more stringent, pathways, 45% of the exposures will not meet the energy intensity requirements implied by the decarbonization pathways by 2030, whereas an additional 38% will be at risk by 2050.

Figure 4.3 Estimates for exposures at risk

Percentages of international exposures



Source: DNB.

Note: own calculations based on two CRREM decarbonization pathways.

Exposures to relatively energy inefficient buildings are largely concentrated in Europe. Approximately 85% of the exposure 'at risk' between now and 2030 are located in Europe in both scenarios. This concerns mostly commercial properties, such as offices and industrial buildings. We estimate that between 45% and 55% of European commercial properties will have challenges in meeting reduction requirements by 2030 under a 2°C scenario. This share increases to between 55% and 60% under a 1.5°C scenario. Although residential properties represent a large share of foreign real estate exposures of Dutch financial institutions, we have limited information on energy characteristics of these properties, making it difficult to conduct system-wide risk analyses. Furthermore, 52 data availability and quality issues make it difficult to conduct extensive analyses on exposures outside Europe, particularly in the US. With these caveats in mind, our discussion of financial risk implications in the next section provides only a first, illustrative assessment.

4.3 Implications for financial risks

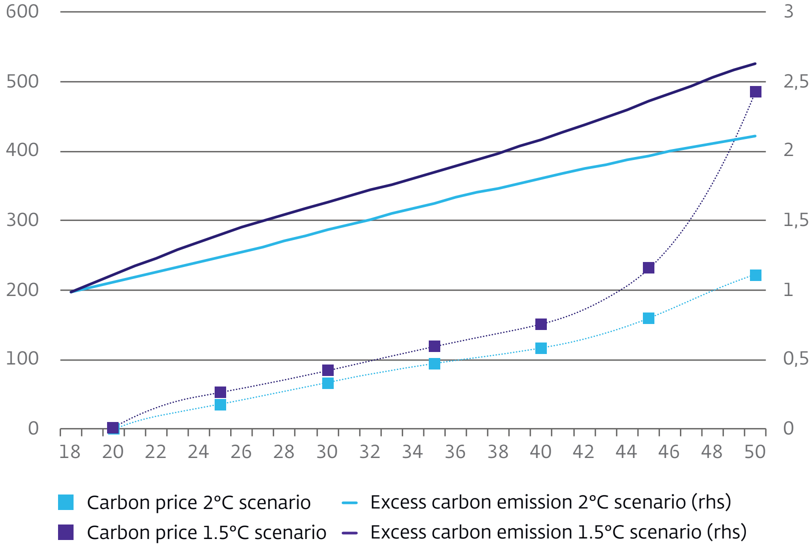
Misalignment with the energy reduction targets could lead to financial risks. Non-compliance is unlikely to trigger real estate assets to become stranded in the short-term, given that the Paris goals are not binding and the legislation is not everywhere in place (yet). However, it seems likely that many countries will further intensify their commitments towards achieving the Paris goals. Given the urgency, it is not unthinkable that governments at some point need to become stricter in enforcing the targets. This could result in a negative impact on the values of properties with high energy intensity. Then, costs need to be incurred in order to meet the increasingly stringent energy efficiency requirements.

To give an indication of possible implications, we quantify transition risks by calculating the value of excess carbon emissions. Making a full-fledged set of calculations is challenging. For instance, there is limited cross-country information on the costs of various approaches to retrofitting. Therefore, this section adopts a simplified approach. Properties that do not meet reduction requirements will emit excess carbon. If the excess emissions are multiplied by a carbon price, this gives an indication of increased costs due the increasingly stringent requirements. While this methodology is subject to assumptions, we take this as a first indication of financial damages. To illustrate this approach, we select the real estate properties in Europe, for which we see a relatively good data coverage and quality. Figure 4.4 panel A shows a steep increase in excess carbon emissions over time.

The increase is considerably steeper under a 1.5°C scenario. Based on the projections made by NGFS, Panel B demonstrates a significant rise in carbon prices to around EUR 250 per ton/CO_2 in 2050 under a below 2°C scenario and further to above EUR 500 per ton/CO_2 under a net zero (i.e. 1.5°C) scenario.[20] Using these paths, we then compute the present value of total excess carbon costs. We find that it is quite sizeable. Our calculations suggest that the present value equals to around 35% of the total assessed property value under a 2°C, and up to 60% under a 1.5°C scenario.[21]

Figure 4.4 Excess carbon emissions and carbon prices

Euro/ton CO_2; million tonnes CO_2



Source: DNB.

20 The calculations are based on projections made by the World Energy Outlook
21 We use a discount rate of 3% per year.

5 Conclusions

This chapter summarizes main findings and implications. Real estate is important when analyzing transition risk. Our analyses of the exposures of Dutch financial institutions underline that there is no room for complacency. Disorderly transition paths would increase the risk that either financing constraints become binding or that property values would be affected. Further investments in availability and quality of data require special attention.

5.1 Summary and future research directions

First and foremost, this study argues that focusing on real estate is important when analyzing climate transition risk from a financial stability perspective. We highlight that real estate plays a key role on the balance sheets of Dutch banks, pension funds, and insurers. Shocks in real estate markets have traditionally been a major source of financial crises. At the same time, the use and construction of real estate is associated with a large share of greenhouse gas emissions. As such, real estate plays an important part in the energy transition. Also, real estate is vulnerable to the consequences of extreme weather conditions, such as floods (Caloia et al. 2021). Overall, real estate is at the nexus between financial stability and climate financial risks.

This study shows how there is no room for complacency. We combine several granular data sources to explore how transition risks in domestic and international real estate exposures could lead to financial vulnerabilities. First, we show that a large part of the real estate exposure is at risk, meaning that the energy transition will have an impact on the value and riskiness of these exposures. A substantial part of this risk could materialize already before 2030. Second, we show that the sizable investments that are needed to retrofit existing buildings affect the value of real estate investments and the credit risk of mortgage loans. Different risk channels play a role: building owners may not be able to finance the investment, or they may only be able to do so by substantially increasing their borrowing. Third, by computing the potential costs of inaction, we show that a substantial part of the value of real estate investments is at stake in the energy transition. Although a complete quantification of the transition risk in real estate exposures is not yet feasible, our results do suggest that the impact is potentially large.

Our study can inform follow-up work on climate risk analytics. At present, the work on climate scenario analysis and stress testing is gaining a lot of traction. To some extent, this is still a 'work in progress'. For instance, there is a need to further examine the extent to which real estate markets have priced in the risks from the physical impact of climate change as well as the transition to a carbon-neutral built environment. Such knowledge would allow for a more precise quantification of the potential impact on the financial sector. Next, we need to better understand how climate change and transition paths can impact the economy, and vice versa. It is important to carry out this analytical work to improve our insights into the relevance and magnitude of the risk channels involved. In addition to highlighting the importance of real estate, this study also shows how an integrated view of both household balance sheets and financial institutions exposures can yield valuable insights. One potential area for follow-up work is to further elaborate on the impact on the credit risk of RRE and CRE loans and integrate this in a full-fledged stress test exercise.

To make further analytical steps, special attention needs to be given to data collection and quality. In a previous DNB study on energy transition risks (Vermeulen et al. 2018), the point was made that "although this study used highly granular data on financial institutions' holdings […], data gaps remain." We can only repeat the same point for our deep dive on real estate exposures. The use of granular information on financial institutions, real estate properties and households has enabled us to make a first attempt to quantify the transition risk in real estate. Yet, there are two important points with respect to data gaps. The first concerns availability. A complete overview of climate-relevant data is not yet readily available. Before focusing on analytical work, much effort is still needed for collecting, checking and combining various data sets. The second point concerns quality. Even when combining all the individual data sets, the overall picture often still remains incomplete, for instance in terms of locations of properties or energy efficiency characteristics. To fully incorporate climate considerations into our risk discussions, clearly additional efforts are needed. This study helps by shedding light on current exposures, and potential vulnerabilities. These insights will help in making future data collections both more efficient and effective.

5.2 Policy implications

Although steps are being taken, financial institutions could further integrate climate risks into their broader risk management frameworks. An increasing number of financial institutions began to devote attention to climate change in their risk management. In some cases climate change has already been embedded, whereas in most cases such effort is still in its infancy (ECB, 2021). A recent DNB study reveals that Dutch financial institutions are often aware of sustainability risks, but have not fully incorporated these risks in their strategies, governance and risk management arrangements. As discussed above, a focal point with respect to real estate, but also in a broader sense, remains the availability of consistent and reliable data for robust analyses. At the same time, the need for improved data should not prevent financial institutions from developing capacity for assessing, monitoring and managing climate-related risks. This occasional study is an example of analytical work on real estate's climate transition risk that can already be conducted based on the currently available data.

Clarity on transition policy can help minimizing transition risks. Assessing and managing transition risk is especially challenging as long as it remains unclear which sustainability requirements will apply to houses, offices and other properties. Clarity on prevailing policy will lead to less uncertainty on financing needs, and it will increase the investment appetite of property owners and investors. The lack of a clear transition path can delay the transition and result in potentially sudden increases in retrofitting costs further into the future. All in all, an orderly and timely transition could achieve the climate goals while minimizing the risks to property owners and financial institutions.

There is a need for just and equitable policies to finance the transition. As our study shows, making all buildings carbon-neutral will require substantial investments. Especially for low income homeowners, financing these investments might be problematic. As a result, they risk being stuck with rising energy bills and lower values on their homes. This could potentially translate into credit risks to financial institutions. A comprehensive policy mix is necessary to stimulate investments, cushion the impact on vulnerable households, and thereby also limit transition risks for financial institutions. In a separate DNB Analyse, we examine in more detail the financing options of different groups of households and the impact of existing policies. We identify the bottlenecks for financing retrofitting and propose targeted policy measures to address them. This will ultimately facilitate a faster transition towards a carbon-neutral built environment.

Even if the results are still uncertain, the systemic nature of climate risks underlines the importance of future work on macroprudential implications. Like the work of other central banks and supervisory authorities, our analyses are still subject to uncertainty. However, this analysis suggests that financial risks related to the energy transition are potentially large. In addition to follow-up analyses it is important to conduct a timely discussion on possible ways to mitigate these systemic risks. At this stage it is important that financial institutions already take account of certain pockets of risk relating to geographic locations or transition paths in their own risk management.

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Appendix A Details on real estate data

This appendix gives details on the various data sources that this study uses.

1. A data collection on real estate investments of pension funds and insurers

Part of the information needed to analyze system-wide transition risks was collected via a customized data collection. To this end, we asked twenty pension funds and six insurers to report relevant characteristics of their real estate exposures (as of end 2020). The scope of the survey included all direct and indirect real estate investments. Institutions were asked to report location and energy consumption characteristics for their investments on both the financial asset and building level.

For the analysis, we linked the data obtained through this data collection to the data from our supervisory reports. By combining these two datasets, we determined for which part of the real estate investments institutions provided granular data on location and energy consumption characteristics. However, only part of the data obtained through the data collection could be linked due to data quality issues.

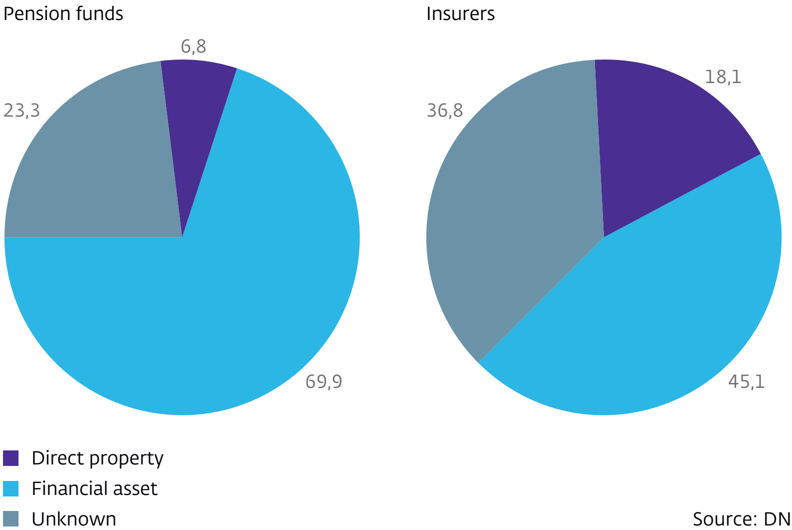
In light of issues with respect to availability and quality, we needed to make various approximations, for instance regarding market values or ZIP codes. By default, the market value from the supervisory reports were used. When these values were missing for certain assets, we used the market value from the survey instead. For buildings with missing ZIP codes, we used reported street addresses and xy-coordinates, which we then linked to the BAG dataset in order to find the ZIP code (on PC4 level).[22]

22 BAG stands for Basisadministratie Gebouwen.

Based on supervisory reports, the total real estate investments of the twenty pension funds and six insurers are EUR 130.4 billion and EUR 21.5 billion, respectively. Through the data collection, the pension funds and insurers provided granular data for 77% (EUR 100.0 billion) and 63% (EUR 13.6 billion) of these investments. Figure A.1 shows how the reported investments are divided among direct property and financial assets with underlying real estate.

Figure A.1 Real estate investments of pension funds and insurers

Percentages

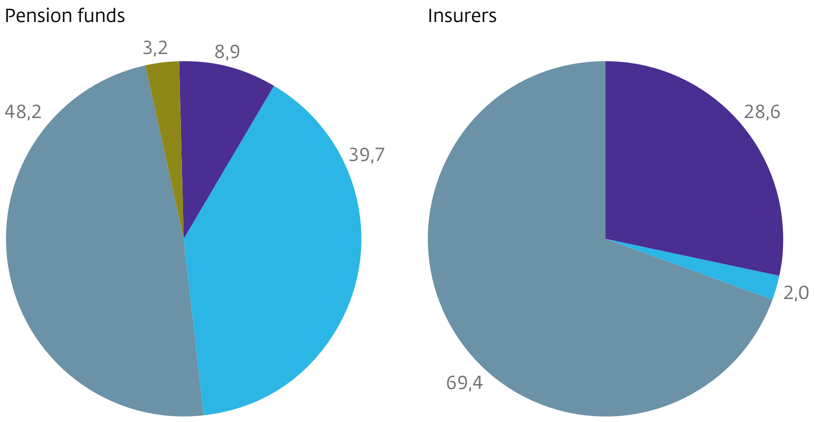


Source: DNB.

Figure A.2 shows the distribution of the investments reported in the data collection across different asset types. The investments of pension funds are mainly in real estate funds (48%) and equity of real estate related corporations (40%). The remaining investments are directly in property (9%)

Figure A.2 Real estate investments of pension funds and insurers by asset type (CIC code)

Percentages



Property (CIC 9x)
Equity of RE related corporation (CIC 32)
Real estate funds (CIC 45)
Real estate risk (CIC 65)

Source: DNB.

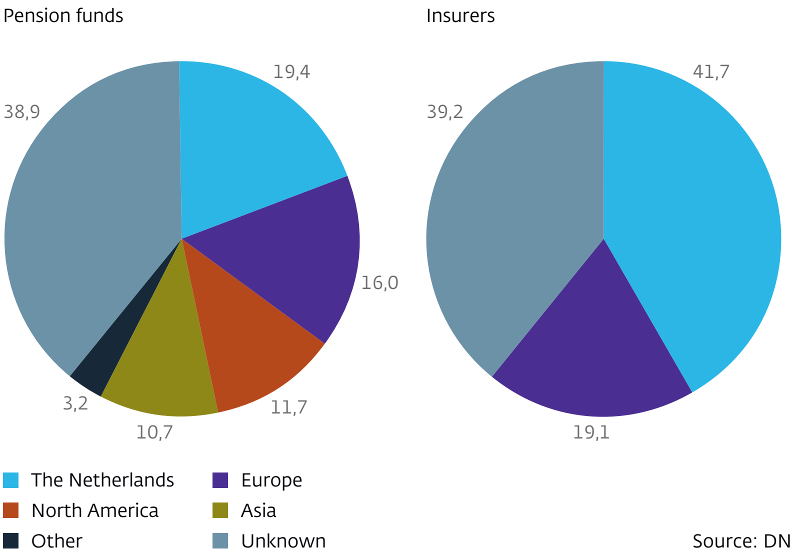
and collateralized securities exposed to real estate risk (3%). Most of the investments for insurers are in real estate funds (69%) as well, followed by property (29%) and equity of real estate related corporations (2%).

Some of the pension funds and insurers have exposures to the same real estate funds. In total, institutions reported 400 unique real estate funds with underlying building information.

When looking at the location, most of the exposures of pension funds are located in the Netherlands (19.4%), followed by other countries in Europe (16.0%), North America (11.7%) and Asia (10.7%). The location data from the insurers are limited to the Netherlands (41.7%) and Europe (19.1%).

Figure A.3 Real estate investments of pension funds and insurers by continent

Percentages



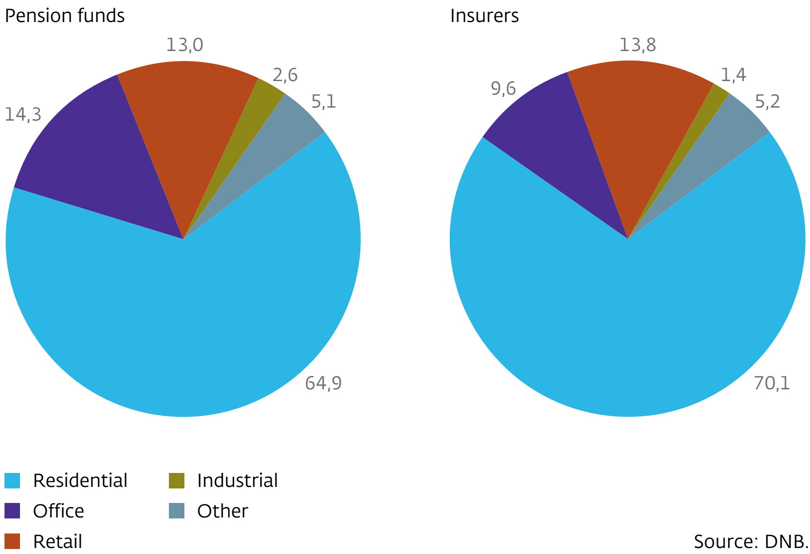
Source: DNB.

Pension funds and insurers reported, respectively, EUR 25.3 billion and EUR 9.0 billion of domestic real estate investments. For both type of institutions, around two third of the domestic exposures are residential, followed by offices and retail.

It looks different for the foreign exposures. Insurers provided only information about investments in Europe, where most of the investments are industrial (53%). The real estate types for foreign investments of pension funds vary a lot across continents. While Europe has most exposures in residential (40%), Asia reported a larger part in the industrial sector (38%). The real estate located in North America are quite evenly distributed over the five different types.

Figure A.4 Domestic real estate investments of pension funds and insurers by real estate type

Percentages



Source: DNB.

2. Microdata on banks' residential and commercial real estate loans

The analysis uses DNB's proprietary data on loans secured by Residential (RRE) and Commercial Real Estate (CRE) loans issued by Dutch banks. The RRE data covers loans secured by owner-occupied houses in the Netherlands originated by the largest ten Dutch banks. It consists of counterparty, contract, instrument and protection characteristics, and covers a total of 71% of the outstanding exposure in the RRE portfolio in the Dutch banking system. The CRE data covers loans secured by income-producing real estate originated by the three main Dutch banks, and contains information for about 59% of the total CRE exposures in the Dutch banking system.

3. Microdata on the residential mortgages of pension funds, insurers and mortgage funds

The analysis includes loan-level data obtained from a regular data collection by DNB among the largest non-bank financial institutions active in the market for residential mortgages. The dataset covers a total of 52 financial institutions (41 pension funds, 6 mortgage funds, 5 insurers) and exposures for a total of EUR 127 billion. The available information covers 25 borrower, property and loan characteristics.

4. Microdata on the population of real estate objects in the Netherlands

The analysis on domestic climate risks uses detailed microdata covering the population of real estate objects in the Netherlands, as well as population data on homeowners. These data are available from Statistics Netherlands. The sources of these data consist of a combination of tax records, cadastral registry information and other sources. These data cover mostly three dimensions:

- Building characteristics. Available information include location, type of real estate object, the construction year, the surface, the type of ownership and use (for rental vs owner-occupied) and the taxable value of the property.
- Energy characteristics. Available information includes the energy performance and energy label, the electricity and gas consumption.
- Homeowner characteristics. Available information includes a full overview of all income and wealth components in households' income statements and balance sheets.

The final dataset covers approximately 7.6 million real estate objects and about 4.3 million owner-occupiers.

5. Microdata on the retrofitting investments

The analysis uses microdata at the building and neighborhood level available from the Dutch Environmental Assessment Agency (PBL). This data contains information on the type of investments required to make buildings carbon neutral and their corresponding amount. The reported investment amounts also cover different residential and non-residential real estate objects. This data is merged with the CBS building level data via the cadastral object and the neighborhood identifiers.

Appendix B Estimating required investments

68 We estimate the retrofitting investments based on the Startanalyse by PBL. The first step is to determine which zero-emission technique (or: 'strategy' in the Startanalyse) will be selected in the three scenarios.

- In the ‘heat pumps’ scenario, all buildings will use individual heat pumps, by assumption. We assume that all buildings will use the heat pump with the lowest investment cost (variant 1A in the Startanalyse). The use of heat pumps requires high energy efficiency of the building shell. Therefore, in line with the Startanalyse, this scenario also implies that the shell of all buildings will be improved to at least shell label B.
- In the ‘green gas’ scenario, each municipality selects the strategy with the lowest total cost, which includes not just the costs for the building owner, but all other costs as well (in the Startanalyse, this is called ‘national costs’). Based on this criterion, 98% of all buildings will be heated by green gas (strategy 4 in the Startanalyse). We assume that investments in energy efficiency will only be made to improve all buildings to the minimum shell label required for the selected strategy. For the green gas strategies, this is label D (except for strategy 4B, which requires label B).
- In the ‘second best’ scenario, we assume that the green gas strategy is not available. Municipalities select from the remaining strategies the strategy with the lowest total national costs. All available strategies require that the shell of buildings is improved to at least shell label B.

In the scenarios ‘green gas’ and ‘second best’, all buildings within a neighborhood use the strategy chosen by the municipality. Neighborhoods and buildings are matched by ‘buurtcode’.

Table B1 gives an overview of the distribution of selected zero-emission heating strategies across all buildings for the ‘green gas’ and ‘second best’ scenarios.

Table B.1 Use of strategies in 'second best' and 'green gas' scenarios

	Second best	Green gass
Strategy 1: individual electric heat pumps		
1A	44%	0%
1B	0%	0%
Strategy 2: heat networks (medium/high temperature)		
2A	0%	0%
2B	0%	0%
2D	22%	2%
2E	14%	0%
Strategy 3: heat networks (low temperature)		
3A	2%	0%
3B	1%	0%
3D	0%	0%
3E	1%	0%
3F	6%	0%
3H	8%	0%
Strategy 4: green gas		
4A	0%	0%
4B	0%	3%
4C	0%	25%
4D	0%	69%
Total	**100%**	**100%**

Once we have determined which strategy will be used, we can compute for each building the building-specific investments that have to be made in each scenario. Again, we use the Startanalyse, which contains detailed estimates of the retrofitting costs. We distinguish three types of costs:

- Insulation costs: for each building, PBL has estimated the costs of improving the energy label of the building shell to label B and D. PBL has calculated the annualized costs assuming full depreciation in 30 years and a 3% discount rate. To determine the investment amount, we convert the annualized insulation costs that are presented in the Startanalyse (K08) back to the initial investment amounts.
- Installation costs: these are the costs for building-specific installations (K09). As the costs may relate to different technologies and installations, PBL uses different depreciation periods (from 15 to 28 years) when converting the initial investments to annual costs. In computing the initial investments, we assume full depreciation in 15 years (and again a 3% discount factor).
- Connection fees: when a heat network is selected, building owners will have to pay a fixed amount to connect to the system. We assume a connection fee of EUR 4098 per address, which is equal to the maximum fee as set by the ACM for 2022.[23]

The required investment per building in each scenario is the sum of the three investment components. We also add VAT, as this will typically have to be paid by the building owner. We assume an average VAT rate of 15% for insulation costs and of 21% for all other costs. We use the cost levels for 2030 from the Startanalyse, which assumes a cost reduction of between 23% and 6%, depending on the measure, compared to 2018 prices.

23 Note that connection fees are not taken into account in the Startanalyse, as they are not part of national costs.

Next, we compare the required investment amounts with the financial position of Dutch homeowners. For this, we use population data on income and wealth available from tax records to determine which homeowners would need credit to finance the sustainability investments and the share of homeowners that would be credit constrained. This is based on the following two assumptions:

- Homeowners prefer using own funds over taking additional credit.
- Homeowners hold precautionary liquidity, which we set as EUR 5,000 in liquid assets (cash, savings and other liquid assets).

As a result of the first assumption, homeowners take credit only if their liquid assets are not sufficient to cover the entire investment amount. As a result of the second assumption, homeowners use own funds only when, and to the extent that, these are above EUR 5,000.

On the basis of these two assumptions, we compute the total credit needed by each homeowner. Then, we compute the share of credit constrained homeowners as the share of homeowners for which the additional borrowing would lead to either a Loan to Value (LTV) or Loan to Income (LTI) above the maximum allowed levels. For the LTI limit, we use the Nibud DSTI limits in combination with the observed value of income as available from tax records.

Appendix C Details on the CRREM approach

This appendix presents details of the approach we use in Chapter 4 to assess transition risks of international real estate exposures of Dutch pension funds and insurers.

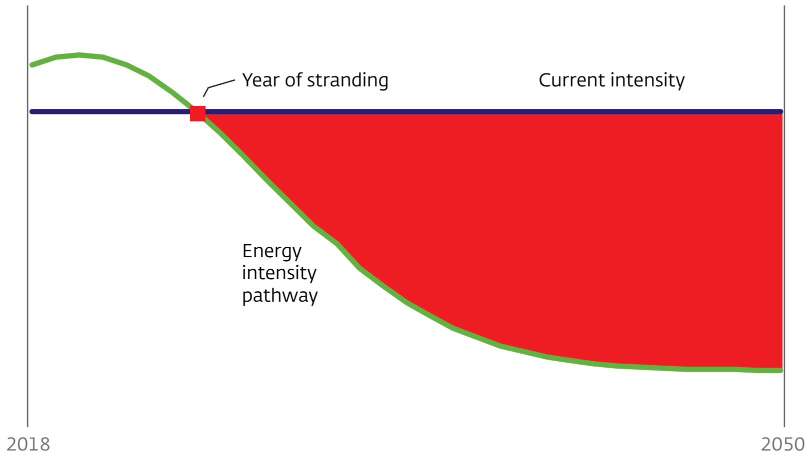
The Carbon Risk Real Estate Monitor (CRREM), funded by the EU and several large institutional investors provides a unique science-based methodology to quantify transition risks across various types of properties in the global real estate market.

The CRREM allocates the global carbon budget associated with each warming scenario across economic sectors, countries, and property types until 2050 using a “multi-step downscaling” approach based on a fair share principle. This process yields country/property-type specific decarbonization targets (expressed in kgCO_2e/m^2/year) and energy use intensity pathways (expressed in kwh/m^2/year) to comply with the Paris climate targets of limiting global warming to 1.5°C or 2°C. In our analysis, we rely on energy use intensity instead of GHG intensity as the latter is less available and is of less quality.

Our analysis covers EUR 12.6 bln exposures towards four major types of properties, namely residential, office, retail (shopping centers) and industrial properties in 30 countries. These four types of properties constitute 90% of the total exposure. We first estimate when the buildings are likely to exceed their energy intensity target without retrofitting, see Figure C.1. For the simplicity of our analysis, we assume a constant energy use intensity and no significant retrofitting. Furthermore, we convert the projected excess energy intensity into excess carbon emissions based on country-specific conversion factors for European countries from the European Environment Agency and for other countries from their respective national counterparties. Using the projected carbon prices calculated by the NGFS, we compute the present value of future excess emissions, which gives us a first indication of potential financial damages.

Figure C.1 Determining stranding risk

Energy intensity (kwh/m²/year)



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