EUROPEAN CENTRAL BANK

EUROSYSTEM

Occasional Paper Series

Investing in Europe's green future

Green investment needs, outlook and obstacles to funding the gap

Carolin Nerlich, Petra Köhler-Ulbrich, Malin Andersson, Carlo Pasqua, Laurent Abraham, Krzysztof Bańkowski, Tina Emambakhsh, Annalisa Ferrando, Charlotte Grynberg, Johannes Groß, Lucia Hoendervangers, Vasileios Kostakis, Daphne Momferatou, Matthias Rau-Goehring, Erzsebet-Judit Rariga, Desislava Rusinova, Ralph Setzer, Martina Spaggiari, Fabio Tamburrini, Josep Maria Vendrell Simon, Francesca Vinci

No 367

Contents

Abstract

The green transition of the EU economy will require substantial investment to 2030 and beyond. Estimates of green investment needs vary between institutions and are surrounded by high uncertainty, but they all point to a requirement for faster and more ambitious action. Green investment will need to be financed primarily by the private sector. While banks are expected to make a key contribution to funding the green transition, capital markets need to deepen further, especially to support innovation financing. Progress on the capital markets union would support the green transition. Public funds will be vital to complement and de-risk private green investment. Structural reforms and enhanced business conditions should be tailored to encourage firms, households and investors to step up their green investment activities.

JEL Codes: E22; E44; G21; Q41; Q50; Q58

Keywords: green transition; investment; financing; fiscal policy; structural policy

Executive summary

Pursuing a successful green transition requires substantial investments across the entire EU economy, including in renewable energy, grid infrastructure, sustainable mobility and energy efficiency. Despite recent progress, much more effort is needed to keep decarbonisation on track to achieve carbon neutrality by 2050. This paper sheds light on the green investment needs in Europe until 2030 by analysing various available estimates. It provides evidence of how these investment needs have been financed so far, how the funding landscape is expected to evolve and whether public funding sources will be adequate. The paper also discusses various policy options to support the green transition, particularly through enhanced green innovation, reduced regulatory burdens, reskilling and tailor-made financing instruments. The main contribution of this paper is to integrate these economic, financial and structural elements, offering a comprehensive view of the complex issue of green investment. The key findings can be summarised as follows.

To effectively achieve the green transition, Europe faces the challenge of mobilising substantial additional investments, estimated as ranging from 2.7% to 3.7% of EU GDP each year until 2030 (measured at constant 2023 prices). However, quantifying green investment needs is a daunting exercise, subject to high levels of uncertainty. Depending on the assumptions and methodologies used, various studies provide estimates for additional green investment needs within this range. If all additional investment were productive, and in net terms, this would imply a considerable increase in the total investment-to-GDP ratio. In recent years, estimates of green investment needs have been rising steadily, largely reflecting more ambitious decarbonisation targets for 2030 and underscoring the urgency and scale of investment required to effectively address climate change and the transition to a sustainable energy future. Understanding the scope of the various estimates and their underlying assumptions is crucial, as the amounts of green investment required are expected to affect the economy and the financial sector to varying degrees.

Investment needs vary across sectors, with investment in clean energy supply being the backbone of Europe's green transition. Europe needs to almost double its renewable energy capacity and further develop its clean technology innovations to ensure energy security. Sizeable investments are also needed on the energy demand side, so that less carbon-intensive energy sources can be used more efficiently, notably in the transport sector, in industry and for residential buildings. Not all sectors are accelerating their green investment activities at the same rate. At the individual firm level, the ECB's Survey on the Access to Finance of Enterprises (SAFE) shows that green investment activities have been relatively limited, particularly in the energy and transport sectors, mainly due to technical barriers and the need to align with public infrastructure investment. By contrast, the manufacturing sector has been more active in green investment than other sectors.

Firms' investment plans suggest that large, high-emitting firms in particular are gradually catching up in their green investment activity.

Despite recent progress, Europe's green investment activities have fallen short of the level required to meet the 2030 climate target. Recent evidence points to a considerable shortfall in the EU average compared with the estimated additional investment needs each year to 2030. This will not only mean higher annual green investment needs in the years to 2030, to compensate for the shortfall, but also implies higher green transition costs, as the climate crisis will worsen without sufficient action being taken, thereby increasing the need for adaptation. Green investment shortfalls are most evident in sectors such as the transport sector, where greenhouse gas (GHG) emissions have increased notably in recent years.

Supporting the green transition requires substantial funding, primarily from the private sector. In a bank-based financial system such as the euro area, banks play a crucial role in ensuring access to finance for the green transition, particularly the funding of firms investing in more established green technologies. The financed emissions in banks' loan portfolios mainly stem from carbon-intensive sectors such as manufacturing, energy and transport. While the exposure of euro area banks to climate risks has remained high and is concentrated within relatively few financial institutions, banks will continue to make a vital contribution to the funding of firms in high-emitting sectors to facilitate their green transition. Moreover, a range of financial instruments, including green bonds, are necessary to support the green transition. The private equity markets in particular are crucial in funding innovative start-ups and backing green technology projects as they climb the production ladder. However, markets for funding innovation continue to make up a small proportion of financial markets in Europe, despite robust growth in recent years. Faster progress with the deepening of the capital markets union (CMU) would help speed up the development of these markets, thus supporting the green transition.

Climate-related risks matter in bank loan approval and pricing decisions. Risks related to climate transition and climate-related physical risks are relevant factors in banks' decisions on loan approvals and lending conditions. While low-emitting firms, and firms that have made considerable progress in their green transitions, tend to receive climate discounts in their bank lending conditions, according to the euro area bank lending survey (BLS), credit standards for high-emitting firms are tighter and they are typically charged higher lending rates. Banks expect the impact of climate-related risks to increase over time, partly due to stricter supervisory and disclosure requirements. Climate-related risks also affect demand for loans, fuelling demand for bank loans from firms that are in transition or have low emissions, especially for the purpose of green investment.

Major funding obstacles are hindering the green transition. The SAFE results confirm that loans benefiting from fiscal support measures, as well as access to equity funding, are having a positive impact on firms investing in the green transition. However, firms have identified several obstacles that hamper their access to finance for green investment, such as high funding costs and insufficient fiscal support measures. These obstacles are particularly relevant for the investments related to the green transition as they tend to be highly capital-intensive and innovation-based.

Moreover, ECB research finds that a tightening of lending conditions is hitting high-emitting firms harder than other firms, as banks charge a premium for the higher climate-related risk.

As well as the total amount of funding needed, funding sources are also important in accounting for the different phases of firms in the innovation cycle. Deepening the CMU may help to fill this gap, by increasing firms' access to different types of financing. Elements that could be particularly beneficial for the green transition include the creation of well-designed savings products to channel European savings towards longer-term, higher-return investments, the development of venture capital markets, which would help to improve access to risk capital for EU firms, and the use of securitisation to transfer risk across the financial sector.

The public sector plays an important role in supporting and complementing green private funding. Survey evidence from the BLS shows that fiscal support measures, such as tax credits and guarantees, improve the chances of loan approval, mitigate the financing costs for firms managing the green transition and support loan demand. However, the beneficial impact on credit supply and demand seems to be substantially lower in 2024 than expected by banks a year ago, as several fiscal support measures have been wound down, also in view of the bounds of the available fiscal space.

The evidence points to a public funding gap in green investment needs to 2030. Sizeable public funds are available at the EU level supporting the green transition, with the largest contributions coming from the Recovery and Resilience Facility (RRF) of NextGenerationEU (NGEU) and the EU budget. To date, there has been a considerable backlog in the absorption of the RRF funds compared with the plans previously submitted. By contrast, the disbursement of green funding related to the EU budget is progressing well. When comparing the investment needs with the available public funds at the EU level, it appears that the funds are sufficient to finance green investment needs during the remaining years of the RRF, i.e. 2025-26. However, a noticeable shortfall of EU public funds may materialise after the RRF expires at the end of 2026, which increases to around €54 billion by 2030. To help close the public funding gap, proposals for an EU fiscal capacity for climate have been put forward to deliver on large cross-border projects that represent European public goods. However, the financing side is a crucial factor in determining the potential scope and viability of such an instrument. Furthermore, the reformed EU fiscal governance framework is designed in such a way that it may encourage further green investment by national governments.

Well-designed green public investment can be expected to act as a catalyst through the crowding-in of green private investment. Macroeconomic simulations suggest that green public investment could yield benefits for the economy in terms of higher nominal output. If the public support schemes are well-designed, with limited risks of unjustified political interference and unsustainable fiscal liabilities, this could create positive feedback loops for public finances. This is even more likely if supported by an overall improvement in the quality of public spending, including cuts to fossil fuel subsidies. However, if productivity grows more slowly than anticipated and green public investment leads to inflation, prompting the

central bank to respond in accordance with its primary mandate of price stability, this might result in a higher debt-to-GDP ratio in the short run. This analysis does not include other factors that could adversely affect the debt-to-GDP ratio, including the long-term costs of climate inaction. Therefore, while green public investment poses certain risks, a lack of sufficient (public) green investment might pose even greater ones, such as tipping points in climate change and long-term economic instability.

Structural reforms and enhanced business conditions are needed to set the right market-based incentives to accelerate the green transition and avoid investment shortfalls. Europe's massive investment needs have to be supported by measures that encourage stronger engagement on the part of the private sector. Structural policies therefore play an important role in fostering green investment and innovation in green technologies. This ranges from improving the availability of skilled staff to a simplified regulatory framework, which would increase the attractiveness of the EU for investors and support the upscaling of green innovations and patenting. This needs to be flanked by fiscal policies setting the right incentives, notably through carbon pricing.

Looking beyond 2030, available estimates point to even higher investment needs in the following two decades to reach the net zero target by 2050. Although these estimates are associated with even greater uncertainty than those presented here, they underscore the need to further accelerate Europe's green investment activities in the long term.

1 Introduction

The green transition is critical for Europe, necessitating substantial investments across various sectors to effectively combat climate change and achieve decarbonisation goals.[1] Although progress has been made in recent years, much greater efforts are needed to get on track for the 2030 decarbonisation target. In this context, understanding the range of estimates is important, as the large amount of green investment required is expected to affect the economy and the financial sector. At the same time, the window for action is closing fast, as climate-related disasters increase in frequency and severity, including in Europe. Postponing the required investment would only result in further increases in transition and adaptation costs.

The green transition is capital-intensive. Funding green investment needs is challenging and has to be sourced from the private sector, with support from the public sector. While banks will continue to play a key role in funding the transition, capital markets have to develop further in order to also support green and sustainable finance, particularly for innovative small and medium-sized enterprises and green start-ups. Reaping the full benefits of more integrated capital markets in Europe is a promising avenue, in view of the extensive green investment needs.

Enhanced policy reforms are key for a smooth green transition. It is important that firms, households and investors have the right incentives to accelerate their green investment activities. Along with comprehensive carbon pricing, policies should aim to remove structural rigidities, improve regulatory and administrative efficiency, foster green innovation and patenting and leverage fiscal support for spillover to the private sector. The green transition may be a factor in more volatile energy supply and energy prices. It will be an element of uncertainty on the transition path in the next few years, while in the longer term it is expected to contribute to more rapid and stable potential growth, compared with a scenario of no, or only delayed, policy action.

This paper discusses a broad range of topics related to green investment. Chapter 2 presents an overview of the most important estimates of green investment needs to 2030, looking at the EU aggregate, sector-specific needs and country-specific challenges. This is complemented with a box on global estimates. Chapter 3 examines the funding landscape of green investment, highlighting the significant role of banks and bank lending conditions, as well as the limited but growing importance of other market segments. This chapter is complemented by a discussion on how firms in the euro area perceive the funding situation for green investment. Chapter 4 provides an overview of the EU public funds available to support the transition and presents some stylised results of a green public funding gap to 2030. Simulations of the macroeconomic impact of green public investment are presented in a box. Chapter 5 discusses a number of policy options to address obstacles to the green

[1] The topic of “green investment and its financing” was for this reason identified as one of the main focus areas in the ECB Climate and nature plan 2024-2025, published in January 2024.

transition and incentivise green investment and its funding, looking at structural, fiscal, financial and regulatory policies at both the national and EU levels. Chapter 6 contains conclusions.

2 Investing towards net zero

Europe has to make substantial investments in green technology and energy efficiency to set decarbonisation and the transformation of the EU economy on track with the net-zero target. The Green Deal aims to transition to climate neutrality by 2050, with a reduction in the EU's net GHG emissions of at least 55% by 2030, compared with 1990 levels.[2] Moreover, as also highlighted by the Draghi report (2024), the green transition is critical for Europe's long-term competitiveness, as it could give the EU a leadership position in emerging clean technologies, while reducing reliance on external energy sources. By decarbonising key industries and innovating in green sectors, Europe can drive sustainable growth, reduce costs and maintain a competitive edge in the global economy. To deliver on the decarbonisation target, the EU has adopted a set of policy measures, including the "Fit-for-55" package, to enable the transformation of the EU's economy. A key element of Fit-for-55 is the reform of the EU emissions trading system (ETS), notably to broaden its coverage and strengthen the price signals for decarbonisation efforts.[3] An additional ETS (ETS II) is to be set up, covering transport and building heating, which will be fully operational in 2027. The package also includes more ambitious national emission reduction targets for the sectors not covered by the ETS, such as agriculture, and strengthens standards to boost sustainable mobility in the transport system, increase the share of renewable energy and improve energy efficiency.

The substantial size of the required green investment is expected to affect the economy and the financial sector: estimates of these needs therefore have to be clearly understood. What is needed in terms of investment largely depends on the current carbon intensity level and the implemented policy environment, such as the underlying carbon price and the regulatory framework. Structural features, including behavioural aspects, related to the green transformation are also important. Quantifications of investment needs are associated with a high degree of uncertainty and usually rely on several simplifying assumptions. Against this background, it is not surprising that the available estimates of green investment needs vary widely across institutions in terms of volume, composition and time scale.

This chapter takes stock of various estimates of green investment needs in the EU to 2030 and aims to shed light on what drives these differences, also in an international context. The purpose is to understand the different conceptual frameworks, sectoral breakdowns and country estimates, as well as the scenarios underlying these estimates. The studies available for the EU comprise estimates of additional green investment needs ranging from roughly 2.7% to 3.7% of EU GDP per year until 2030 (measured at 2023 prices). The investment needs vary across sectors, with investment in clean energy supply being the backbone of Europe's green transition. Recent evidence points to considerable shortfalls, as actual

2 See European Commission (2021a).

3 The ETS is a cornerstone of the EU's climate policy. It is based on a "cap and trade" principle, with allowances being traded at on average €65 per tCO2 in 2024. Set up in 2005, the framework has been gradually strengthened over time. In its current version, it covers emissions from electricity and heat generation, manufacturing, aviation and (since 2024) maritime transport.

investment is falling significantly short of the required levels. This is particularly true in the transport sector, in which GHG emissions have even increased.

2.1 Approaches for defining investment needs

Green investment needs can be expressed either as additional needs on top of past investment or as their sum. i.e. total investment. Estimates of additional green investment needs are compared with the envelope previously invested, while total green investment needs are the sum of past green investment and what is needed as additional investment within a certain period (**Chart 1**). These concepts are defined in line with a certain target, which in this paper is the 2030 Green Deal decarbonisation target.

The estimates are usually presented for a set of different scenarios to account for the uncertainty surrounding policy action. Scenarios typically range from business-as-usual or announced policy pledges by governments to those meeting a specific policy target, such as carbon neutrality by 2050. Scenarios may also explicitly assume technological advances.

In this paper we concentrate on investment estimates to achieve the EU's 2030 carbon emissions reduction target.[4] Most published estimates are presented as annual averages, lacking details on the expected time profile, both intra-year and in the years to 2030. It is important to note that the concept of green investment discussed here is broader than that used under gross fixed capital formation in national accounts, as it also includes spending on low carbon-emitting durable consumption goods such as electric vehicles. However, other cost factors, such as operating expenditures or the indirect costs of upskilling labour supply, are not captured in these estimates. Also, it is assumed that the estimates are not driven by macroeconomic trends.

One important indicator in assessing whether the investment agenda is on track is the green investment gap. The gap indicator is determined by the difference between the average annual target level – for example, the annual investment needed to reach the 2030 target or a country's pledged investment ambitions – and the actual green investment undertaken in a certain year. The green investment gap can help to detect any shortfalls early on and can be used for regular monitoring of the progress made with respect to green investment, although it usually assumes a constant annual investment target. By contrast, the concept of an investment funding gap compares investment needs with available funding. Measures to close the funding gap are discussed in Chapter 5.

To evaluate the macroeconomic and financial impact of green investment needs, it is essential to understand their net effect on total investment, domestic demand and funding requirements. A key question in determining the

[4] In 2024, the European Commission published the green investment needs to reach carbon emissions reduction targets in 2040, assuming different levels of ambition. For example, to reduce carbon emissions by 90% by 2040 compared with 1990 levels would require additional green investment needs of around €800 billion per year between 2031 and 2040 (compared with 2011-20 levels).

net effect on the economy is whether the additional green investment will mainly replace fossil fuel investment or will be done at the expense of other consumption. One example would be installing a heat pump rather than buying a gas boiler. In this case, the net effect on domestic demand would mainly be determined by the different expenses involved in terms of equipment and manpower. By contrast, new additional green investment (i.e. the green investment comes on top of past investment, for example the expansion of the grid infrastructure in the European Union) is expected to boost the total volume of investment and economic activity and would require additional funding. Positive spillover effects are mainly expected from productive investment. Notably, investment in green innovation could turn the decarbonisation process into an opportunity – as also pointed out in the Draghi report (2024) – with positive implications for productivity, competitiveness and potential growth. By contrast, investment in, for example, the retrofitting of residential buildings would not be regarded as productive investment. Although beyond the scope of this paper, it is important to also consider the different depreciation rates of green versus fossil fuel investment projects – for example, the life cycle of a solar power plant is potentially shorter than that of a coal power plant – and to assess the risk of stranded assets for capital stock. In this context, whether green investment should mainly be seen as a demand or a supply shock to the economy depends on many factors, including the type of investment and the time horizon. An in-depth assessment of the impact of green investment on the economy is, however, beyond the scope of this paper. Stylised effects on the macroeconomic impact of green public investment are shown in Box 2.

2.2 Taking stock of EU investment need estimates

Europe will have to invest sizeable amounts until 2030, estimated at up to €1.2 trillion per year, to support the green transition in line with its 55% GHG reduction target. Analysis by the European Commission shows that on average, €764 billion per year was invested in the EU in the decade to 2020 in reducing GHG emissions (Chart 1, panel a). This corresponds to 5.1% of 2023 EU GDP and around 24% of 2023 EU total real investment. To reach the 2030 target, the European Commission estimates that additional green investment of €477 billion per year (3.2% of 2023 GDP) is needed.[5] Simply adding the additional investment to historical averages would increase total green investment needs to €1.2 trillion per year (8.3% of 2023 GDP). Most of the additional investment will be required to green the transport sector and boost energy efficiency in the residential building sector (Chart 1, panel a). The task is undeniably daunting.

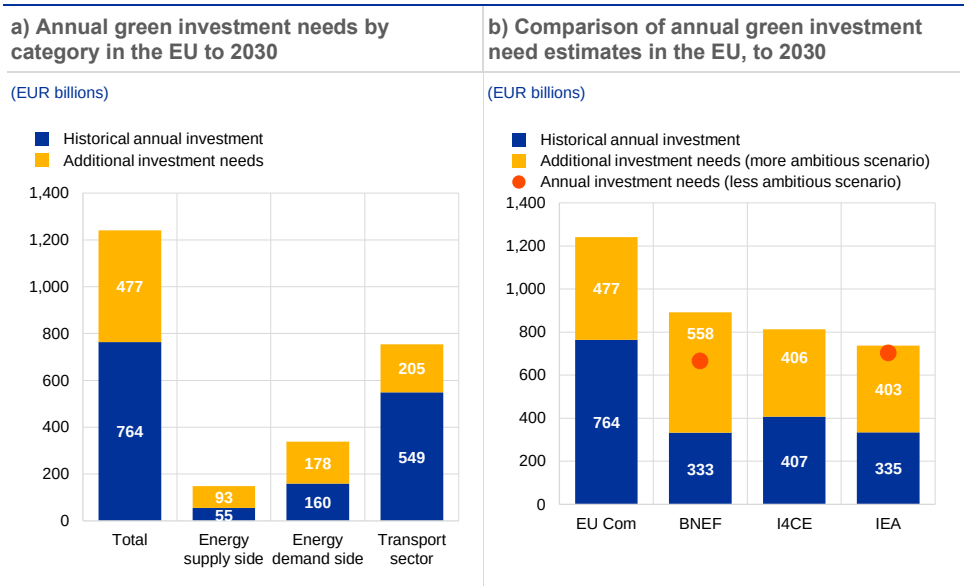
The studies quantifying green investment needs comprise a range of estimates. Quantification is associated with a high degree of uncertainty, and estimates are determined according to the underlying assumptions. Compared with

[5] The investments required to cater for RePowerEU, the Net-Zero Industry Act and the environmental targets would further add to this figure, amounting to €620 billion per annum, as presented in European Commission (2023b). Moreover, funding pressure will increase further if disaster relief and adaptation investment are also considered. The climate-related investment need estimates presented in Draghi (2024) are broadly comparable.

the European Commission estimates for the period to 2030, the estimates of other institutions point to a smaller overall envelope for total green investment, ranging from €738 billion from the International Energy Agency (IEA) to €891 billion from Bloomberg NEF (BNEF) (Chart 1, panel b). Looking at additional green investment needs to 2030, the IEA estimate of €403 billion and the Institute for Climate Economics (I4CE) estimate of €406 billion are broadly comparable with those of the European Commission, while BNEF points to much higher additional green investment needs to 2030 of €558 billion. These estimates are based on the most ambitious scenarios in terms of the decarbonisation pathway. In Chart 1, panel b), the red dots indicate the investment needs assuming less ambitious scenarios.[6] In an international comparison, the investment gaps in countries outside the EU are even larger compared with the actual investment (Box 1).

Chart 1

Green investment need estimates in the EU



Sources: European Commission (2023a), IEA (2024), BNEF (2024), Institute for Climate Economics (2024) and ECB calculations.
Notes: The additional annual investment estimates reflect the needs to 2030, in addition to past investment, to achieve the Green Deal targets for 2030. Total green investment needs are the sum of the historical and additional investments in the EU. Panel a) shows the green investment needs estimates of the European Commission. Historical investments refer to the period 2011-20. Panel b) shows the annual estimates of green investment needs of various institutions to 2030. Historical investment refers to annual averages: European Commission (2011-20), BNEF (2023), I4CE (2022) and IEA (2021-23). The IEA and BNEF estimates are adjusted for fossil fuel investments. For Bloomberg, the historical investment figure pertains to the EU-27 countries, whereas the estimates for additional investment needs include the EU-27 as well as Norway and Switzerland, as no EU average was available. The BNEF and IEA estimates in the more ambitious Net Zero Scenario are compared with the less ambitious scenario: the Economic Transition Scenario for BNEF and the Announced Pledged Scenario for the IEA. See also footnote 6.

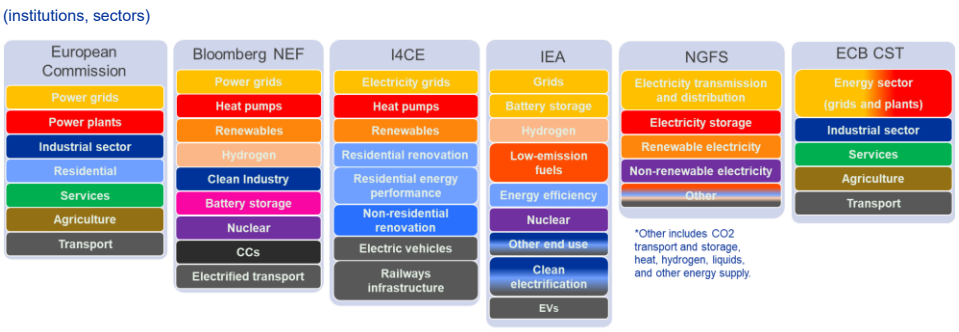
Several factors may explain the sometimes sizeable differences across estimates. First, the historical benchmarks of the green investment estimates vary significantly between studies. For instance, there is no common methodology for the reference period used as the benchmark. The European Commission based its

6 The BNEF estimate refers to its "net zero scenario" (NZS), which assumes that governments will double down on emissions-reducing technologies in order to reach net zero by 2050. This scenario comprises energy technologies, including rapid deployments of clean power generation electrification, an increased use of hydrogen and carbon capture and storage. BNEF's "economic transition scenario" (ETS) is, in turn, less ambitious and relies solely on mature technologies (see Bloomberg, 2024). The different investment need estimates of these two scenarios can be seen in Chart 1, panel b). For the IEA, the less ambitious scenario is the "announced pledged scenario", which describes countries' announced targets to reach net zero by 2050.

analysis on the 2011-20 period average, whereas other studies referred to more recent years. For example, the IEA estimates are benchmarked against the 2021-23 period average, while BNEF used 2023 and I4CE used 2022 as their respective reference years. The reference period, in turn, has an effect on the costs involved. Many of the green technology solutions that are now more established, such as electric vehicles and solar panels, were still in their infancy in the last decade and were initially characterised by very high production costs. These costs have fallen considerably as the technologies have matured[7], which may partly explain why the historical green investment estimates of the European Commission are much higher than those of the other studies. Different production cost assumptions are also significant and may be one reason for the substantial differences between the two BNEF scenarios. Second, the estimates differ according to whether the full costs of a green investment are taken into account, or only the difference compared with an investment when the old technology is used. For example, for electric vehicles, the estimates of the European Commission and I4CE include the full costs of electric vehicles, while the IEA only considers their battery costs. Third, the institutions' estimates of investment needs cover different sectors and sub-sectors (Figure 1). For example, BNEF and the IEA include investments in hydrogen and nuclear in the "energy supply" category, as well as carbon capture and storage technologies, while these elements are not included in the estimates of the European Commission or I4CE. Fourth, the components considered in each sector also play a role. For example, the components of the "transport" category, the sector with by far the largest investment needs, differ across studies, as explained in more detail in Section 2.3. Fifth, the methodological approaches used vary across studies. The European Commission used a suite of different models and approaches, while the I4CE estimates rely on a bottom-up approach.[8]

Figure 1

Sectors included in the estimates of green investment needs: comparison across institutions



Sources: ECB authors, based on information from the European Commission, I4CE, BNEF, the IEA, the Network for Greening the Financial System (NGFS) and the ECB. For the European Commission, services and agriculture are included in the tertiary sector for the 2030 targets.

7 At the same time, however, the volume of green investment increased in the past decade, albeit from a low starting point.

8 Institute for Climate Economics (2024) take a bottom-up approach, aggregating gross public and private climate investment needs across 22 sectors (excluding agriculture, industry and climate change adaptation) in real terms.

Estimates of green investment needs have been rising steadily in recent years, partly to meet the increasingly ambitious decarbonisation targets by 2030 in view of an accelerating climate crisis (Chart 2). In 2019, the European Commission presented the European Green Deal, estimating that achieving the 2030 targets would require €260 billion per year of green investment in addition to the amounts already invested.[9] In 2020, the estimates were substantially revised upwards due to the more ambitious climate targets set to tackle the accelerating climate crisis, assuming that each year in the period 2021-30 the European Union would have to invest €350 billion more than in the period 2011-20.[10] In 2021, the additional annual investment required was revised slightly to €392 billion to 2030, and this estimate was kept unchanged in 2022.[11] In 2023, the estimated required investment leapt to €477 billion per year to 2030, due to methodological changes and a revised deflator.[12]

Despite the progress that green investment has been making over time, recent evidence points to considerable shortfalls, as actual investment is falling significantly short of the required levels. Investment shortfalls indicate a delayed transition and underscore the need for accelerated action. The lower the investment in mitigation, the higher the need for investment in adaptation later on.[13] Access to finance and climate policy uncertainty are possible reasons for shortfalls in green investment.[14] While comparable data are scarce, insights can be derived from the regularly updated investment estimates of the IEA on clean energy investments. According to the IEA, investment in clean energy increased substantially from €193 billion (annual average in the period 2016-20) to €335 billion (annual average in the period 2021-23).[15] The IEA's most recent estimate indicates that investments will plateau at €341 billion in 2024, compared with an average target of €403 billion in the Net Zero Scenario. This suggests an average investment shortfall of approximately €66 billion per year since 2021. To compensate for the shortfalls in past years, green investments have to be higher than the annual target level.

9 See European Commission (2019).

10 See European Commission (2020a). Following the European Green Deal communication, the Commission increased the emissions reduction target from 40% to 55% compared with 1990 levels, which explained the higher investment needs in the period to 2030.

11 See European Commission (2021b) and European Commission (2022), respectively.

12 See European Commission (2023a). The investment needs documented until 2022 were expressed at 2015 prices, while from 2023 onwards the estimates are shown at 2022 prices.

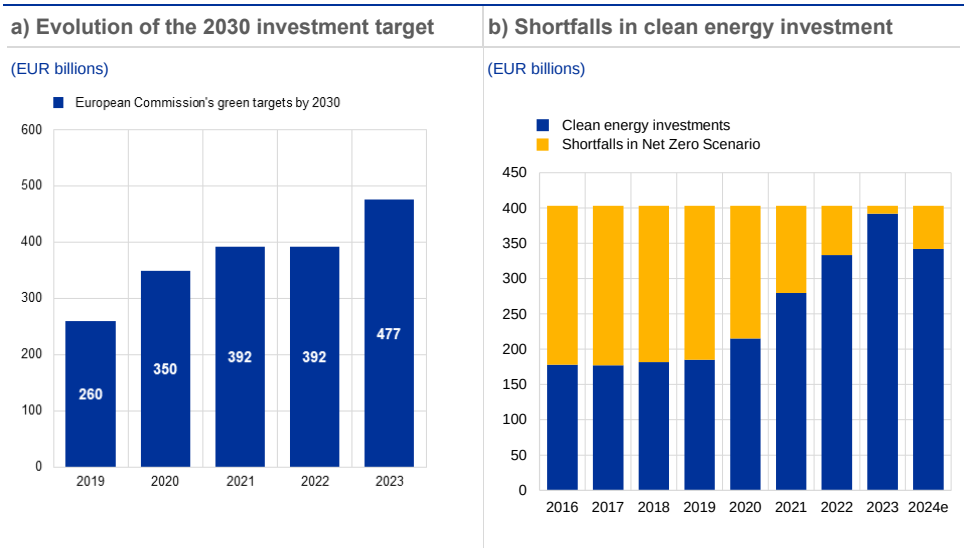
13 Adaptation means anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause, or taking advantage of opportunities that may arise. Mitigation means reducing the severity of the impacts of climate change by preventing or reducing the emission of greenhouse gases (GHG) into the atmosphere (see EEA, 2024). According to the World Bank (2024), climate adaptation needs in the EU are estimated at €15 billion to €64 billion per year to 2030.

14 For a discussion of possible obstacles preventing sufficient green investment, see Chapter 3.3.2. on access to finance and Chapter 5.1. on obstacles to cleantech investments. EIB (2024a) also stresses the importance of clear policies on the speed and future pathway of the net-zero transition.

15 IEA (2024a) and IEA (2023a).

Chart 2

The 2030 investment target over time and shortfalls in clean energy investments



Sources: ECB calculations based on European Commission and IEA data.
Notes: Panel a) shows the evolution of the European Commission's estimate for additional annual green investment needs over the years, where figures are taken from various European Commission documents from 2019 to 2023. The investment needs to 2021 are in 2015 prices, while for 2023 onwards the estimates are in 2022 prices. Panel b) shows the clean energy investment shortfalls from 2016 to 2024 (estimated) based on IEA data. Clean energy investments exclude fossil fuel investments. The shortfalls (yellow bars) are calculated as the difference between the average investment needs until 2030 in the IEA's Net Zero Scenario, which we kept fixed at €403 billion, and actual clean energy investments (the blue bars).

Investment shortfalls with respect to the 2030 target would result in higher overall green investment needs. This is shown by the second ECB economy-wide climate stress test, which estimated granular firm-level investment needs for euro area corporates to 2030.[16] Two categories of investments are considered in the ECB climate stress test: investments in carbon mitigation activities and investments in the expansion of renewable energy capacity. Firm-level investments in carbon mitigation activities are assumed to be proportional to the reduction in total GHG emissions projected for the individual firms[17] between 2023 and 2030, multiplied by the cost of mitigating those emissions[18]. Investments in renewable energy, meanwhile, are mainly taken up by the electricity sector to meet the higher demand for green energy of the other sectors, assuming that renewable energy is then distributed to firms in the form of purchased electricity. Three scenarios are considered. While the accelerated and late-push transition scenarios both follow net-zero emission targets, the latter entails higher investment costs and therefore generates higher green investments from 2026 onwards, once the transition speeds up (Chart 3, panel a). The delayed transition is the least ambitious scenario, falling behind in terms of both

16 See Emambakhsh et al. (2023). The scenarios analysed in the ECB climate stress test are the accelerated transition, late-push transition and delayed scenarios. The accelerated transition assumes an immediate intensification of the transition that rapidly brings the economy onto the net-zero by 2050 pathway. In the late-push transition scenario, it is assumed that transition efforts will not accelerate until 2026, but will then be ambitious enough to catch up to a level of emissions reduction in line with the EU 2030 target. The delayed transition scenario assumes similar transition timing but more limited policy action, less investment and hence less emissions reduction by 2030.

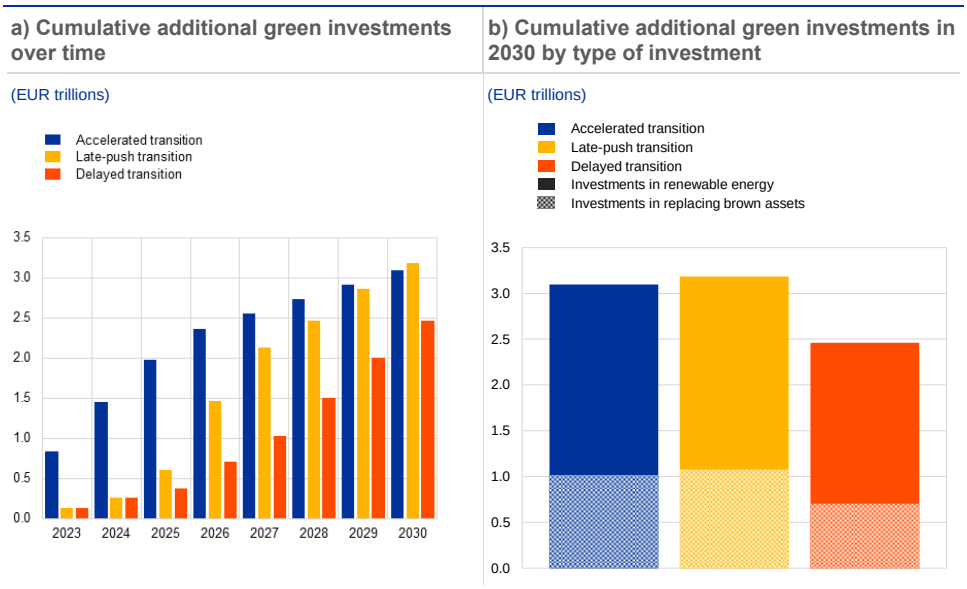
17 The GHG emissions pathways are available at regional level in the NGFS scenarios and have been downscaled at the country-sector level on the basis of a newly developed ECB methodology. Further details can be found in Annex 1 of Emambakhsh et al. (2023).

18 The underlying mitigation costs are derived from the calculations provided in the IPCC report and differ across sectors, depending on the mitigation options available and their potential contribution to the reduction of emissions (see IPCC, 2022).

emission reductions and additional green investments to 2030. Firms experience the most marked reduction in investment costs once renewable energy capacity rapidly increases.[19] In the accelerated transition scenario, there is already a 70% drop in investment costs in 2025 relative to 2022 levels, therefore incentivising firms to invest in the transition. In the late-push transition, investment costs only fall substantially from 2026 onwards, but still remain slightly higher than in the accelerated transition scenario. In total, investments in carbon mitigation activities comprise around one-third of total additional green investment needs, with investments in renewable energy making up the other two-thirds (Chart 3, panel b).

Chart 3

Composition of additional green investment needs in the transition scenarios of the ECB economy-wide climate stress test



Sources: ECB calculations based on Orbis, Urgentem, Eurostat, NGFS and BMPE macroeconomic projections and IRENA (2021) and IPCC (2022) data.
Notes: The scenarios analysed in the ECB climate stress test are the accelerated transition, late-push transition and delayed scenarios. The accelerated transition assumes an immediate intensification of the transition that quickly takes the economy onto the pathway to net-zero by 2050. In the late-push transition scenario, it is assumed that transition efforts will not accelerate until 2026, but will then be ambitious enough to catch up to a level of emissions reduction in line with the EU 2030 target. The delayed transition scenario assumes similar transition timing, but more limited policy action, less investment and hence less emissions reduction by 2030. See Emambakhsh et al. (2023).

The estimates for additional green investment needs can be seen as a lower bound in view of investment slippages and the only selective coverage of sectors. Despite recent progress, Europe's green investment activities have so far fallen short of what would have been needed annually until 2030 to achieve the decarbonisation target. Shortfalls were particularly noticeable during the pandemic. To compensate for the considerable shortfalls compared with the target levels, more investment will be required in the remaining years to 2030.[20] If this is not achieved, a

19 The investment costs for the generation and supply of renewable energy are assumed to be time and scenario-dependent and are modelled using the "learning curves" method. Learning curves capture the efficiency gains from the experience of producing a good. The assumption is that the more times a task has been performed, the less time is required on each subsequent iteration (Wright's Law). Various factors may be drivers of learning, such as labour and resource efficiency, standardisation, product re-design, network effects, etc.

20 That said, breakthroughs in green innovation and a favourable impact of green investment on potential growth will reduce the additional investment required for the green transition.

delay in the green transition would imply additional costs for adaptation. Possible reasons for the shortfalls are poor access to, or high cost of, finance and a policy framework that fails to support, or even hinders, the green transition, as discussed below. Another reason why the estimates of investment may be understating the actual needs relates to the sectoral coverage. As discussed in the next section, some estimates do not include the full spectrum of sectors that will be impacted by the green transition. Taken together, this implies that the estimates outlined here should be considered the lower bound.

2.3 Sector-specific investment needs

The various estimates of green investment needs cover different sectors and sub-sectors. The European Commission identifies substantial EU investment needs for the net-zero emission transition in the transport sector, as well as in energy supply (power grids and power plants) and energy demand (mainly the industrial and residential building sectors).[21] The European Commission estimates broadly represent the investment needs of the entire economy, while estimates from BNEF, the IEA and I4CE do not explicitly consider services and agriculture (Figure 1).

The transport sector is a major GHG-emitting sector, where emissions are increasing and investment needs are sizeable. Growing demand for travel and goods transportation poses a real challenge to transition in this sector. Investing to ramp up electrification and increase energy efficiency and the use of biofuels plays a major role in the decarbonisation of road transport, although the price level of electric cars and regulatory uncertainty constitute obstacles, amid cuts in subsidies. The available green investment estimates cover electric and hydrogen vehicles, as well as recharging/refilling infrastructure and heavy-duty road vehicles. However, there are some discrepancies in the coverage, with the European Commission estimates also comprising railway carriers[22], while the BNEF estimate also contains aviation and maritime transport, including the related infrastructure. The I4CE estimates exclude aircraft, shipping and railways infrastructure. According to the European Commission estimates, the transport sector will need by far the largest amount of green investment in the period 2021-30, at €205 billion per year (Chart 4). I4CE estimates a gap of €147 billion per year and BNEF a gap of €184 billion. Public transportation is not covered in any of these estimates. In the ECB climate stress test, the estimates for the transport sector are small, reflecting the fact that the analysis is based on firm-level data (Chart 4, panel d).

Investment in energy supply should be the backbone of energy transition in Europe. Further deployment of wind and solar panels would provide the main source of renewable power. Nuclear energy is only included in the BNEF and IEA estimates. Within the wind power sub-sector, while fixed onshore and offshore will remain the main technology used, the EU also expects to install 10 GW of floating wind by 2030: by then the floating hybrid platform, combining different types of marine renewables,

21 See European Commission (2023a).

22 ibid., page 10, footnote 25.

is expected to have become the dominant technology.[23] Solar photovoltaics includes photovoltaic modules for electricity generation, concentrated solar power plants and thermal storage as a source of electricity and heat. The EU plans to add 7 GW of the latter by 2030, while solar thermal collectors are already installed in over ten million EU households. In addition to these standard technologies, investment is also planned in additional renewable technologies, such as fuel cells for hydrogen, biomethane, tidal and wave energy devices. The large, expected proportion of variable generation in the energy mix and the ambitious plans for offshore wind generation lead to a substantial need for investment in smart grids, overseas interconnector lines and distribution lines.[24] However, I4CE reports varying progress in the renewable energy transition. While investments in wind power represented about one-fifth of total annual investment needs in 2023, investments in solar panels amounted to about four-fifths of total annual investment needs.

One particular challenge is the smooth integration of renewable energy sources into power grids, in order to meet the expected increase in demand for electricity in the years to come. There are challenges in both matching the physical grid capacity to accommodate supply and demand connections and ensuring that the network is stable. The European Commission estimates the related investment need at about €100 billion per year, notably in power grids and power plants. Moreover, cooperation between energy market stakeholders (transmission operators, regulators, renewable energy developers, industries and power consumers) is necessary to ensure the smooth coordination of the energy system.

The ECB economy-wide climate stress test estimates that the bulk of green investments will be borne by the energy sector, with annual investments of €270 billion. One major assumption in the exercise is that renewable energy will be centrally distributed via renewable-based electricity: the electricity sector is therefore the biggest investor in green energy.

Investment to make energy demand more efficient is another important component of the transition, notably in the industrial and residential building sectors. In the industrial sector, investment in energy and material efficiency measures are important levers to reduce GHG emissions. Some concrete examples are (i) reducing energy consumption by deploying the best available technologies; (ii) waste heat recovery; (iii) process integration; (iv) recycling; (v) less material-intensive product design; (vi) carbon capture and storage; and (vii) the deployment of other renewables-based technologies based on biomass, geothermal and solar thermal. Emission reductions in hard-to-abate industries such as steel, aluminium and cement production are particularly challenging due to their heavy reliance on fossil fuels and high-temperature heating requirements. In the residential building sector, heating systems in buildings have to be decarbonised and made more energy efficient through the use of mature technologies, such as heat pumps and district heating. Geothermal energy is another source of renewable heat for buildings. IC4E estimates that the investment need for heat pumps will be almost equal to that of wind power. I4CE estimates a need for an additional €137 billion in

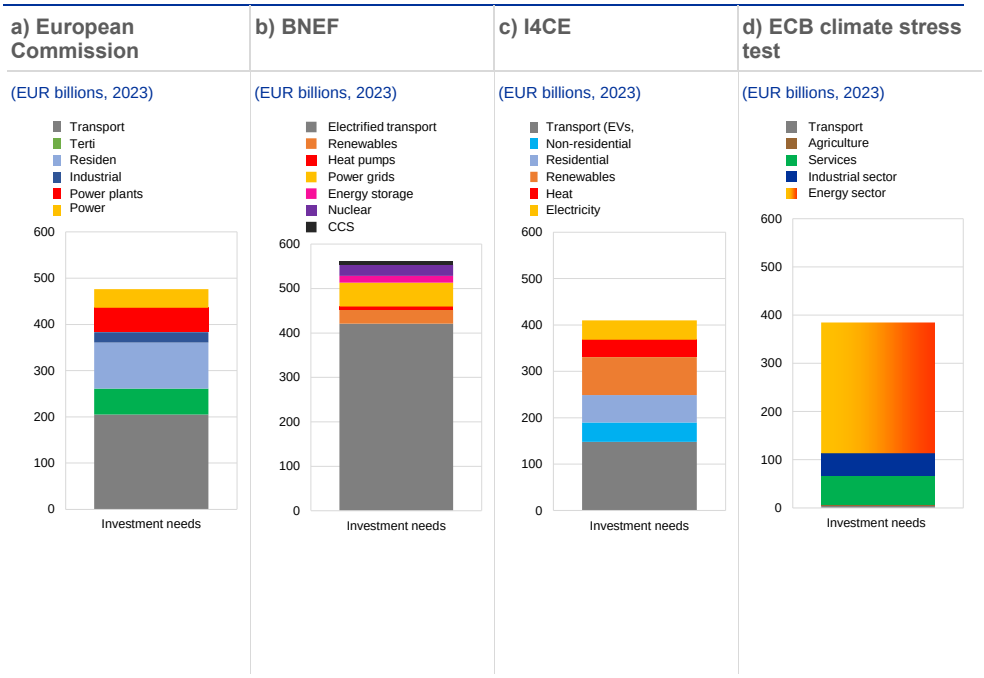
[23] ibid.

[24] ibid. These needs are estimated at more than €580 billion cumulatively by 2030.

the building segment, comprising residential and non-residential renovation, as well as installation of heat pumps and improving energy performance. The European Commission assesses the investment needs in the three areas at almost €180 billion per year (Chart 4, panel a). However, not all institutions include the retrofitting of buildings in their green investment estimates.

Chart 4

Annual additional investment needs per sector



Sources: European Commission, BNEF, I4CE, ECB economy-wide climate stress test and ECB calculations.
Notes: All **the** panels show the annual additional green investment needs **to** 2030 in the EU. Panel a) shows the European Commission estimates for the period 2021-30 (€ billions 2022). Panel b) shows the BNEF estimates for the EU-27, plus Norway and Switzerland, for the period 2024-30 (€ billions 2023). Panel c) shows the I4CE estimates for the period 2024-30 (€ billions 2022). Panel d) shows the annual additional investment needs according to the ECB economy-wide climate stress test (2023). The figure is an average across the "accelerated transition" and "late-push transition" scenarios. For more information, see Chapter 2.2. and Emambakhsh et al. (2023). The energy sector includes the power grid and power plants sectors.

At the firm level, evidence from the SAFE shows that green investment activity among firms varies significantly across economic sectors, with those in fossil fuel-intensive industries facing the greatest challenges in the green transformation.[25] Firms in less energy-intensive sectors, such as services and trade, provide heterogeneous responses on their investment activity in the past five years and their future investment plans, according to the survey (Chart 5). Conversely, most firms in the manufacturing sector (blue dots in the chart), reflecting their high overall energy intensity, tend to invest or plan to invest more than the average sector in reducing their carbon emissions. Green investment activity in the manufacturing sector seems to be positively correlated with their current fossil energy consumption level.[26] The lowest level of green investment– and,

[25] The survey on the access to finance of enterprises (SAFE) provides quarterly information on the latest developments in the financial situation of enterprises in the euro area. In the second quarter of 2023, the SAFE added specific ad hoc questions related to the impact of climate change on euro area firms (see Ferrando, Gross and Rariga, 2023).

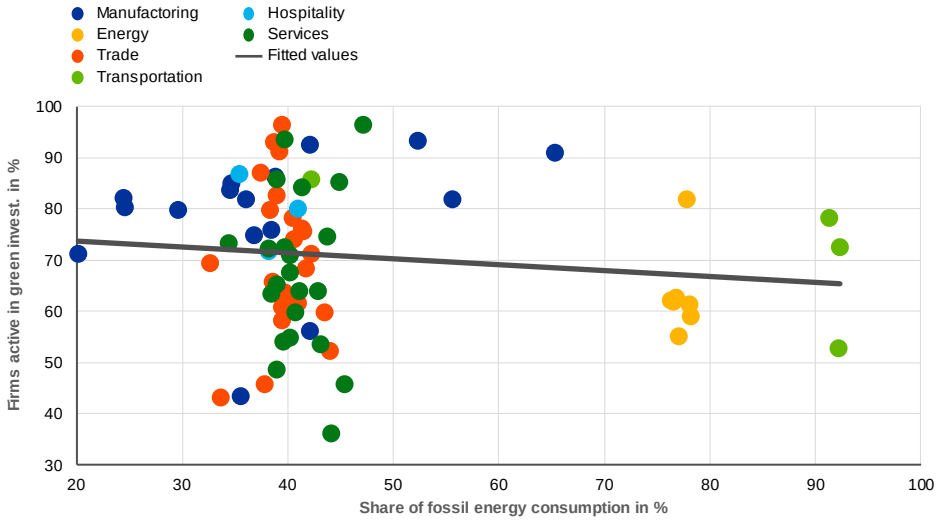
[26] Using Belgian data, Bijnens et al. (2024) report that the profits of energy-intensive businesses did not recover fully after the recent surge in energy costs, which has limited internal sources of financing for the green transition within the carbon-intensive industries.

consequently, the most significant challenges – is reported by firms in the energy as well as the passenger and freight transportation sectors. This is due, among other factors, to technical barriers and the need to fund sizeable public infrastructure investments in these sectors, which are currently still experiencing high GHG emissions. These sectoral challenges are reflected in a slightly negative correlation between overall current fossil energy intensity and green investment activity across sectors (black line in the chart).

Chart 5

Green investment activity and energy consumption

(fossil energy as a percentage of total energy consumption, percentage of firms active in green investments)



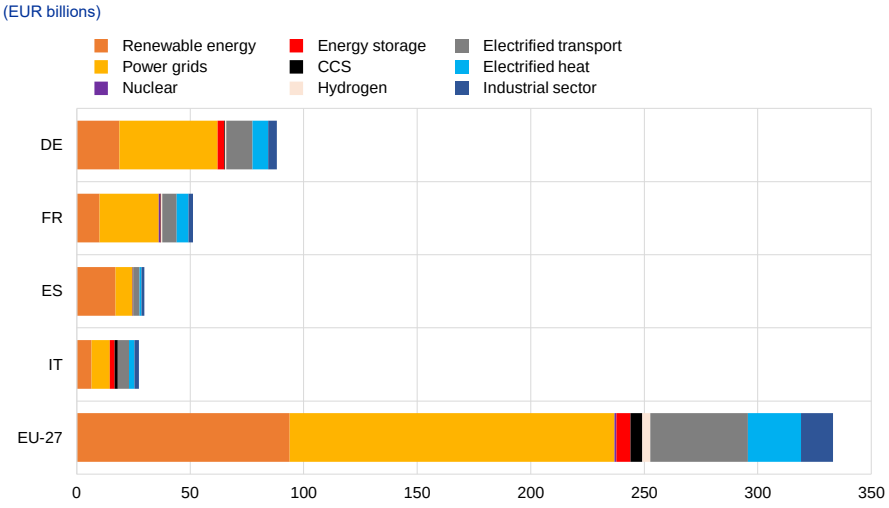
Sources: ECB and European Commission SAFE, Eurostat industry energy consumption statistics and ECB calculations.
Notes: NACE-4 sector average percentages of firms that have already invested in the last five years or plan to invest in the next five years in green transformation as reported in the SAFE are plotted against fossil energy consumption as a percentage of total energy consumption by sector.

2.4 Country-specific investment needs

The largest EU countries have been among the most active worldwide in green investment, particularly in energy transition, in recent years. The BNEF data, which are the only publicly available country data on actual green investment in energy transition, show that in 2023, Germany, France, Spain and Italy were among the top ten countries worldwide investing in energy transition (including energy generation and electrified transport) in absolute amounts, with the bulk of the investment occurring in the electrified transport category, which also includes the purchase of electric vehicles by households (Chart 6). Spain also invested a substantial amount in renewable energy. As a proportion of the total investment recorded in the national accounts, the energy transition investment is estimated at 7% for Italy and 13% for Germany.

Chart 6

Investment in green energy transition in the larger EU countries in 2023



Source: BNEF.

Information on investment needs from the updated National Energy and Climate Plans of the EU Member States is largely missing. The National Energy and Climate Plans are the main strategic policy planning tool for Member States to describe how they will meet the objectives and targets set in the energy union and stay on track to achieve climate neutrality by 2050. EU countries are required to submit their investment need estimates and provide information on concrete measures to attract private finance. However, although the deadline passed in June 2024, country-specific investment estimates are not yet available.

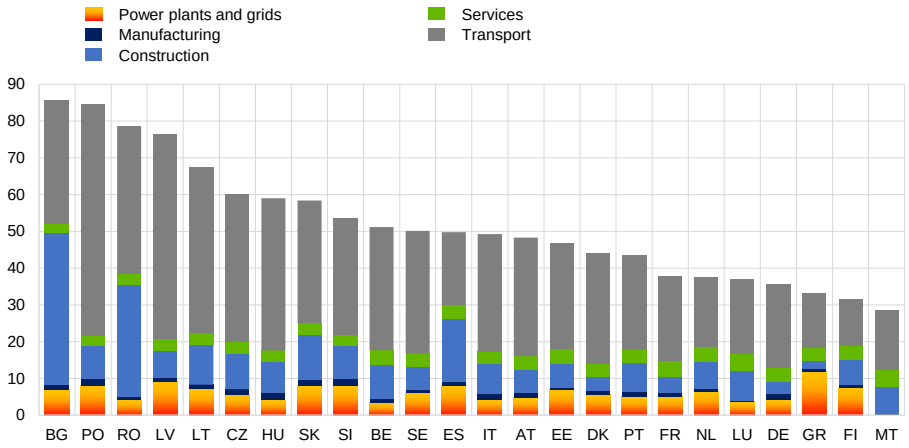
Estimates of investment needs by country depend on the country-specific economic structures. While country-specific estimates of investment needs are not publicly available, a proxy of individual country investment needs can be obtained using total EU needs, assuming that sectoral investment needs are proportional to current investment by sector in the economy. On the basis of the Commission estimates presented in Section 2.2., the investment needs of sectors are roughly mapped onto Nomenclature of Economic Activities (NACE) sectors.[27] Then, assuming that the current state of technology and the investment needs per unit of current investment (green and brown) are equal across countries, their annual investment needs can be allocated. The different investment needs per unit produced between sectors, along with the different weightings of sectors in the various economies, result in different sectoral breakdowns of investment needs (Chart 7). For instance, countries with relatively large transport sectors (e.g. Poland, Hungary, Denmark, Belgium and Sweden) have to shoulder a higher burden in terms of investment and adjustment needs.

27 To allocate green investment in transport, we use data on the transportation and storage (NACE sector H). The NACE definition covers investment in car fleets, trucks, buses, trains and ships, which are either company-owned or publicly owned. It does not cover private vehicle purchases, which are classified as durable consumption. Thus, this definition is different from the one used for the estimates shown in Chapter 2.2.

Chart 7

Estimated shares of green investment needs by sector and EU country

(percentage of total investment in 2021, per year)



Sources: European Commission, Eurostat and ECB calculations.
Notes: The European Commission estimates of annual investment needs in 2021-30 (European Commission, 2023c, Table 9) are distributed across countries and sectors according to their share of EU total actual gross capital formation (both brown and green) for each NACE sector in 2021. Thus, the sum of countries' investment estimates for a given sector is equal to the total EU investment needs of this sector. The mapping of sectors between the European Commission estimate and national accounts is done as follows: "Power plants and power grids" for the European Commission corresponds to sector "D. Electricity, gas, steam, and air conditioning supply"; "Industry" corresponds to "C. Manufacturing"; "Tertiary" corresponds to the sum of sectors G to U, excluding H; "Transport" corresponds to "H: Transporting and storage"; and "Residential" is approximated by "F. Construction". Data are missing for IE, HR and CY. Full data coverage is only available for 2021.

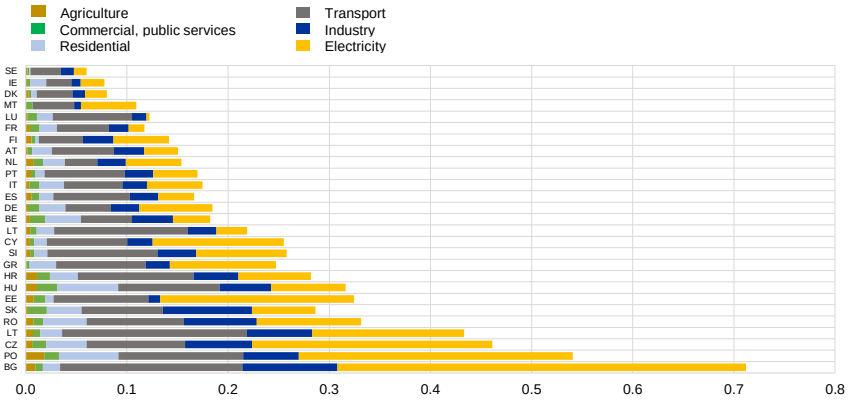
Data on current emissions also suggest that the additional investment needed varies across countries. The calculation for Chart 7 assumes, rather unrealistically, that all countries are identical in terms of GHG emissions per unit produced in the same sector. However, the starting position of each country is different: the extent of a country's use of GHG-emitting technologies in production and power generation, as well as the availability of natural carbon sinks, have a significant impact on how easily a country can decarbonise.[28] GHG emissions data can be used as an alternative starting point to gauge countries' different green investment needs. Chart 8 shows the CO_2 emissions of each EU country, broken down by sector, using the IEA's sectoral definitions. These data confirm that, in absolute terms, electricity generation and transport account for a large proportion of GHG emissions in most countries.

[28] See, for instance, McKinsey (2020).

Chart 8

CO2 emissions due to fossil fuel combustion by country and sector, 2021

(million tCO2 per EUR millions of GDP)



Sources: IEA and ECB calculations.
Note: Both emissions and GDP data refer to the year 2021.

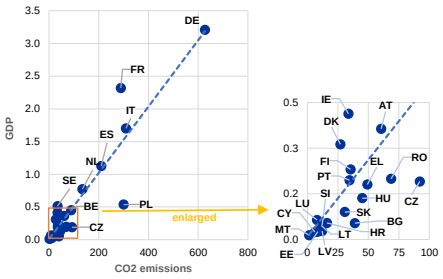
Country-specific factors, such as the energy sources used and the age of capital equipment, play a role in the intensity of GHG emissions, and therefore the investment efforts needed. Data on GHG emissions can shed light on these differences between countries. Chart 9, panel a) plots emissions against the countries' real GDP. Considering emissions per unit produced, most countries appear to be on a roughly similar level (around the trend line). However, some individual differences are noticeable, likely driven by the age and maintenance of the capital stock and, in the case of the energy sector, the energy sources used. In particular, two clusters stand out. On the one hand, countries such as Ireland, Sweden and Denmark emit less GHG than would be suggested by the size of their economies. On the other, there is a cluster where the opposite is the case: these are mostly the central and eastern European EU countries with high GHG emissions, which might be due to older capital stock or lower maintenance investment. Panel b) focuses on the energy sector ("electricity and heat production"), juxtaposing energy sector-related emissions and overall sectoral investment (brown and green) for the NACE sector "Electricity, gas, steam and air conditioning". In this case, the dispersion of individual countries around the trend line is greater. In particular, in France and Spain, emissions are lower than what would have been expected given the size of their energy sectors. This might mainly be due to the use of low-emission nuclear energy (63% and 20% of total generation, respectively), but in the case of Spain it also reflects a strong emphasis on renewable energy, as shown in Chart 6.

Chart 9

Comparison of CO_2 emissions with overall GDP and investment

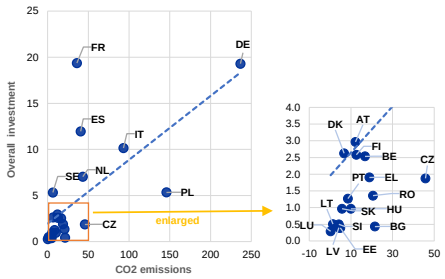
a) Emissions and GDP, total economy

(CO_2 emissions in million tonnes, GDP in EUR billions)



b) Emissions and investment, energy-producing sector

(CO_2 emissions in million tonnes, overall investment in EUR billions)



Sources: IEA and Eurostat.
Notes: Total GDP is taken from Eurostat and covers data for 2021, measured in chain-linked 2015 euro. The emissions data are taken from the IEA and include CO_2 emissions from fuel combustion only. The dotted line is a trend line.

Box 1
Global green investment needs

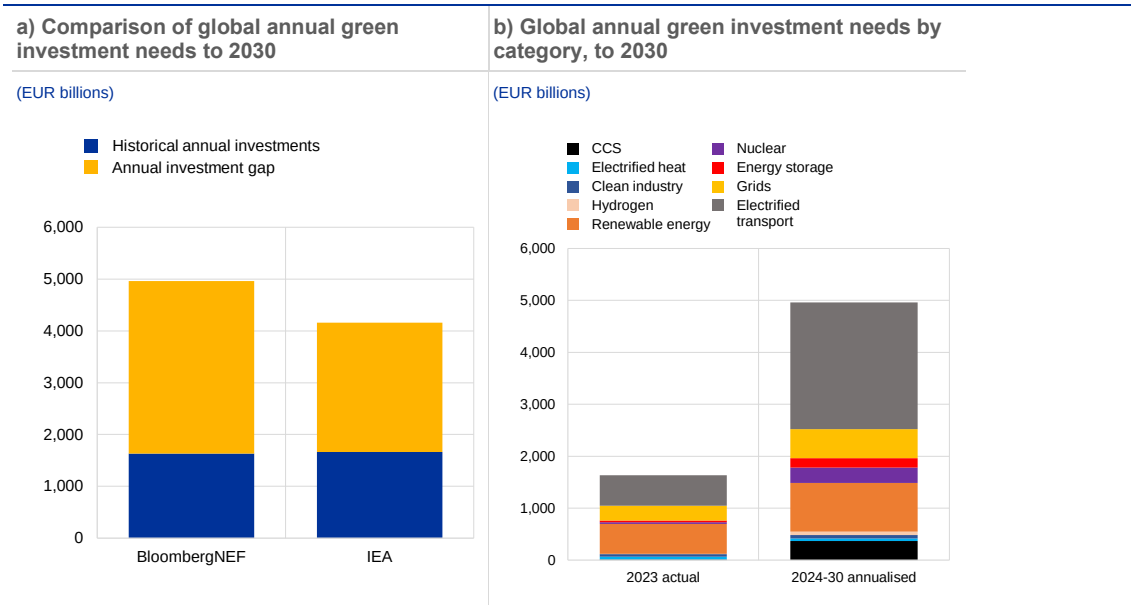
This box presents a brief overview of global green investment trends. It highlights significant regional disparities, with most green investments occurring in advanced economies and China. Despite a notable acceleration in clean energy investments in recent years, a substantial discrepancy remains between current annual investments and the annual investment required in the period to 2030 to meet the targets set for net-zero emissions. Current available estimates indicate that additional investments of between €2.5 trillion and €3.4 trillion per year will be necessary at the global level until 2030 to stay on track to achieve net-zero emissions. These figures underscore the urgency and scale of the investment needed to address climate change effectively and transition to a sustainable energy future.

EU green investment should be seen in the broader context of the global shift from fossil fuel to green investment, which is characterised by large regional discrepancies. According to the IEA (2023), the investment ratio of clean energy technologies to fossil fuels has shifted significantly in the past five years. The ratio of clean investments to fossil fuel investment increased from 1:1 in 2018 to 1:1.7 in 2023. This means that for every dollar invested in fossil fuels, USD 1.70 is now being allocated to clean energy technologies such as renewable power, nuclear energy, grids, energy storage, low-emission fuels, efficiency improvements and electrification. Several factors have contributed to this shift. Volatile fossil fuel prices have made investments in this sector less attractive. In addition, there is stronger alignment with climate goals, which has encouraged more investment in sustainable energy solutions. Furthermore, an increased focus on energy security has increased the diversification of energy sources and reduced dependency on fossil fuels. Collectively, these factors have boosted investments in clean energy. However, large regional discrepancies continue to persist. China stands out, with an investment in 2023 of €626 billion equivalent, which is more than the combined investment of the EU-27 and the United States. BNEF's analysis by region shows that the Asia-Pacific region (47% of global green investment) and Europe, Middle East and Africa (31%) dominate global green investment. Despite the Inflation

Reduction Act (IRA) launched by the United States in 2022, the proportion of global investment of North and Latin America was only 22% in 2023.

Chart A

Global green investment needs



Sources: BNEF (2024a), IEA (2023) and ECB calculations.
Notes: In panel a), historical investment refers to the year 2023 for BNEF and IEA. BNEF and IEA figures have been converted from USD to EUR. The annual investment gap is the additional annual investment needs to 2030 to reach a net-zero emission scenario for BNEF and a 1.5°C pathway for the IEA The sum of the historical and additional investment gives the total annual investment needs. In panel b), 2023 actual represents the current energy transition investment in 2023. The 2024-30 annualised levels are the required investment needs according to BNEF (2024a). The 2023 figures have been converted from USD to EUR with an exchange rate of 0.9241, while the 2022 figures have been converted using an exchange rate of 0.951.

Despite recent progress, global clean energy investment falls considerably short of achieving the net-zero goal by 2050. In 2023, global investment reached €1.6 trillion, increasing by 17% year-on-year, as reported by BNEF.[29] However, BNEF projects that, to stay on track for the Net Zero Scenario, global investments must increase to an annual average of almost €5 trillion between 2024 and 2030.[30] This perspective is broadly echoed by the IEA, which notes that while €1.7 trillion was invested in clean energy in 2023, the total annual investment requirement would be closer to €4.2 trillion by 2030 (Chart A, panel a).[31] According to the NGFS[32], the global energy supply investments required are estimated at between €2.4 trillion and €3.7 trillion per year on average in the period 2020-50, of which around 30% would have to be directed towards renewables. The "Net Zero 2050" scenario requires the highest level of investment, while in the "Current policies" scenario, which only includes climate policies already implemented, global annual

29 ECB calculation based on BloombergNEF (2024b).

30 Estimates are provided with reference to BNEF's Net Zero Scenario and are the results of own calculations based on BloombergNEF (2024a).

31 ECB calculation based on IEA (2023c), using the Net Zero Scenario.

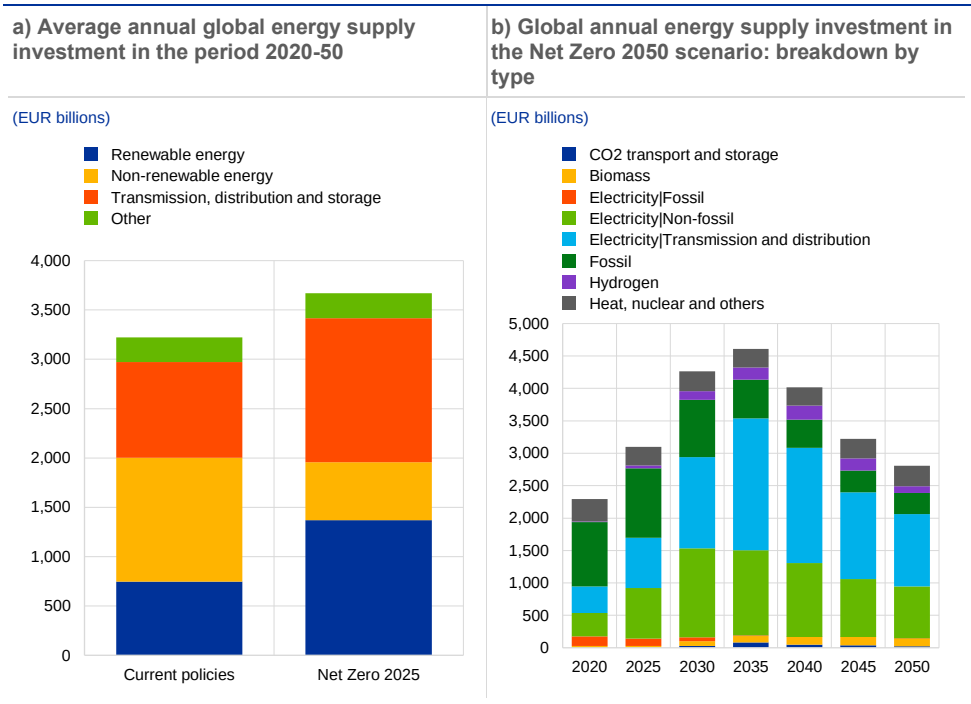
32 The Network for Greening the Financial System (NGFS) is a group of central banks and supervisors committed to sharing best practices. For more details, see NGFS. Since 2018, the NGFS has been developing climate scenarios using different assumptions in terms of transition policies and physical risks. These scenarios provide information on the evolution of energy systems and energy mixes according to different climate policy ambitions, including the investments needed in the specific sectors. The NGFS scenarios can be grouped into four categories – orderly transition, disorderly transition, too-little-too-late and hot house world scenarios – and their implied level of investment depends on both the final temperature/emissions target and the pathway to that target.

investments would amount to €3.2 trillion per year, 12% lower than in the "Net Zero 2050" scenario (Chart B, panel a).[33]

The investment flows required for renewable energy supply vary over time and are mainly allocated to the mass deployment, storage and distribution of renewable-based electricity. In all NGFS scenarios, investment flows are expected to peak between 2030 and 2040, in line with green technology developments. Focusing on the "Net Zero 2050" scenario, some initial legacy capital investment in fossil fuel extraction will almost disappear by 2050 (Chart B, panel b). In the same period, the annual investment in renewable electricity and storage will increase to about €2.2 trillion per year on average, around €0.8 trillion more than in the "Current policies" scenario. As a result, in the "Net Zero 2050" scenario, renewables and biomass are projected to deliver roughly 75% of global primary energy by 2050.

Chart B

Global investments in the NGFS climate scenarios



Source: NGFS climate scenarios.
Notes: Phase V scenarios (as of November 2024) are based on the REMIND-MAgPIE 3.3-4.8 model. "Other" includes CO_2 transport and storage, nuclear and other energy supply.

[33] These figures are obtained via complex integrated assessment models that – given a certain narrative, temperature pathway and corresponding level of GHG emissions – are able to capture the evolution of energy systems and quantify the investments required to transform them.

3 How can green investment needs be financed? The role of the private sector

The substantial green investment needs require additional financing, primarily via the private sector. In the bank-based financial system of the euro area, banks play a crucial role in ensuring access to financing for the transition towards a net-zero emission economy in the period to 2050. While banks appear to have adjusted only marginally their loan portfolios towards low-emitting firms, their assessment of climate risks affects their loan approval and pricing decisions, on the back of stricter supervisory and disclosure requirements. The banks expect this impact to increase over time. By contrast, the proportion of green and sustainable financing in euro area capital markets – while growing rapidly – is so far limited and will have to grow further in the coming years to provide more support for the achievement of the net-zero target. Evidence from bank and firm surveys and firm-level data confirm that financing conditions and fiscal support can either facilitate or hinder the green investment decisions of firms, particularly small and medium-sized enterprises (SMEs). In addition, the financial health of firms and the regulatory burden are important factors in their green investment planning.

This chapter provides an overview of the current financing landscape as regards carbon emission financing and progress in green and sustainable financing. It finds that banks are still heavily exposed to carbon emissions, with high amounts of emissions by firms that can be linked to funding from euro area banks in the manufacturing, energy and transport sectors. Carbon emission financing is also concentrated within a few banks, indicating that these banks have a substantial exposure to transition risk. While bank-financed emissions have to be lowered to achieve more progress in the green transition, banks will continue to make a vital contribution to the funding of firms in high-emitting sectors to facilitate their green transition. Public support may facilitate climate-related funding, by mitigating the financing costs for firms managing the green transition.

3.1 Current financing landscape

3.1.1 The role of banks in financing carbon emissions

Given the importance of bank lending in the financing of euro area firms, banks play an important role in financing carbon emissions (Chart 10).[34] Banks contribute to the financing of corporate carbon emissions primarily by granting loans,

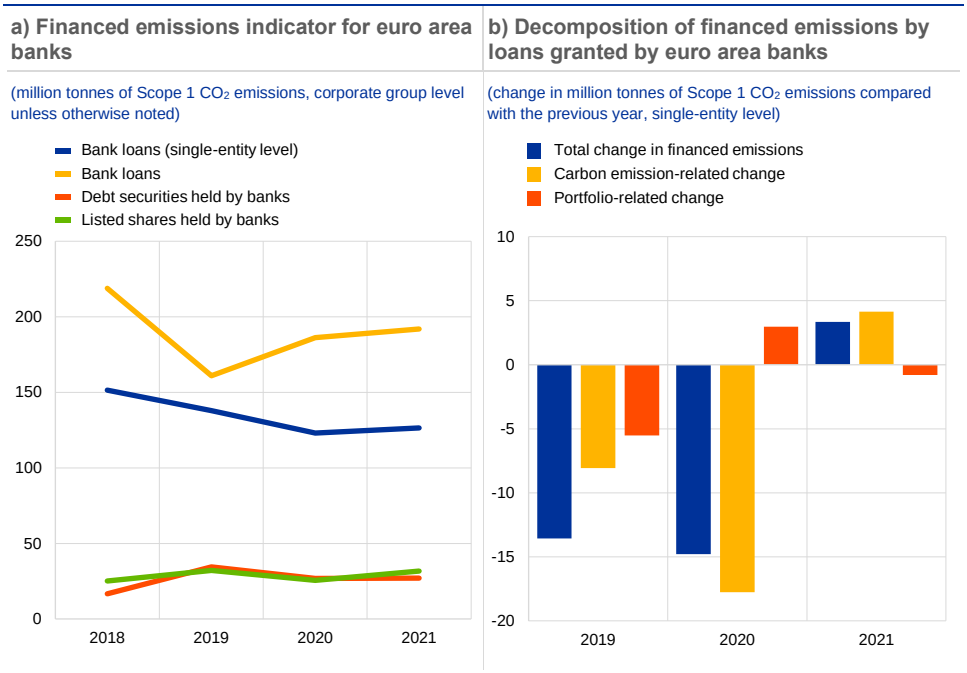
[34] The financed emissions (FE) indicator tracks the amount of total carbon emissions from non-financial corporations (NFCs) that can be linked to funding from financial institutions, based on a set of identifiable securities and loan portfolios. See the climate indicators published on the ECB website and European Central Bank (2024b) for a detailed explanation of these analytical indicators, including their limitations, mainly related to data availability.

and to a smaller extent by holding corporate securities. For euro area firms' emissions within the euro area, carbon emissions financed by euro area banks have been trending downwards since 2018, with a minor increase in 2021. Chart 10, panel a suggests that euro area banks have reduced their financed emissions more within the euro area than globally for euro area firms, probably due to the stricter climate policies in Europe than elsewhere.

The carbon emissions that can be linked to funding from euro area banks increased slightly, after a decrease in 2020, while the banks appear to have adjusted their loan portfolios only marginally towards low-emitting firms (Chart 10, panel b).[35] A change in bank-financed carbon emissions may either be due to an adjustment of banks' loan portfolios or a change in firms' carbon emissions. After the decrease in corporate carbon emissions in 2020, related to the steep fall in economic activity during the pandemic, firms' carbon emissions made a positive contribution to the financed emissions of euro area banks in 2021. By contrast, on average over the period 2019-21, adjustments of banks' loan portfolios made only a marginal contribution to a decrease in financed emissions for euro area bank loans. This suggests that banks, on average, have so far not tended to actively reduce their portfolios of loans to high-emitting firms.

Chart 10

Indicators of carbon emissions financed by euro area banks



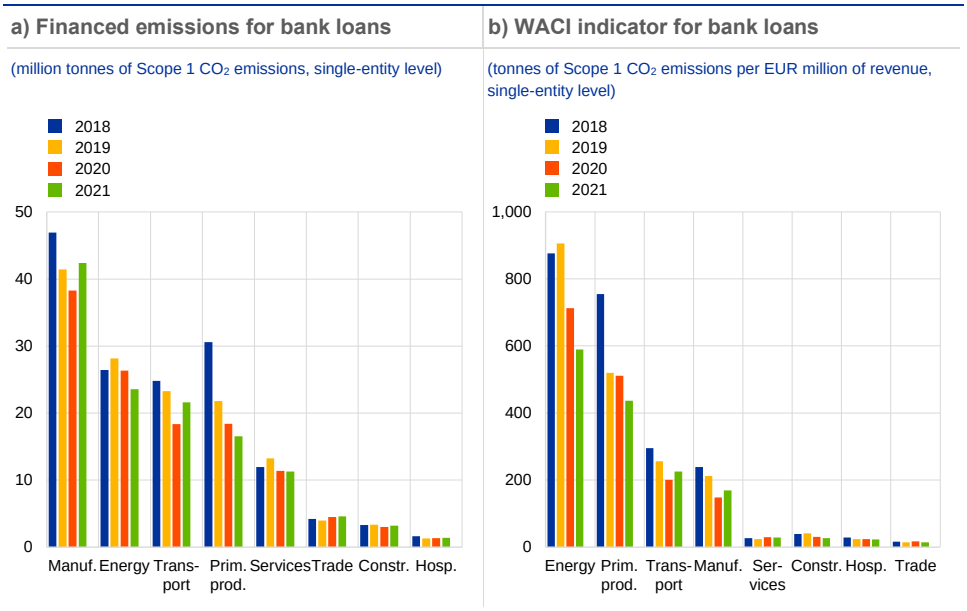
Sources: For the corporate group level, European System of Central Banks (ESCB) calculations based on data from the Register of Institutions and Affiliates Database (RIAD), the Centralised Securities Database (CSDB), Securities Holding Statistics (SHSS) and the International Statistical Standards (ISS). For the single-entity level, ESCB calculations based on data from AnaCredit, RIAD, EU ETS and Eurostat air emissions accounts. See European Central Bank (2024b) for a detailed explanation of these analytical indicators, including their limitations.
Notes: Based on Scope 1 carbon emissions as single-entity and group-level indicators based on AnaCredit encompass only Scope 1 emissions, i.e. an entity's direct emissions. "Banks" are deposit-taking corporations, excluding central banks. The "single-entity level" denotes firms' emissions at the location of the firms, i.e. within the euro area, financed by euro area banks. The "corporate group level" considers the global carbon emissions of euro area firms financed by euro area banks.

[35] See European Central Bank (2024b).

Bank loan financed emissions largely stem from the manufacturing, energy and transport sectors (Chart 11, panel a). These sectors have some of the highest green investment needs. Specifically, high bank-financed emissions in the manufacturing sector point to the substantial green investment activities of firms in this sector compared with other high-emitting sectors (as shown in Chapter 2).[36] The exposure of euro area financial institutions to transition risk can also be measured by the weighted average carbon intensity (WACI) indicator[37]. Relative to corporate revenues and standardised with banks' loan portfolios based on WACI, banks have the highest sectoral transition risk exposure to the energy and primary production sectors (Chart 11, panel b). The transition risk of banks based on WACI is comparatively lower for the manufacturing sector. Compared with the WACI level in 2018, the transition risk of banks due to corporate carbon emissions has decreased overall in most economic sectors. At the same time, this assessment does not account for transition risks that stem, for instance, from climate-related risks in firms' business models.

Chart 11

Indicators of carbon emissions across economic sectors, financed by euro area banks



Sources: ESCB calculations based on data from AnaCredit, RIAD, EU ETS and Eurostat air emissions accounts. See European Central Bank (2024b) for a detailed explanation of these analytical indicators, including their limitations.
Notes: Based on Scope 1 carbon emissions, as single-entity indicators based on AnaCredit encompass only Scope 1 emissions, i.e. an entity's direct emissions. Sector classification following NACE level 1 revision 2. "Manuf." is manufacturing, "Prim. prod." is primary production, "Constr." is construction and "Hosp." is hospitality. Primary production refers to agriculture, forestry and fishing as well as mining and quarrying.

A substantial proportion of corporate carbon emissions in the euro area is financed by a limited number of banks, pointing to a concentration of climate-related credit risks. A subset of banks bears substantial transition risk in their loan

[36] Note that emissions from buildings are considered across NACE codes and not specifically allocated to the construction sector, as they are not regarded as an economic activity of enterprises, which would be covered by the NACE industry classification.

[37] The weighted average carbon intensity (WACI) indicator shows the intensity of corporate carbon emissions (relative to corporate revenues), standardised by financial institutions' overall loan or securities portfolio.

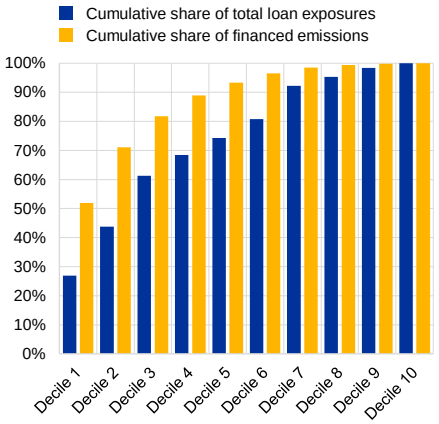
portfolios. Based on the sample of euro area significant institutions (SIs)[38], mainly consisting of global systemically important institutions and investment banks, only 10% of these banks (with the first decile corresponding to about ten banks, ordered by their weighted average carbon footprint) finance about 50% of the total carbon emissions of firms, while holding around 30% of total corporate loans in the euro area. This higher share of carbon emissions relative to their share of corporate loans indicates a concentration of financed emissions in the loan portfolios of a few banks (Chart 12, panel a). In addition, the trendline in Chart 12, panel b**)** shows that there is a positive relationship between banks' financed emissions and their share of loans to the top 25% of the highest emitting euro area firms. This suggests that banks with larger financed emissions hold portfolios that are slightly more inclined towards high-emitting firms, possibly indicating some specialisation of banks in lending to firms in high-emitting sectors.[39]

Chart 12

Concentration of carbon emissions in euro area banks' corporate loan portfolios

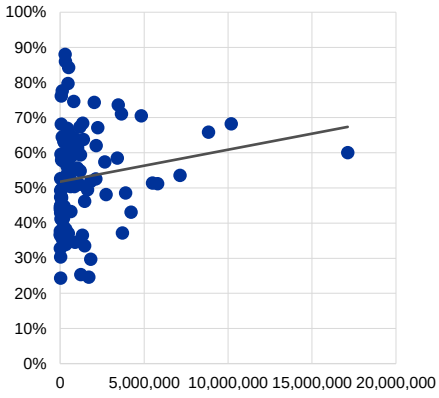
a) Cumulative share of loan exposures and financed emissions of euro area banks' corporate loan portfolios, by decile

(y-axis: cumulative shares in percentages; x-axis: deciles of banks ordered by their total financed emissions)



b) Correlation of financed emissions and share of highest emitters within loan portfolios, by bank

(y-axis: share of loan exposures to the top 25% of highest emitting firms; x-axis: total financed emissions in tonnes of CO_2)



Sources: ECB calculations based on Orbis, Urgentem and Anacredit (2022) data.
Notes: In Panel a), each data point on the x-axis represents the corresponding decile of banks' loan portfolios, ordered by banks' weighted average carbon footprint, which is defined as the average of debtor-level emissions weighted by debtors' loan exposures within each bank's loan portfolio. In panel b, each dot represents a bank. Sample of 105 SIs in the euro area presented. The grey line corresponds to the linear trendline. Emissions refer to absolute Scope 1, 2 and 3 CO_2 emissions using the 2023 economy-wide climate stress test data. Firms are considered to be high emitters if their absolute emission levels in tonnes of carbon dioxide fall within the top twenty-fifth percentile of the distribution of absolute emissions for the entire sample of firms borrowing from euro area banks.

3.1.2 Financing the green transition via financial markets and non-banks

Capital markets play a crucial role in the green transition at the global level by mobilising and allocating financing, thus complementing bank lending and

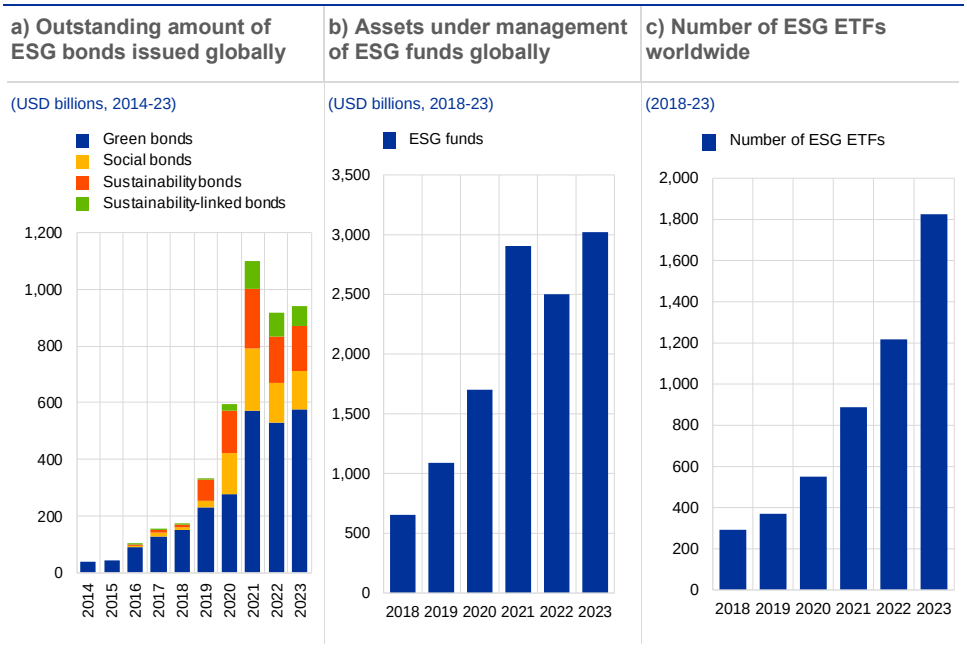
[38] Significant institutions refer to the list of banks under direct supervision of the Single Supervisory Mechanism. The full list can be found via this link.

[39] Evidence shows that more than 60% of banks' interest income is derived from NFCs operating in carbon-intensive sectors (SSM, 2022). Furthermore, Blickle et al. (2023) show that banks specialise their loan portfolios in certain industries, mainly to obtain informational advantages in assessing credit risk.

public funding. In this sense, the size of green financial markets is a key indicator of the extent to which financial markets support the transition to a low-carbon economy. In recent years, green capital markets have experienced rapid growth globally, with the outstanding amounts of sustainable debt securities issued globally increasing sixfold since 2018. This growth accelerated following the pandemic, but has recently stagnated (Chart 13, panel a). Furthermore, globally, the assets under management of investment funds and institutional investors with explicit green or sustainable mandates have experienced similar growth since 2018 (Chart 13, panel b), fuelled by an increase in the number of financial institutions committing to net-zero targets. However, recent withdrawals by several major institutions from private sector-led net-zero initiatives highlight the challenges in sustaining collective momentum, particularly in the face of increasing concerns over greenwashing. Similarly, the recent growth in the number of environmental, social and governance (ESG) exchanged-traded funds (ETFs) globally (Chart 13, panel c) has been driven by the proliferation of ESG market indices, including from MSCI, FTSE, S&P and Euronext. This expansion has facilitated individual investors' access to green financial markets but has also increased the complexity of ESG markets, as the diversity of available products and the varying methodologies may complicate investors' ability to assess the alignment of these financial instruments with their specific ESG objectives.

Chart 13

Growth of green finance since 2018P



Sources: Bloomberg and ECB calculations.

At the euro area level, despite the robust growth in green and sustainable financing, sustainable markets still account for only 10% of the euro area investment fund sector and less than 7% of outstanding bonds. Maintaining the momentum and increasing the total amount of green finance requires a strengthening of capital markets in Europe to help channel investments towards

green projects (see discussion in Chapter 5). In parallel, financial markets are designing new products, such as blue bonds to protect marine areas and other instruments to incentivise sustainable investments. To help counter the risk of greenwashing in the sustainable finance sphere, it is important to ensure consistent disclosure requirements, the Taxonomy[40] alignment of green investment and consistent standards for green bonds and ESG investment funds.[41]

In the euro area, sustainable debt securities have more than doubled in the last three years. ECB data[42] show that green and social projects have registered significant growth, while sustainability-linked bonds have recorded the highest relative increase, despite challenges associated with a perceived lack of credible sustainability performance indicators and targets (Chart 14, panel a). Similarly, since 2021, holdings of sustainable debt securities in the euro area have grown steadily, with local investors favouring euro area issuances. As a whole, the euro area is a net buyer of sustainable finance instruments, i.e. its holdings outperform its issuances. At the country level, France and Germany are the top issuers, and together account for more than half of the market. While governments, financial institutions and corporations lead in terms of issuances (Chart 14, panel b), institutional investors such as investment funds, insurance corporations and pension funds are the primary holders. Most green bonds held across sectors have obtained a second party opinion[43], reflecting strong market demand for validated sustainability claims.

40 Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 (OJ L 198, 22.6.2020, p. 13).

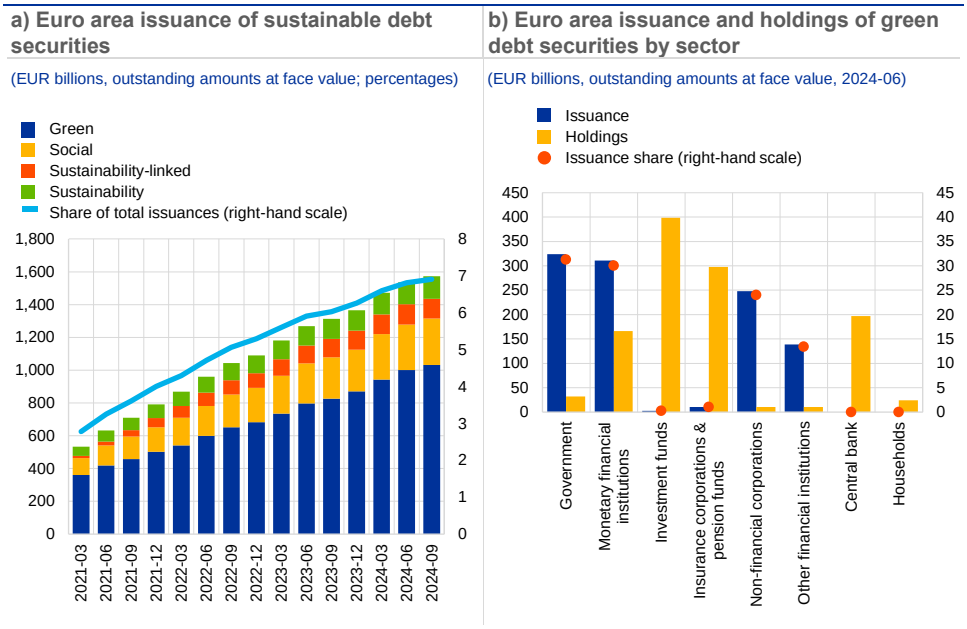
41 This is also discussed in Chapter 5. See also Section 4.2.2.2, European Central Bank and European Systemic Risk Board (2023). ESG stands for “environmental, social and governance”.

42 See the experimental indicators on sustainable finance published on the ECB website and European Central Bank (2024b) for a detailed explanation of these indicators.

43 The validation is supposed to be carried out by independent, external reviewers that check the alignment of labelled green bonds with international standards and the expected contribution of the financed projects to climate outcomes.

Chart 14

Sustainable debt landscape in the euro area



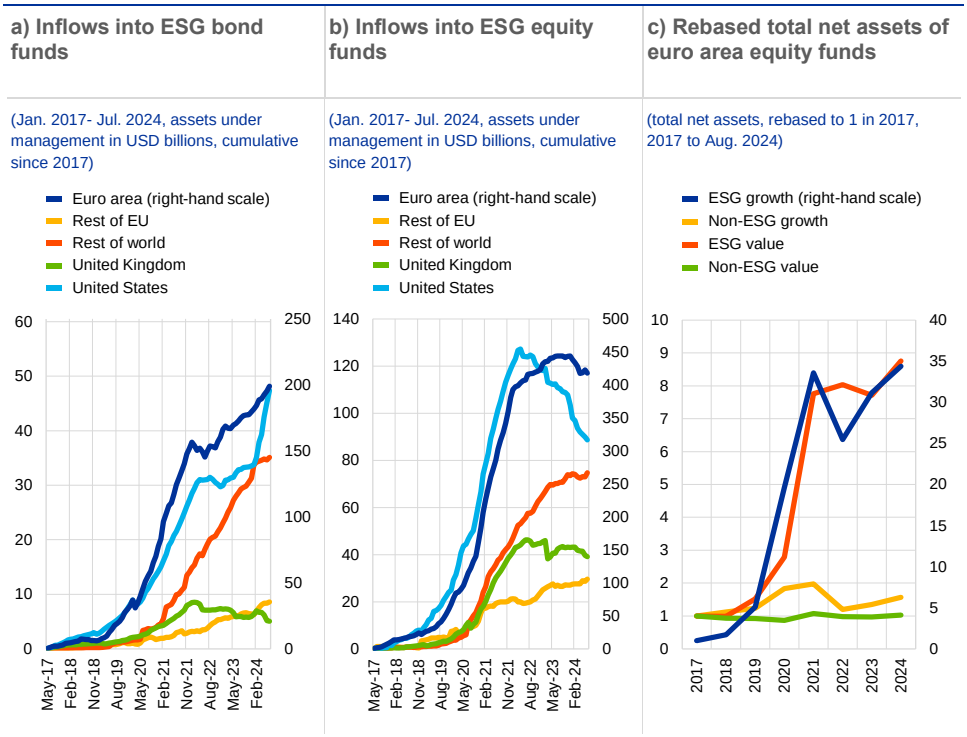
Sources: Centralised Securities Database, Securities Holdings Statistics and ECB.
Notes: In panel a), "Share of total issuances" refers to all sustainable securities as a proportion of all debt securities issued in the euro area. In panel b), "Issuance share" refers to all green debt securities as a proportion of all green debt securities issued in the euro area.

Euro area investors have pivoted towards ESG funds, particularly since the announcement of the European Green Deal in 2019. Cumulative inflows into bonds and, in particular, equity ESG funds have outpaced the growth of such inflows in other jurisdictions (Chart 15, panel a and panel b) and proven more resilient than other types of funds.[44] Since 2017, the assets of ESG growth funds, which mainly invest in young, innovative companies, have grown much faster than those of non-ESG growth funds (Chart 15, panel c). The gradual wealth transfer to millennials and increasing investor awareness of climate change and related policies, particularly among those with long-term investment horizons, are expected to support capital flows towards ESG funds in the future. However, in the first half of 2024, ESG equity funds in the euro area experienced net outflows, mirroring a trend that began earlier in the United States. These outflows were primarily driven by political uncertainty and shifts in portfolio allocations based on changing return expectations.

44 See Capota et al. (2023).

Chart 15

Cumulative inflows into ESG funds by jurisdiction and euro area ESG growth funds



Sources: Economic Policy Forum (EPFR) and ECB calculations.
Note: The chart in panel c) is based on a representative sample of euro area equity funds in EPFR's Flow and Allocation data.

Private equity markets, which play an important role in funding and scaling up innovation, have grown rapidly in recent years, albeit from low levels.[45] Private markets can benefit future economic growth by financing smaller, riskier and innovative firms. In particular, the equity segment of private markets − venture capital, for instance – is playing an important role in funding the innovation essential for the green transition. Data from data provider PitchBook show that growth in private impact investment funds[46] has more than doubled globally in the last five years, with the United States accounting for almost half of this growth in terms of assets under management (Chart 16, panel a). In the EU, private equity makes up 34.5% of capital raised in the past decade by funds categorised as supporting the green transition (Article 8 of the Sustainable Finance Disclosure Requirements)[47], while private debt funds account for around 17% (Chart 16, panel b). Real assets funds (e.g. infrastructure) and real estate funds have garnered almost 45% of commitments to EU-domiciled Article 8, as this asset class attracts a host of investors looking to capitalise on ESG-related opportunities in the energy transition and ESG-compliant construction.

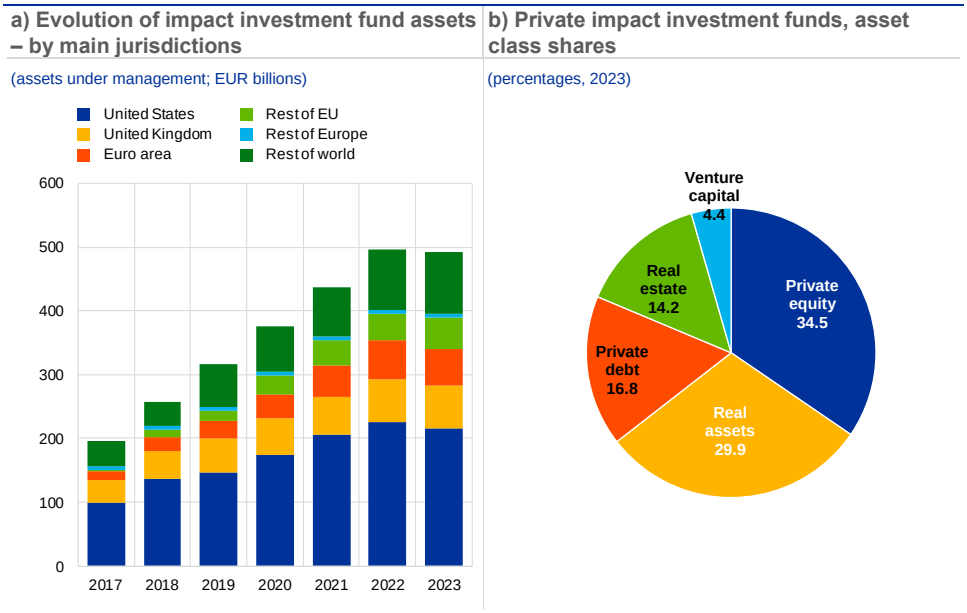
45 See Cera et al. (2024).

46 Private impact investment funds are a type of private fund that pools money from multiple investors to invest in ventures with the goal of generating both financial returns and positive social or environmental impacts.

47 The definition of an Article 8 fund in the Sustainable Finance Disclosure Requirements (SFDR) is "a fund which promotes, among other characteristics, environmental or social characteristics, or a combination of those characteristics, provided that the companies in which the investments are made follow good governance practices".

Chart 16

Private market ESG and impact investment



Sources: Pitchbook and ECB calculations.
Notes: In panel a), the assets under management of a private fund include the net asset value (NAV) of the fund's portfolio and its "dry powder", i.e. its committed, but not yet called, capital.

3.2 Bank lending conditions for financing green investment

3.2.1 Credit supply

While low-emitting firms and firms in transition appear to receive a climate discount in their bank lending conditions, credit standards for high carbon emitters are tighter and they are charged higher lending rates. The availability of bank loans and the conditions under which banks are willing to lend play an important role in the transition towards a greener economy, especially in the light of the bank-based euro area financial structure. Banks have indicated in the euro area BLS that climate change has a net easing effect on their credit standards (i.e. banks' internal guidelines and loan approval criteria) for loans to low-emitting firms and firms in transition (Chart 17, panel a).[48] In fact, banks appear to apply a "climate discount" on the general credit risk premium to low-emitting firms and firms in transition. Firms in transition are an important group of firms for the green transition, as they are likely to engage in green investment. At the same time, climate change has a net tightening effect on loans to high-emitting firms. This suggests that banks charge a

[48] See the euro area bank lending survey, especially European Central Bank (2023a and 2024c). Based on an annual question, banks reported in the July 2023 and July 2024 BLS the impact of climate change on their credit standards, terms and conditions and loan demand from firms. The BLS distinguishes firms based on their carbon emissions. "Green firms" (low-emitting firms) are defined as firms that do not contribute at all or do not contribute significantly to climate change, "firms in transition" as firms that contribute to climate change but are making considerable progress in the transition and "brown firms" (high-emitting firms) as firms that contribute significantly to climate change and have not yet started the transition or have made little progress.

climate risk premium when lending to high-emitting firms, on top of a general credit risk premium based on the business situation and outlook of the firms. Some high-emitting firms may have so far postponed green investment due to technological or political uncertainty, as well as limited financial or managerial capacity to manage the transition.[49] Any delay in the green transition may lead banks to question the business model of these firms, especially if they have not yet started to plan the transition but belong to sectors with high transition needs, and may also lead to rejections of loan applications.

Monetary policy rate hikes have led to tighter bank lending conditions, especially for high carbon emitters, which are charged a climate-related risk premium (Chart 17, panel a). In an environment of inflation above the ECB target and key ECB interest rate hikes, bank credit standards for euro area firms tightened substantially in 2022-23, leading to a considerable weakening in lending volumes.[50] Lending conditions have been tightened more for high-emitting firms than for other firms, as banks charge a premium for the higher climate risk. This suggests the existence of a climate-related risk-taking channel in bank lending policies. BLS banks' climate-related responses are consistent with bank-firm level analysis by Altavilla et al. (2023) of banks charging higher lending rates for high-emitting firms and lower lending rates for low-emitting firms and for firms with a decarbonisation strategy, when controlling for firms' general default risk.[51] The paper also provides evidence of a stronger monetary policy tightening effect, leading to a more pronounced reduction in lending for high carbon emitters compared with low carbon emitters. A lower credit risk premium related to lower carbon emission intensity of firms is also found in studies of the syndicated loan market.[52]

The impact of climate change on bank lending conditions is likely to increase over time, as banks have to further adjust their risk management with a view to climate risks. As firms increasingly disclose their climate transition plans and corporate sustainability reporting requirements, banks will be able to reduce information asymmetries and distinguish the climate risks of firms in greater detail. At the same time, the complexity of sustainable finance legislation and a potential lack of enforcement may limit the intended positive impact of greater transparency (Chapter 5). In addition, banks that meet the criteria of the European Banking Authority on Pillar 3 disclosures of ESG risks have been required to disclose these risks since 2023 (since 2024 for some indicators), with data as of the end of the previous year. They are also required by ECB Banking Supervision to incorporate climate-related and environmental (C&E) risks in their risk management framework by the end of 2024.[53] Against this background, banks have reported in the BLS that they expect the impact of climate change on bank lending conditions to increase

---

49 See European Investment Bank (2024a) and Costa et al. (2024).

50 Changes in credit standards are closely correlated with actual growth in loans to euro area firms, leading actual loan growth by around five to six quarters. See Hünnekes and Köhler-Ulbrich (2022).

51 See Altavilla et al. (2023). The authors find that the spread charged by banks on loans to firms in reaction to monetary policy tightening of 25 basis points reaches 39 basis points after one year. For high-emitting firms, they find an additional immediate spread increase of 2 basis points, decreasing to 1 basis point after one year. For low-emitting firms, the spread increase in reaction to monetary policy tightening is reduced by 5 basis points on impact and 9 basis points after one year.

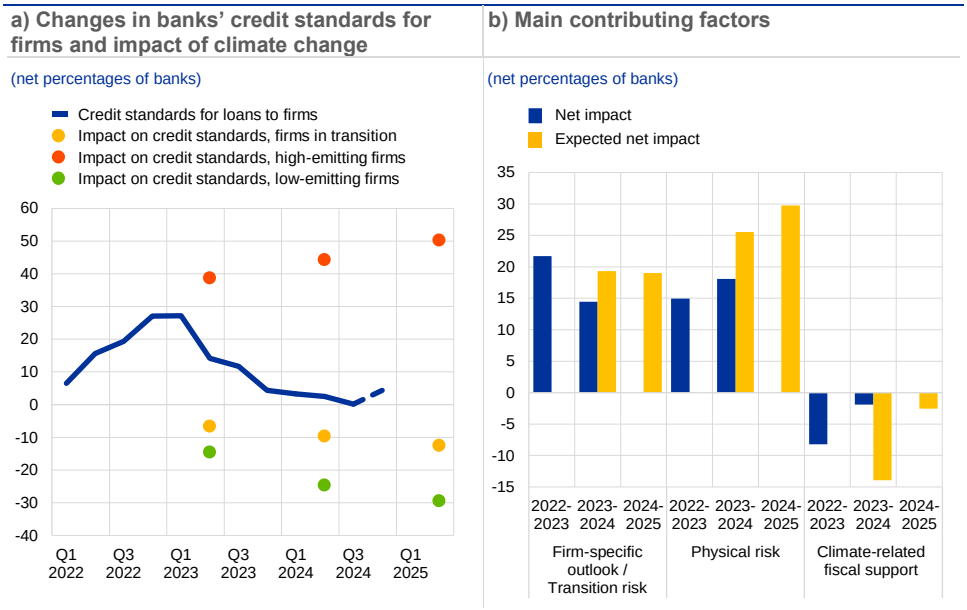
52 See Ehlers et al. (2022), D'Arcangelo et al. (2023) and Kleimeier and Viehs (2018).

53 See European Central Bank (2023b).

over time. At the current stage, there is still a substantial misalignment between banks' actual corporate loan portfolios and net-zero-aligned corporate loan portfolios.[54] Moreover, the evidence is mixed on whether the explicit climate commitments of banks in their financial statements have an effect on actual lending, compared with banks that do not make such commitments.[55]

Chart 17

Impact of climate change on bank lending conditions for euro area firms



Sources: ECB (BLS) and ECB calculations.
Notes: In panel a), net percentages are defined as the difference between the percentages of banks reporting a tightening of credit standards (blue line) or a tightening impact of climate change (dots) and the percentages of banks reporting an easing or easing impact. The solid line refers to actual values over the past three months, while the dashed part of the line refers to banks' expectations over the next three months. The dots refer to actual values in the past 12 months, except for the last dot, which refers to banks' expectations for the next 12 months. Panel b) shows the main factors that contribute, according to the banks, to an easing (negative values) or tightening (positive values) impact of climate change on bank lending conditions for firms. Each period starts in the third quarter and ends in the second quarter of the following year. The blue bars show actual values in the past 12 months, while the yellow bars refer to the expected net tightening impact reported by banks for the respective period, which they indicated 12 months ago.

Transition risk affecting the firm-specific situation and outlook is a relevant tightening factor for banks when deciding on loan approvals and lending conditions for firms in response to climate risks (Chart 17, panel b). The extent to which firms have to invest in climate change differs considerably across economic sectors (Chapter 2). In addition, financing innovative green technologies often entails higher uncertainty regarding the return on investment of green projects and may require high upfront investment volumes to be financed. This increases the credit risk premium for transition financing, as indicated by the net tightening impact of climate risks on bank credit standards related to the firm-specific situation and outlook. In addition, firms that fall short in their decarbonisation progress are likely to face a higher default risk in the medium term, a factor that banks must consider in their risk management. The physical risk of firms, which affects the value of collateral and the company value more generally, is also a relevant factor that banks take into account

54 See European Central Bank (2024a) and Section 3.1.1 above.

55 See Sastry et al. (2023), Giannetti et al. (2023), Altavilla et al. (2023), Gambacorta et al. (2023) and Reghezza et al. (2021).

in their lending policies and is expected by banks to play an increasing role in the future.[56]

Climate-related fiscal support improves the chances of loan approval and mitigates the financing costs for firms managing the green transition, but the beneficial impact was substantially lower in 2024 than expected by banks one year ago (Chart 17, panel b).[57] The lower exposure to financial and credit risks for firms and banks in financing green investment helps to support the green transition. Following a substantial easing impact of climate-related fiscal support reported by banks with regard to their lending policies in 2022-23, the easing impact became comparatively small in 2023-24, much smaller than expected by banks one year ago, and is expected to remain small in 2024-25. This may be partly related to the unwinding of fiscal support measures and the expectation of further fiscal tightening (Chapter 4).

Euro area credit register data confirm that harmonised action across policy areas may be conducive to an accelerated climate transition, as the higher interest rates imposed by banks on more polluting firms are even higher in countries and sectors with higher levels of policy stringency.[58] Complementing the survey-based evidence from the BLS and Altavilla et al. (2023), additional data indicate that the policy dimension of transition risk is relevant and affects the loan pricing decisions of banks. Transition risks are a function of both regulatory and country-specific policy efforts to reduce emissions, as well as firms' exposure to such actions. The banks are responding to climate-related policies by incorporating transition risk into their loan pricing decisions, leading to higher (bank) borrowing costs for more polluting firms. Two results stand out: first, firm-level analysis shows that the (unconditional) effect of carbon emissions on loan spreads is economically substantial. Second, incorporating the country-level policy dimension shows that this effect is driven by firms located in countries with stringent policies and loans issued after the adoption of the Paris Agreement[59]. All other things being equal, a high-emitting firm in a country in the top tenth percentile of policy stringency pays loan spreads that are 30 basis points higher than a similar firm in a country in the bottom tenth percentile.

---

56 Physical risk refers to the risk related to the financial impact of banks' exposure to a changing climate, including more frequent extreme weather events and gradual climate changes, as well as the impact of environmental degradation, which may affect the value of collateral and the repayment capacity of borrowers.

57 For the favourable impact of fiscal support on bank lending conditions, see also Faccia et al. (2024), Buchetti et al. (2024) and Altavilla et al. (2023).

58 Based on Fuchs, M. and Spaggiari, M., "Climate Policy Action and the Pricing of Bank Loans", Working Paper (draft). Two indicators of climate policy action are considered. The first is the climate change performance index provided by Germanwatch (2023), which tracks emission reduction efforts by country. The second is an indicator computed on the basis of the comprehensive OECD Climate Actions and Policies Measurement Framework, which distinguishes between market-based and non-market-based sectoral, cross-sectoral and international policies. The sectors included are electricity, transport, buildings and industry. See Nachtigall et al. (2022).

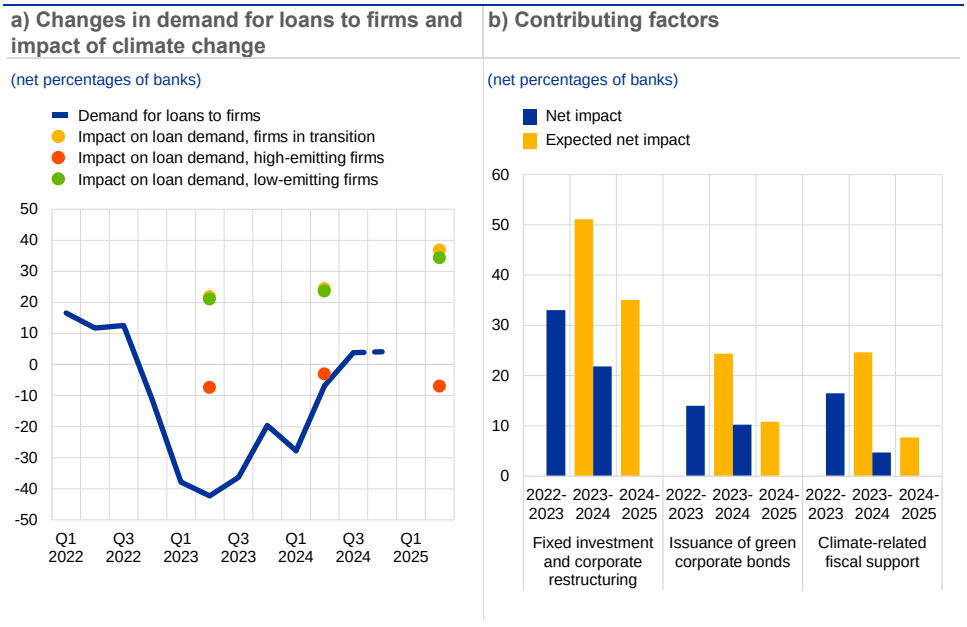
59 The Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCCC).

3.2.2 Credit demand

Climate risks fuel bank loan demand on the part of low-emitting firms and firms in transition, especially for the purpose of green investment (Chart 18, panel a). Climate change has a positive impact on loan demand from low-emitting firms and firms in transition to decarbonising their business, according to the BLS. By contrast, the BLS points to a negative impact of climate change on loan demand from high-emitting firms, which have not yet started or have so far not made much progress with the transition. The most important reason for loan demand from firms in response to climate change are financing needs for fixed investment related to climate change (Chart 18, panel b).[60] While this impact has been substantial, banks had expected an even higher positive impact in net terms. The main reason for this shortfall has to be seen in the context of weak loan demand and subdued lending to firms from mid-2022 until 2024.[61] The issuance of green corporate bonds has also made a positive contribution to climate-related loan demand according to the banks, suggesting a positive complementary relationship between these two financing sources.

Chart 18

Impact of climate change on demand for bank loans to euro area firms



Sources: ECB (BLS) and ECB calculations.
Notes: In panel a), net percentages are defined as the difference between the percentages of banks reporting an increase in loan demand (blue line) or a positive impact of climate change on loan demand (dots) and the percentages of banks reporting a decrease or negative impact. The solid line refers to actual values in the past three months, while the dashed part of the line refers to banks' expectations for the next three months. The dots refer to actual values in the past 12 months, except for the last dot, which refers to banks' expectations for the next 12 months. Panel b) shows the factors that contribute, according to the banks, to the impact of climate change on bank loan demand from firms. Each period starts in the third quarter and ends in the second quarter of the following year. The blue bars show actual values in the past 12 months, while the yellow bars refer to the expected net impact reported by banks for the respective period, which they indicated 12 months ago.

60 The BLS factor, "Fixed investment and corporate restructuring related to climate change", refers to both decarbonising the business of firms and reducing physical risk.

61 Loan demand is closely correlated with actual growth in loans to euro area firms, leading actual loan growth by around three quarters (see Hünnekes and Köhler-Ulbrich, 2022).

The impact of climate-related fiscal support remained positive in 2023-24, albeit less than in the previous survey period and also less than expected by banks a year ago. As mentioned above, this may be due to the unwinding of fiscal measures (Chapter 4). In addition, technological and policy uncertainty and financial and managerial capacity, including possible knowledge gaps, may delay the demand for green investment financing.[62] Overall, the positive impact of climate change on loan demand, driven in particular by financing needs for fixed investment related to climate change, helps to cover the substantial green investment needs (Chapter 2). Banks expect the positive impact of climate change on firms' loan demand to increase in the next 12 months, also supported by the positive impact of climate-related fiscal support (Chapter 4).

3.3 How do firms assess their transition towards net zero?

3.3.1 Relative importance of financing instruments for the green transition

In addition to the important role of bank loans, firms also report non-bank financing sources as relevant for financing green investment (Chart 19). In line with the evidence presented above, firms have reported in the SAFE that bank loans, including loans benefiting from fiscal support, are the most relevant source of financing for their business in general (blue bars).[63,64] Specifically, for green transition-related investment purposes (green bars), a large proportion of firms plan to use loans in combination with fiscal support schemes (36%), compared with loans without fiscal support (26%), suggesting that firms expect substantial public support for the green transition (Chapter 4). Plans to use loans with fiscal support are more often reported by SMEs than large firms, as fiscal support measures are often targeted at SMEs. At the same time, large firms report a higher proportion of retained earnings (49%) allocated to green investment. Looking at the difference between the use of each instrument as a proportion of firms' overall investment activity in recent years (yellow bars) and firms' plans to use them for green investment may provide some indications of specific features of their green investment financing structure. For instance, the SAFE results suggest that the availability of fiscal support measures is considered much more important for green investment projects than for firms' overall investment activities.

---

62 See EIB (2024a) and Costa et al. (2024).

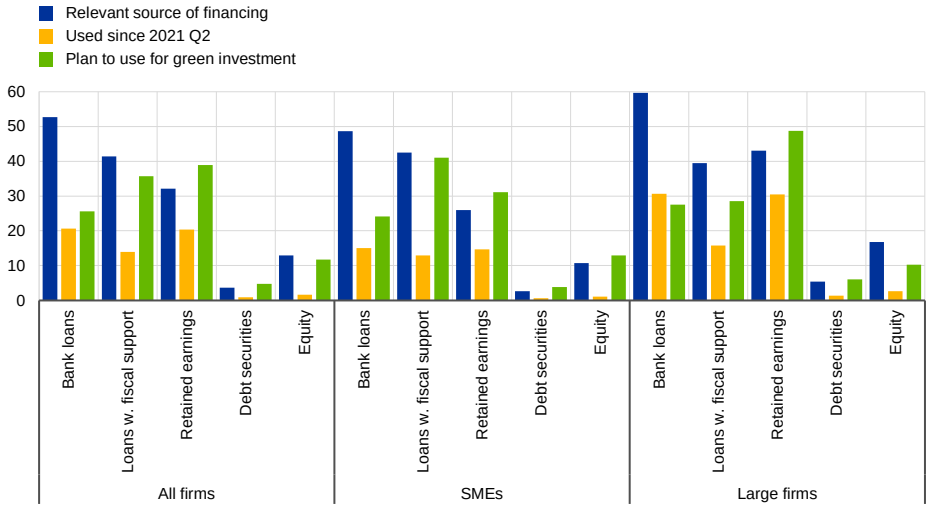
63 In the second quarter of 2023, the SAFE added specific ad hoc questions on the impact of climate change on euro area firms, including questions on the various financing sources they used or planned to use to fund climate change-related investments (see Ferrando, Gross and Rariga, 2023). The SAFE pilot round included a smaller sample of euro area firms than the regular survey. The sample was chosen using a stratified random sampling by country, size class and economic activity, to keep it representative of the population of euro area firms. The total sample size was 5,733 firms, of which 5,233 (91%) were SMEs (with fewer than 250 employees).

64 Accetturo et al. (2024) find a large positive elasticity of green investments to credit supply, which is concentrated among larger, older, more liquid and more profitable firms that are less likely to be financially constrained.

Chart 19

Use of financing sources for firms planning to invest in the green transition

(percentages)



Sources: ECB and European Commission SAFE and ECB calculations.
Notes: The blue bars show the proportion of firms in the SAFE that consider certain types of financing relevant for their overall investment activity (have used them in the past or consider using them in the future). The yellow bars show the proportion of firms that have used a certain type of finance in their investment activity since the second quarter of 2021. The green bars show the proportion of firms that plan to use certain types of financing for investment in the green transition in the next five years.

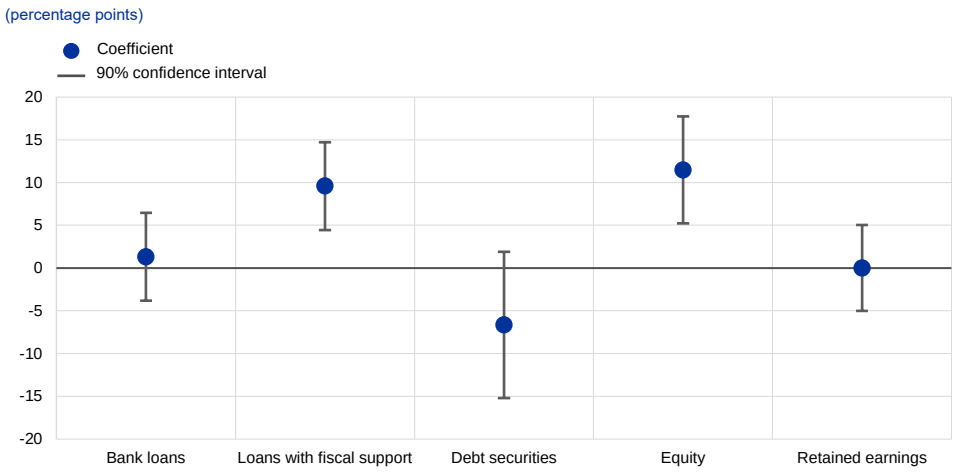
Loans benefiting from fiscal support measures and equity financing are expected to have a positive impact on investment in the green transition (Chart 20). Firm-level reduced-form regressions investigating the joint impact of the sources of finance on planned investment to reduce the carbon emissions of firms over the next five years indicate that the use of loans combined with fiscal support and equity increases the investment probability by 10 percentage points and 12 percentage points, respectively.[65] In addition, the results reveal that bank loans offered under less attractive conditions and retained earnings do not significantly impact medium-term investment plans when combined with the availability of loans benefiting from public support or equity financing.[66]

65 Bacchiocchi et al. (2024) and Bouchmel et al. (2024) analyse data from European companies to understand the factors that influence green investments and emphasise the importance of both internal financial resources and external financial support, such as subsidies, for their green investments.

66 Cecere et al. (2018) show that access to public funds and fiscal incentives is effective in improving a firm's ability to introduce eco-innovations, and that public funding is perceived by firms as complementary to other external sources of finance.

Chart 20

Impact of sources of finance on funding the green transition



Sources: ECB and European Commission SAFE and ECB calculations.
Notes: Regression coefficients for sources of financing for euro area enterprises on planned investment related to climate transition. The dummy variables of subsidised loans, non-subsidised loans, debt securities, equity and retained earnings take a value of 1 if the firm indicates that it plans to use these sources of financing for green transition. The dependent variable is a dummy variable that takes a value of 1 if firms plan to invest within the next five years in mitigating the risk of their own negative environmental impact and 0 if the firms do not plan to invest. The regression covers size, time, industry and location fixed effects on the NUTS1 level. The whiskers represent 90% confidence intervals.

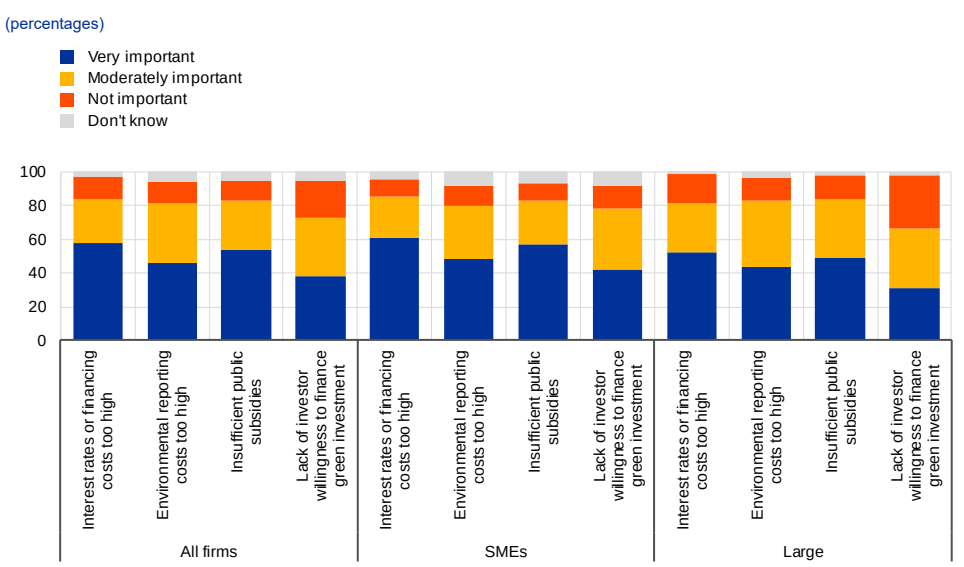
3.3.2 Obstacles and drivers for green investment from the perspective of firms

Firms have identified high interest rates and financing costs and insufficient public subsidies, amongst other factors, as the biggest obstacles to accessing finance for future green investment (Chart 21). More than half of the firms that took part in the SAFE ad hoc round on climate impacts in the second quarter of 2023 identified too high interest rates or financing costs and insufficient public subsidies as being major obstacles to their planned investment in green transition in the next five years.[67] This evidence is broadly in line with the dampening impact reported by banks in the BLS of the level of interest rates on loan demand in the corresponding period and the positive impact of climate-related public support, if available (**Section 3.2**). Firms may consider the costs of green investment to be high, as they might not be sufficiently internalising the benefits of addressing climate change risks. Too high environmental reporting costs were also cited as a major obstacle by 45% of firms, whereas 37% of firms regarded the lack of investors' willingness to finance green investment as a very important concern. For SMEs, all obstacles to securing financing for investment are of greater concern than for large firms.

67 This is higher than in the EPO/EIB Cleantech Survey (2024), in which more than 30% of the EU companies reported that access to finance is as a major obstacle to investment in cleantech innovations. The survey also stressed that SMEs in particular see this as an obstacle, as they find it harder to secure financing.

Chart 21

Obstacles to securing financing for planned investment for climate transition



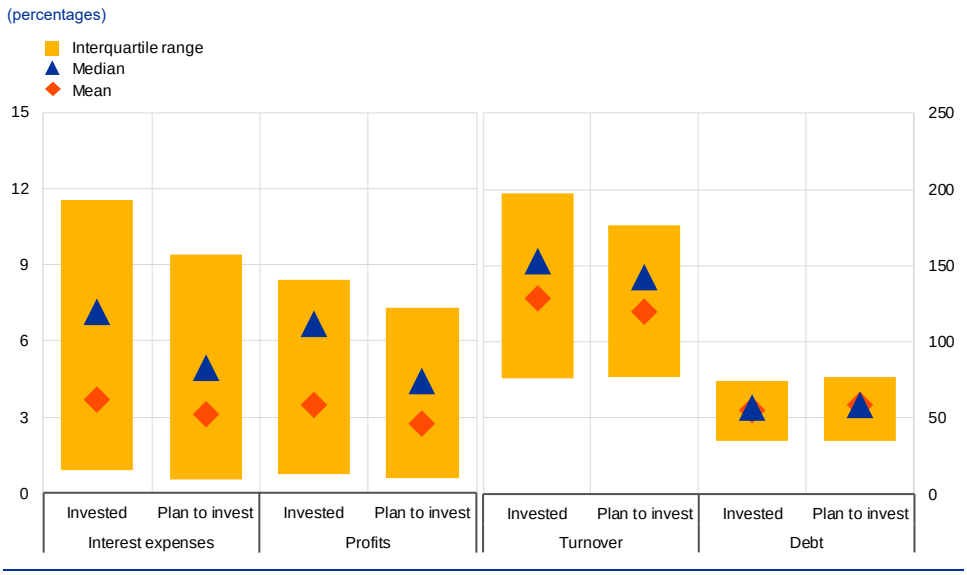
Sources: ECB and European Commission SAFE and ECB calculations.
Notes: Firms were asked to indicate how important the obstacles are to securing financing for planned investment over the next five years to comply with stricter climate standards on a scale of 1 (not at all important) to 10 (extremely important). On the chart, the scale has been divided into three categories: not important (1-3), moderately important (4-6) and very important (7-10).

Firms that have already invested in their green transition are slightly outperforming those still planning to invest in the next five years according to different measures of financial strength (Chart 22). The progress made by firms with investment in the green transition can be linked to firm characteristics. At the firm level, survey responses on investments in the green transition can be matched with the financial statements to define a profile of the firm's ability to generate funds or repay its debts.[68] Chart 22 shows that median turnover and profitability are slightly lower for firms that plan to invest in the green transition in the next five years compared with firms that have already invested. In terms of the financing situation, the median firm planning to invest has a broadly similar debt-to-assets ratio, but faces lower interest expenditures, measured as a share of profits, than the median of the sub-group of firms that have already invested. The chart also shows significant heterogeneities within the sub-groups of firms that have already invested and those that still plan to invest in the green transition. For average interest expenses (relative to profits), turnover and profits, the distribution is more widespread for firms that have invested, relative to those that plan to invest. By contrast, there are no significant differences in terms of sector, size or age between firms that are planning green investments and firms that have already invested.

[68] A proprietary ECB database that matches surveyed firms with balance sheet and profit/loss accounts information taken from the Orbis database.

Chart 22

Firms' financial strength and green investment



Sources: ECB, European Commission SAFE and BvD Orbis and ECB calculations.
Notes: Median, mean and interquartile ranges for financial ratios for firms that plan to invest and those have already invested. Interest expenses are measured as total interest paid over profits before tax; profits are measured as net income over sales; turnover is defined as sales over total assets; and debt is defined as total debt over total assets. These ratios are measured based on balance sheet data for 2021, the latest available observation date.

High-emitting firms are accelerating their green investment activities, particularly large firms (Chart 23). The carbon intensity of firms, grouped into high-emitting and low-emitting sectors, shows substantial differences in their investment activity and plans to reduce their carbon emissions. While most large firms in high-emitting sectors[69] have already invested in the last five years or at least plan to invest in the green transition, fewer than 50% of SMEs invested in the same period. Around 30% of high-polluting SMEs indicate that they do not have investment plans in place to reduce their environmental footprint, potentially as a result of the obstacles they face, as reported in Chart 21. Nevertheless, for large firms and SMEs in high-emitting sectors, the analysis reveals that the proportion of firms planning to invest in the next five years is higher than the proportion of firms in the low-emitting sectors, supporting their substantial investment needs.[70]

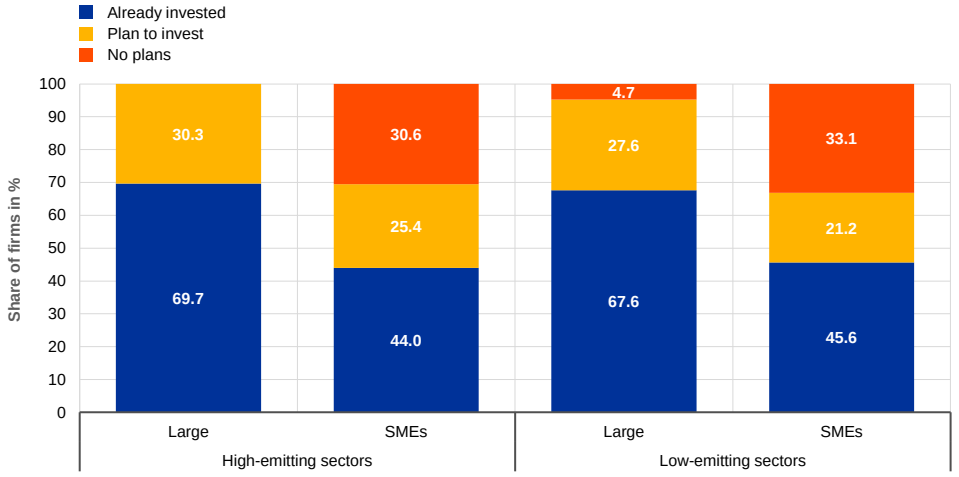
69 High-emitting sectors are classified as such if their sector average Scope 1 and 2 carbon emissions over revenues is higher than the seventy-fifth percentile of the cross-sectional distribution.

70 De Hass and Popov (2023) find that CO2 emissions per unit of value-added decline with stock market development, especially in carbon-intensive sectors.

Chart 23

Green investment activity by sector greenness

(percentages)



Sources: ECB and European Commission SAFE, Urgentum and ECB calculations.
Notes: Firms are classified as high-emitting if their NACE-4 sector average carbon intensity (Co2/Rev) is higher than the seventy-fifth percentile of the cross-sectoral distribution, and are otherwise classified as low-emitting. The sector carbon intensity is defined by their 2021 reported Scope 1 and Scope 2 emissions over revenue (tCO2/USD millions of revenue).

4 The role of the public sector as a catalyst to unlock private capital

The public sector has to complement private finance in the green transition. Public gross fixed capital formation amounts to around 16% of total investment in the EU (2023), which corresponds to 3.5% of 2023 EU GDP, albeit with substantial heterogeneity by country. Given the sizeable investment needs that have to be met within a short period for the green transition, stronger public support is warranted to complement private funding. Moreover, green investments may be particularly exposed to high levels of uncertainty related to potential failures of new green technologies and innovations, supply chain disruptions and unforeseen changes in regulatory and policy frameworks, all of which increase risks for banks and financial investors. Public sector support could thus help to de-risk the green investment activities of the private sector and mobilise private funding. The preferred extent of public sector engagement in green investment depends on various factors, including the sectoral composition of green investment needs, the maturity of the available technologies, market conditions, access to finance, geographic location, national preferences and available fiscal space.

The public sector can support the green transition by several means. Public sector support can be provided either directly via green public investment, or indirectly in form of subsidies, public loans, tax credits and guarantees. In view of the limited fiscal space, the available public resources have to be used in the most efficient way, and should focus on areas with the highest potential in order to crowd in private investment. Direct public support should focus on clearly defined areas with network effects, such as public transport, grid infrastructures and green research and development expenditure. Carbon pricing at both the EU and national levels generates funding revenues that can support the green transition. Moreover, ambitious carbon pricing and structural reforms are key to setting the right incentives for the private sector to accelerate and finance the green transition, as discussed in Chapter 5.

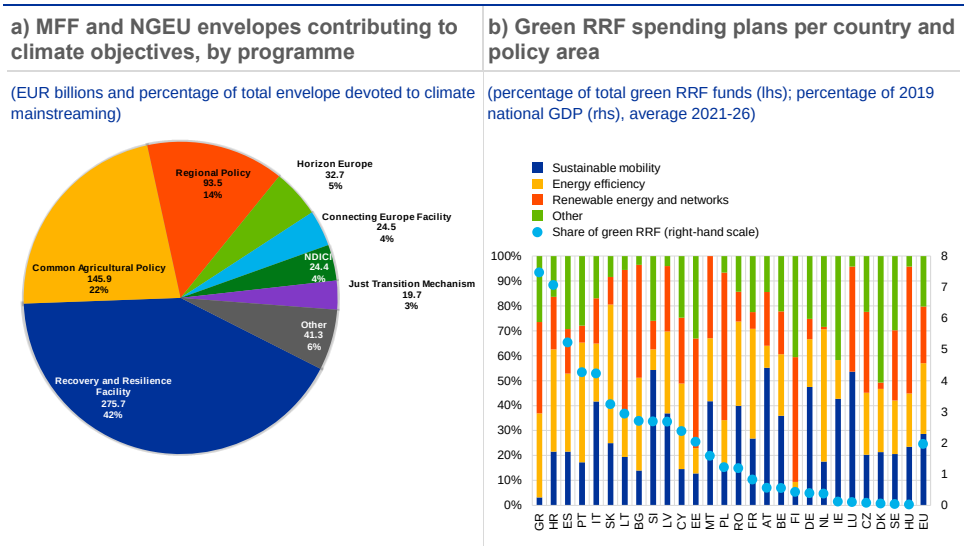
This chapter provides an overview of the available funding sources in the EU and discusses whether they will be sufficient to support the green transition. Based on a stylised exercise, we find that there will be a public funding gap of, on average, €20 billion per year as of 2025 until 2030. However, the gap is expected to vary over time. After the RRF expires at the end of 2026, this is expected to trigger a sizeable shortfall. Macroeconomic simulations suggest that green public investment may, if well-designed, act as a catalyst through the crowding-in of green private investment, while the feedback loops for public finances depend on the monetary policy response.

4.1 Public funding sources of green investment in the EU

To support the green transition, public funds are available at EU and national level, with the largest contribution coming from the RRF. At the EU level, climate is a key priority of the current 2021-27 budgetary period. At least 30% of the combined funds from the EU budget – the Multiannual Financial Framework (MFF) for the period 2021-27 – and NGEU (from 2021 to 2026) must contribute to climate objectives. In practice, the Commission has stated that a total of €658 billion will go towards supporting the climate objective in the period 2021 to 2027 in its overall green budgeting, as reported in the Programme Performance Statements.[71] The instrument that will make the largest contribution is the RRF, which is the centrepiece of NGEU (Chart 24, panel a). A substantial contribution is also expected from major programmes under the MFF, notably the Common Agricultural Policy and Regional Policy. However, the high number of facilities in the EU budget increases the risk of complexity, potentially hindering the effective deployment of funds.[72] EU countries are also funding the green transition at national level, although in proportions that vary across countries.

Chart 24

EU public funds available for the green transition



Sources: Panel a): Programme Performance Statements, Green Budgeting and ECB calculations. Panel b): European Commission, Eurostat and ECB calculations.
Notes: In panel a), the RRF is the centrepiece of NGEU. All other instruments are part of the MFF. NDICI stands for Neighbourhood, Development and International Cooperation Instrument – Global Europe. Facilities contributing less than €10 billion to climate mainstreaming are included in "Other". They comprise: InvestEU, European Social Fund+, the International Thermonuclear Experimental Reactor and the European Maritime Fisheries and Aquaculture Fund. The chart does not include the Innovation Fund, which also contributes to climate mainstreaming but is a special instrument outside the MFF. In panel b), the committed green RRF funds are decomposed by policy area (sustainable mobility, energy efficiency, renewable energy and other). The blue dots show the green RRF spending plans as a proportion of GDP. The latest observation is for June 2024.

71 See European Commission Programme Performance Statements, 2024.

72 As emphasised in Draghi (2024), the fragmentation of financing instruments at both the national and EU levels dilutes their impact. The report recommends streamlining these facilities to simplify governance, reducing unnecessary bureaucracy and fragmentation.

RRF funds committed to the climate objectives significantly exceed the target of at least 37% of total funds set out in the RRF regulation.[73] The minimum threshold of 37% that each EU country must spend on climate objectives corresponds to €240 billion in cumulative terms for the EU over the period 2021-2026.[74] In reality, in most countries the amounts committed on the climate objectives in the context of the RRF exceed this target level, reaching on average 42% of total RRF funds (around €275 billion). However, the proportion of climate spending commitments relative to the respective national RRF funds varies between countries, ranging from 69% in Luxembourg, Malta and Denmark to 37% in Lithuania. In GDP terms, Greece and Croatia are set to spend the biggest proportion, at around 7% each (Chart 24, panel b). Together with Spain, Italy and Portugal, these are also the countries with the largest total RRF envelope as a percentage of GDP. The main policy areas linked to green RRF spending plans, such as renewable energy, energy efficiency and sustainable mobility, vary considerably across countries.

RRF funds are an important source to mobilise private investment. The private sector is the largest recipient of RRF funds, amounting to at least 46% of RRF climate expenditure, the bulk of which is channelled to firms (43%). Most RRF funds can be expected to come in addition to what has already been planned, thereby providing a fiscal stimulus.[75] The support measures to firms mainly take the form of subsidies and tax credits that aim to promote green investments in areas such as energy infrastructure, electric company vehicle fleets, and more energy-efficient retrofitting of real estate. Furthermore, substantial parts of RRF expenditures (around 40%) are also used for direct government capital spending (Chart 25, panel a).[76]

For the time being, however, there is a considerable backlog in the absorption of RRF funds. Although the committed amounts exceed the minimum requirement, the absorption rate of climate-related RRF funds has so far been low. By mid-2024 , i.e. after the programme mid-term, only 20% (around €55 billion) of the RRF funds earmarked for climate had been disbursed.[77] Assuming the full take-up of the RRF funds allocated to the green transition by the end of the horizon, in total 80% (€220 billion) will still be available for spending by 2026 (Chart 25, panel b).[78] With an unchanged breakdown by policy area compared with the first three years, the biggest proportion of climate-related spending for 2024-26 would go to energy efficiency, followed by sustainable mobility and renewable energy and networks.

---

[73] However, the European Court of Auditors (2024b) argues in a recent report that the contribution from the RRF to the green transition may be overestimated. Arguments range from too-broad coverage of RRF-funded projects to the methodology used to track climate actions.

[74] The climate objectives include mostly measures that contribute to the green transition.

[75] Although a breakdown specifically for the climate objective is not available, the ESCB Working Group on Public Finance estimates that 81% of RRF-based expenditure in the euro area is additive in nature, i.e. it provides a genuine fiscal stimulus, rather than substituting already planned expenditure (see Bańkowski et al., 2024).

[76] These figures are based on ESCB calculations and only reflect euro area countries.

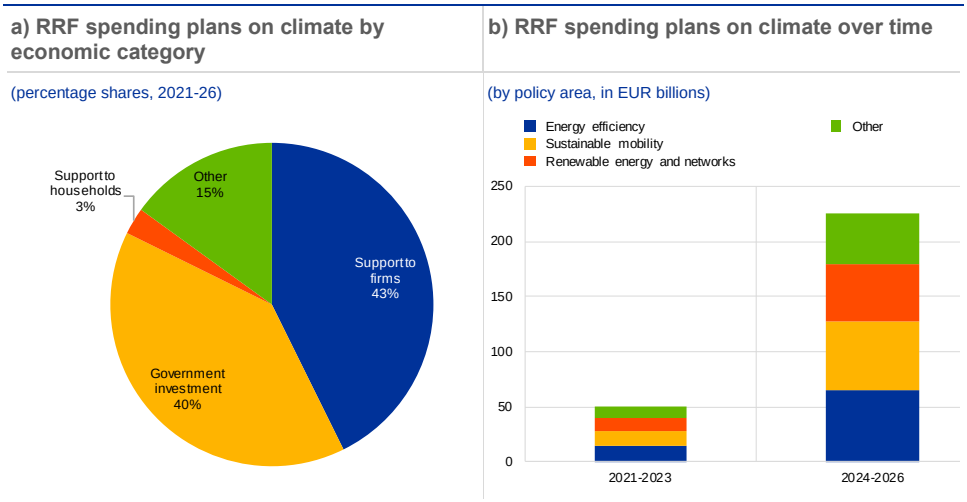
[77] These figures on the absorption rate only reflect the amounts disbursed after pre-defined milestones and targets had been met. Some of the funds may have been spent but have not yet been recorded. The figures account for the funds paid by the European Commission.

[78] The RRF spending plans cover the period 2021-26. Funds not requested by the end of 2026 will be lost, according to the RRF Regulation. However, according to a recent report by the European Court of Auditors, the timely absorption and completion of the measures is in question. See European Court of Auditors (2024c).

Several factors can explain the low absorption rate of RRF funds, which is also low compared with other EU funding programmes. For example, the more complex governance structure is likely to have played a role. The RRF is the EU's first major performance-based funding programme, which provides direct financial support upon the fulfilment of pre-defined milestones and targets. This process is more complex than the cost-based funding used in other EU programmes. Moreover, administrative capacity at national level might have created a bottleneck, particularly when combined with an ambitious timeline. Other obstacles preventing the timely absorption of RRF funds relate to public procurement issues and state aid rules.[79] Also, supply-side bottlenecks in the form of shortages of specific inputs, including labour supply, as well as higher energy costs, have probably had a dampening effect on green investment activities funded by the RRF.

Chart 25

RRF climate-related spending plans



Sources: Panel a): ESCB, European Commission and ECB calculations; Panel b): European Commission, ESCB and ECB calculations.
Notes: In panel a), The economic categories of the disbursed RRF spending on climate are based on the assessment by the ESCB Working Group on Public Finance of the euro area average in the period 2021-26. The shares are applied to the EU Commission data on the RRF spending plans on climate for the EU. The category "Other" includes government consumption expenditure, health-related support and other expenditure measures. The latest observation is for August 2024. In panel b), the components of the absorbed RRF spending in 2021-23 are based on the Working Group on Public Finance (WGPF) assessment for the euro area and applied to the EU average. The category "Other" includes smaller expenditure spending, such as green research and development and climate change adaptation. It is assumed that the RRF funds will be fully absorbed by the end of 2026 with constant spending shares.

Beyond the RRF, the MFF programmes for 2021-27 also have a strong focus on climate, with the related disbursements progressing steadily. Under the EU's Common Agricultural Policy, a total of €146 billion is set to contribute to a reduction of GHG emissions from the agricultural sector over the MFF horizon (Chart 24, panel a). This entails investments in physical assets and forest area development, as well as payments granted to farmers who commit to specific agricultural practices. The EU's Regional Policy funds projects that contribute to climate objectives, amounting to around €94 billion. They support investment in energy-efficient buildings and sustainable urban mobility. Due to the co-financing requirements in the Regional Policy framework, these funds are expected to crowd in public as well as private

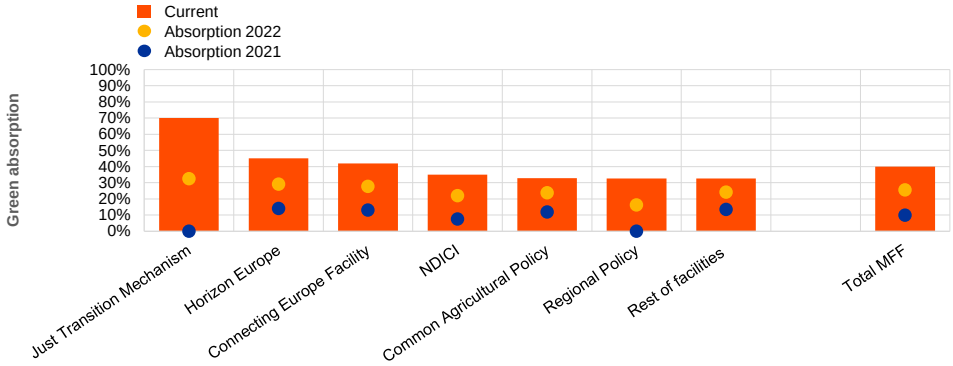
[79] See Bańkowski et al. (2024) and European Court of Auditors (2024c).

investment at regional level. Horizon Europe provides financing to research projects aimed at decarbonising the energy and transport sectors. By the end of 2023, 40% of climate-related funds committed under the MFF in the period 2021-27 had been disbursed. The Just Transition Mechanism was the best performer, having already implemented 70% of its planned contribution to climate (Chart 26). Looking ahead, MFF funds committed to climate objectives for 2024 to 2027 are estimated at around €57 billion per year.

Chart 26

Absorption of MFF funds contributing to climate objectives

(percentages of total green funding, 2021, 2022 and 2023)



Sources: Programme Performance Statements, Green Budgeting and ECB calculations.
Notes: This figure shows the funding contributing to climate objectives that is reported as implemented in each facility, as a share of the total contribution to climate objectives planned over the period 2021-27. NDICI stands for Neighbourhood, Development and International Cooperation Instrument – Global Europe. The bar chart includes only facilities investing more than €10 billion over the whole MFF in green budgeting.

Public development banks provide important additional sources of funding for the green transition in Europe. Multinational and national development banks play a critical role in scaling up advanced green technology and leveraging additional investments from public and private sources, often channelled via national projects. For example, the European Investment Bank (EIB) supported climate action and environmental sustainability in the amount of €49 billion in 2023, partly backed by EU programmes such as InvestEU. It aims to double this amount to around €100 billion annually by the end of the decade.[80]

Finally, national budgets are contributing to the green transition beyond the RRF via national policy initiatives. One important source of green funding comes from the auctioning of ETS allowances. In 2022, almost €30 billion of total auctioning revenues went directly to EU Member States, which in most countries were all earmarked for climate (Chart 27). However, a systematic overview of national fiscal policies supporting the green transition will be difficult, as long as green budgeting, by which fiscal measures are tagged according to their contribution to a country's climate target, is not fully established by EU countries. Green budgeting should be fully integrated into the regular budgetary cycle, to guide and align national fiscal

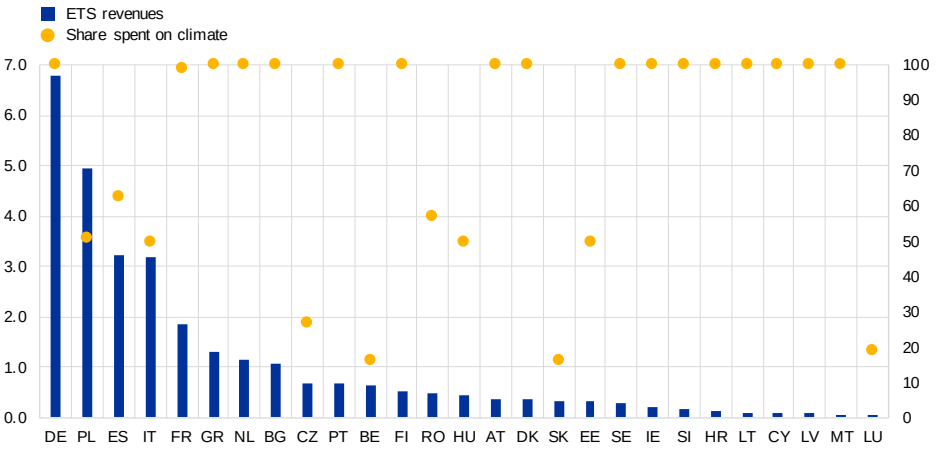
[80] In 2023, the EIB Group signed new financing contracts for close to €88 billion. In cumulative terms, the EIB Group targets blended finance of €1 trillion between 2021-30. See European Investment Bank (2023) and European Investment Bank (2024b).

policies towards national climate targets.[81] Data collected by the ESCB's WGPF point to a small fiscal stimulus of legislated discretionary green measures (excluding RRF funds) of, on average, 0.2% of GDP per year for the euro area countries in the period 2021 to 2026. These additional discretionary measures are mainly related to subsidies, tax credits, government investment and capital transfers.[82] Yet, as fiscal space is limited in most EU countries, it is important for national fiscal measures supporting the green transition to be efficient and for the scope to improve the greenness of national budgets to be fully exploited. This includes cutting environmentally harmful subsidies, as discussed in more detail in Chapter 5.

Chart 27

ETS revenues

(lhs: in EUR billions, 2022; rhs: percentage share of revenues spent on climate)



Sources: European Commission (2023c) and ECB calculations.
Notes: EU Member States are currently required to use at least 50% of ETS revenues for climate purposes. In 2022, on average 76% of ETS revenues were earmarked for climate and energy-related projects.

For Europe, evidence points to the public sector mobilising private funding. On energy infrastructure, the leverage ratio is found to be higher than one for national and EU-level financial support schemes, ranging between 1.3 to 1.6, depending on the type of financial instrument involved. Financial instruments that are specifically tailored towards supporting SMEs seem to have even higher financial leverage, given the greater importance of de-risking for smaller firms.[83] The EIB estimated the leverage ratio of its public funding at 1.4.[84] These findings are in line with the survey-based information presented in Chapter 3, according to which public sector support may have a positive impact on bank lending conditions and loan demand from firms, by lowering funding costs and credit risk for banks.

81 To date, only a handful of EU countries have green budgeting practices in place or have announced plans to implement such practices in the near future (see Boutron, 2023).

82 The most important single measure relates to the Italian "Superbonus" that supported energy efficiency improvements and seismic renovations. It amounts to around €180 billion in cumulative terms (around 8.5% of 2023 GDP), but has been partially phased out since the end of 2023.

83 See European Commission (2023c and 2024).

84 See IEA-ECB-EIB High-Level International Conference: Background document, September 2023.

4.2 Will there be a public funding gap?

While the lion's share of the funding of green investment has to be borne by the private sector, a substantial proportion has to come from public sources. This raises questions over how strongly the public sector would have to contribute to funding the green transition and whether the available public funds would be sufficient (Bouabdallah et al., 2024). While keeping fiscal sustainability concerns in mind, it should be acknowledged that a too-large public funding gap may hinder the public sector's ability to act effectively as a catalyst and crowd in private investment. There is no established benchmark determining the optimal role of the public sector.[85] The public sector's warranted engagement depends on factors that include incentives set by climate policies, the complementarity of public and private investment, the need for strategic cross-border investment, the financial situations of firms and households and their access to finance. A rough indication of what the public sector's role might be in financing green investment is shown below in a stylised manner. Starting with the European Commission's additional green investment needs estimate of €477 billion per year until 2030, as presented in Chapter 2, investment needs can be broken down into what is expected to be financed by the private sector versus the public sector. The share covered by public investment is derived from the sum of the public investment percentages for each sector, weighted by the European Commission's additional investment estimates per sector (Chart 28, panel a). The public investment percentages for the EU as a whole are taken from the literature and historical averages, and vary significantly across sub-sectors.[86] This exercise results in an overall public sector share of around 17% of the additional climate-related investment needs, corresponding to €83 billion per year in the period 2021-30.[87] The remaining share of the additional green investment needs would be covered by the private sector. According to this stylised exercise, this amounts to €394 billion per year (Chart 28, panel b).

When considering the available EU funds alone, the analysis points, on average, to a relatively small public funding gap for the public investment needed to meet the 2030 climate target. Comparing the public sector investment needs for the green transition with the funding available at EU level, the analysis results in a public funding gap of €20 billion per year on average (around 24% of public funding needs) in the period 2025-30. However, the results are sensitive to the underlying assumptions. For example, in the exercise it is assumed that the entire RRF and MFF envelopes will be used. The RRF is expected to cover over the full horizon €46 billion per year on average until 2026, while EU instruments other than the RRF and the EIB programme will together cover €30 billion per year on average (Chart 28, panel b). Funding from national budgets is not taken into account, due to a lack of comparable data on national programmes. Moreover, the calculations assume that the private sector will fully cover its estimated share of additional green

85 A recent study by Seghini and Dees (2024) attempts to determine an optimal role for the public sector in mitigating climate change.

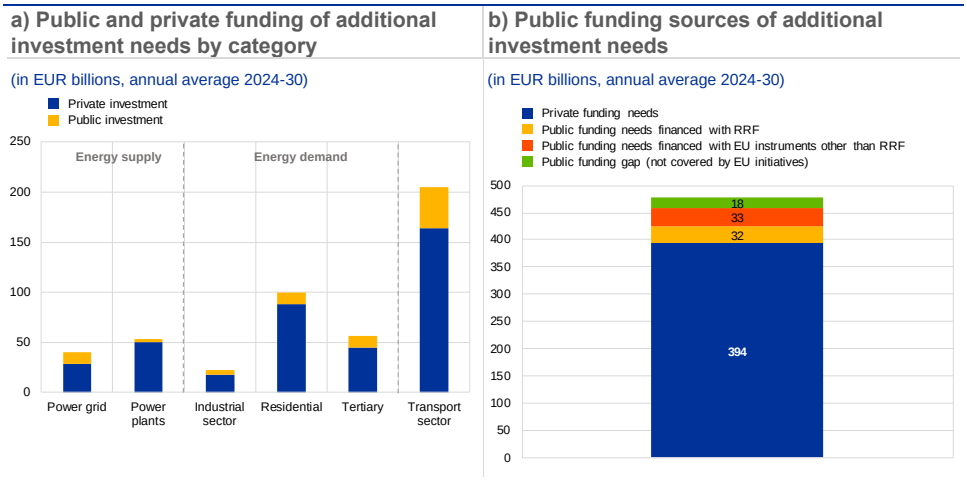
86 The estimated public sector shares per sector range between 5% and 30%. See, also Baccianti (2022) and the European Commission (for residential and industrial sectors). The public sector share of the tertiary sector is assumed to resemble that of the industrial sector.

87 The public sector share would be somewhat higher when looking at broader measures of green investment needs, including environmental protection (see also Bouabdallah et al., 2024).

investment needs. If, however, private funding sources are insufficient, this may require some further policy action, either to increase the incentives for additional private funding or to provide more public funds. Furthermore, with respect to spending, the calculations do not consider compensatory measures (e.g. to allow for a just transition) and the need to offset green investment shortfalls in previous years, as discussed in Chapter 2.2.

Chart 28

Shares of public funding sources



Sources: Panel a): European Commission, Baccianti (2022) and ECB calculations. Panel b): European Commission, EIB, EDF and own calculations.
Notes: In panel a), the chart shows the additional investment needs by category per year, based on the European Commission, to 2030. The public investment shares for the respective sectors are based on Baccianti (2022) and the European Commission (for residential and industrial sectors). The public sector share of the tertiary sector is assumed to resemble the industrial sector. In panel b), the funding of the additional investment needs of €477 billion per year are decomposed into what is expected to be covered by the public and private sectors and what has already been legislated for. The envelopes for the EU budget (MFF) and InvestEU are assumed to remain constant until 2030. The Recovery and Resilience Facility (RRF) will expire by the end of 2026, while the Social Climate Fund will become operational. EIB funds are included. ETS II proceeds and national funds are not considered.

However, the public funding gap varies over time: while EU public funding will help to close the gap until 2026, the expiration of the RRF may trigger a sizeable shortfall (Chart 29). In the years 2021-24, the public funding gap (green columns) is mostly the result of the low absorption rate of the RRF (yellow columns). In this exercise, it is assumed that the absorption rate will increase substantially between 2025 and 2026 to benefit from the full amount available under the RRF, as otherwise these funds would be lost, as outlined in Section 4.1. During this period, available public funding will exceed the public investment needs by €40 billion in 2025. This negative funding gap will increase to €46 billion in 2026, when the Social Climate Fund becomes operational.[88] However, from 2027 onwards, with the expiration of the RRF instrument, the funding situation will reverse, as a public funding gap will again emerge, even wider than in the period 2021-2023. This will take place in a context where the repayment of the principal of NGEU debt is set to start in 2028, possibly limiting the availability of EU public funding. Including interest costs, this may represent around €175 billion, to be paid cumulatively over the next

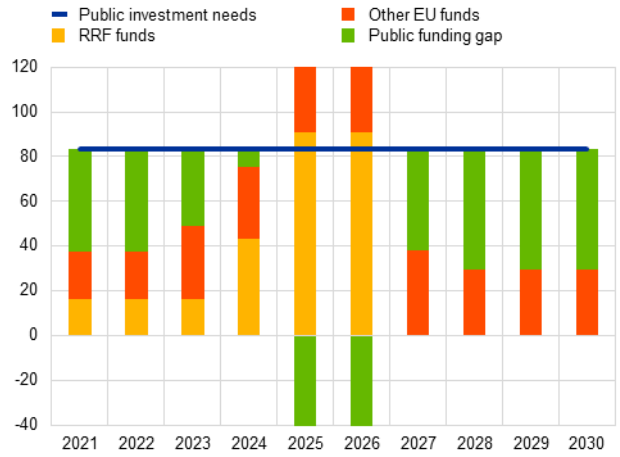
88 The Social Climate Fund, which will become operational in 2026, will provide additional financing (up to €65 billion in total in 2026-32). The funds will be used to support the most vulnerable households and firms and to bolster investments in energy-efficient buildings, renewable energy and sustainable mobility solutions.

MFF cycle (2028-35).[89] At the same time, green public investment activities are expected to crowd in private investment at least partly, with a positive impact on potential growth in the long term. Neither the repayment nor the potential growth stimulus are accounted for in the calculations underlying Chart 29.

Chart 29

Annual green public funding gap

(in EUR billions, 2021-30)



Sources: European Commission, EIB, EDF and ECB calculations.
Notes: The same methodology as that used for Chart 28, based on the additional investment needs. The blue line shows the average green public investment needs. The public funding gap (green) is considered negative in the years 2025-26, as RRF funds and other EU funds are expected to exceed the public investment needs.

4.3 Crowding-in or crowding-out of green private investment

Whether public investment can act as a catalyst, through the crowding-in of private investment, has been a longstanding debate in the economic literature, with mixed empirical evidence. Crowding-in may happen when public investments, particularly in infrastructure, technology and innovation, reduce the fixed costs of private projects or alleviate credit constraints, thereby encouraging private sector investment. Public investment may also create spillover effects that benefit the private sector. By contrast, crowding-out may occur when increased government spending drives up demand for resources, leading to higher interest rates and inflation, which may deter private investment. Recent studies on the United States found crowding-in effects, while older contributions suggested mixed results (Moretti et al., 2023 and 2019, Howell, 2017 and David et al., 2000). Focusing on Europe, several contributions estimating the multiplier effects of Cohesion Policy grants found positive sizeable effects on investment (Cohelo, 2019, Canova, 2024 and Durand and Espinosa, 2021). De Santis, Freier and Vinci (2022) found multipliers larger than one for private investment, implying that €1 spent through the Cohesion Policy funds is associated with €2 in private investment cumulated over time. A brief overview of the empirical literature and simulations of the impact of green public investment on the economy are shown in Box 2.

89 See Claeys et al., (2023).

Box 2
The macroeconomic impact of green investment

This box presents a brief overview of the main findings in the literature on the possible consequences of green investment, looking at key macroeconomic variables, and reviews lessons from past EU investment initiatives. This will be complemented by stylised simulations of the impact of the additional green public investment needs identified in section 4.2**.** on the EU economy.

1. What do we know from the literature?

Literature on the economic impact of green investment is scarce. Crowding-in effects may materialise in areas where public and private investment are complementary, such as investment in renewable infrastructure and green R&D . A recent study by IMF staff found that the growth impact of green investment spending – both private and public – is likely to be greater than that of carbon-intensive investment (by two to seven times, depending on the underlying sectors and available technologies). The multiplier specifically associated with investment spending on renewable energy is systematically higher than for fossil fuel energy investment, ranging between 1.1 and 1.5, compared with around 0.5 (Batini et al., 2021). The higher multiplier for renewable energy spending can be explained by the sector being more labour-intensive and therefore spreading more widely across the economy. Bertarelli et al. (2023) analyse the impact of climate change policies on green innovation in a panel of advanced and emerging economies and find that these lead to an increase in green patents, especially when they entail R&D subsidies and technology support instruments, such as low-carbon R&D expenditures, which implicitly suggests crowding-in effects on green innovation.

Green innovation may support potential growth, at least in the long run. Green technological progress will lead to productivity gains in the long run (Acemoglu et al., 2012). However, during the transition period the positive impact is less certain, and productivity may even slow down temporarily. The overall impact depends on whether the green investment is primarily additive, boosting the total volume of investment, or whether it is mainly replacing existing carbon-intensive investment. Only productive green investment can be expected to impact potential growth, which is why for example investment in retrofitting the building sector is normally not considered in the economic impact assessment.[90] These characteristics are sector-specific, making an overall assessment challenging (Pisani-Ferry and Mahfourz, 2023, Victor, 2022). Empirical studies show that for green investment that is replacing existing investment, productivity may decline temporarily, by around one-third of a percentage point of GDP per year (see Pisani-Ferry and Mahfourz, 2023). Moreover, cuts in carbon-intensive investment may also imply job losses in specific sectors.

The expected impact of green investment on inflation varies across studies, depending on the time horizon, the sectors and the assumed monetary policy responses.[91] In the short term, green investment is expected to lead to greater inflationary volatility or inflationary pressures, due to initially high capital costs for green technology and grid infrastructure, supply-chain constraints for critical minerals and higher production costs due to higher labour demand.[92] The transition will also entail marked relative price changes and higher energy prices, depending on the

90 See also Draghi (2024) and discussion in Section 2.1..

91 The literature on the inflation impact of climate policies and the role of monetary policy mainly focuses on carbon taxes or subsidies. See, for example, Del Negro, di Giovanni and Dogra (2023) and Olovssen and Vestin (2023).

92 See Svartzman et al. (2023) and Pisani-Ferry and Mahfourz (2023).

underlying carbon price. This could lead to a re-evaluation of some of the carbon-related capital stock (stranded assets) in carbon-intense sectors. In the longer term, however, the inflationary effects of green investment will disappear, assuming that green technology will lead to productivity gains (Acemoglu et al., 2012) and higher energy efficiency.

2. Lessons from the past

Assessments of past EU investment initiatives provide useful insights into their economic impact. In 2015, the European Fund for Strategic Investments (EFSI) was launched as part of the so-called Juncker Plan, to mobilise investment, mainly in the area of infrastructure and innovation, predominantly for SMEs, and to close the investment gap that followed the global financial crisis. Model-based analysis estimated that by 2025, EFSI-supported investments, which amounted to around €545 billion by the end of 2020, would increase GDP by 2.4% and create 2.1 million jobs in the EU. While these short-term effects were expected to be temporary and to fade over time, structural effects due to advances in infrastructure and technology were expected to have a more persistent impact on growth and employment (estimated at 1.6% and 1.3 million, respectively, by 2040). Spillover effects due to the high interlinkages in the European economy explained around 40% of the estimated GDP impact (EIB, 2021).[93] NGEU is another prominent example of an EU-wide investment package, as discussed in Chapter 4. Early estimates point to a potential increase in real GDP of 1.2% in 2026, compared with a no-policy-change baseline and long-term productivity improvements (Pfeiffer, Varga and in t'Veld, 2022). Bańkowski et al. (2022) find a significant small but positive impact of NGEU on growth, but a limited impact on inflation due to supply bottlenecks. Generally, to ensure the efficient use of the public support schemes, their design features have to be carefully crafted to mitigate risks related to strong political interference in the corporate sector and high fiscal liabilities.[94] In the Draghi report (2024), the macroeconomic impact of massive EU investment has been analysed using two different models. However, the results are only presented in qualitative terms.

3. What can we expect from green public investment?

Green public investment, beyond its environmental benefits, can serve as a powerful macroeconomic tool. Productive government investment is generally recognised for its significant impact on output, demonstrated by a relatively high fiscal multiplier. This effect arises from two main factors. First, government investment directly contributes to GDP as a component of final demand, unlike taxes, assuming that the investment goods are not imported. Second, such investment builds public capital, thereby enhancing the economy's productive capacity. However, the overall macroeconomic impact may be tempered by the response of private sector components, depending on their degree of substitutability with public investment. In the context of green government investment, concerns about crowding-out private investment are likely minimal, as discussed above, particularly in areas less attractive to the private sector. Given the immense scale of the green transition required, there remains substantial scope for investment in this area.

Macroeconomic simulations suggest that the necessary green public investment could yield significant benefits for the euro area economy. To analyse the effects of such investment the ECB-BASE model is used, a large-scale, semi-structural model with a comprehensive

93 The analysis uses the RHOMOLO-EIB model, a special computable general equilibrium model with 267 regions and ten sectors for the EU-28 countries.

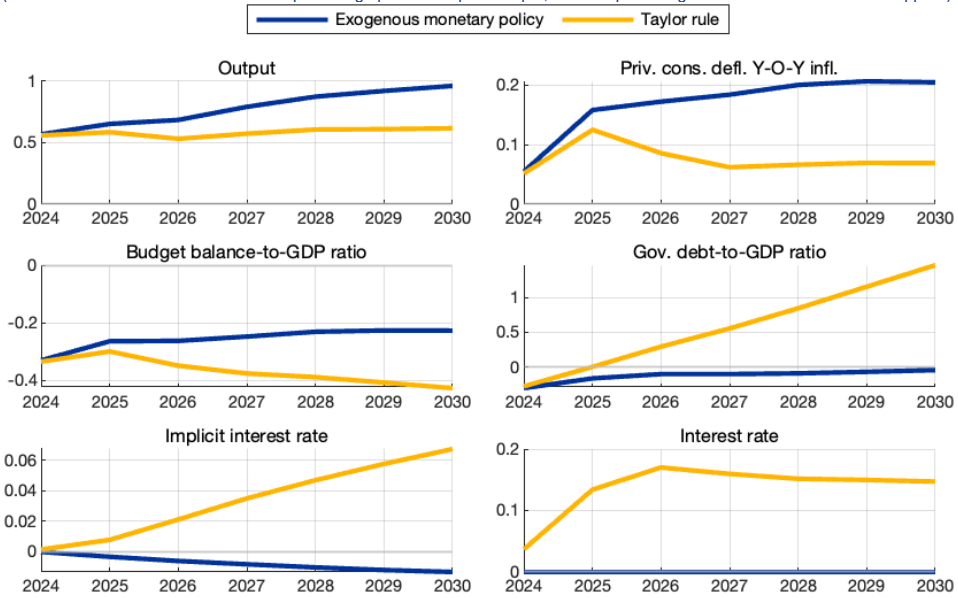
94 See the recent assessment by the European Court of Auditors (2024a) on spending errors in the EU Cohesion Policy.

representation of the government sector.[95] This model incorporates productive government investment, which, in the absence of a more specialised instrument, can be used to analyse green government investment. However, the model does not allow different fiscal multipliers to be accounted for depending on the type of green public investment. Simulations using the ECB-BASE model indicate that productive green investment of approximately 0.5% of GDP per year would significantly and permanently boost euro area GDP (Chart A).[96] If not counteracted by monetary policy, this investment would also lead to moderate, though persistent, inflationary pressures. The gains in nominal output would create a positive feedback loop for public finances, effectively offsetting much of the initial cost of the investment.

Chart A

Macroeconomic effects of green public investment with ECB-BASE

(absolute deviations from the baseline in percentage points except for output, to which percentage deviation from the baseline applies)



Notes: The annual green public investment figure presented in Chapter 4.2. is rescaled to the euro area.

The ultimate impact of green government investment, particularly in terms of costs, is highly dependent on the monetary policy response. In a hypothetical scenario in which monetary policy remains unchanged, with interest rates held constant**,** green investment would have minimal impact on the government debt-to-GDP ratio (Chart B, panel a). The increased spending would be largely offset by additional macroeconomic momentum, undeterred by monetary policy price objectives. Specifically, the rise in nominal GDP due to higher green public investment, which is the combined result of both real economic activity and higher price levels, would lead to a favourable denominator effect for public finances in the short term. Additionally, the improved euro area economy would boost government revenues, easing pressure on the budget balance, while abstracting from longer-term costs of higher inflation.

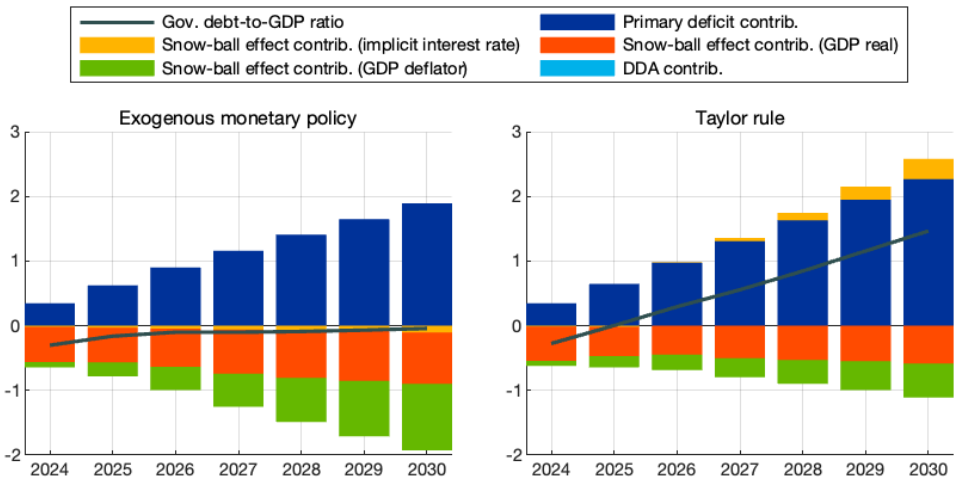
95 For a description of the model, including its fiscal block, see Bańkowski (2023).

96 The simulations are based on the public sector part of the green investment estimates of the European Commission, but subtracting public investment in residential building so that only productive public investment is accounted for.

Chart B

Decomposition of debt-to-GDP ratio

(absolute deviations from the baseline in percentage points)



Note: The above decomposition follows the usual decomposition of debt-to-GDP ratio change often used in debt sustainability analysis.

However, in a more realistic set-up, with a central bank responding to higher inflation in accordance with its primary mandate of price stability, the fiscal cost will be more evident. In this scenario, curbing inflation and raising interest rates may diminish some benefits for the budget balance and the debt-to-GDP ratio. In addition, monetary tightening might increase the cost of servicing government debt. Under a monetary policy regime following a Taylor rule, the cost of green government investment, as reflected in changes to the debt-to-GDP ratio, would become more apparent (Chart B, panel b). It is essential to recognise that the model simulations do not account for potential disinflationary effects arising from a transition to renewable energy or green innovation. This is intrinsically hard to account for in such a modelling exercise. Therefore, while green public investment may be costly for public finances, a lack of sufficient (public) investment might come with far greater costs, such as tipping points in climate change and long-term economic instability. For future analyses, it is therefore crucial to consider the long-term advantages of green public investment for sustainability and economic resilience.

5 Policy options supporting green investment

Europe's massive investment needs have to be supported by structural, fiscal, and financial policies that foster stronger engagement on the part of the private sector and ensure the efficient use of public funds. Credible climate policies are essential to incentivise firms and households to invest in decarbonisation strategies. Moreover, good business conditions are needed to support investment and innovation in clean technologies (cleantech) and their diffusion, including policies to reduce red tape, foster green patenting and encourage upskilling. Efforts at both the national and EU levels are required to help green technologies to mature, be widely adopted and obtain the necessary funding.

This chapter looks at policy options supporting the green transition. It finds that the supporting factors fostering green investment and innovation mainly relate to the access to financing of firms, the availability of skilled staff and labour market regulations. These should be flanked by fiscal policies setting the right incentives, notably through carbon pricing. At the EU level, a joint fiscal capacity could help to deliver large cross-border projects that represent European public goods. Funding the green transition is not only about the amounts of funding needed but also has to take into account the different phases of firms in the innovation cycle. Deepening the CMU might help to fill this gap by increasing firms' access to different types of financing. Improved transparency may facilitate the reallocation of capital into green projects, although the complexity of the current framework poses challenges.

5.1 Structural policies to support green investment

Structural policies are playing an important role in supporting the transition to a climate-neutral economy. The objective of carbon neutrality makes significant structural changes to the European economy unavoidable. Structural policies enable a greater role for private sector investment in the green transition, thereby also reducing the need for public investment. The green transition requires appropriate business conditions that facilitate the reallocation of resources from high-carbon to low-carbon activities, incentivise green innovation and new business models and provide a favourable environment for the deployment and diffusion of low-carbon technologies. While being essential for all countries, structural policies to improve business conditions are particularly important for countries with low fiscal space and high green investment needs. Regulatory frameworks that promote competition, facilitate the entry and exit of firms, encourage entrepreneurship and stimulate innovation and its deployment are associated with higher productivity growth.[97] By potentially accelerating sustainable growth in the longer run, well-designed structural reforms - for example to shorten the time needed to open a business, streamline

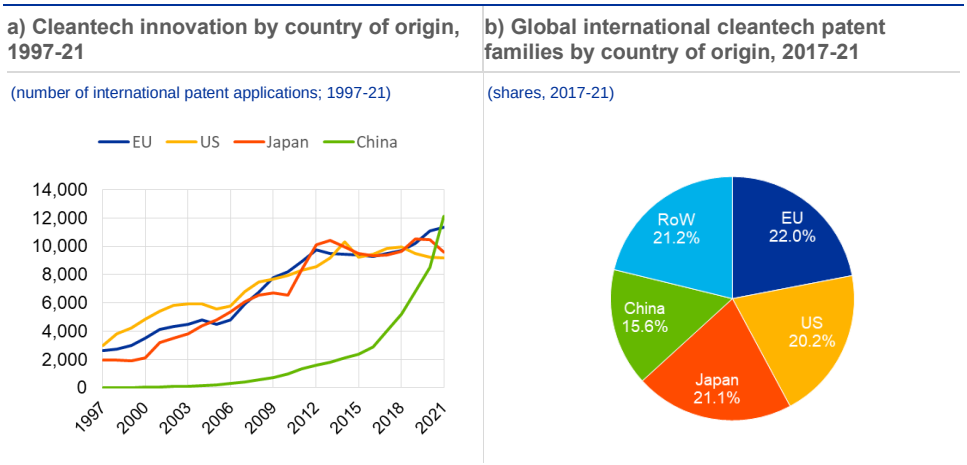
[97] See Masuch, Anderton, Setzer and Benalal (2018) and ECB (2021).

licensing and other administrative processes and increase the efficiency of insolvency frameworks - create fiscal space that can be used to scale up green public investment or to implement measures that help ease unwelcome distributional effects of climate policies.[98]

Green innovation activity in the EU is comparable to other large regions, although China is catching up.[99] Developing new low-carbon technologies and making them widely available is a precondition of effectively addressing climate change.[100] In the EU, following a strong increase between the late 1990s and early 2010s, innovation in clean technologies stagnated from 2012, before picking up again from 2017 (Chart 30, panel a). Low-carbon energy technologies, including renewable energy generation and energy storage solutions such as batteries, are the leading cleantech sectors, followed by plastic recycling and alternatives and clean and sustainable transportation. In the 2017-21 period, the EU accounted for over one-fifth of clean and sustainable technologies developed globally, which is broadly similar to the respective shares of Japan and the United States (Chart 30, panel b), with China catching up at a fast pace and overtaking other major regions by 2021.

Chart 30

Cleantech innovations and international patents



Source: European Patent Office (EPO).
Note: The analysis is based on international patent families (IPFs), which capture sets of patent applications filed in more than one country to protect an invention.

Patenting is important for green innovators to attract venture capital or to serve as debt collateral. Capital market imperfections discourage investments in research and development, given the important asymmetric information inherent in these activities. Patents may mitigate such financing constraints, as they serve as important signals when assessing the outlook of young companies.[101] For Europe, in order to maintain its strong role in cleantech innovation, patenting and scaling up, it is key to reap the full benefits of the Single Market and tackle regulatory

98 See Budina et al. (2023).

99 Innovation is measured by international patent families (IPFs), capturing sets of patent applications filed in more than one country to protect an invention. The discussion and charts included on patents are based on European Patent Office (EPO) data, access to which is gratefully acknowledged.

100 See Hasna et al. (2023).

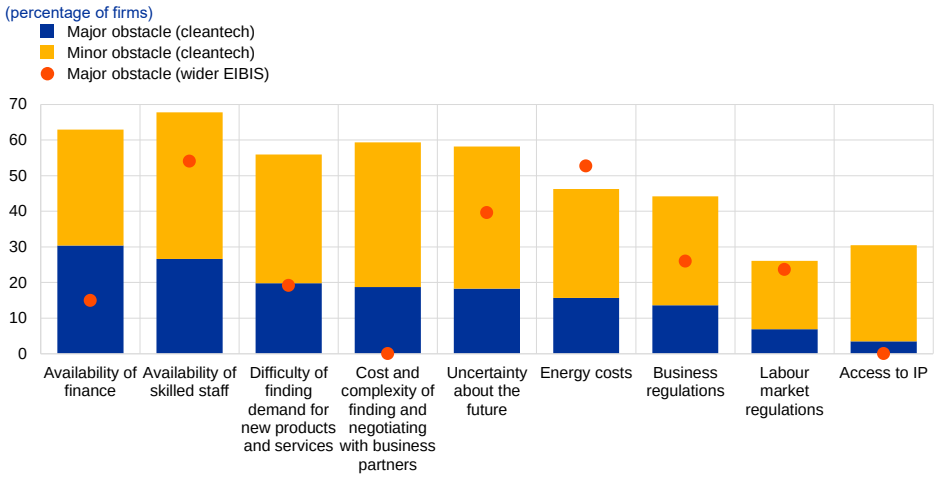
101 See Bellucci et al. (2023).

fragmentation. More expedient procedures for cleantech applications could be an area to explore. A first step in this direction is the Unitary Patent system, launched in 2023, which makes it possible to get patent protection in 17 EU Member States by submitting a single request to the European Patent Office (EPO).

A recent survey by the EPO and the EIB revealed significant structural barriers to green investment. Availability of finance was reported as a major obstacle to investment for around 30% of cleantech firms.[102] This is double the percentage reported by the broader range of non-financial firms surveyed in the wider EIB Investment Survey[103] (Chart 31) and in line with the findings of the SAFE that financing costs are considered too high (Chapter 3.4).

Chart 31

Obstacles to EU business activities related to clean and sustainable technologies



Sources: EPO/EIB Cleantech Survey and European Investment Bank Investment survey (EIBIS) 2023.
Notes: EIBIS does not include information on cost and complexity of finding and negotiating with business partners or on access to intellectual property (IP). For details on the Cleantech Survey, see EPO and EIB (2024).

Increasing the availability of skilled staff is important for the green transition. Skills shortages are a major challenge, in particular for medium-sized and larger firms (EPO and EIB 2024). Cleantech innovators have reported that a lack of skills results in failure or delay in bringing new technologies to the market, scaling up and entering new markets (Chart 31). This is also further exacerbated by difficulties in finding demand for new products and services, as well as high costs and the complexity of finding and negotiating with business partners, the latter being a significantly larger obstacle to green investment compared with other types of business investment. Low statutory retirement ages and early retirement incentives

102 The EPO/EIB Cleantech Survey is a joint initiative on the part of the EPO and the EIB to analyse innovation trends in the field of clean technologies. The survey is conducted among European patent applicants and owners in the field of clean technologies and aims to provide insights on the latest developments, trends and challenges in this sector. The authors gratefully acknowledge access to the underlying data used in the discussion and charts in this section.

103 The annual EIB Group Survey on Investment and Investment Finance (EIBIS) is an EU-wide survey that gathers qualitative and quantitative information on the investment activities of both small businesses (with between five and 250 employees) and larger corporates (with more than 250 employees), their financing requirements and the difficulties they face. The survey collects data from approximately 13,300 businesses in total, across the EU-27, the United Kingdom and, since 2019, the United States, covering manufacturing, services, construction and infrastructure.

may contribute to a further lack of experienced staff in the coming years, delaying the green transition as large cohorts of baby-boomers approach retirement. The demand for green skills, which include technical knowledge, expertise and abilities that enable the development and effective use of green technologies and processes in professional settings, is apparently growing at a much faster pace than their supply.[104] Policies to improve the quality of education, upskilling and reskilling of the labour force are therefore key in supporting green investment activities, as also highlighted in the recent Draghi and Letta[105] reports and the 2024 country-specific recommendations agreed by the European Council. In addition, the green transition would benefit from higher labour mobility, which would accelerate the shift in employment from high-emission to low-emission firms and sectors.[106] Employment transitions are more than twice as common in the United States as in Europe. It takes just one quarter, compared with about one year, for 5% of workers to change employment in the United States compared with the euro area countries with the lowest labour mobility (Italy, Greece and Slovakia).[107]

A simplified regulatory framework for green innovative activities, including cleantech, would increase the attractiveness of the EU and support their scaling up. While most regulations reflect justified concerns over the protection of the environment and human health, they may have unintended costs for the green transition. Complex planning and approval procedures are serious obstacles to green investment projects (for example in the grid and storage infrastructure) in many EU countries (Chart 31). The burden of regulation has increased in almost all EU countries (Chart 32), which may hinder the adoption of green technologies by restricting access to product and services markets or limiting the use of technologies or data. By increasing the costs of market entry for new high technology firms, the high regulatory burden also constrains technology spillovers. The Draghi report on the future of European competitiveness also highlights the key role that simplifying and harmonising regulations at the national and EU levels might play in supporting innovation and the scaling-up of EU firms.[108] The report calls for the establishment of European Innovative Company status (EIC), with which companies would be able to operate across the EU subject to only a limited and harmonised set of legal obligations, including corporate law, insolvency procedures, and some key aspects of labour law and taxation. EIC status could tackle the often-cited problem that compliance costs are disproportionately high for SMEs compared with larger companies. Implementing such a regime also for mid-caps could facilitate the scaling-up of firms.

---

104 See the LinkedIn Global Green Skills Report 2023, according to which the proportion of green talent in the workforce grew by 12.3% between 2022 and 2023, while the proportion of job postings requiring at least one green skill grew by 22.4%.

105 See Letta (2024).

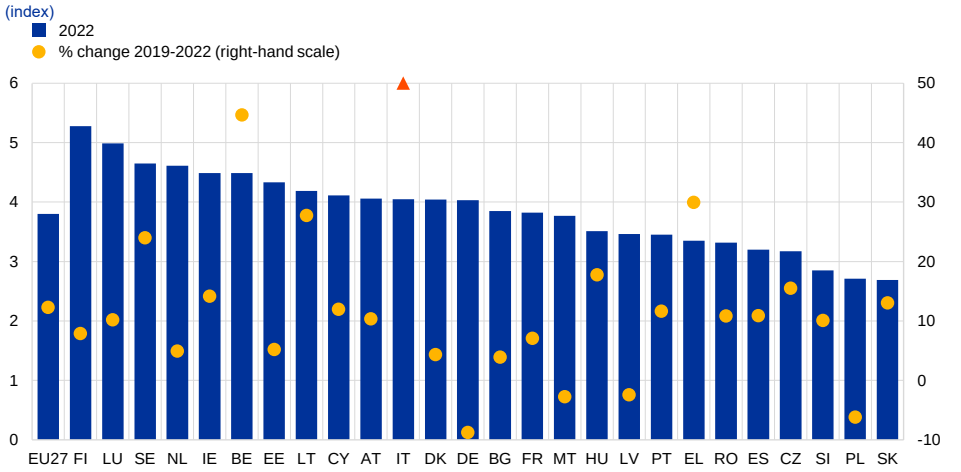
106 See Bluedorn and Hansen (2022).

107 See Causa et al. (2021).

108 As mentioned by Draghi (2024) "[…] innovative companies that want to scale up in Europe are hindered at every stage by inconsistent and restrictive regulations. […] The net effect of this burden of regulation is that only larger companies – which are often non-EU-based – have the financial capacity and incentive to bear the costs of complying. Young innovative tech companies may choose not to operate in the EU at all."

Chart 32

Burden of regulation for EU firms



Sources: World Economic Forum, via European Commission Single Market Scoreboard.
Notes: Higher values indicate higher regulation, based on the reply to the question "In your country, how easy is it for companies to comply with government regulation and administrative requirements (e.g. permits, reporting, legislation)? (1 = extremely easy; 7 = overly complex)". Percentage change 2019-22 for IT: 96.92%; no data for HR.

5.2 How can fiscal policies incentivise green investment?

Fiscal policies can support green investment through various channels. Besides its role in supporting the funding of the required green investment, as discussed in Chapter 4, the public sector can set its fiscal policy instruments and fiscal rules in ways that help incentivise green private investment. Positive stimulus for green investment may arise from ambitious carbon taxation, a better quality of public spending, which includes moving away from fossil fuel subsidies, and an investment-friendly governance framework. In addition, by providing a credible and stable policy environment, fiscal policies can contribute to reap the full benefits for green investment.

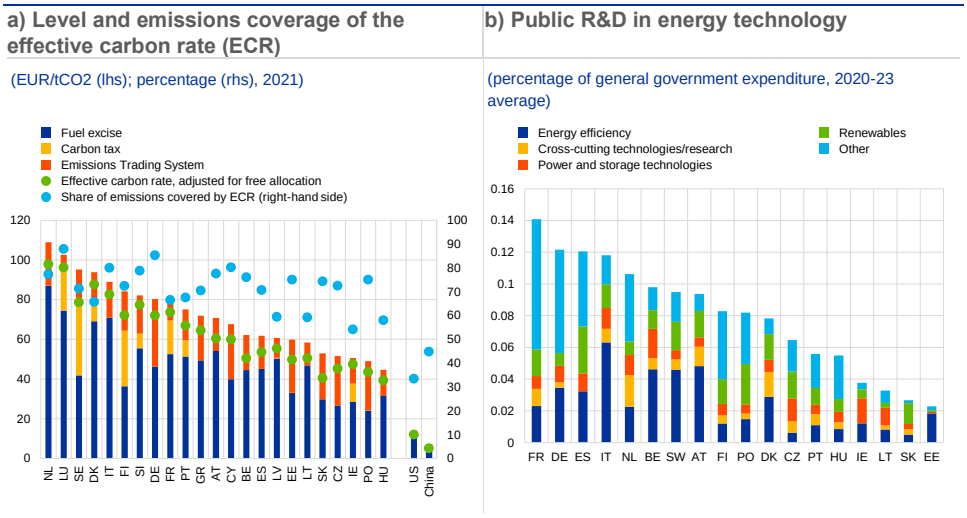
Carbon taxation, which is widely seen as the most efficient policy instrument to channel private investment towards energy efficiency and green innovation, has to be accelerated.[109] In Europe, the EU's ETS works indirectly as a carbon tax with the carbon price being determined via auctions of emission permits. The scheme has been gradually improved since its launch in 2005. Under the Fit-for-55 package, it will be further reformed and complemented with an additional ETS (ETS II) for transport and building heating. Germany and Austria recently introduced a national ETS for these sectors, which will eventually be replaced once ETS II is fully operational at the EU level. Moreover, several countries have explicit carbon taxes in place, albeit mainly with a limited tax base and rate. The OECD summary indicator of the effective carbon rate combines carbon pricing with emission coverage. It is

[109] See also the discussions in Delgado, Ferdinandusse and Nerlich (2022) and Aghion et al. (2016). Känzig (2023) finds evidence that an increase in carbon prices stimulates green innovation, as measured by low-carbon patenting. ECB research points to the important complementary role of reforms and regulations, as well as direct subsidies to green research and development. See Benatti et al. (2024).

defined as the emissions-weighted sum of ETS prices, actual carbon taxes and fuel excise taxes per country. In 2021, the effective carbon rate stood at €72 per tCO2 for the EU average (excluding Malta), while its emission coverage ranged from 88% in Luxembourg to 54% in Ireland (Chart 33, panel a).[110] Even though the effective carbon rate in Europe is considerably higher than the rate observed in the United States and China, for example, it is still well below the effective carbon rate that would be needed to achieve the EU' 2030 climate target.[111] To ensure social acceptability and political support going forward, it will be important to complement carbon pricing with other climate policies to limit potentially adverse macroeconomic and distributional effects. Rechannelling some carbon tax revenues to vulnerable households and firms, as encouraged under the Fit-for-55 package, may provide a buffer against any adverse effects.[112]

Chart 33

National fiscal instruments supporting the green transition



Sources: Panel a): OECD (2023), ECB calculations. Panel b): IEA, ECB calculations.
Notes: In panel a), the left-hand scale shows the effective carbon rate indicator of the OECD as the emissions-weighted sum of the average ETS price (in 2021) and the carbon and fuel excise tax rates (April 2021). The green bars account for free allocation of permits under the ETS. The triangles refer to the right-hand axis and show the share of emissions covered by the effective carbon rate per country. No data are available for Malta. In panel b), there are data available for GR, LU, MT, CY, LV, HR, SI, BG and RO. "Other" include public R&D in nuclear and hydrogen.

Improving the quality of public spending, especially by cutting fossil fuel subsidies, may indirectly support green investment. A general shift from government consumption to growth-enhancing government investment may be beneficial for green public investment, as it may increase the available fiscal space. A more immediate impact, however, can be expected if subsidies for the use of fossil fuels are cut,[113] thereby removing perverse incentives and creating fiscal space that could be used for green investment, either directly through public investment or indirectly through supportive fiscal measures, such as green subsidies or green

110 See OECD (2023).

111 Achievement of the EU's 2030 reduction target requires an effective target rate of €120/tCO2. See OECD (2021).

112 See Känzig (2023). According to the European Commission, the Social Climate Fund is expected to mobilise €86.7 billion from ETS II revenue in the 2026-32 period.

113 Subsidies for the use of fossil fuels vary across countries, ranging from 2% to 18% of total public expenditure: see Delgado, Ferdinandusse and Nerlich (2022).

public R&D. A large part of green public R&D has been devoted to energy efficiency in a number of EU countries (Chart 33, panel b).

Furthermore, the revised EU governance framework is designed in such a way as to encourage also green public investment. One suggestion put forward in the public debate was to introduce a green golden rule that would stimulate green public investment while fulfilling fiscal sustainability.[114] However, this proposal was abandoned, as green golden rules may lead to greenwashing due to the generous classification of public investments as green and could reduce incentives for governments to reprioritise spending within the available budgetary space. Instead, with the adoption of the EU governance reform in April 2024, the EU went a different route, linking fiscal consolidation needs to incentives for growth-enhancing investments and reforms, including green investment. Compared with the previous governance framework, Member States are now given more time to implement their fiscal consolidation plans and put their debt trajectories on plausibly declining paths.[115] The budgetary adjustment phase will start in 2025, and governments can stretch their adjustment requirements from four to up to seven years in case of credible investment and reform plans. If fully taken up, this may create fiscal space of up to €700 billion in total in the EU in the period 2025-31.[116] The additional fiscal space may, in turn, help to close the public funding gap for green investment, as identified in Chapter 4.3. Moreover, in the medium term, Member States will be allowed to keep their structural public deficits at 1.5% of GDP, which is more generous than under the previous framework.

5.3 Proposals for EU funding initiatives to support green investment

The possible establishment of new EU-level instruments could improve the coordination of national initiatives and support cross-border and pan-European projects. The literature has discussed several proposals for an EU fiscal capacity for climate. Such a fiscal capacity could help to address the expected green public investment gap, described in Chapter 4.2. IMF staff suggests putting in place an EU fiscal capacity that could include a “climate investment fund”.[117] Panetta (2022) makes the case for an EU fiscal capacity for investment in European public goods and discusses the main features of its design. Abraham et al. (2023) propose a Climate and Energy Security Fund to help address the issue of limited returns on Member States’ individual actions and the associated risk of free riding and to facilitate that the required investment occurs in an efficient way. Bakker et al. (2024)

---

114 See, for example, Darvas and Wolff (2021). Under a green golden rule, green public investment spending would not be included in what is regarded as public spending, thereby reducing the fiscal effort. This could set incentives for more green investment to spill over into private sector engagement. However, green golden rules also imply risks. They may lead to greenwashing, as governments may have an incentive to classify public expenditure as green investment excessively, as a way to ease budgetary pressures. For a discussion of the various arguments, see Box 3 in Delgado, Ferdinandusse and Nerlich (2022).

115 See Haroutunian et al. (2024).

116 See Bouabdallah et al. (2024).

117 See Arnold et al. (2022).

argue for the establishment of a temporary EU fund for European public goods until 2030, which should be targeted at enabling the twin transition and strengthening European competitiveness and growth potential, focusing in particular on cross-border and EU-wide investments. Schang and Vinci (2024) show that a European public-goods-focused central fiscal capacity could reallocate costs across regions over the business cycle, resulting in de facto stabilisation, while addressing common investment needs.

On the spending side, there are several ways to design an EU fiscal capacity for climate. While some proposals focus solely on financing green investment, others investigate on delivering a broader set of European public goods, such as digital infrastructure, innovation or defence. There is a wide range of approaches to EU spending that can be considered and combined, from facilities directly administered by the EU to grants provided to Member States for national or cross-border projects. For example, the RRF's performance-based approach of financing national or cross-border investments and reforms through grants based on pre-agreed plans could be combined with stronger incentives for cross-border and pan-European projects to increase the European public good dimension. Such a capacity could also build on new EU budget instruments such as the Social Climate Fund or the Strategic Technologies for Europe Platform (STEP). Existing EU investment programmes, such as Cohesion Policy, could also be reformed and strengthened to deliver more room for funding green investment.

Financing is a crucial factor in determining the potential scope and viability of an EU funding instrument. The current MFF represents just over 1% of the EU's GDP. If this benchmark is used for the 2028-2034 MFF, there would be limited room to increase green public investment without significantly affecting funding devoted to other priorities, also in a context where technological developments and geopolitical fragmentation generate competing investment priorities. From this perspective, ensuring sufficient funding for green fiscal capacity will likely require a combination of more efficiency in the EU budget and new funding sources.[118]

The Draghi report makes the case for investing in energy infrastructure and decarbonisation as a way to boost the competitiveness of EU firms and proposes avenues to deploy the EU budget more effectively for this purpose. The report recommends focusing resources on joint strategic projects, such as clean tech and innovation, by creating a "Competitiveness Pillar" within the next EU budget. The budget should be streamlined, with simpler access to funds and increased flexibility to reallocate resources where needed. Moreover, it should better leverage private investment, expanding financial instruments such as InvestEU to help take on higher-risk projects. Additionally, the report stresses that the EU should consider issuing common debt to finance cross-border investments. These steps aim to align the EU budget with the EU's strategic priorities, such as decarbonisation, and maximise its impact on competitiveness.

[118] Proposals made also include adopting new EU own resources and issuing common debt (see, for example, Panetta, 2023).

5.4 The need for progress on the capital markets union

Further developing EU capital markets is essential to facilitate companies' access to different types of funding and support the green innovation. As discussed in Chapter 3, the bulk of the additional financing for the green transition has to come from the private sector. However, many firms – especially SMEs – report that they are finding it difficult to get access to finance for investing in the green transition. Green investments may differ from other investments because of the higher risks associated with funding emerging technologies, such as higher depreciation rates, technological volatility and significant long-term uncertainty. This affects the expected future value of underlying collateral, making traditional debt finance providers more hesitant or even unable to offer bank loans or other necessary funding. Alternative financing sources such as venture capital and listed equity markets may be better suited to address these risks and provide the necessary scale and liquidity.[119]

Despite efforts to progress on CMU in the past decade, the structure of EU capital markets has not changed significantly. The Commission has developed three action plans and put forward a large number of legislative and non-legislative proposals since 2015. Some of these proposals have been successfully implemented: for example, there has been progress on cutting red tape, improving transparency, enhancing investors' access to finance and making it easier for smaller companies to go public. However, actions related to structurally challenging topics, such as taxation, insolvency, pensions and supervision, have only been partially addressed. National political constraints have made it hard to reach sufficient consensus on ambitious initiatives, leading to measures that were either too limited or too hard to implement to achieve their desired outcomes. Additionally, many proposals either stalled in the legislative process or made progress only in the form of non-binding actions. Overall, while several CMU initiatives have improved the existing regulatory framework, their impact on capital market development has been modest, often taking years to show results.[120]

Recently, there has been renewed political momentum for CMU. In March 2024, EU finance ministers published a statement identifying measures that should be taken forward in the next legislative term.[121] The ECB Governing Council also published a statement welcoming this work and highlighting key priorities for CMU.[122] The debate on CMU was further informed by several landmark reports aiming to formulate a policy agenda for the new institutional cycle. The reports by Enrico

---

119 For example, research suggests that carbon-intensive industries reduce emissions faster in economies with deeper stock markets. The main channel underpinning this finding is that deeper stock markets facilitate green innovation in carbon-intensive sectors, resulting in lower carbon emissions per unit of output (see de Haas and Popov, 2023).

120 For a detailed assessment, see Arampatzi, A., Christie, R., Evrard, J., Parisi, L., Rouveyrol, C., and van Overbeek, F. (2025).

121 See the Statement of the Eurogroup in inclusive format on the future of Capital Markets Union, 11 March 2024.

122 See Statement by the ECB Governing Council on advancing the Capital Markets Union, 7 March 2024.

Letta[123], the French taskforce chaired by Christian Noyer[124] and Mario Draghi identified some similar priorities in areas such as supervision, market infrastructure integration, securitisation and the promotion of long-term savings and investment products. However, they differed in their focus and level of ambition.

This renewed political momentum has arisen at a critical moment: advancing the CMU agenda is urgently needed to achieve the EU's strategic objectives, including the green transition. ECB analysis has outlined five key objectives for the CMU agenda going forward: supporting innovation, financing the green and digital transitions, shoring up pension savings, promoting private risk-sharing and fostering convergence and inclusion.[125] Concrete progress in these areas would contribute to improving the EU's growth, competitiveness and resilience. To foster integration, policy priorities would have to focus on further convergence and centralisation of capital market supervision, targeted legal and regulatory harmonisation in areas such as insolvency regimes, accounting frameworks and securities law and further harmonisation and consolidation in the trading and post-trading landscape.

Some elements of the CMU agenda could be particularly beneficial for the green transition.[126] The following measures have the potential to support the achievement of the EU's climate objectives by promoting green investment and innovation.

- The creation of **well-designed savings products** would help to channel European savings towards longer-term, higher-return investments. Policy advances in this area could proceed along two tracks: (1) product design, for example the development of a label for funds that meet agreed criteria; and (2) tax incentives and pension schemes to make such products attractive.

- Measures to **promote firms' access to finance**, in particular through the development of venture capital markets, would help to enhance access to risk capital for EU firms and ensure that innovative ideas can be successfully developed and commercialised. In the short term, the European Investment Fund (EIF), which is already active in the venture capital market, could be further mobilised to provide both funding and expertise to develop the venture capital ecosystem. This could be accompanied by measures to broaden the investor base, for example through tax incentives.

- **Securitisation** can be used to channel private capital towards the green transition. Securitisation is a technique that can be used to free up banks' balance sheet capacity and transfer the credit risk of the underlying assets to

123 On 10 April 2024, former Italian Prime Minister Enrico Letta published a report on the future of the Single Market, as requested by the European Council in June 2023, to provide recommendations for the European Council's 2024-2029 strategic agenda.

124 On 25 April 2024, a task force of French public and private-sector leaders, mandated by the French finance ministry and chaired by former Banque de France Governor Christian Noyer, published a report setting out four key recommendations on CMU, detailing the priorities identified by the French Government for CMU.

125 See Arampatzi, A., Christie, R., Evrard, J., Parisi, L., Rouveyrol, C., and van Overbeek, F. (2025). See also Lagarde (2021) and Lagarde (2024).

126 Ibid.

investors, leading to a more balanced distribution of risks across the financial sector. In the short term, the EU could fine-tune the regulatory and prudential framework governing securitisation and take measures to foster transparency and standardisation. Looking further ahead, an EU platform – potentially coupled with a public guarantee – could be a powerful tool to support the development of the market.[127] One concrete example could be a securitisation scheme targeting the green segment. At the same time, the effectiveness of such a measure has to be carefully monitored and securitisation has to be well regulated and supervised, also to prevent risks to the sustainability of public finances.

5.5 More transparency and disclosure could support the green transition

Enhanced transparency can facilitate and speed up the reallocation of capital into green projects.[128] Disclosure obligations have been the primary tool of sustainable finance initiatives in all jurisdictions, with the aim of enhancing transparency. If investors have clear and reliable information on the impact of their investments, they can take financial decisions consistent with their own preferences for sustainability and rebalance their portfolios towards sustainable assets.[129] Moreover, transparency enables investors with sustainability preferences to identify green assets. This may result in a marginally lower cost of capital for green projects.[130] In addition, transparent and harmonised rules help to limit greenwashing and capital misallocation.

The EU has put enhanced transparency and disclosures at the centre of its sustainable finance regulatory framework (Table 1). These EU disclosure and reporting initiatives are expected to increase transparency, but there are limits on their potential to trigger additional capital flows into green investments. Corporate and product-level disclosures reduce uncertainty and information asymmetries between debtors and creditors. They allow investors and financial institutions to consider sustainability aspects and price climate risks and sustainability factors more adequately in their lending conditions to borrowers (Chapter 3). However, while greater transparency could marginally lower the cost of funding of capital for green projects, as well as facilitate and speed up the reallocation of capital, initiatives based on transparency alone appear unlikely to trigger the meaningful shift in capital flows necessary to close the green investment gap.

127 See, for example, the proposal by Mack (2024).

128 See Steuer and Tröger (2022).

129 For an analysis of sustainable investing from an asset-pricing perspective, see Pástor, Stambaugh and Taylor (2021) and Goldstein, Kopytov, Shen and Xiang (2022).

130 However, empirical evidence suggests that the reduction in the cost of capital brought about by sustainable finance initiatives (e.g. the “greenium” of green bonds or the price impact of ESG funds) is generally small. See Pietsch and Salakhova (2022) and ESMA (2023).

Table 1

Overview of EU legislation to enhance transparency and disclosure

EU legislation to enhance transparency and disclosure in support of green investment
– The **Corporate Sustainability Reporting Directive (CSRD)**: requires all large companies and listed SMEs in the EU to disclose detailed, audited information on environmental, social and governance issues, based on common EU reporting standards (the European Sustainability Reporting Standards, ESRS). First reporting is required for some large firms in 2025 for reference period 2024 and additional firms are gradually required to report thereafter.
– The **EU Taxonomy**: requires large and listed companies to disclose how and to what extent their activities qualify as environmentally sustainable while satisfying minimum safeguards. First disclosures were required by non-financial undertakings in 2023 for reference period 2022. Financial institutions are required to disclose their Taxonomy alignment information in 2024 for reference period 2023.
– The **Sustainable Finance Disclosure Regulation (SFDR)**: requires financial market participants providing portfolio management and investment advice services to disclose information on the share of Taxonomy-aligned investments for financial products promoting environmental or social characteristics and those with a sustainable finance objective. First disclosures under SFDR were required in 2023 for reference period 2022.
– The **European Green Bonds (EUGB)** regulation: introduces a voluntary label requiring issuers to align the allocation of proceeds with the EU Taxonomy, make specific disclosures in their prospectuses, publish pre- and post-issuance review reports, an impact report as well as externally reviewed allocation reports.

The complexity of the rules currently limits the positive impact of these initiatives on green investments; streamlining the framework without backtracking on the enhanced transparency would be beneficial. The significant complexity of the regulatory framework may affect its overall effectiveness. The rapid and sequential introduction of parallel disclosure obligations has led to a complex framework, with duplications and occasional inconsistencies. The complexity poses compliance problems[131], and the demanding nature of the rules may in some instances generate unintended consequences, ultimately deterring, rather than incentivising, the provision of sustainable finance.[132] For instance, the high threshold for an investment to qualify as fully aligned with the EU Taxonomy might prevent many green investment opportunities from benefiting from the tool.[133] Similarly, the high cost of compliance with the voluntary European Green Bonds (EUGB)[134] standard, and the limited universe of Taxonomy-aligned investments to which it can be applied, might discourage issuers from making full use of the standard. This problem has been acknowledged by the European Commission, which has undertaken to work on improving the usability of the legal framework, including by reviewing the Sustainable Finance Disclosure Regulation (SFDR)[135] and through the work of the Platform on Sustainable Finance on data and usability.[136] Without

131 See Mezzanotte (2023).

132 For example, disclosure requirements under the SFDR are stricter for investment funds with higher sustainability credentials ("Article 9" funds) compared with conventional funds.

133 For instance, compliance with the "Do No Significant Harm" criterion of the Taxonomy has been recognised as a prominent usability challenge. See Platform on sustainable finance (2022).

134 Regulation (EU) 2023/2631 of the European Parliament and of the Council of 22 November 2023 on European Green Bonds and optional disclosures for bonds marketed as environmentally sustainable and for sustainability-linked bonds (OJ L, 2023/2631, 30.11.2023).

135 Regulation (EU) 2019/2088 of the European Parliament and of the Council of 27 November 2019 on sustainability-related disclosures in the financial services sector (OJ L 317, 9.12.2019, p. 1).

136 See European Commission (2023), Communication: A sustainable finance framework that works on the ground, 13 June 2023, and Platform on Sustainable Finance (2022).

backtracking on the fundamental objective of enhancing sustainability transparency, streamlining the regulatory framework and improving its usability might not only reduce the unnecessary reporting burden but also increase its usefulness for investors and end-users.

Another caveat relates to the fact that transition finance has to be better recognised. For example, the Taxonomy sets a high bar for the classification of an investment as "green" that many companies are currently unable to achieve, while its binary nature means that many investments contributing to the transition, but falling below the Taxonomy thresholds, might fail to be recognised as sustainable. This binary approach may prove too restrictive, potentially distorting investment decisions in favour of a narrow set of "dark green" investments and ultimately failing to appropriately incentivise firms to invest in green activities. In this spirit, EU policymakers should place greater emphasis on transition finance and build on the 2023 recommendations on transition finance[137], which was the approach of the European Banking Authority (EBA), for example, in its response to the European Commission's call for advice on green loans and mortgages[138].

Finally, enforcement and supervision of disclosures remains a challenge. The data emerging from these initiatives are presented in the form of public disclosures on the part of firms, rather than structured reporting to the relevant competent authorities. This makes the enforcement and supervision of the disclosures more arduous. Ensuring data quality is far more challenging, with currently only a limited assurance audit envisaged under the Corporate Sustainability Reporting Directive (CSRD)[139]. Accessing the information in machine-readable format in one centralised location will not be possible until the European Single Access Point goes live: this is currently scheduled for 2027.

---

137 Commission Recommendation (EU) 2023/1425 of 27 June 2023 on facilitating finance for the transition to a sustainable economy (OJ L 174, 7.7.2023, p. 19).

138 See EBA (2023). The EBA proposed a voluntary EU green loan label based on a two-tier approach: a first tier based on the EU Taxonomy; and a second tier that is more flexible, to facilitate market participants' credible efforts in contributing to environmental objectives.

139 Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting (OJ L 322, 16.12.2022, p. 15).

6 Conclusion

In this paper, we look at the expected green investment needs in Europe until 2030, outline the current and expected funding landscape and discuss policy options that would help to support the green transition. Five key messages emerge from this analysis.

First, the green investment needed in Europe, in addition to previous investment, is substantial. Available estimates of additional investment needs for the period to 2030 across institutions vary from €403 billion to €558 billion per year, or from about 2.7% to 3.7% of EU GDP (in 2023 prices) as they cover different sectors and/or sub-sectors, use different methodologies and are based on different assumptions to calculate the investment needs. Given the level of uncertainty, these estimates, which provide rough approximations of the investment needs, are therefore usefully complemented by a range of scenarios. A comparison of the investment needs to reach the 2030 target with actual green investment activities reveals significant shortfalls in recent years. These would add to the annual investment needs to 2030. The challenges are even greater at the global level.

Second, banks play a crucial role in ensuring access to finance for the green transition, while the role of capital markets is still limited. Evidence based on the BLS survey suggests that euro area banks have started to reflect climate-related risks in their loan approval and pricing decisions. At the same time, the share of green financing from capital markets is still relatively low, in particular for venture capital, although the growth of green market segments has gained pace. This aligns with the findings of the SAFE, which indicate that firms – SMEs in particular – consider financing costs an obstacle to green investments.

Third, although the lion's share of the green investment funding has to come from the private sector, the public sector can play an important role to crowd in private investment and mobilise private funding. At the EU level, significant amounts of public funds are available to support the green transition. The largest contribution comes from the RRF, assuming full absorption of the funds until the end of 2026. Stylised calculations which compare the investment needs with the available funds until 2030 suggest however a green public financing gap in particular in the outer years with the expiry of the RRF. To what extent this can be supplemented with national funding depends on the fiscal space, which is, however, limited in several countries. While an in-depth assessment of the macroeconomic impact of green investment is beyond the scope of this paper, simulations indicate that green public investment can provide economic benefits. However, the government-debt-to-GDP ratio may increase if such investment led to inflation and prompted a response from the central bank in line with its primary mandate. At the same time, while green public investment may pose fiscal risks, a lack of sufficient (public) investment might pose even greater risks, such as potential tipping points in climate change and long-term economic instability. For future analyses, it is therefore

crucial to also consider the long-term advantages of green public investment for climate sustainability and economic resilience.

Fourth, structural reforms and appropriate business conditions are essential to support European firms to innovate in, diffuse and fund green technologies. Lack of green skills and high regulatory burden are seen by European firms as obstacles which have to be addressed. Further support would also come from fiscal policies, notably via higher and more comprehensive carbon pricing. The new fiscal governance framework is expected to incentivise green investment activities.

Fifth, to accelerate green funding, the institutional setting of the green funding landscape needs to be reviewed. Private sector funding of green projects would benefit substantially from a more integrated European capital market. Various proposals on how this could be achieved are currently being discussed, including at the ECB. While the enforcement of the disclosure requirements would strengthen transparency, the high complexity of the requirements in their current form may limit their positive impact on green investment. In terms of green public funding, the expected gap after the expiry of the RRF raises questions on how this gap could be filled with the next EU budget.

Looking beyond the 2030 green investment target, which is the scope of this paper, available estimates point to even higher investment needs than what is considered until 2030. Although these estimates are associated with even greater uncertainty than those presented here, they underscore the need to further accelerate Europe's green investment activities to help contain changes in the climate trend.

References

Abraham, L., O'Connell, M. and Arruga Oleaga, I. (2023), "The Legal and Institutional Feasibility of an EU Climate and Energy Security Fund", *Occasional Paper Series*, No 313, ECB, March.

Accetturo, A., Barboni, G., Cascarano, M., Garcia-Appendini, E. and Tomasi, M. (2024), "Credit Supply and Green Investments", *Working Papers*, No 1456, Banca d'Italia, February.

Acemoglu, D., P. Aghion, Bursztyn, L. and Hémous, D. (2012), "The environment and directed technical change", *American Economic Review*, Vol. 102, No 1, pp. 131-166.

Adrian, T., Bolton, P. and Kleinnijenhuis, A.M. (2022), "The Great Carbon Arbitrage", *Working Papers*, No 107, International Monetary Fund, June.

Aghion, P., Dechezleprêtre, A., Hémous, D., Martin, R. and van Reenen, J. (2016), "Carbon Taxes, Path Dependency, and Directed Technical Change: Evidence from the Auto Industry", *Journal of Political Economy*, Vol. 124, No 1, pp. 1-51.

Altavilla, C., Boucinha, M., Pagano, M. and Polo, A. (2023), "Climate Risk, Bank Lending and Monetary Policy", *CEPR Discussion Papers,* No 18541, Centre for Economic Policy Research, October.

Altavilla, C., Ellul, A., Pagano, M., Polo, A. and Vlassopoulos, T. (2023), "Loan Guarantees, Bank Lending and Credit Risk Reallocation", *Finance Working Papers*, No 994, European Corporate Governance Institute, December.

Arampatzi, A., Christie, R., Evrard, J., Parisi, L., Rouveyrol, C., and van Overbeek, F. (2025), "Capital Markets Union: a deep dive - Five proposed measures to foster a single market for capital", *Occasional Paper Series* (forthcoming), ECB.

Arnold, N., Balakrishnan, R., Barkbu, B., Davoodi, H., Lagerborg, A., Lam, W., Medas, P., Otten, J., Rabier, L., Roehler, C., Shahmoradi, A., Spector, M., Weber, S. and Zettelmeyer, J. (2022), "Reforming the EU Fiscal Framework: Strengthening the Fiscal Rules and Institutions", *Departmental Papers*, No 014, International Monetary Fund, September.

Azoulay, P., Zivin, J., Li, D. and Sampat, B. (2019), "Public R&D Investment and Private Sector Patenting: Evidence from NIH Funding Rules", *The Review of Economic Studies*, Vol. 86, Issue 1, pp. 117-152.

Bacchiocchi, A., Bellocchi, A. and Giombini, G. (2024), "Green Investment Challenges in European Firms: Internal vs. External Resources", *Sustainability*, Vol. 16, Issue 2, pp. 1-20.

Baccianti, C. (2022), "The public spending needs of reaching the EU's climate targets", in Cerniglia, F. and Saraceno, F. (eds.), *Greening Europe: 2022 European Public Investment Outlook*, Open Book Publishers, Cambridge, pp. 107-128.

Bakker, A., Beetsma, R. and Buti, M. (2024), "Investing in European Public Goods While Maintaining Fiscal Discipline at Home", *Intereconomics*, Vol. 59, No 2, pp. 98-103.

Bańkowski, K. (2023), "Fiscal policy in the semi-structural model ECB-BASE", *Working Paper Series*, No 2802, ECB, March.

Bańkowski, K., Benalal, N., Bouabdallah, O., De Stefani, R., Dorrucci, E., Huber, C., Jacquinot, P., Modery, M., Nerlich, C., Rodríguez-Vives, M., Zorell, N. and Zwick, C. (2024), "Four years into NextGenerationEU: what impact on the euro area economy?", *Occasional Paper Series*, No 362, ECB, December.

Bańkowski, K., Bouabdallah, O., Domingues Semeano, J., Dorrucci, E., Freier, M., Jacquinot, P., Modery, W., Rodriguez-Vives, M., Valenta, V. and Zorell, N. (2022), "The economic impact of Next Generation EU: a euro area perspective", *Occasional Paper Series*, No 291, ECB, April.

Batini, N., di Serio, M., Fragetta, M., Melina, G. and Waldron, A. (2021), "Building back better: how big are green spending multipliers?", *Working Papers*, No 087, International Monetary Fund, March.

Bellucci, A., Fatica, S., Georgakaki, A., Gucciardi, G., Letout, S. and Pasimeni, F. (2023), "Venture Capital Financing and Green Patenting", *Industry and Innovation*, Vol. 30, Issue 7, pp. 947-983.

Benatti, N., Groiss, M., Kelly, P. and Lopez-Garcia, P. (2024), "The impact of environmental regulation on clean innovation: are there crowding out effects?", *Working Paper Series*, No 2946, ECB, June.

Bettarelli, L., Furceri, D., Pizzuto, P. and Shakoor, N. (2023), "Environmental Policies and Innovation in Renewable Energy", *Working Papers*, No 180, International Monetary Fund, September.

Bijnens, G., Duprez, C. and Hutchinson, J. (2024), "Obstacles to the greening of energy-intensive industries", *The ECB Blog*, ECB, 17 September.

Blickle, K., Parlatore, C. and Saunders, A. (2023), "Specialization in Banking", *NBER Working Papers*, No 31077, National Bureau of Economic Research, April.

BloombergNEF (2024a), New Energy Outlook 2024, May.

BloombergNEF (2024b), Energy Transition Investment Trends 2024.

BloombergNEF (2024c), Energy Transition Investment Trends 2024 (Abridged version), Executive Summary.

BloombergNEF (2024d), *New Energy Outlook 2024: Data Viewer (1.1)*.

Bluedorn, J. and Hansen, N.-J. (2022), "The Right Labor Market Policies Can Ease the Green Jobs Transition", *IMF Blog*, International Monetary Fund, 13 April.

Bouabdallah, O., Dorrucci, E., Hoendervangers, L. and Nerlich, C. (2024), "Mind the gap: Europe's strategic investment needs and how to support them", *The ECB Blog*, ECB, 27 June.

Bouchmel, I., Zied Ftiti, Z., Louhich, W. and Omri, A. (2024), "Financing sources, green investment, and environmental performance: Cross-country evidence", *Journal of Environmental Management*, Vol. 353.

Boutron, C. (2023), "Greener, better, stronger: factors for the successful implementation of green budgeting in EU Member States", Institute for Climate Economics, June.

Buchetti, B., Miquel-Flores, I., Perdichizzi, S. and Reghezza, A. (2023), "Greening the Economy: How Public-Guaranteed Loans Influence Firm-Level Resource Allocation", February.

Budina, N., Ebeke, C., Jaumotte, F., Medici, A., Panton, A., Mendes Tavares, M. and Yao, B. (2023), "Structural Reforms to Accelerate Growth, Ease Policy Trade-Offs and Support the Green Transition in Emerging and Developing Economies," *Staff Discussion Notes*, No 007, International Monetary Fund, September.

Canova, F. (2024), "The Macroeconomic Effects of EU Regional Structural Funds," *Journal of the European Economic Association*, April.

Capotă, L-D., Giuzio, M., Kapadia, S. and Salakhova, D. (2022), "Are ethical and green investment funds more resilient?", *Working Paper Series*, No 2747, ECB, November.

Carradori, O., Molitor, P. and Schölermann, H. (2022), "Making euro area equity markets fit for green and digital innovation", *Financial Integration and Structure in the Euro Area*, ECB, April.

Causa, O., Luu, N. and Abendschein, M. (2021), "Labour market transitions across OECD countries: Stylised facts", OECD Economics Department Working Papers, No 1692, Organisation for Economic Co-operation and Development, December.

Cecere, G., Corrocher, N. and Mancusi, M. (2020), "Financial constraints and public funding of eco-innovation: empirical evidence from European SMEs", *Small Business Economics*, Vol. 54, No 1, pp. 285-302.

Cera, K., Daly, P., Hermans, L., Molitor, P., Schwartz-Blicke, O., Sowiński, A. and Telesca, E. (2024), "Private markets, public risk? Financial stability implications of alternative funding sources", *Financial Stability Review*, ECB, May.

Claeys, G., McCaffrey, C. and Weslau, L. (2023), "What will it cost the European Union to pay its economic recovery debt?", *Bruegel Analysis*, 9 October.

Coelho, M. (2019), "Fiscal Stimulus in a Monetary Union: Evidence from Eurozone Regions", *IMF Economic Review*, Vol. 67, International Monetary Fund, pp. 573-617.

Costa, H., Demmou, L., Franco, G. and Lamp, S. (2024), "Making the grass greener: The role of firm's financial and managerial capacity in paving the way for the green transition", *OECD Economics Department Working Papers*, No 1791, Organisation for Economic Co-operation and Development, February.

D'Arcangelo, F.M., Kruse, T., Pisu, M. and Tomasi, M. (2023), "Corporate cost of debt in the low-carbon transition: The effect of climate policies on firm financing and investment through the banking channel", *OECD Economics Department Working Papers*, No 1761, Organisation for Economic Co-operation and Development, June.

Darvas, Z. and Wolff, G. (2021), "A green fiscal pact: climate investment in times of budget consolidation", *Bruegel Policy Contribution*, Issue 18, September.

David, P.A., Hall, B.H. and Toole, A.A. (2000), "Is public R&D a complement or substitute for private R&D? A review of the econometric evidence", *Research Policy*, Vol. 29, Issues 4-5, pp. 497-529.

Del Negro, M., di Giovanni, J. and Dogra, K. (2023), "Is the Green Transition Inflationary?", *Staff Reports,* No 1053, Federal Reserve Bank of New York, December.

Delgado, M., Ferdinandusse, M. and Nerlich, C. (2022), "Fiscal policies to mitigate climate change in the euro area", *Economic Bulletin*, Issue 6, ECB.

De Santis, R., Freier, M. and Vinci, F. (2022), "Business investment and the Next Generation EU instrument – crowding in or crowding out?", *Economic Bulletin*, Box, Issue 5, ECB.

Draghi, M. (2024), "The Future of European Competitiveness Part A" and "The Future of European Competitiveness Part B", September.

Emambakhsh, T., Fuchs, M., Kördel, S., Kouratzoglou, C., Lelli, C., Pizzeghello, R., Salleo, C. and Spaggiari, M. (2023), "The Road to Paris: stress testing the transition towards a net-zero economy", *Occasional Paper Series*, No 328, ECB, September.

European Banking Authority (2022), "EBA publishes binding standards on Pillar 3 disclosures on ESG risks", *press release*, 24 January.

European Banking Authority (2023), "Response to the call for advice from the European Commission on green loans and mortgages", December.

European Central Bank (2021), "Climate change and monetary policy in the euro area", *Occasional Paper Series*, No 271, September.

European Central Bank (2023a), "The euro area bank lending survey – Second quarter of 2023", July.

European Central Bank (2023b), "SSM supervisory priorities 2024-2026".

European Central Bank (2024a), "Risks from misalignment of banks' financing with the EU climate objectives", January.

European Central Bank (2024b), "Climate change-related statistical indicators", *Statistics Paper Series*, No 48, April.

European Central Bank (2024c), "The euro area bank lending survey – Second quarter of 2024", July.

European Central Bank and European Systemic Risk Board (2023), "Towards macroprudential frameworks for managing climate risk", December.

European Commission (2019), "The European Green Deal", communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, December.

European Commission (2020a), "Stepping up Europe's 2030 climate ambition – Investing in a climate-neutral future for the benefit of our people", communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, September.

European Commission (2020b), "Sustainable and Smart Mobility Strategy – putting European transport on track for the future", communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, December.

European Commission (2021a), "Delivering the Green Deal", July.

European Commission (2021b), Impact assessment report accompanying the proposal for a directive of the European Parliament and the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652, July.

European Commission (2022), "Towards a green, digital and resilient economy: our European Growth Model", communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, March.

European Commission (2023a), "Investment needs assessment and funding availabilities to strengthen EU's Net-Zero technology manufacturing capacity", March.

European Commission (2023b), "Sustainability and people's wellbeing at the heart of Europe's Open Strategic Autonomy", *2023 Strategic Foresight Report*, July.

European Commission (2023c), Progress Report 2023 – Climate Action, October.

European Commission (2023d), "EU wide assessment of the draft updated National Energy and Climate Plans: an important step towards the more ambitious 2030 energy and climate objectives under the European Green Deal and RePowerEU", communication from the Commission to the European Parliament, the Council, the

European Economic and Social Committee and the Committee of the Regions, December.

European Commission (2024), Financial instruments and models for transmission and distribution – Investors dialogue on energy, January

European Court of Auditors (2024a), "EU cohesion spending: control system not working", 8 July.

European Court of Auditors (2024b), "Green transition – Unclear contribution from the Recovery and Resilience Facility", *Special Reports*, No 14, September.

European Court of Auditors (2024c), "Absorption of funds from the Recovery and Resilience Facility – Progressing with delays and risks remain regarding the completion of measures and therefore the achievement of RRF objectives", *Special Reports*, No 13, September.

European Environment Agency (2024), "What is the difference between adaptation and mitigation?", August.

European Investment Bank (2021), "Macroeconomic impact of the European Fund for Strategic Investments – Complementary section to the evaluation of the European Fund for Strategic Investments 2021", June.

European Investment Bank (2023), "Mid-term review of the EIB Group Climate Bank Roadmap", November.

European Investment Bank (2024a), Investment Report 2023/2024: Transforming for competitiveness, especially Chapter 5, "Investing in green transformation", February.

European Investment Bank (2024b), "Financing and borrowing activities 2023", May.

European Investment Bank and European Patent Office (2024), "Financing and commercialisation of cleantech innovation", April.

European Securities and Markets Authority (2023), "The European sustainable debt market – do issuers benefit from an ESG pricing effect?", *ESMA TRV Risk Analysis*, October.

Faccia, D., Hünnekes, F. and Köhler-Ulbrich, P. (2024), "What drives banks' credit standards? An analysis based on a large bank-firm panel", *Working Paper Series*, No 2902, ECB, February.

Ferrando, A., Groß, J. and Rariga, J. (2023), "Climate change and euro area firms' green investment and financing – results from the SAFE", *Economic Bulletin*, Issue 6, ECB.

Gambacorta, L., Polizzi, S., Reghezza, A. and Scannella, E. (2023), "Do banks practice what they preach? Brown lending and environmental disclosure in the euro area", *Working Paper Series*, No 2872, ECB, November.

Germanwatch (2023), "The Climate Change Performance Index 2024: Results", December.

Giannetti, M., Jasova, M., Loumioti, M. and Mendicino, C. (2023), "Green lending: do banks walk the talk?", *The ECB Blog*, ECB, 6 December.

Goldstein, I., Kopytov, A., Shen, L. and Xiang, H. (2022), "On ESG investing: heterogeneous preferences, information, and asset prices", *NBER Working Papers*, No 29839, National Bureau of Economic Research, April.

Haas, R. and Popov, A. (2023), "Finance and Green Growth", *The Economic Journal*, Vol. 133, Issue 650, pp. 637-668.

Haroutunian, S., Bańkowski, K., Bischl, S., Bouabdallah, O., Hauptmeier, S., Leiner-Killinger, N., O'Connell, M., Arruga Oleaga, I., Abraham, L. and Trzcinska, A. (2024), "The path to the reformed EU fiscal framework: a monetary policy perspective", *Occasional Paper Series*, No 349, ECB, May.

Hasna, Z., Jaumotte, F., Kim, J., Pienknagura, S. and Schwerhoff, G. (2023), "Green Innovation and Diffusion: Policies to Accelerate Them and Expected Impact on Macroeconomic and Firm-Level Performance", *Staff Discussion Notes*, No 008, International Monetary Fund, November.

Howell, S. (2017), "Financing Innovation: Evidence from R&D Grants", *American Economic Review*, Vol. 107, No 4, pp. 1136-1164.

Hünnekes, F. and Köhler-Ulbrich, P. (2022), "What information does the euro area bank lending survey provide on future loan developments?", *Economic Bulletin*, Issue 8, ECB.

Institute for Climate Economics (2024), "European Climate Investment Deficit report, I4CE, Paris, February.

Intergovernmental Panel on Climate Change (2022), "Climate Change 2022: Impacts, Adaptation, and Vulnerability", Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

International Energy Agency (2023a), World Energy Investment 2023, May.

International Energy Agency (2023b), Global Energy and Climate Model, Documentation – 2023.

International Energy Agency (2023c), Net Zero Roadmap A Global Pathway to Keep the 1.5 °C Goal in Reach: 2023 Update.

International Energy Agency (2024a), "Past and future energy investment in the European Union in the Announced Pledges Scenario and the Net Zero Emissions by 2050 Scenario, 2016-2030".

International Energy Agency (2024b), "Annual investment in clean energy by selected country and region, 2019 and 2024".

International Energy Agency (2024c), World Energy Investment 2024, June.

International Monetary Fund (2020), "Mitigating Climate Change – Growth- and Distribution-Friendly Strategies", *World Economic Outlook*, October.

International Renewable Energy Agency (2021), "Renewable Capacity Statistics 2021", technical report, April.

International Renewable Energy Agency (2022), "Renewable power generation costs in 2021", technical report, July.

Känzig, D. (2023), "The unequal economic consequences of carbon pricing", *NBER Working Papers*, No 31221, National Bureau of Economic Research, May.

Kleimeier, S. and Viehs, M. (2018), "Carbon Disclosure, Emission Levels, and the Cost of Debt", January.

Lagarde, C. (2021), "Towards a green capital markets union for Europe", speech at the European Commission's high-level conference on the proposal for a Corporate Sustainability Reporting Directive, 6 May.

Lagarde, C. (2024), "Follow the money: channelling savings into investment and innovation in Europe", speech at the 34th European Banking Congress, 22 November.

Letta, E. (2024), "Much More Than a Market. Speed, Security, Solidarity: Empowering the Single Market to deliver a sustainable future and prosperity for all EU Citizens", April.

Mack, S. (2024), "Handle with care – how Europe can reap the benefits of securitization", *Policy Briefs*, Hertie School-Jacques Delors Centre, March.

Masuch, K., Anderton, R., Setzer, R. and Benalal, N. (2018), "Structural policies in the euro area", *Occasional Paper Series*, No 210, ECB, June.

McKinsey (2020), "Net-Zero Europe – Decarbonization pathways and socioeconomic implications", November.

Mezzanotte, F.E. (2023), "EU Sustainable Finance: Complex Rules and Compliance Problems", *Review of Banking and Financial Law*, Vol. 42, Issue 2, pp. 845-896.

Moretti, E., Steinwender, C. and Van Reenen, J. (2023), "The Intellectual Spoils of War? Defense R&D, Productivity, and International Spillovers", *The Review of Economics and Statistics*, pp. 1-46.

Nachtigall, D., Lutz, L., Cárdenas Rodríguez, M., Haščič, I. and Pizarro, R. (2022), "The climate actions and policies measurement framework: A structured and harmonised climate policy database to monitor countries' mitigation action", *OECD Environment Working Papers*, No 203, Organisation for Economic Co-operation and Development, November.

Olovssen, C. and Vestin, D. (2023), "Greenflation?", *Working Paper Series*, No 420, Sveriges Riksbank, May.

Organisation for Economic Co-operation and Development (2023), "Effective Carbon Rates 2023 – Pricing Greenhouse Gas Emissions through Taxes and Emissions Trading", November.

Panetta, F. (2023), "Investing in tomorrow: Future-proofing fiscal policies and governance in Europe", opening remarks at the joint workshop of European independent fiscal institutions and the European System of Central Banks on "European fiscal policy and governance reform in uncertain times", 20 September.

Pástor, Ľ., Stambaugh, R.F. and Taylor, L.A. (2021), "Sustainable investing in equilibrium", *Journal of Financial Economics*, Vol. 142, Issue 2, pp. 550-571.

Pfeiffer, P., Varga, J. and in t'Veld, J. (2023), "Quantifying spillovers of coordinated investment stimulus in the EU", *Macroeconomic Dynamics*, Vol. 27, Issue 7, pp. 1843-1865.

Pietsch, A. and Salakhova, D. (2022), "Pricing of green bonds: drivers and dynamics of the greenium", *Working Paper Series*, No 2728, ECB, September.

Pisani-Ferry, J. and Mahfouz, S. (2023), "The economic implications of climate action: a report to the French Prime Minister", November.

Platform on Sustainable Finance (2022), "Platform recommendations on Data and Usability as part of Taxonomy reporting", October.

Platform on Sustainable Finance (2024), "Monitoring capital flows to sustainable investments: Intermediate Report", April.

Reghezza, A., Altunbas, Y., Marques-Ibanez, D., Rodriguez d'Acri, C. and Spaggiari, M. (2021), "Do banks fuel climate change?", *Working Paper Series*, No 2550, ECB, May.

Sastry, P., Marques-Ibanez, D. and Verner, E. (2023), "Business as Usual: Bank Net-Zero Commitments, Lending, and Engagement", December.

Schang, C. and Vinci, F. (2024), "Marrying fiscal rules & investment: a central fiscal capacity for Europe", *Working Paper Series*, No 2962, ECB, July.

Seghini, C. and Dees, S. (2024), "The Green Transition and Public Finances", *Working Paper Series*, No 949, Banque de France, May.

Single Supervisory Mechanism (2022), 2022 climate risk stress test, July.

Steuer, S. and Tröger, T.H. (2022), "The Role of Disclosure in Green Finance", *Journal of Financial Regulation*, Vol. 8, Issue 1, pp.1-50.

Svartzman, R., Dee, S., Miller, H. and Dikau, S. (2023), "The Stumbling Block in 'the Race of our Lives': Transition-Critical Materials, Financial Risks and the NGFS Climate Scenarios", *Working Paper Series*, No 907, Banque de France, February.

Victor, P.A. (2022), “The Macroeconomics of a Green Transformation: The Role of Green Investment”, Heinrich Böll Stiftung, March.

World Bank (2024), Climate Adaptation Costing in a Changing World, Washington, September.

Acknowledgements
We would like to thank, in alphabetical order, Katrin Assenmacher, Giuseppe Barilla, Ursel Baumann, Lorenzo Burlon, Ettore Dorrucci, Francesco Drudi, Benoit Hallinger, Irene Heemskerk, Daniel Kapp, Niels Krieghoff, Hermans Lieven, Paloma Lopez-Garcia, Philipe Molitor, Christiane Nickel, Gilles Noblet, Laura Parisi, Philipp Rother, Michiel de Smet, Livio Stracca and David Sondermann for their valuable comments. We thank the ESCB WGPF for sharing their data on green measures. We are grateful to the European Investment Bank (Deborah Revoltella, Laurent Marin, Chiara Fratto, Huyen Tran, Georg Weiers, Andrea Brasili and Annamaria Tueske), the European Commission (Miguel Gil Tertre and Clement Serre), the International Energy Agency (Tim Gould, Tanguy Debienassis and Cecilia Tam) and the European Patent Office (Ilja Rudyk) for sharing their data and analysis. Sarah Frost contributed to an earlier version of the paper. The views expressed are those of the authors and all errors and omissions are their own.

Carolin Nerlich
European Central Bank, Frankfurt am Main, Germany; email: carolin.nerlich@ecb.europa.eu

Petra Köhler-Ulbrich
European Central Bank, Frankfurt am Main, Germany; email: petra.koehler-ulbrich@ecb.europa.eu

Malin Andersson
European Central Bank, Frankfurt am Main, Germany; email: malin.andersson@ecb.europa.eu

Carlo Pasqua
European Central Bank, Frankfurt am Main, Germany; email: carlo.pasqua@ecb.europa.eu

Laurent Abraham
European Central Bank, Frankfurt am Main, Germany; email: laurent.abraham@ecb.europa.eu

Krzysztof Bańkowski
European Central Bank, Frankfurt am Main, Germany; email: krzysztof.bankowski@ecb.europa.eu

Tina Emambakhsh
European Central Bank, Frankfurt am Main, Germany; email: tina.emambakhsh@ecb.europa.eu

Annalisa Ferrando
European Central Bank, Frankfurt am Main, Germany; email: annalisa.ferrando@ecb.europa.eu

Charlotte Grynberg
European Central Bank, Frankfurt am Main, Germany; email: charlotte.grynberg@ecb.europa.eu

Johannes Groß
European Central Bank, Frankfurt am Main, Germany; email: johannes.gross@ecb.europa.eu

Vasileios Kostakis
European Central Bank, Frankfurt am Main, Germany; email: vasileios.kostakis@ecb.europa.eu

Daphne Momferatou
European Central Bank, Frankfurt am Main, Germany; email: daphne.momferatou@ecb.europa.eu

Matthias Rau-Goehring
European Central Bank, Frankfurt am Main, Germany; email: matthias.rau-goehring@ecb.europa.eu

Erzsebet-Judit Rariga
European Central Bank, Frankfurt am Main, Germany; email: erzsebet-judit.rariga@ecb.europa.eu

Desislava Rusinova
European Central Bank, Frankfurt am Main, Germany; email: desislava.rusinova@ecb.europa.eu

Ralph Setzer
European Central Bank, Frankfurt am Main, Germany; email: ralph.setzer@ecb.europa.eu

Martina Spaggiari
European Central Bank, Frankfurt am Main, Germany; email: martina.spaggiari@ecb.europa.eu

Fabio Tamburrini
European Central Bank, Frankfurt am Main, Germany; email: fabio.tamburrini@ecb.europa.eu

Josep Maria Vendrell Simon
European Central Bank, Frankfurt am Main, Germany; email: josep-maria.vendrell-simon@ecb.europa.eu

Francesca Romana Vinci
European Central Bank, Frankfurt am Main, Germany; email: francesca_romana.vinci@ecb.europa.eu

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

PDF ISBN 978-92-899-6997-0, ISSN 1725-6534, doi:10.2866/4426620, QB-01-25-015-EN-N