



INVESTMENT REPORT
2021/2022



Recovery as
a springboard
for change

Chapter 6

Living up to Europe's green ambitions

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Recovery as a springboard for change

Part III Recovery as a springboard for structural change

Chapter 6 **Living up to Europe's green ambitions**

Investment Report 2021/2022: Recovery as a springboard for change.

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About the Report

The EIB annual report on Investment and Investment Finance is a product of the EIB Economics Department. It provides a comprehensive overview of the developments and drivers of investment and its finance in the European Union. The report combines an analysis and understanding of key market trends and developments with a more in-depth thematic focus, which this year is devoted to Europe's progress towards a digital and green future in the post-COVID-19 era. The report draws extensively on the results of the annual EIB Investment Survey (EIBIS) and the EIB Municipality Survey. It complements internal EIB analysis with contributions from leading experts in the field.

About the Economics Department of the EIB

The mission of the EIB Economics Department is to provide economic analyses and studies to support the Bank in its operations and in the definition of its positioning, strategy and policy. The director of Economics Department, Debora Revoltella, heads a team of 40 economists.

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Chapter 6

Living up to Europe's green ambitions



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Chapter 6

Living up to Europe's green ambitions

Europe has made significant progress with its climate policies in recent years. The **European Green Deal** outlined its ambition to become the first carbon-neutral continent by 2050, and set an interim goal of cutting emissions by 55% (compared to 1990 levels). The **Fit for 55 package** proposes concrete legislative steps to meet the climate objectives. Other initiatives, such as the **EU Taxonomy for sustainable activities** and the new requirements for corporate disclosure of climate-related information, are improving the understanding and transparency of sustainable activities. Financial intermediaries and investors should now be able to measure and assess climate risks. At the same time, the **Recovery and Resilience Facility**, which is providing EUR 723.8 billion in loans and grants to EU members, will allocate at least 37% of its funds to climate investment and reforms. The European Investment Bank (EIB) has committed to its role as a climate bank by setting operational targets outlined in its **Climate Bank Roadmap**. Taken together, these elements illustrate the central role the climate is playing in European policymaking.

Within this framework, the decisions public and private sector players make about tackling climate change today will affect their future prosperity and determine the ultimate success of decarbonisation efforts. Firms are critical to closing the yawning gap for climate investments and reaching the goal of carbon-neutrality. Pricing climate risks accurately will help the financial sector evaluate projects and potentially redirect savings. In parallel, local governments need to guide the transformation at a local level. Innovation is essential, as some green technologies are still being developed.

The EIB Investment Survey (EIBIS) shows that European firms' climate investments stalled during the COVID-19 crisis, but firms are now eager to restart those investment plans. Large firms and those in green (low-emission) or brown (high-emission) sectors are more likely to invest in climate measures. Small firms and those in transition sectors are less aware of the effort required. Advancements in the regulatory framework are crucial, as uncertainty about regulation and taxation remains the biggest obstacle for EU firms' climate investments. As the framework evolves, EU firms will benefit from a clear path to decarbonisation set out at the national and EU level. Advice on funding and technical support is important to help accelerate the green transition. Those firms with more advanced green management practices are more likely to invest.

The green transition also relies on the transformation of the financial sector and local governments, as well as an enhanced focus on innovation. EU corporate bond markets are showing evidence of a "greenium," or a premium paid for green assets. Urban areas are responsible for a large share of global emissions, making their future infrastructure decisions and other projects essential to tackling climate change. An analysis from the EIB Municipalities Survey shows that addressing climate-related issues is a challenge for smaller municipalities, which can oftentimes lack technical capacity and funding. The climate transition also presents opportunities, particularly in Europe, which already has an early lead in green innovation. If Europe can become a market leader in emerging green technologies, it could reap economic benefits comparable to those gained by the United States because of its digital dominance.

Introduction

Adapting to the potential effects of climate change is a complex and ongoing process requiring actions by firms, individuals, local and national governments, financial market players and international agencies. While the COVID-19 crisis stalled climate investment, the road to recovery presents an opportunity to act and contribute to regional and international climate objectives. The ambitious European Green Deal set out long and short-term decarbonisation targets and a comprehensive set of measures aligning market incentives with the green transition. The Recovery and Resilience Facility will also unleash resources conditional on climate investment and reforms. Overall, the European Union's recovery strategy has the potential to be the much-needed push to accelerate the response to the climate emergency and to contribute to the EU pledge of becoming the first carbon-neutral continent by 2050.

Against this background, this chapter aims to act as a guide for understanding and interpreting the ongoing changes and strategies developed in response to the climate threat. It relies on data from the EIBIS, the EIB Municipalities Survey, and other external data sources to answer key questions concerning the transition to a low-carbon and sustainable economy.

The chapter starts by discussing the greenhouse gas emissions trends in the European Union and the evolution of EU policies addressing the green transition. It then looks in depth at firms' carbon strategies, and assesses the role of the perception of climate risks, the availability of financial resources and other firm characteristics that factor into decision-making. The chapter also focuses on the transformation of the financial sector and provides initial evidence of the existence of a "greenium" (a premium paid by investors with strong preferences for green assets). It then turns to the public sector and assesses how the current transition is forming sustainable development models among municipalities and examines Europe's innovation activities by assessing strengths and weaknesses in the areas of energy and transport and mobility. Lastly, it provides policy recommendations on how to address the obstacles on Europe's road to a clean, affordable and secure energy future.

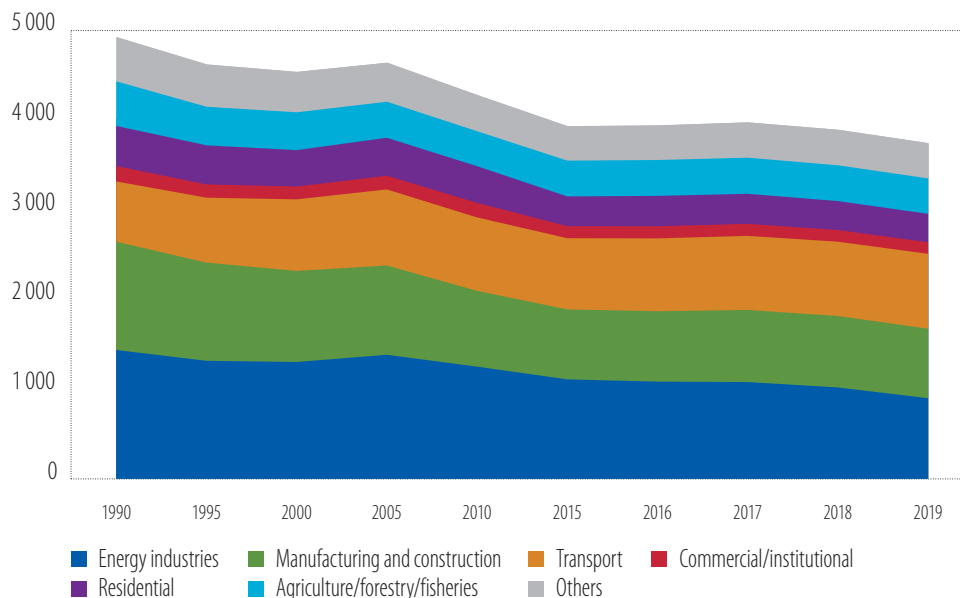
EU policies to address climate change

Europe has made significant progress in acting on its decarbonisation ambitions in recent decades. With the European Green Deal, the European Union clearly stated its goal of becoming the first carbon-neutral continent by 2050 and set an interim goal of cutting emissions by 55% (compared to 1990 levels) by 2030. Greenhouse gas emissions data for the European Union are only available through 2019 (before the COVID-19 crisis), but they point to a 26% overall decline in emissions vs. 1990 levels. Emissions likely fell further in 2020 and the first half of 2021, but the reductions were most probably COVID-19-related and temporary. Similarly, the COVID-19 crisis temporarily resulted in global emissions reductions of 5.8% in 2020, but emissions quickly rose again with the economic recovery.

Before the COVID-19 crisis, decarbonisation efforts were mainly focused on energy efficiency and renewable energy. Figure 1 shows the trend of greenhouse gas emissions in Europe and their distribution across sectors, including households, since 1990. All sectors reduced their greenhouse gas emissions from 1990 to 2019, except for the transport sector. Energy industries and manufacturing accounted for about 55% of the decrease from 1990 to 2019, while the residential sector accounted for about 13%.

By the end of 2019, the overwhelming majority of greenhouse gas emissions in the European Union were from non-residential sources, underlining the importance of reducing emissions in key areas like manufacturing, energy industries and transport. Energy industries, together with transport and manufacturing, accounted for two-thirds of emissions in 2019. By contrast, households represented 8% of greenhouse gas emissions, resulting mostly from higher demand for electricity and heating.

Figure 1
Greenhouse gas emissions from energy and non-energy sources in Europe (Mtoe), 1990-2019



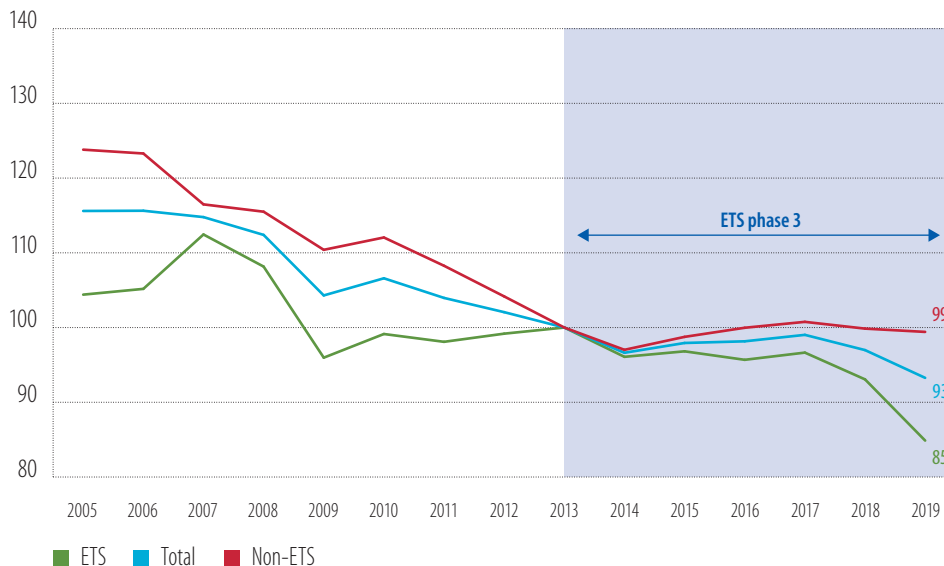
Source: Eurostat.

Notes: Mtoe stands for metric tonnes of oil equivalent.

Most sectors are not held liable financially for the social cost of their emissions, and hence have little incentive to reduce their carbon footprint. If sectors had to pay the true social cost of their emissions, they would be motivated to cut them by changing production and organisational processes, employing different technologies, introducing innovations or simply reducing output. Greenhouse gas emissions could be reduced by making emitters pay for the costs that they impose on others — whether by introducing a tax per unit of emitted greenhouse gas or by requiring the purchase of emission credits.

The European Union Emissions Trading System (ETS), the first large-scale greenhouse gas emissions trading scheme in the world, is showing how greenhouse gas emissions can be reduced by placing a price on them. The EU ETS began operating in 2005 with emission permits mostly freely allocated to greenhouse gas emitting sectors in participating countries. Permit allocations have been centralised since 2013, and many are now auctioned. The ETS has led to a noticeable decline in greenhouse gas emissions from the sectors participating in the scheme compared to those not covered (Figure 2). Free allocations are mostly limited to very carbon-intensive industries (that are included in the carbon-leakage list), whose competitiveness internationally may be endangered by higher production costs. However, the emissions trading system currently only covers 40% of the EU economy.

Figure 2
EU greenhouse gas emissions of ETS and non-ETS sectors (2013=100)



Source: European Environment Agency and European Commission.
Note: The shaded region marks phase 3 of the EU ETS.

Public policies are needed to address market failures, barriers to the abatement of greenhouse gases and distributional impacts. Innovation in decarbonisation technologies needs to rapidly accelerate for enough greenhouse gases to be abated to meet the climate targets. Without government intervention, innovation will remain below the optimal level. Furthermore, information asymmetries prevent investors from assessing how exposed their investments are to climate risks and hinder the mobilisation of private capital for green investment. Lastly, lower income groups are disproportionately affected by carbon pricing because many goods with high carbon content are considered necessities, and spending on these necessities eats up a larger share of income. Government support is therefore needed to address these issues.

The European Green Deal and the subsequent Fit for 55 package constitute a major step forward in strengthening policies to deal with climate change. The European Green Deal and the **European Climate Law**, which codifies Europe's climate targets, represent a credible commitment to the Paris Agreement. Fit for 55 (European Commission, 2021) is a comprehensive package of legislative proposals aimed at meeting the intermediate target of reducing greenhouse gas emissions by 55% by 2030 (relative to 1990 levels). The package contains sweeping measures that, if implemented, will make achieving the 55% target feasible. Directives on renewable energy and energy efficiency contain even more ambitious targets.

Under Europe's climate policies, the Emissions Trading System will be expanded and strengthened, while its distributional impacts will be mitigated. The proposed policy package reinforces carbon pricing by expanding the existing trading system to include the construction and transport sectors from 2026. Further measures, including changes to the framework of EU energy taxes, will also help decarbonise these two sectors. Recognising the implications of these measures on different social groups, the European Commission proposed a Social Climate Fund that will use revenues from the new ETS to help vulnerable households and small businesses integrate these new policies. In addition, the European Union will put in place a carbon border adjustment mechanism to ensure that products from carbon-intensive industries remain competitive and do not have to face imports from regions with less stringent climate policies.

In addition, the Fit for 55 package has updated the Effort Sharing Regulation (ESR) to assign more ambitious emissions reduction targets to EU members. The ESR concerns all sectors that are not covered by the ETS,¹ which together are responsible for about 60% of total EU emissions. Unlike the Emissions Trading System, the ESR is not based on EU-wide price signals. Instead, it consists of regulatory mechanisms that aim to promote specific measures for energy efficiency, renewable energy, eco-design, buildings' energy performance, carbon emission standards for cars and charging infrastructure. Under the ESR, each EU member is assigned a specific emission target based on the country's relative wealth, as measured by gross domestic product per capita.

The introduction of standards for sustainable investments and green bonds, and of new climate disclosure rules for financial investments, will help flow more money to sustainable investment. The European Union is putting in place new regulations to improve the transparency of green investments. The **EU Taxonomy for sustainable activities** (in force since July 2020) provides a common classification system that determines whether an economic activity qualifies as "environmentally sustainable." The taxonomy applies to (i) financial market participants; (ii) entities² falling within the scope of the Non-Financial Reporting Directive (NFRD, in force since 2014); and (iii) EU members and the European Union more generally when setting out requirements for financial products dealing with environmentally sustainable investments. The **European Green Bond Standard** (July 2021) creates a gold standard for issuers seeking to use green bonds to raise funds on capital markets. The Sustainable Finance Disclosure Regulation (in force since 2019) requires financial market participants and financial advisers to provide investors with sustainability-related information for financial products and the underlying assets. The regulation set out clear guidelines on how financial intermediaries should measure and assess climate risks embedded in their portfolios, and included provisions for climate stress tests.

Requiring firms to be more transparent about the climate risks they face will improve the flow of information, and therefore capital. The Non-Financial Reporting Directive requires large public companies with more than 500 employees to disclose information on environmental protection, social responsibility, respect for human rights, diversity, and anti-corruption and bribery. The European Commission adopted the Corporate Sustainability Reporting Directive (CSRD) in April 2021, which effectively amends NFRD reporting requirements. The proposal (i) extends the NFRD's scope to all large companies and all companies listed on regulated financial markets (except listed micro-enterprises); (ii) requires the audit (assurance) of reported information; (iii) introduces more detailed reporting requirements according to mandatory EU sustainability reporting standards; and (iv) requires companies to digitally tag the reported information. All of these measures are helping to build a regulatory framework around climate risk and environmental sustainability.

Enhanced transparency and the recognition of climate risks will likely put pressure on the prices of assets related to carbon-intensive activities. Higher carbon prices and EU targets for renewable energy and energy efficiency, enhanced corporate disclosure and increased investment in sustainability activities will eventually push investors to offload assets in carbon-related industries. Those shifting investment patterns will reduce the value of carbon-related assets and increase the cost of finance. Many assets will become too costly to operate or will simply become obsolete because of new regulations (stranded assets). Carbon-related assets will slowly be replaced by greener, more sustainable ones. Whether these new assets will be more productive and make the economy more efficient is unclear. In the benign scenario, the new assets will result in higher productivity that will ease the cost of the green transition, while in a more conservative scenario, the new assets will just replace the old assets.³

1 Agriculture, buildings (such as commercial services), transport, waste management and small industry.

2 Large listed companies, banks and insurance companies with more than 500 employees are required to disclose non-financial information under the NFRD.

3 Box A elaborates further on this issue.

Box A**Transition policies from a macroeconomic perspective**

This box discusses the implications of climate mitigation policies on the wider economy. Climate policies primarily aim to cut greenhouse gas emissions by absorbing the social cost of carbon emissions into market prices. These social costs will eventually increase the price of carbon-intensive goods and services, making them less competitive. As climate targets become binding, part of the existing capital stock might have to be written off before its economic life is over. The speed of the transition to a carbon-neutral economy will partly determine how much productive capital will need to be written off before the natural end of its economic life.

The less optimistic view is that that large-scale asset substitution could negatively affect economies (Pisani-Ferry, 2021). In the short to medium term, the high level of investment required for the green transition will increase aggregate demand and therefore boost economic activity and create new jobs. However, if the rise in aggregate demand is not accompanied by a rise in productivity, the positive effects of green investments might be limited. As the green investments would replace discarded brown ones, they would not necessarily increase supply. The degree to which aggregate demand would benefit from new, green investments therefore would depend on existing slack in capacity. Otherwise, increasing investment would put pressure on prices and real interest rates, and would absorb more savings.

For individual firms, their leverage will likely increase as green investments simply replace brown assets. The totality of a firm's assets will remain broadly unchanged, while investment in new, green assets will be financed, at least partially, with debt. The increased leverage would likely affect the firms' ability to borrow, especially firms that are already highly leveraged. Moreover, not all firms will survive the transition to a low-carbon economy. A firm's success will depend on its financial condition, managerial skills and existing production technologies. The very nature of some industries (like coal mining) means they are destined to vanish. The losses incurred from such stranded assets pose a threat to the financial sector, too, as firms losing money or forced to write off assets will have less collateral to offer investors and could more generally fail to repay their loans. Significantly large losses could adversely affect the supply of credit, which would further weigh on investments — creating a vicious cycle.

The green transition will also burden the public sector. Governments will need to increase investments in green infrastructure and in spending to compensate vulnerable households for the increased cost of living. Revenues from carbon taxes could help finance part of this expenditure, but probably not all (Pisani-Ferry, 2021). Furthermore, if the green transition slows down economic growth, it will create deficits in public finances already stretched by the pandemic. Less developed countries will have more difficulty raising money for green projects, because their ability to borrow is more restricted and because they tend to pay higher interest rates.

The more optimistic views factor in a significant role for innovation in reducing the cost of greening the economy. The economic literature suggests that innovation is endogenous and can be steered by policies (Acemoglu, 2002). Higher carbon prices will squeeze the market for carbon-intensive goods and therefore likely stimulate innovation, effectively reducing the cost of the green transition. Another well-established feature of innovation is path dependency – once knowledge starts accumulating in a certain area, it facilitates and accelerates further innovations in that area. Past experience attests to the power of directed technical change and path dependency. Aghion et al. (2016), for instance, find that high oil prices boosted energy efficiency innovations in the automobile industry. The impressive decline in the cost of renewable energy in recent decades also points at the potential role of innovation. Stiglitz and Stern (2021) stress that progress in green innovation so far has taken place with modest policy support. They argue that well-designed policies could further boost the pace of innovation.

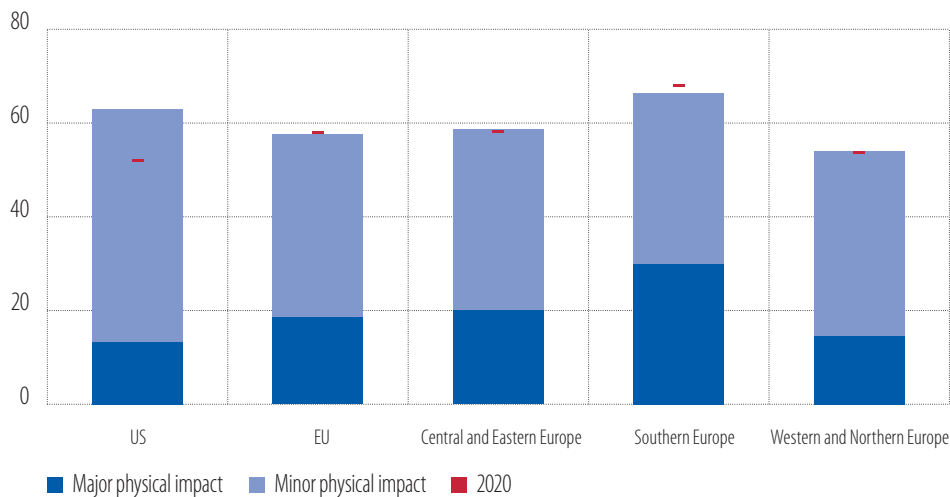
Despite the formidable uncertainties involved, it is widely accepted that the green transition is the only way forward. Most experts liken the effect of higher carbon prices to the oil shock of the 1970s, although policy decisions steer carbon prices, and governments have some freedom in their path. Moreover, other challenges exist, such as providing the workforce with the skills needed to meet the new era, and the need for countries to coordinate policies. Innovation, however, could facilitate the transition by boosting productivity, and therefore could be more akin to a process of creative destruction on a massive scale.

Firms' awareness of climate change

Perceptions of physical risks

A myriad of extreme weather events across the globe in 2021 resulted in human and economic loss. From extreme heatwaves and wildfires in western North America to deadly flooding in Western Europe and Asia, weather events are having repercussions that can be felt by firms. The widespread flooding in Europe in early July alone killed more than 200 people and caused an estimated EUR 2.5 billion in property damage⁴. The consequences of climate change will differ across regions and sectors.

Figure 3
Firms (in %) whose business activities are affected by physical climate risks, by region



Source: EIBIS 2020 and EIBIS 2021.

Base: All firms (data not shown for those who said don't know/refused to answer).

Question: Thinking about climate change and the related changes in weather patterns, would you say these weather events currently have a major impact, a minor impact or no impact at all on your business?

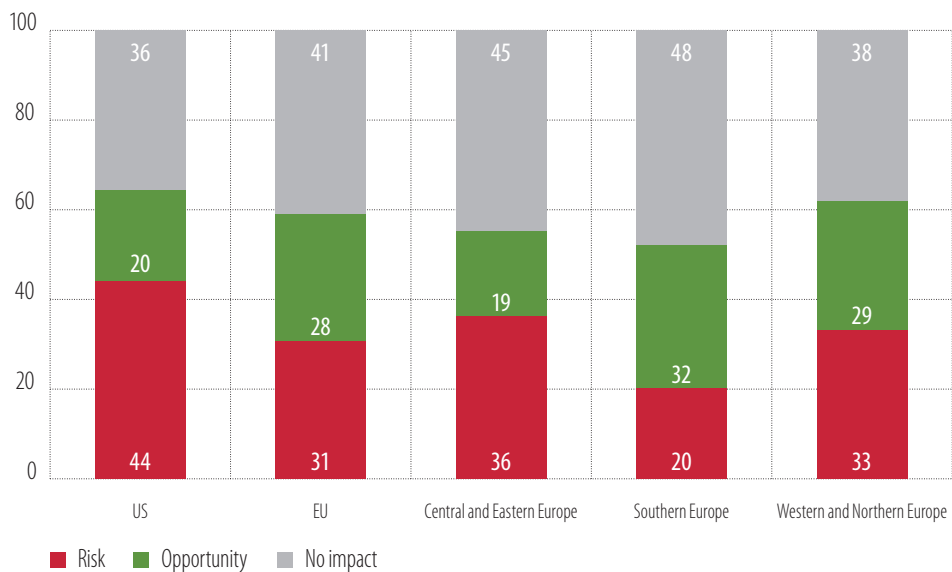
Firms have a rather good understanding of the physical risks of climate change. According to the EIBIS 2021, 58% of European firms say they are affected by physical risks (Figure 3). In the United States, 63% of firms say they face a physical risk from climate change – a substantial increase of 11 percentage points compared to the previous year. Within the European Union, more firms in the southern countries say they are vulnerable to physical risks. Spain has the highest share of firms that feel exposed to physical risks, followed by Romania and Portugal.

⁴ Berenberg sees USD 2 billion to 3 billion in reinsurance losses from European floods, overall losses higher | Reuters

Firms' perceptions of transition risks

Limiting global warming to 1.5°C compared to pre-industrial levels, in line with the climate pledges made at COP26, will require transforming business models. Besides tackling physical climate risks, firms must also prepare for the transition risks caused by the shift to net-zero emissions. Firms face risks as they transform their businesses and adapt to new regulations. They also have to deal with changing market preferences and standards as a country embarks on the path to decarbonisation.

Figure 4
Impact of the energy transition on firms (in %), in the United States and European Union



Source: EIBIS 2021.

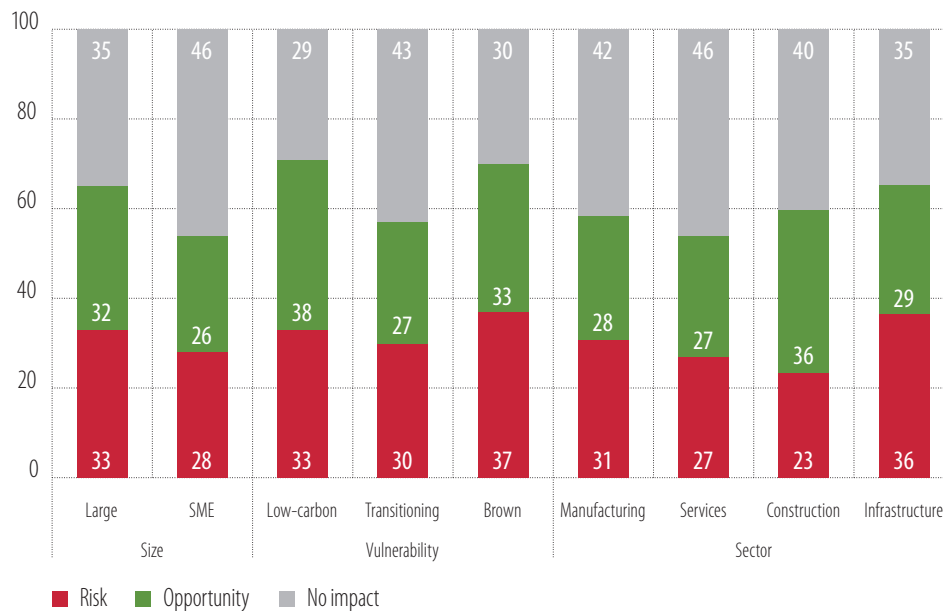
Base: All firms (data not shown for those who said don't know/refused to answer).

Question: Thinking about your company, what impact do you expect this transition to stricter climate standards and regulations will have on your company over the next five years?

The majority of firms in the United States and the European Union expect the green transition to have an impact on their business, with US firms being more concerned about overall negative effects. In the European Union, 41% of firms (Figure 4) believe the transition will not affect their business. This figure is substantially lower than the previous year (51%), signalling that firms are preparing themselves as EU climate ambitions and new regulations come into force. While the majority of EU firms acknowledge that the transition will affect their business, they have a balanced view of whether it presents a risk or an opportunity. US firms overwhelmingly feel that the climate transition represents a risk to their business, with only 20% feeling that they are in a good position to gain from it.

A higher share of firms in Western and Northern Europe believe the transition to a low-carbon future will affect their activities. Nevertheless, these firms hold relatively balanced views on whether the transition will present a risk or an opportunity for their business. Firms in Central and Eastern Europe, on the other hand, seem to be more afraid of the risks, while firms in the south are more focused on opportunities emerging from the green transition.

Figure 5
Impact of the energy transition on EU firms (in %), by firm characteristics



Source: EIBIS 2021.

Base: All firms (data not shown for those who said don't know/refused to answer).

Question: Thinking about your company, what impact do you expect this transition to stricter climate standards and regulations will have on your company over the next five years?

The perception of transition risks varies according to firms' areas of activity, with firms in green and brown sectors⁵ being more aware of risks and opportunities. Almost two in five firms in brown sectors state the climate transition represents a risk (Figure 5). Brown sectors are often subject to increasing regulations related to emissions as well as environmental concerns such as local air quality, water, soil pollution and safety. In contrast, 38% of firms in low-carbon sectors consider they are well positioned to gain from the transition. Firms in transition sectors, which represent the bulk of the EU firms interviewed for the EIBIS, are less worried about the effect the transition will have on their businesses, with 43% expecting no impact.

Large firms tend to cite more transition effects than small firms. Around two-thirds of large firms believe that they will be affected by the climate transition (either positively or negatively), whereas almost half of small and medium-sized enterprises (SMEs) do not perceive any impact (Figure 5). Large firms are more likely to be subject to regulations such as the EU Emissions Trading System (ETS) and have already accounted for the energy transition objectives in their business strategies. However, progressively more restrictive regulation and policy developments could lead to uncertainty and the associated risks.

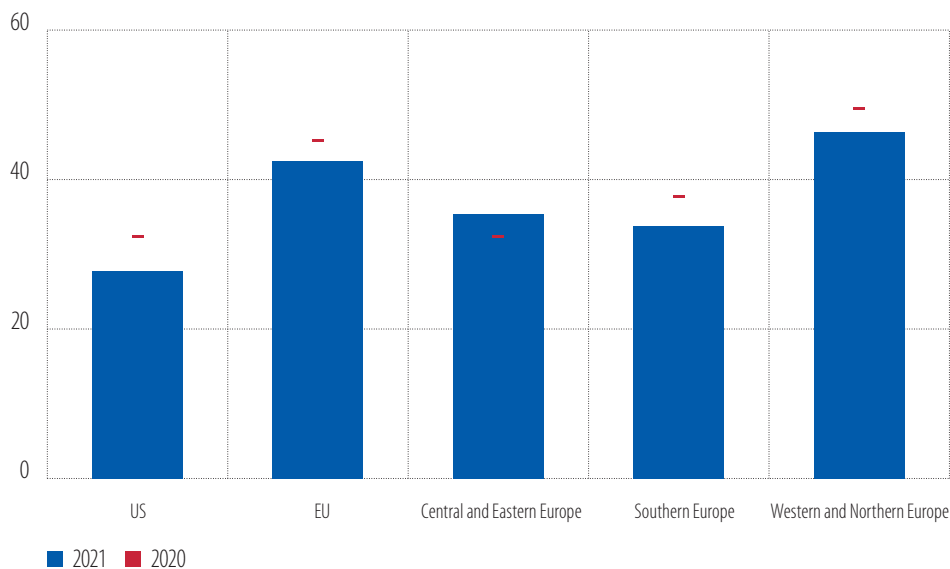
5 The classification takes into account the EIB's climate risk assessment framework and allocates sectors at NACE-4 digit level into the three categories based on their transition risk profiles. For example, railways and electricity networks are considered as low-carbon; consumer goods and retail, and automotive as transitioning; and oil, gas and mining as brown sectors.

Firms' climate investment strategies

Investment in climate change

Around 43% of European firms invested in climate measures to address physical and transition risks, more than in the United States, despite some investment stalling because of the pandemic. The proportion of firms investing in climate measures is marginally below the 45% reported in 2020 (Figure 6), which could be driven by the repercussions of the pandemic on firms' investment plans. Overall, the share of EU firms investing in the climate remains significantly higher than in the United States, where this share dropped to 28% from 32% in the previous year. Firms in Western and Northern Europe are more likely to invest, with the share of firms investing being the highest in the Netherlands.

Figure 6
Firms (in %) investing in climate-related measures to tackle climate change risks



Source: EIBIS 2020 and EIBIS 2021.

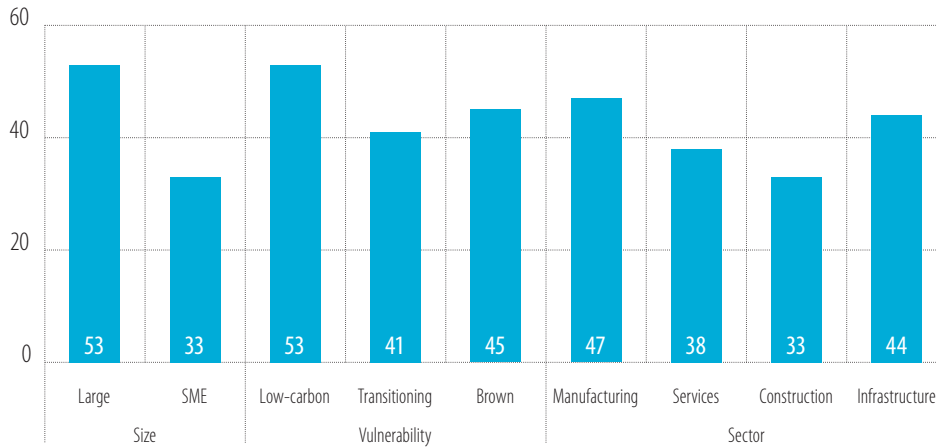
Base: All firms (data not shown for those who said don't know/refused to answer).

Question: Has your company already invested to tackle the impacts of weather events and reduction in carbon emissions?

Energy-intensive and large firms are more likely to invest in climate measures. Energy is an important input for the production process of these firms, and as a result they give higher priority to climate-related projects (Kalantzis and Revoltella, 2019). By contrast, SMEs and less energy-intensive firms consider investments in energy efficiency as low priority, devote fewer resources to energy management, and exhibit lower adoption rates for climate-related measures (Cagno et al., 2010; Gruber and Brand, 1991). The attitude of small firms goes hand in hand with lower awareness of transition risks.

European firms operating in low-carbon sectors are much more likely to invest in climate-related measures, whereas those in transition sectors are investing the least. Some 53% of firms in low-carbon sectors indicate they invest in climate measures (Figure 7), whereas this share drops to 45% in brown sectors and 41% in transitioning sectors. Furthermore, firms in manufacturing and infrastructure are much more likely to invest in climate-related measures. Firms in infrastructure tend to be large, are subject to significant investment costs and are often covered by the EU Emissions Trading System.

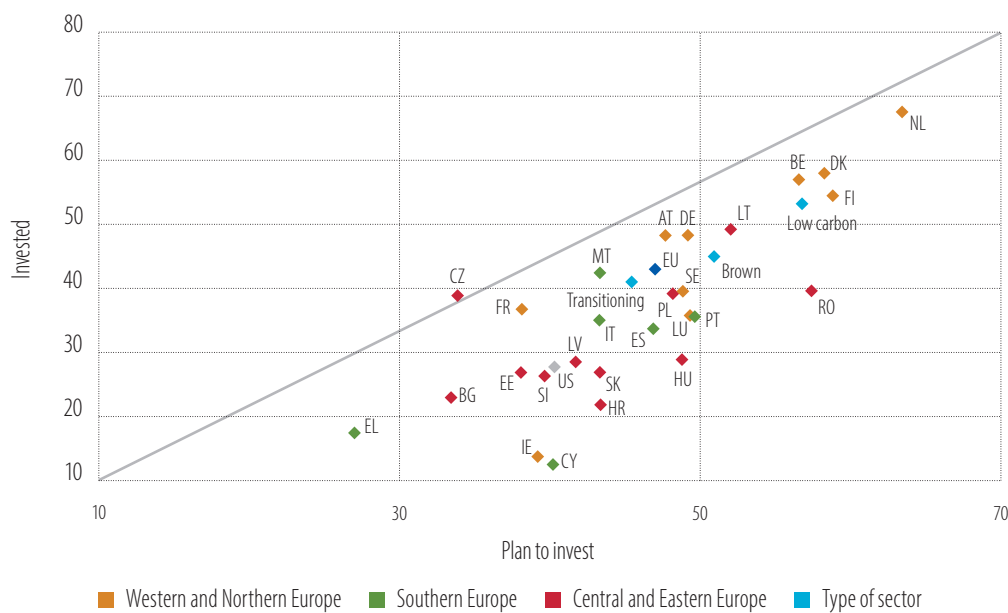
Figure 7
Firms (in %) investing in climate-related measures to tackle climate change risks, by sector and score



Source: EIBIS 2021
Base: All firms (data not shown for those who said don't know/refused to answer)
Question: Has your company already invested to tackle the impacts of weather events and reduction in carbon emissions?

Looking ahead, 47% of EU firms report that they have plans to invest to address climate issues. More European firms plan to invest in climate measures than in the United States, where 40% of firms have investment plans and only 28% have already invested (Figure 8). Within Europe, more firms in Western and Northern countries have invested and are planning to do so in the future than in the rest of Europe.

Figure 8
Past and planned investment in climate-related measures (in %), by country and sector



Source: EIBIS 2021.
Base: All firms (data not shown for those who said don't know/refused to answer).
Questions: Has your company already invested to tackle the impacts of weather events and reduction in carbon emissions?
Does your company plan to invest (more) to tackle these impacts in the next 3 years?

Box B

Five facts on adaptation to climate change

Investments in adaptation will help the existing infrastructure and assets to become climate-resilient and will make the economy less vulnerable to climate change effects that are widespread, rapid and continue to intensify. The funding gaps in adaptation are large, even if there are still considerable uncertainties over the amount of investments needed. Two different estimates show that the European Union will need to invest EUR 35 billion to EUR 500 billion annually (European Commission, 2017). Public sources alone will not be sufficient to meet countries' adaptation needs, meaning that the participation of the private sector is crucial for achieving its goals.

Given the amount of resources that will need to be allocated to adaptation in the coming years, understanding how firms are preparing to invest will be key for policymakers. Using the results from the EIB 2020 add-on module survey, which interviews SMEs in the manufacturing and services sectors, this box presents five facts characterising firms that are already investing or planning to invest in adaptation in the next three years:

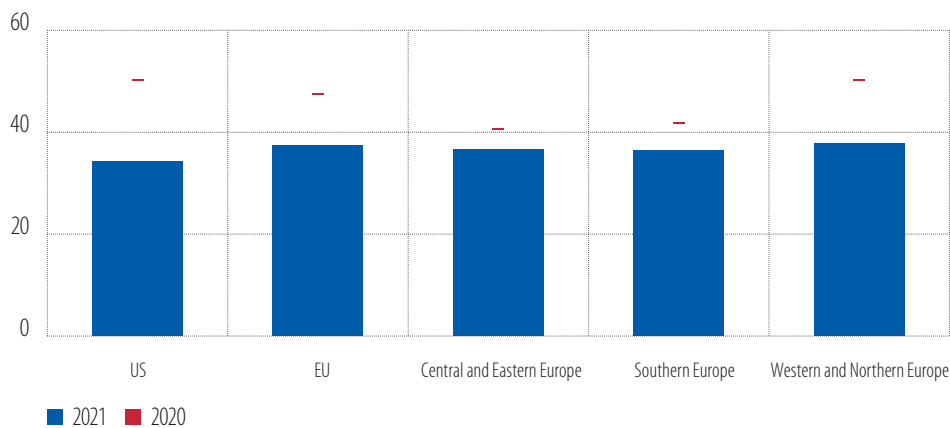
- (1) Plans to invest in adaptation are more frequently mentioned by medium-sized firms than small ones. Approximately 32% of EU SMEs already invest or plan to invest in adaptation over the next three years. Medium-sized firms (39%) are more likely to mention adaptation investment activities or plans than small ones (25%).
- (2) Firms investing in adaptation or with plans to do so are more likely to state that climate change has had an impact on their businesses. Around 52% of firms planning or already making investments in adaptation are aware of climate-induced physical risks, 8 percentage points higher than the share of firms that have no adaptation investments or plans.
- (3) Uncertainty about regulation and taxation, the obstacle most frequently cited by EU firms as reducing the likelihood of investing in climate measures, is also a relevant barrier for firms investing in adaptation or with plans to do so (78%). Clarity on what constitutes an investment in adaptation is also crucial for developing appropriate incentive measures. The European Union's new taxonomy regulation and specific screening criteria for sustainable activities will help reduce uncertainties and improve transparency.
- (4) Almost half of the firms that have received public funding to make their business activities climate-resilient are likely to invest in adaptation. Some 49% of firms that received public support for making climate change investments over the past three years are currently investing in adaptation or are planning similar investments, as opposed to 42% of firms that have not received this public support.
- (5) Almost half of the firms that used the crisis as an opportunity to accelerate already planned changes to their business processes already invest or have plans to invest in adaptation (47%). On the other hand, firms for which the crisis poses an existential threat to their business are less likely to state that they are investing or plan to invest in adaptation in the next three years (36%).

Overall, these insights show the urgency of appropriate policies to support adaptation, not only to enhance awareness, but also to remove barriers to finance by actively providing public funding to support investments. Having the appropriate policies in place will be especially relevant for national governments that need to decide how and where to invest the Recovery and Resilience Facility funds that the European Commission has dedicated to the transition to a greener economy. As part of the EIB's new Climate Adaptation Plan, the Bank is considering increasing its share of adaptation finance to 15% of its total climate commitment, which calls for climate action and environmental sustainability to account for 50% of lending by 2025.

Energy efficiency investments

With the pandemic raging, energy efficiency investments slowed down on both sides of the Atlantic in 2021. However, the share of EU firms investing in energy efficiency decreased less than that in the United States (Figure 9). The significant drop in the share of EU firms investing in energy efficiency was primarily driven by firms located in Western and Northern Europe.

Figure 9
Firms (in %) investing in energy efficiency measures



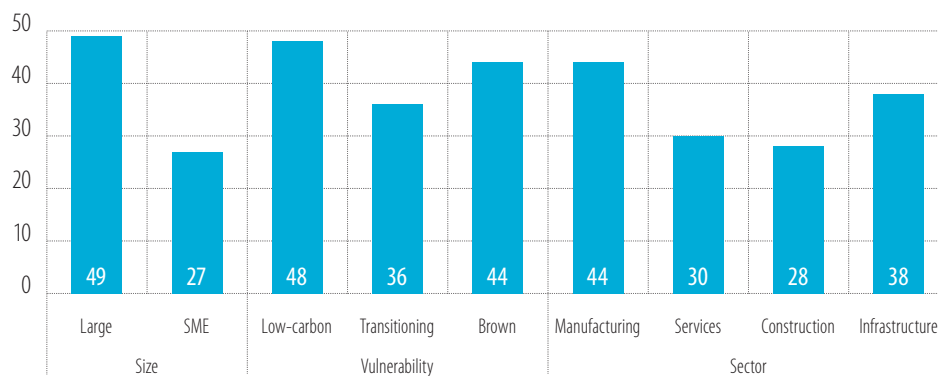
Source: EIBIS 2020 and EIBIS 2021.

Base: All firms (data not shown for those who said don't know/refused to answer).

Question: What proportion of the total investment was primarily for measures to improve energy efficiency in your organisation?

Large firms and those in low-carbon sectors were the most likely to invest in energy efficiency. Similar to climate investments, large firms invested substantially more in energy efficiency than SMEs (Figure 10). Some 48% of firms operating in low-carbon sectors also invested in energy efficiency, compared with 44% of firms operating in brown sectors and 36% in transitioning sectors. The manufacturing sector had the highest share of firms investing in energy efficiency, followed by the infrastructure sector.

Figure 10
Firms (in %) that invested in energy efficiency, by firm characteristics



Source: EIBIS 2021.

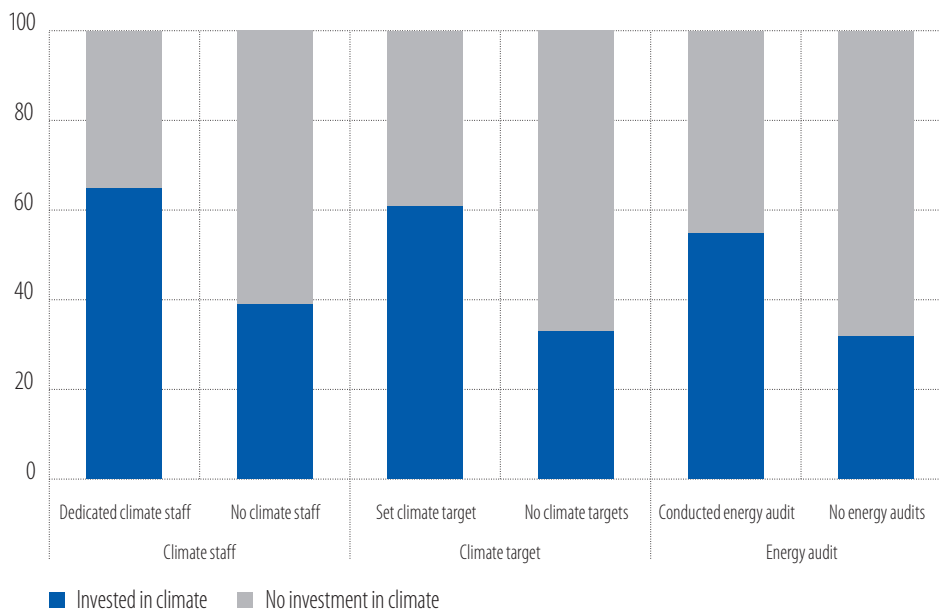
Base: All firms (data not shown for those who said don't know/refused to answer).

Question: What proportion of the total investment was primarily for measures to improve energy efficiency in your organisation?

The role of green management practices and climate perceptions in investment

Green management practices are an important determinant of firms' decisions to invest in climate-related measures. European firms that make an effort to improve their preparedness by implementing energy audits, hiring dedicated climate staff, and setting and monitoring decarbonisation targets are more likely to invest in climate measures (Figure 11).⁶ Around 65% of firms that have dedicated climate staff invested in climate measures, compared with 39% of firms without. Similarly, 61% of firms with internal climate targets and 55% of firms that had an energy audit in the past four years invested in climate measures. In contrast, only 33% of firms that do not set internal climate targets and 32% of firms that have not had an energy audit in the past four years invested in climate measures.

Figure 11
Firms (in %) investing in climate measures



Source: EIBIS 2020.

Base: All firms (data not shown for those who said don't know/refused to answer).

Question: Did your company set and monitor internal targets on carbon emissions and energy consumption? In the past four years has your company had an energy audit? By this, I mean an assessment of the energy needs and efficiency of your company's building or buildings.

⁶ As shown in the EIBIS 2020 (EIB, 2021), a positive link exists between implementing green management practices to improve access to information about climate needs and investment in climate-related measures.

Box C

Corporate disclosure of climate-related information

Corporate disclosure of climate-related information is an important predictor of whether firms' will invest in the climate transition. From the EIBIS 2021, we estimate that half of European firms set and monitor internal targets on carbon emissions and energy consumption. This is a much larger share than in the United States (21%). The share is much higher for large firms (62% in the European Union).

The following text mining analysis assesses how often EU firms disclose their climate-related information based on keywords proposed in the literature. An algorithm in Bloomberg browses all the EU company filings to supervisory authorities and corporate communication documents and traces these keywords at different instances in time, namely in 2015 and 2020. The different elements of climate-related information and examples of keywords used (in parenthesis) were:

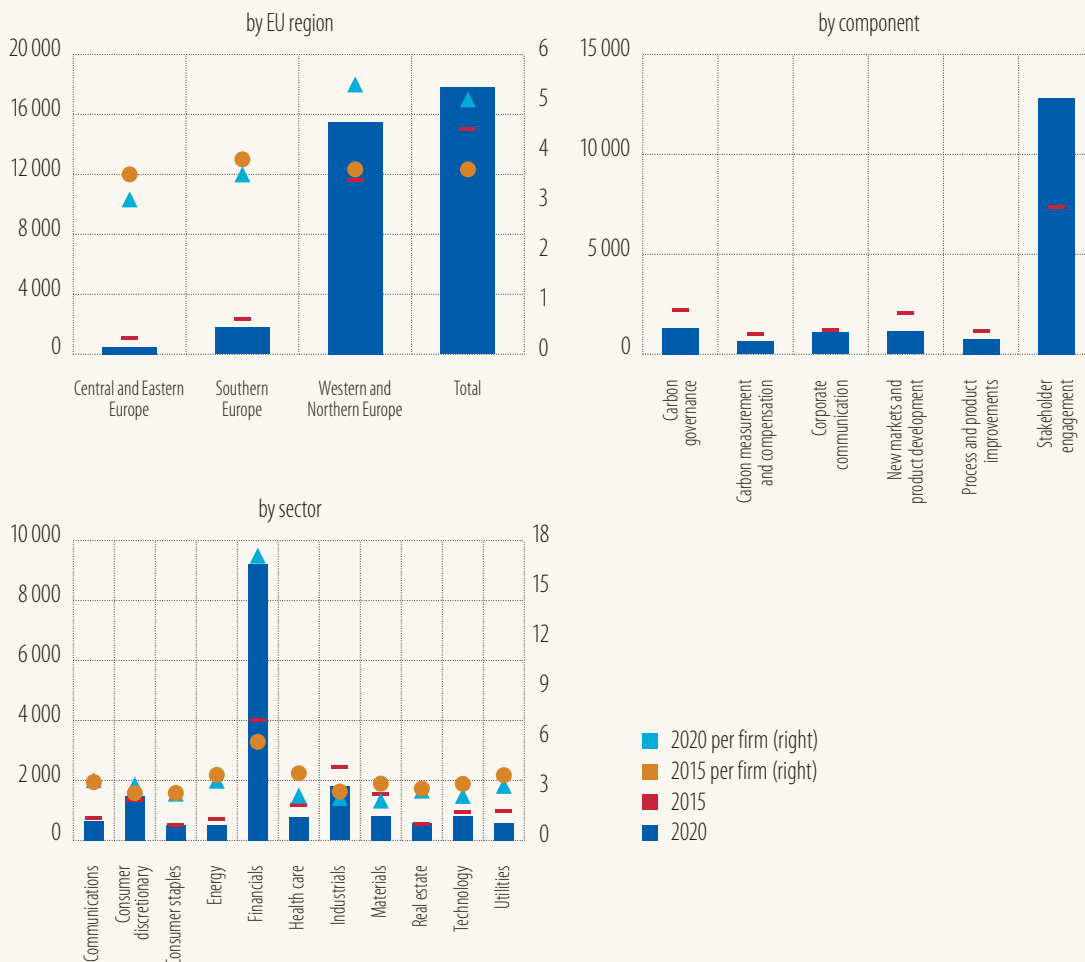
- Carbon governance spanning organisational involvement and risk management (plans for organisational involvement; environment committee; workshops; dedicated climate staff; energy managers; energy/climate risk management; risk management procedures; climate change risks and opportunities).
- Carbon measurement and compensation (greenhouse gas emissions inventory; emission reduction targets; monitoring of emission reduction targets; carbon compensation/offsetting; Joint Implementation (JI); Clean Development Mechanism (CDM); Emissions Trading System (ETS)).
- Corporate communication (Global Reporting Initiative (GRI); Carbon Disclosure Project (CDP); ISO26000).
- New markets and product development (new products/markets; research partnerships).
- Process and product improvements (eco-friendly; energy-efficient products; product improvements; new energy-saving equipment; fuel switch; renewable energy sources; process improvements; carbon emissions saved; energy savings), and stakeholder engagement (voluntary initiatives and agreements with non-governmental organisations (NGOs); research institutes related to climate change mitigation voluntary initiatives).

The occurrence of climate-related information in companies' communications has increased compared to 2015 (Figure C.1). The occurrence is particularly pronounced for companies in Western and Northern Europe — where the largest companies in the European Union are located. These firms tend to be covered by regulation on climate-related disclosures. The global trend to move capital towards more sustainable economic activities and the regulatory push in that direction are likely behind the increased occurrences, as well as social awareness of climate change adaptation and mitigation.

Firms are increasingly communicating about their climate preparedness to shareholders and the general public. Communications on climate-related issues increased in last half decade, while corporate communication remained stable. Increased awareness of sustainability issues among stakeholders, demand from business partners and changing social preferences could all be behind the increased communication.

The financial and consumer products sectors drove the increase over time. Climate-related communications from European firms in the consumer goods sector were stable. In contrast, the increase in climate-related communication was most striking for European firms in the financial sector. The rise could be driven by increased regulation for financial disclosures and prudential regulations related to climate change for financial firms.

Figure C.1
Number of occurrences, by EU region, component and sector



Source: Bloomberg and authors' calculations.

European firms aware of physical and transition risks tend to invest more in climate measures. In 2021, 46% of European firms whose business was affected by physical risks invested in climate measures, while 38% of firms that did not see an impact still invested (Figure 12). Firms that believe they are well positioned to gain from the climate transition also invested more. Around 60% of EU firms that see the energy transition as an opportunity invested in climate measures. The share drops to 41% for firms that see climate risk as a threat. Firms that do not expect the transition to affect their business activities invested less frequently, with only 31% of those firms investing in climate measures.

Figure 12
Climate investment by firms (in %), according to their perception of physical and transition risks



Source: EIBIS 2021.

Base: All firms (data not shown for those who said don't know/refused to answer).

Question: Has your company already invested to tackle the impacts of weather events and reduction in carbon emissions? Thinking about climate change and the related changes in weather patterns, would you say these weather events currently have a major impact, a minor impact or no impact at all on your business? Thinking about your company, what impact do you expect this transition to stricter climate standards and regulations will have on your company over the next five years?

Box D

Firms' profiles and carbon strategies

Firms' climate investment choices and green practices are part of overarching carbon strategies emerging in businesses. With climate change being recognised as a topical issue affecting business, new literature has explored various corporate carbon strategies in different contexts.

Based on cluster analysis, Lee (2012) identifies six types of strategies using data on six different carbon management activities. The defined firm carbon groups are: "wait-and-see observers," "cautious reducers," "product enhancers," "all-round enhancers," "emergent explorers" and "all-round explorers." While a significant relationship between a firm's carbon strategy and its sector and size was found, no significant relationship between a carbon strategy and firm performance was confirmed.

Other studies have followed a similar approach using clustering techniques and have identified similar corporate carbon strategies. Using firm survey data on emission reduction targets, policies, activities and measurement, and their perceptions of climate change, Kolk and Pinkse (2005) also identify six profiles firms can adopt to address components related to climate change: "cautious planner," "emerging planner," "internal explorer," "vertical explorer," "horizontal explorer" and "emissions trader."

Following a similar line of thought, this analysis opts for a deterministic clustering approach to identify different profiles. Choosing to invest in the climate, planning to do so in the future and setting climate

targets are indicators that communicate part of a firm's carbon strategy. The approach partitions firms into distinct groups based on their similarities across these indicators. Five corporate carbon strategies are then identified: "wait-and-see observers," "planners," "cautious reducers," "short-term explorers," and "forward-looking explorers," as illustrated in Table D.1.⁷

- **Wait-and-see observers** are firms that have not invested in climate measures, do not have any plans to do so in the future and have not set climate targets.
- **Planners** are firms that have not yet invested in climate measures, but have plans to do so in the next three years, irrespective of whether they set climate targets or not.
- **Cautious reducers** are firms that have invested in climate measures but do not have plans to continue these investments in the future. This group also accounts for firms who have set climate targets but have not yet invested in climate nor have plans to do so.
- **Short-term explorers** are firms that have set climate targets and have invested in the past. They are perceived to be short-term thinkers because they do not have further plans to continue investing in climate measures in the future.
- **Forward-looking explorers** follow the most sophisticated strategy with a long-term vision. This group accounts for firms who are investing in climate measures and have plans to continue such investments in the next three years, as well as firms that fulfil the three criteria: they have invested in climate measures, have plans to continue in the future and have set climate targets.

Table D.1
Deterministic cluster approach

	Wait-and-see observer	Planner	Cautious reducer	Short-term explorer	Forward-looking explorer
Climate targets	No	No, Yes	No, Yes	Yes	Yes, No
Climate investments	No	No, No	Yes, No	Yes	Yes, Yes
Climate plans	No	Yes, Yes	No, No	No	Yes, Yes
Observations	3 564	3 380	2 084	1 121	2 516

Source: EIBIS 2021.

Base: All firms (data not shown for those who said don't know/refused to answer).

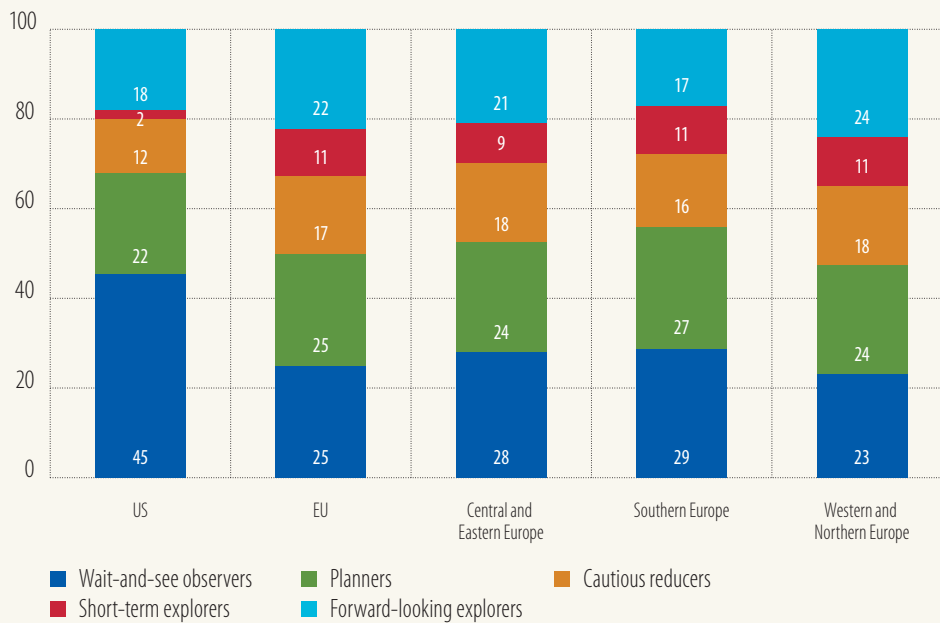
Question: Has your company already invested to tackle the impacts of weather events and reduction in carbon emissions? Does your company plan to invest (more) to tackle these impacts in the next three years? Did your company set and monitor internal targets on carbon emissions and energy consumption?

European firms adopt more climate-friendly strategies than those in the United States (Figure D.1). While the most prevalent carbon strategies among European firms are wait-and-see and planners, the share of wait-and-see observers is substantially lower than the 45% in the United States. Among the more sophisticated strategies, short-term and forward-looking explorers represent 33% of European firms, while this number drops to 20% in the United States. Within Europe, Western and Northern European firms present the lowest share of wait-and-see observers in the European Union and exhibit the largest share of sophisticated strategies in the region.

⁷ The last two clusters encompass more sophisticated strategies, with firms incorporating at least two of the three more active criteria onto their practices

Firms' carbon strategies are positively associated with their perceptions of climate risks. Figure D.2 shows that the marginal effect — or the likelihood that a firm will adopt a certain carbon strategy — depends on their perception of climate risks or their other characteristics. Firms that are aware of physical risks are more likely to be planners or forward-looking explorers than those that do not feel vulnerable to the effects of climate change. Similarly, if firms perceive the energy transition to be a threat, the probability of being planners or forward-looking explorers is higher than for those that do not acknowledge any impact. On the other hand, if a firm feels it is well positioned to gain from the transition, the likelihood of being a forward-looking explorer increases even further. Finally, the results also suggest that firms that are more aware of climate-related risks are less likely to be wait-and-see observers, especially if they have a positive view of the transition.

Figure D.1
Firms' carbon strategies (in %), by region



Source: EIBIS 2021.

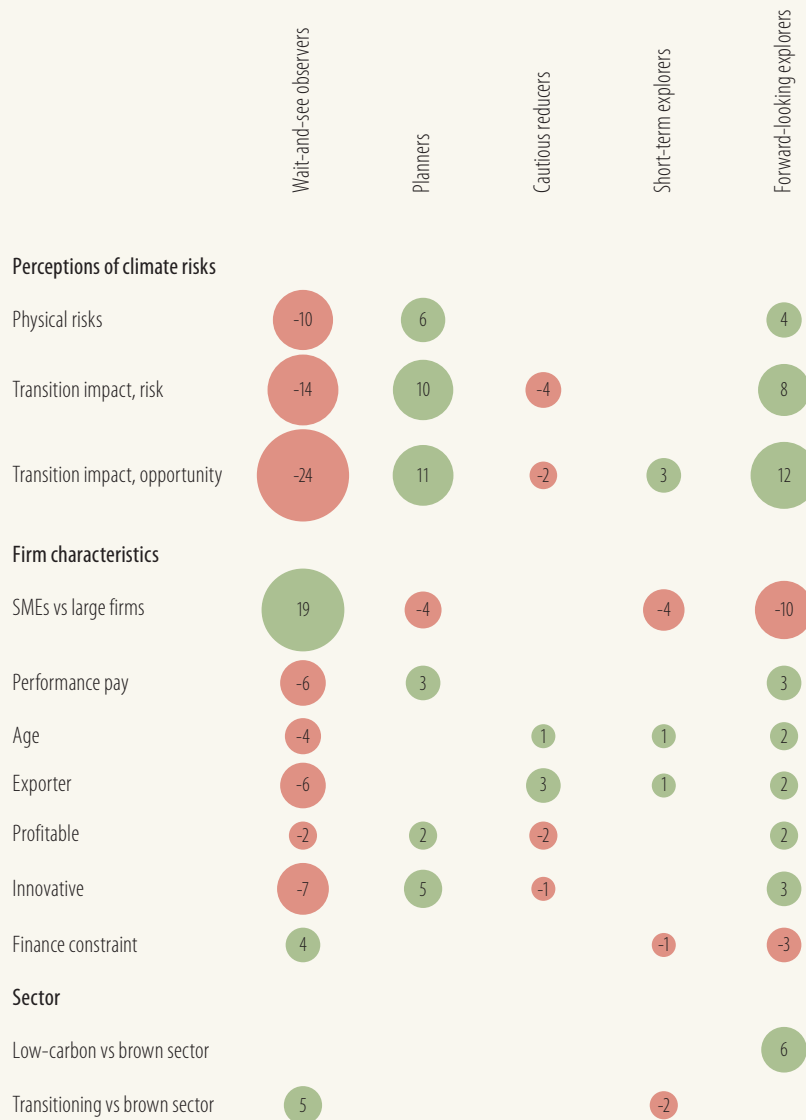
Base: All firms (data not shown for those who said don't know/refused to answer).

Question: Has your company already invested to tackle the impacts of weather events and reduction in carbon emissions? Does your company plan to invest (more) to tackle these impacts in the next three years? Did your company set and monitor internal targets on carbon emissions and energy consumption?

Frontier firms are also more likely to employ more active strategies, namely forward-looking explorers. The probability of companies adopting a forward-looking strategy increases with age, when firms are engaged in an exporting activity, as well as in innovative activities. Similarly, firms with advanced management practices, such as those with performance pay systems, are also more likely to adopt forward-looking strategies.

Conversely, SMEs are more likely to be wait-and-see observers compared to larger companies. Being an SME also decreases the probability of a firm employing a forward-looking strategy. Firms operating in low-carbon sectors are more likely to be forward-looking explorers than those in brown sectors. Meanwhile, the probability of being a wait-and-see observer increases for firms in transitioning sectors compared to brown sectors. This suggests that firms in brown and low-carbon sectors are more motivated to adopt active profiles than those in transitioning sectors.

Figure D.2
Marginal effects of the determinants of carbon strategies



Source: Authors' estimates

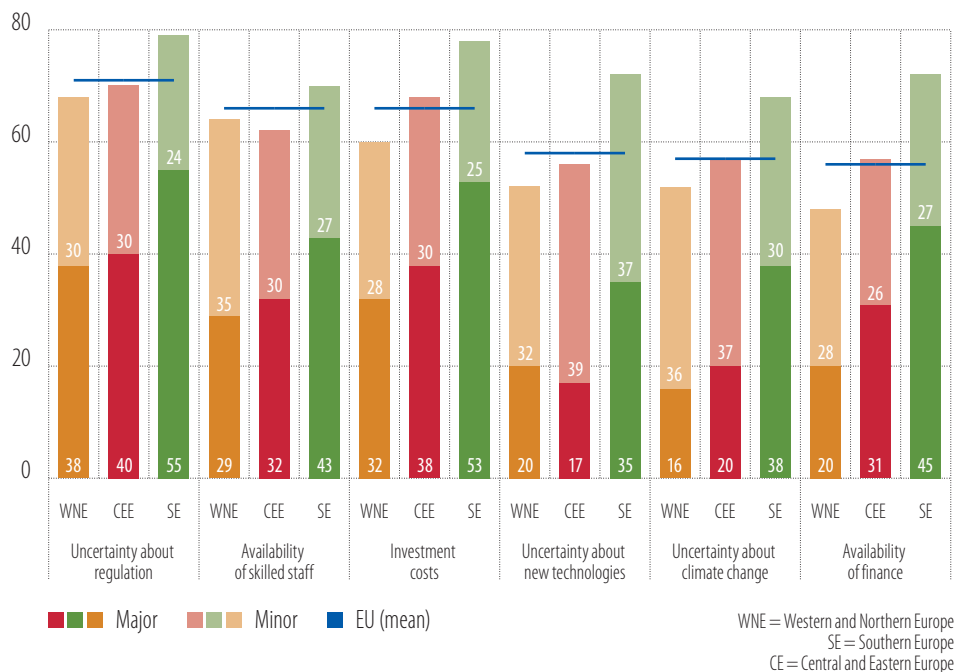
Note: The marginal effects have been estimated based on a multi logit regression, where the dependent variable reflects the carbon strategy (wait-and-see observers, planners, cautious reducers, short-term explorers and forward-looking explorers) and the independent variables concern perceptions of climate-related risks and firm-specific characteristics. The results show only statistically significant coefficients of at least 10%.

Obstacles to climate investment and areas of support for small and medium-sized enterprises

A majority of SMEs (71%) cite uncertainty about regulation and taxation as a factor that would reduce their likelihood of investing in climate measures (Figure 13). Regulations and taxation affect the cost-benefit analysis of climate investments and thus need to be structured in a way that facilitates long-term

climate objectives. Uncertainty about regulation can cause firms to delay or cancel investment plans, as firms need a full picture of the expected cost benefits before investing. These findings are supported by the results of a special module of the EIBIS targeting SMEs in the manufacturing and service sectors.

Figure 13
Obstacles to climate investment in the European Union (in %)



Source: EIBIS 2021 add-on module (AOM) – sample of EU SMEs in manufacturing and services.

Base: All firms (data not shown for those who said don't know/refused to answer).

Question: To what extent, if at all, is each of the following an obstacle to investing in activities to tackle the impacts of weather events and carbon emissions reduction?

High upfront costs and difficulties in finding skilled staff are the other main issues small and medium firms say constrain their investments. SMEs consider high upfront costs to be a significant constraint despite their long-term returns. Firms often do not consider climate change investment to be a core business investment activity, and thus they neglect low-risk investments that have a predetermined and relatively short payback period. To address this issue, firms require specific expertise to conduct the necessary due diligence and successfully identify climate opportunities. However, a large share of SMEs report that a lack of skilled staff prevents them from investing in climate measures.

Small and medium firms in Southern Europe are more likely to identify obstacles to climate investments than firms in the rest of Europe (Figure 14). This is true for all six obstacles. In addition, over three-quarters of firms in Southern Europe report high upfront investment costs as an impediment to climate investment, much higher than the EU average.

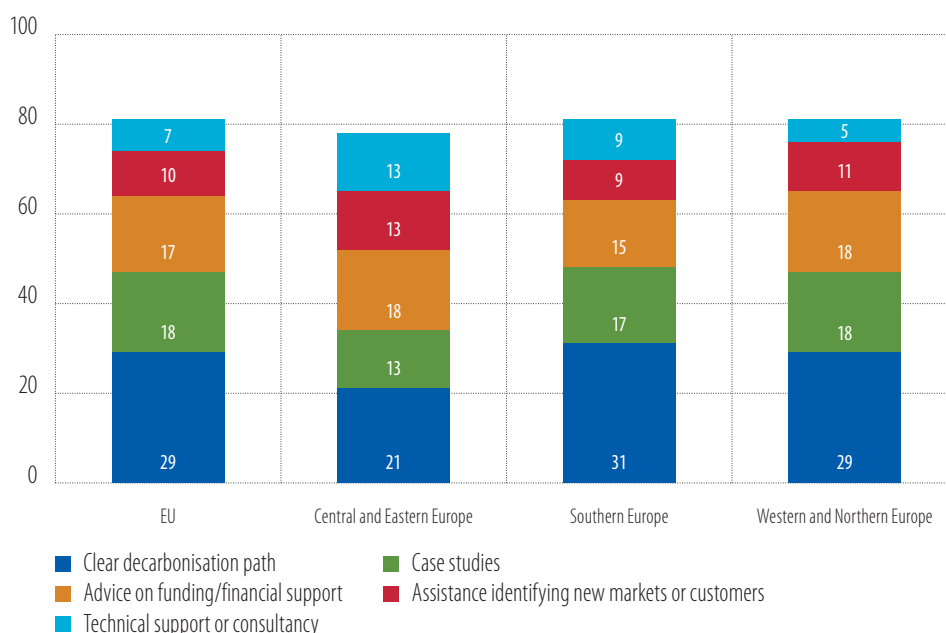
Measures to incentivise climate-related investment take several forms. To identify areas of support, the EIBIS 2021 asked firms which measures would encourage them to pursue climate investments, including:

- Advice on funding/financial support available.
- Assistance identifying new markets or customers.
- Technical support or consultancy.

- Case studies of investments and actions that have a positive impact on weather events and carbon emissions.
- A clear decarbonisation path set out at the national or EU level.

Some 29% of small and medium firms say that setting a clear decarbonisation path for the European Union would encourage them to make climate investments. Technical and advisory support would also help. These results follow on previous evidence that regulation and taxation are the most prevalent constraints for climate investment. Advice on the funding and financial support available for projects and technical support or consulting services could also help EU firms to invest in climate measures.

Figure 14
Identified areas of support to advance climate investments in the European Union (in %)



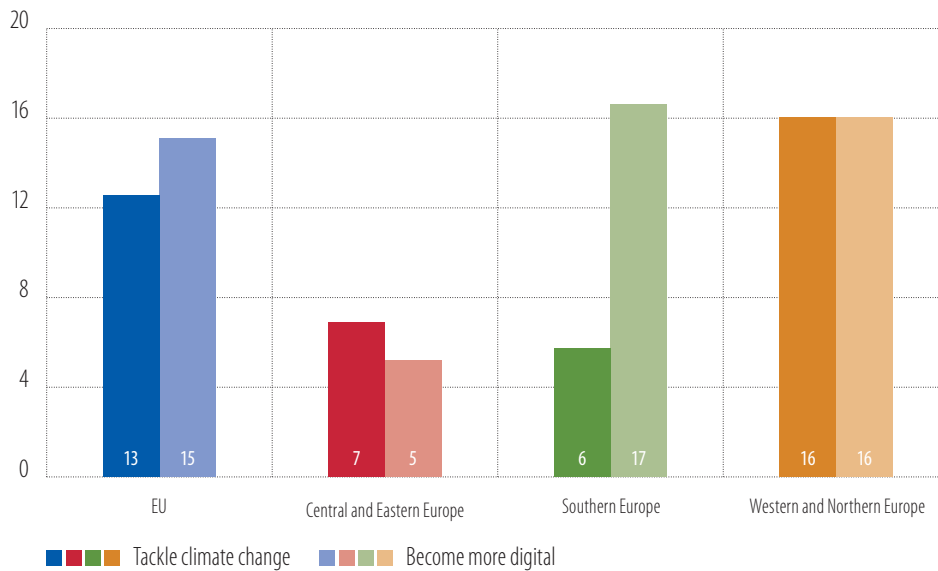
Source: EIBIS 2021 AOM – sample of EU SMEs in manufacturing and services.

Base: All firms (data not shown for those who said don't know/refused to answer).

Question: When thinking about investments or actions to tackle the impact of weather events and carbon emissions reduction, which of the following would you find most helpful?

Providing firms with adequate financial support could encourage them to undertake climate investments despite the high upfront investment costs. Over the past three years, policy support has more often targeted digitalisation than it has climate change efforts, and more EU firms have benefited from public support to advance digital rather than climate investments. Although small, the difference between support for digital and climate investments (2 percentage points more firms received support for digital purposes) is driven largely by firms in Southern Europe, where 6% of firms report receiving public support to tackle climate change compared with 17% of firms who received funds to improve digitalisation. In Central and Eastern Europe, direct support for digitalisation and climate change was substantially lower than in other regions.

Figure 15
Firms (in %) receiving public support to advance climate and digital investments



Source: EIBIS 2021 AOM – sample of EU SMEs in manufacturing and services.
 Base: All firms (data not shown for those who said don't know/refused to answer).
 Question: Have you received in past three years public support (e.g. government grants, subsidies, subsidised finance from the public sector) to accelerate investments in order to ...

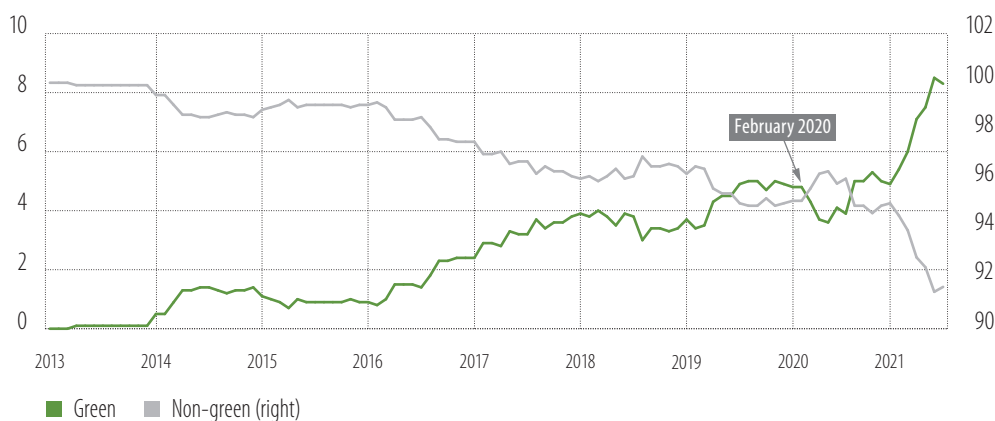
The emergence of a green premium in climate financing — evidence from corporate green bonds

The green transition is also linked to the transformation of the financial sector and the emergence of a premium paid for climate-friendly activities. Recent evidence suggests two different sources of a green premium, or greenium, emerging. On one side are investors with a strong appetite for green assets, fuelling demand over and above that of vanilla bonds. These investors might favour assets and companies with a sustainable profile — whether it comes from environmental, social and governance (ESG) standards or the area of activity — and may be ready to pay a premium. At the other end of the spectrum, climate risks might affect the valuations of firms exposed either to physical or transition risks.

Evidence of a green premium in market pricing is gradually emerging. The European Central Bank (ECB, 2021) shows that firms disclosing a climate target have reduced their emissions more than other firms. More ambitious and forward-looking targets are associated with better credit ratings. The EIB Investment Report 2020-2021 shows that as European companies' ESG standards rise, their shares tend to outperform the rest of the European equity market, while a portfolio of green equities has typically outperformed a portfolio of brown equities since the global financial crisis. Alessi et al. (2021) show the existence of a negative green trend in the European equity market. Investors are willing to earn lower returns to hold greener stocks, but only if these companies are also more transparent about their environmental performance. ECB (2021) also notes that initial evidence of a pricing of transition risks is beginning to emerge.

The following analysis investigates the emergence of a greenium in the EU corporate bond market — an initial sign of shifting trends in EU corporate bond markets. The issue of green corporate bonds in Europe has reached record highs. The arrival of the coronavirus pandemic coincided with a significant increase in the issuance of European corporate bonds whose proceeds were earmarked for green projects or activities promoting climate change mitigation or adaptation, or for other environmental sustainability purposes. The share of green bonds in total European corporate bond issuances almost doubled within a year to 8.3% at end-2020 — a record high — and continued increasing (Figure 16). In contrast, the share of non-green corporate bond issues shrank to 92% of total issuances at end-2020. The introduction of the European Green Deal in December 2019 was a defining moment, signalling the determination of the European Union to build a new economic model and make the continent climate-neutral by 2050. Financial investors and firms took note of the new EU climate strategy, implemented the structural changes for their financing required by the incoming regulation and progressively increased the share of green bonds in total corporate bond issuances.⁸

Figure 16
Green bonds (in %) in total European corporate bond issuances



Source: Bloomberg and authors' calculations.

Looking ahead, the share of green bonds in total corporate bond issuances is expected to increase. The further standardisation of green bonds is expected to spark more investor interest and to accelerate the increase in the share of green bonds in total corporate bond issuances. Greater standardisation will improve the comparability of bonds and address concerns about greenwashing or bond issuers' exaggerated claims concerning the environmental quality of underlying projects.

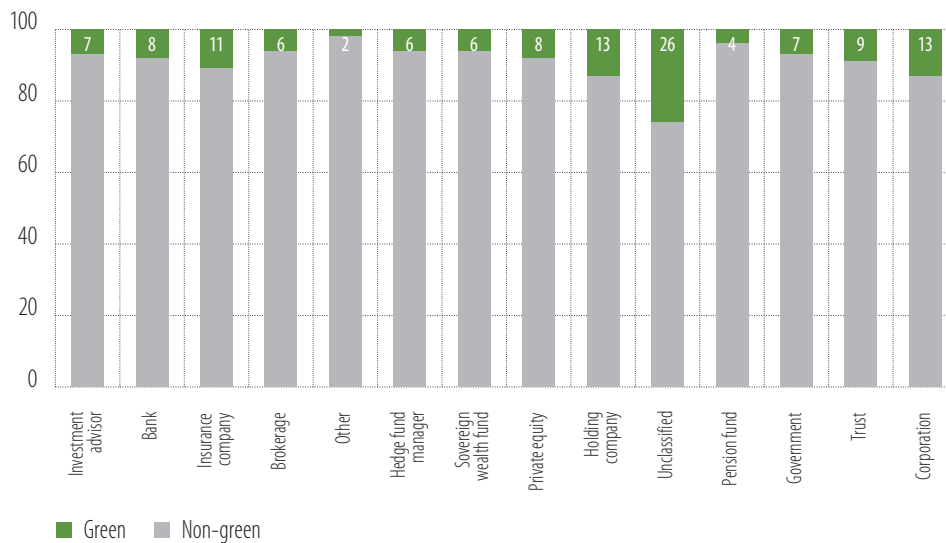
To that effect, the European Commission has proposed the European Green Bond Standard. This initiative aims to create a gold standard for green bonds that can be compared to, and potentially aligned with, other market standards. Its key features include:

- **Inclusivity:** it will be open to all EU and non-EU issuers.
- **Voluntary nature:** it will be a voluntary standard setting out uniform requirements.
- **Alignment with the EU taxonomy:** issuers must allocate 100% of the issue proceeds to economic activities that meet the EU Taxonomy Regulation EU/2020/852.
- **Support for issuers during the transition:** green bonds can be used to fund long-term projects of up to ten years that are engaged in an economic activity aligned with the Taxonomy Regulation's environmental objectives.

⁸ The battery of regulations that followed with the Taxonomy Regulation in 2020, the Sustainable Financial Disclosure Regulation and the adoption of the EU Green Bond Standard in 2021.

- **External review:** European green bonds will be subject to external review to ensure that the bonds are compliant with the requirements proposed by the standard.
- **Grandfathering:** should the EU taxonomy Technical Screening Criteria (TSC) change after a bond issuance, issuers can continue to qualify under pre-existing criteria for a further five years.

Figure 17
Green bonds (in %) in European corporate bond holders' portfolios, by investor type



Source: Bloomberg and authors' calculations.

Non-green corporate bonds dominate investors' bond holdings. The share of non-green corporate bonds in investors' total corporate bond portfolios exceed 70% for most types of investors, and rises to 96% for pension funds (Figure 17). The largest holders of green bonds are corporations, holding companies and insurance companies, in that order.

Box E

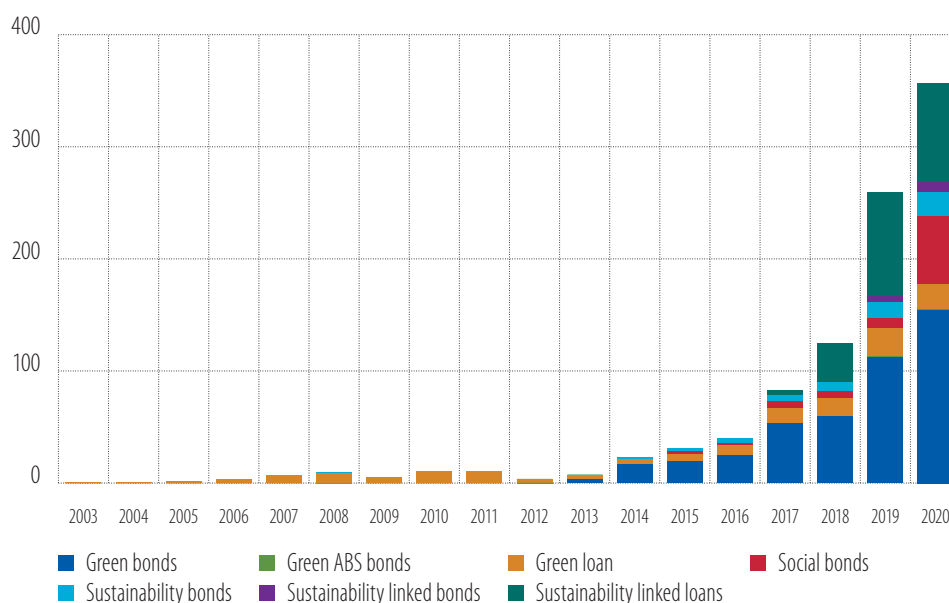
Classification of sustainable debt labels

European firms are issuing record numbers of ESG bonds, with the number of social bonds increasing significantly. Bloomberg categorises sustainable debt as follows (although other labels do exist):

- **Green bond/loan:** proceeds of the fixed income instrument will be applied to green projects or activities that promote climate change mitigation or adaptation, or other environmental sustainability purposes.
- **Sustainability bond:** proceeds will be applied to projects that are dedicated to environmentally sustainable outcomes (a combination of green and social activities as eligible projects).
- **Social bond:** proceeds will be applied toward projects that promote improved social welfare and positive social impact directly for underprivileged, low income, marginalised, excluded or disadvantaged populations.
- **Sustainability-linked bonds:** proceeds where the terms of a fixed income security are aligned with company's (issuer/borrower) performance against relevant predetermined sustainability targets to boost their sustainability profile.

Investors favour ESG bonds over time. According to the above-mentioned sustainable bond classification (see Box E), the issuance of ESG bonds by European entities increased substantially to almost USD 350 billion in 2020, from USD 259 billion a year earlier and USD 40 billion five years before that, attesting to the growing demand for the asset class (Figure 18). The increase was the most pronounced for social bonds, which rose to USD 61 billion in 2020 from USD 8 billion in the previous year, as the coronavirus pandemic increased the financing needs for social welfare projects and projects designed to prevent vulnerable people from sinking further into poverty.

Figure 18
ESG debt issued by European entities (USD billion), by debt type



Source: Bloomberg and authors' calculations. ABS refers to asset-backed securities.

Table 1
Determinants of European corporate bond metrics

Variables	(1) Spread	(2) Rating	(3) Probability of default
ESG	-1.09* (0.56)	0.05* (0.03)	-0.02** (0.01)
Debt to assets ratio	0.28 (0.25)	0.002 (0.01)	0.03*** (0.01)
Revenue (log)	-6.55** (2.61)	2.59*** (0.18)	-0.01 (0.05)
Constant	204.8*** (37.41)	-11.02*** (2.19)	4.68*** (0.94)
Observations	1 120	1 120	1 120
R-squared	0.28	0.27	0.39
Country fixed effects	YES	YES	YES
Sector fixed effects	YES	YES	YES

Source: Authors' estimates.

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

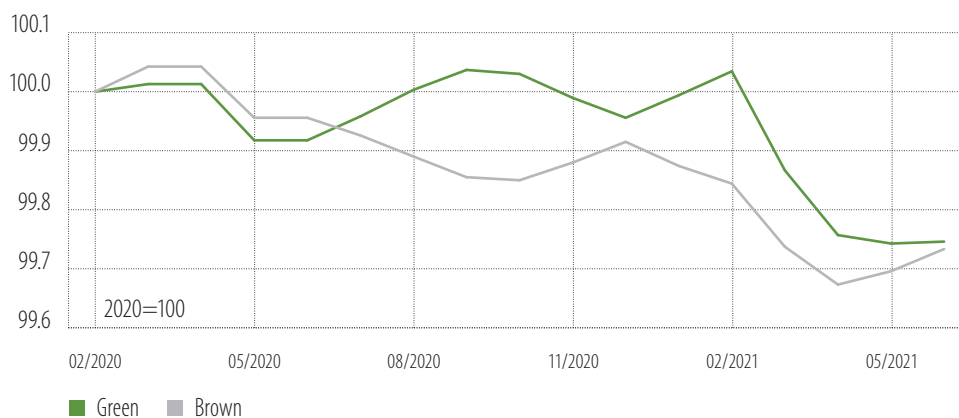
Climate considerations affect the pricing of European corporate bonds. These considerations can be measured through a firm's environmental, social and corporate governance (ESG) score, which reflects a firm's performance on a wide range of environmental, social and governance topics.

Higher ESG scores lead to a lower yield spread of European corporate bonds, relative to comparable sovereign yields. This implies that ESG investments are valued more highly than normal corporate investments (Table 1).⁹ A higher ESG score also results in a lower risk of default and a better debt rating for European corporate debt issuers. This implies that the debt of more environmentally aware European firms is of better quality. A better quality fixed income instrument is more likely to be included in investment portfolios, increasing the demand for such assets.

The impact on debt costs is consistent with the available literature. For example, Ginglinger and Quentin (2019) found that greater climate risk led to lower leverage in the period after 2015 and Capasso et al. (2020) suggested that companies with a high carbon footprint were perceived by the market as more likely to default. In addition, Allman (2020) reports that firms exposed to higher sea level rises in the United States pay a premium when issuing bonds, while Bolton and Kacperczyk (2021) report that firms with higher emissions compensate investors by offering higher returns.

Portfolios of green European corporate bonds slightly outperform brown bonds, suggesting that the corporate bond greenium is priced in. The analysis subsequently builds on a brown and green corporate bond portfolio using euro-denominated, bullet, fixed coupon, investment grade European corporate bonds issued after the global financial crisis and available from Bloomberg. On the one hand, the green portfolio consists of equally weighted corporate bonds with an ESG score higher than the median ESG score of corporate bonds issued after the global financial crisis. On the other hand, the brown portfolio includes equally weighted corporate bonds with an ESG score lower than the median ESG score of corporate bonds issued after the global financial crisis. Zooming in on the last two years, which saw a spike in the issuance of green corporate bonds, the analysis finds that the price of the green European bond portfolios observed is higher than that of the brown portfolios, even though the two started at the same level, suggesting that there is a premium for greener corporate bonds (Figure 19).

Figure 19
Prices of green and brown portfolios of European corporate debt (EUR index)



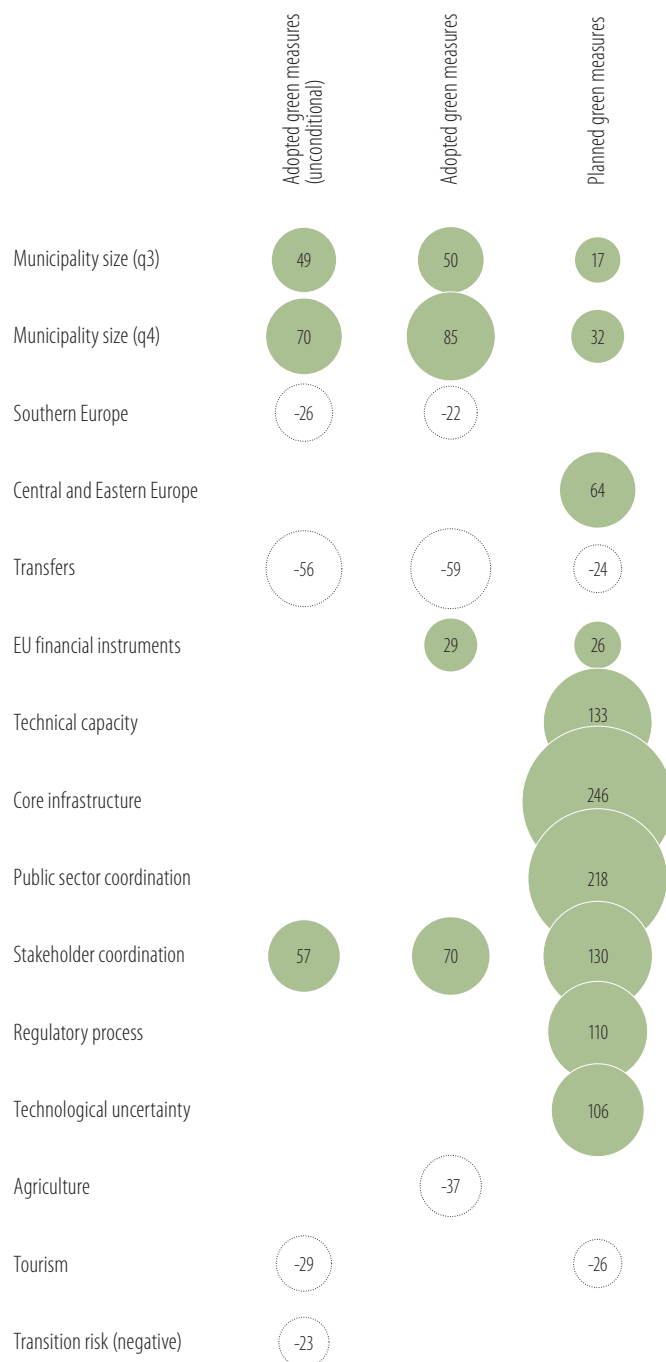
Source: Bloomberg and authors' calculations.

⁹ The analysis is performed at issuance, for the EU corporate bonds issued since 2010 for which all data were available from Bloomberg. In Table 1: spread is the spread between corporate and government bond yields of comparable maturities; rating is the corporate bond rating provided by Bloomberg (the higher the better); probability of default is the corporate bond's default probability calculated by Bloomberg (the higher the worse off); debt to assets ratio is self-explanatory; revenue (log) is the logarithm of company revenues; and ESG is Bloomberg's ESG score (the higher the better).

Municipalities' investment in climate measures

Municipalities are key players in the climate transition. Making use of the EIB 2020 Municipality Add-On Module Survey, an analysis was performed on the factors that influence municipalities' adoption of green initiatives and projects. A number of factors were identified, such as a municipality's geographical position and size, financing sources for recent infrastructure investments, primary sector of employment and the perceived barriers and risks to the green transition (Figure 20).

Figure 20
Factors influencing the planning and adoption of green measures



Source: EIB Municipality add-on module 2020.

Note: The table shows results from poisson regressions. The reported figures are exponentiated coefficient to express percentage differences in the number of measures planned/adopted. The omitted categories are: for regions, Western and Northern Europe; for sectors, the service sector as main employer; for barriers, no barriers reported. Only statistically significant coefficients of at least at $p < 0.1$ are reported.

Larger municipalities and those located in Western and Northern Europe are leading the green transition. The larger municipalities have adopted nearly twice as many green measures. The results also show that municipalities in Southern Europe have adopted about 20% fewer measures than those in Western and Northern Europe, while plans to do so are similar. At the same time, municipalities in Central and Eastern Europe are more ambitious in the number of planned measures, even when those already adopted are taken into account.

The adoption of green measures is linked with municipalities' ability to tap their own financial resources. Municipalities that were able to finance their recent infrastructure investment from their own revenues report having adopted green budgeting. At the same time, municipalities that have financed their recent infrastructure investments largely from project-specific transfers cite a smaller number of measures adopted. In addition, the analysis indicates that municipalities that have recently benefited from EU-funded financial instruments report more green measures, both already adopted and planned.

Municipalities in areas dominated by agriculture are lagging behind. Municipalities engaged in mainly agricultural activities tend to have adopted about 40% fewer green measures than those where employment is dominated by the services sector. In addition, these municipalities are lacking plans to adopt additional measures. The analysis also shows that municipalities that rely more heavily on tourism lag behind when it comes to the number of measures already adopted, but they are making ambitious plans to speed up their climate transition. Municipalities with an extensive financial services sector are more likely to budget for green projects, while those engaged primarily in construction are less active, and are refraining from adopting smart energy grids.

Green transition leaders tend to bemoan a lack of coordination, whereas green planners report issues with infrastructure and technical capacity. When municipalities are asked what is holding them back from green infrastructure investment, the main obstacle mentioned is a lack of financing. However, municipalities' perceptions differ widely depending on where they stand in the green transition. Municipalities with more measures already adopted ("leaders") more frequently mention coordination with stakeholders and prospective users as a key barrier.¹⁰ At the same time, municipalities that have not yet adopted green measures, but are motivated to plan several ("planners"), also cite other barriers. Ambitious planners are more likely to consider a lack of core infrastructure and difficulties in coordinating with other municipalities or higher levels of regional government as the most pressing issues.

Municipalities leading the green transition view climate risks as less pressing. Perceptions of economic gains or losses related to the physical and transition risks of climate change are not only related to actual climate change hazards. They also depend on the steps already taken. Municipalities that have already adopted several green measures are somewhat less likely to expect negative economic consequences from climate risks, and are even less likely to expect a negative outcome from transition risks. Specifically, municipalities that have adopted smart grid technology are less worried about the negative consequences of the green transition.

Innovation and climate change

Patenting for climate change mitigation technologies in the European Union

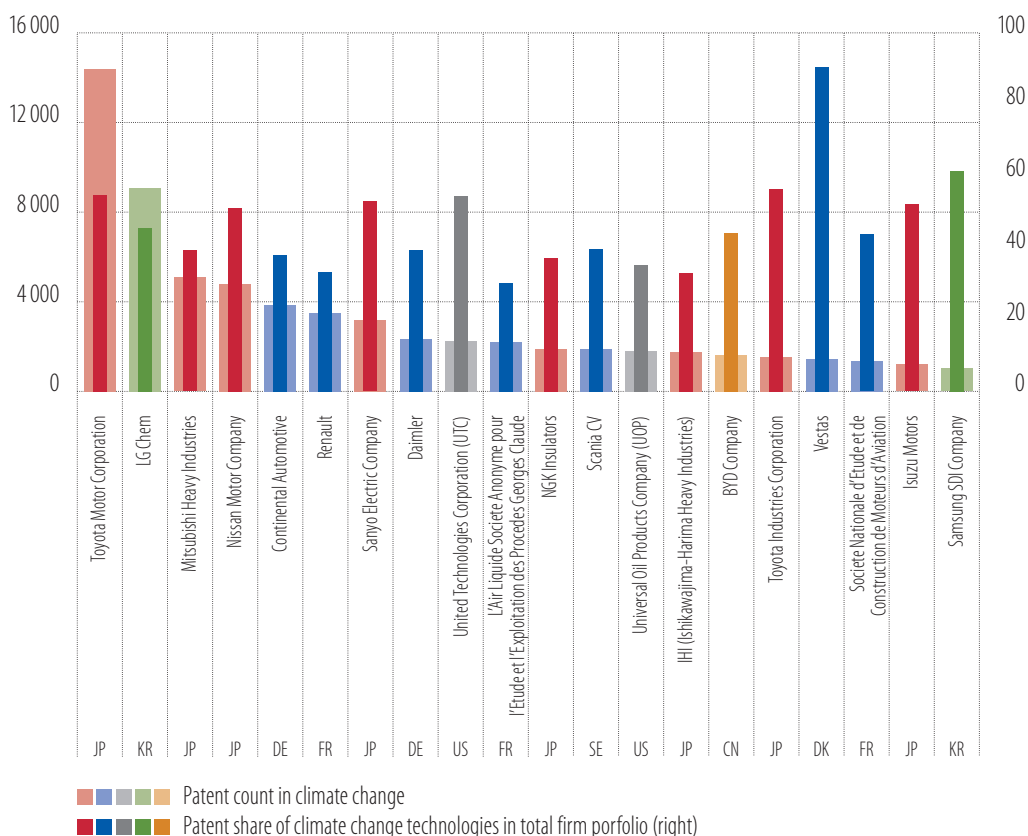
The development and rollout of technologies that generate environmental benefits is crucial for green growth. It is evident that the climate change challenge cannot be tackled without technological

¹⁰ These findings are similar to Aguiar et al. (2018), where barriers to climate change adaptation include insufficient resources and dependence on external financial support, technical capacity, political commitment and uncertainty.

advances (Aghion et al., 2019). Technical progress must be made in a variety of sectors, and green innovations covering a wide array of fields are key. Investing in environmentally friendly technologies and supporting innovation in the private sector are clearly stated ambitions of the European Green Deal (European Commission, 2019). Even though the European Union is one of the main players in green patenting (as discussed in Chapter 2), the trend in climate change-oriented patents appears to be stagnating following a decline in recent years. This seemingly stands in contrast with the high need for new technologies to be developed in this area.

The top 20 companies for climate change patenting are located in the European Union and Japan. The United States and South Korea only have two players and China one (Figure 21). The leading companies in climate change innovation can be measured by the number of patents they hold as well as by the share of climate change patents in their total patent portfolio. Figure 21 clearly shows that the number of patents is not always proportional to the share. A company like Vestas in Denmark, for example, is not at the absolute top for the number of patents produced, but it has a very high relative specialisation in climate change innovations (with more than 90% of the firm's patents in this area). Most of the other companies in the top 20 seem to have a more diversified patent portfolio and do not focus exclusively on climate change innovations.

Figure 21
Top 20 players in climate change innovation worldwide (left axis: patent count; right axis: patent share in %)



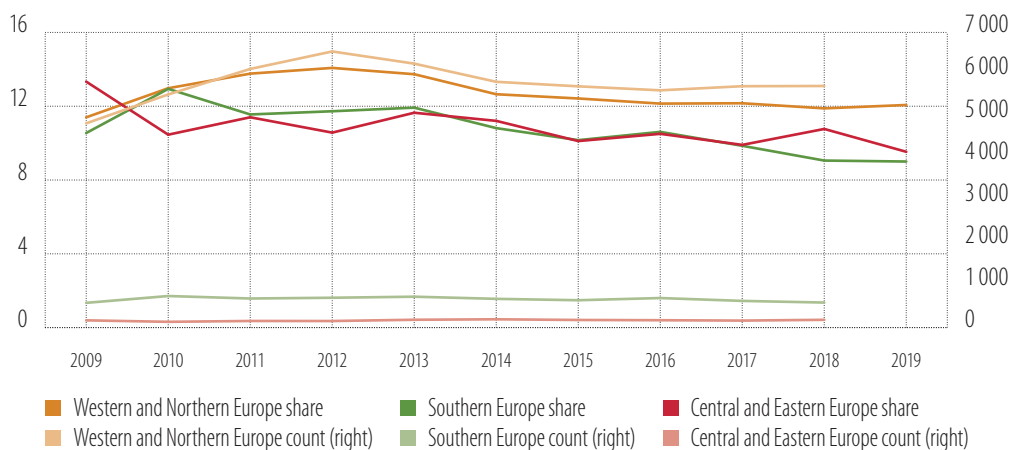
Source: The European Patent Office's Worldwide Patent Statistical Database (PATSTAT). Patent Cooperation Treaty (PCT) data prepared in collaboration with the Centre for Research and Development Monitoring (ECCOM).

Note: The bars reflect the number of climate change patents as well as the share of climate change patents in their patent portfolio for each company from 2000 to 2018. The figure only includes companies with a minimum share of 30% climate change patents in their total patent portfolio. The colours refer to different countries (blue = European Union; red = Japan; grey = United States; orange = China; green = Korea).

Within the European Union, Western and Northern Europe dominate climate change patenting (Figure 22). The number of patents created in Western and Northern Europe surpasses the numbers in Southern Europe and Central and Eastern Europe by an impressive margin. Nevertheless, although Southern Europe and Central and Eastern Europe have a relatively low overall patent count, their relative specialisation levels in innovations tackling the impacts of climate change are similar to those in Western and Northern Europe.

Figure 22

Climate change patents in the European Union (left axis: patent share in %; right axis: green patent count), 2009-2019



Source: PATSTAT (PCT) data prepared in collaboration with ECOOM.

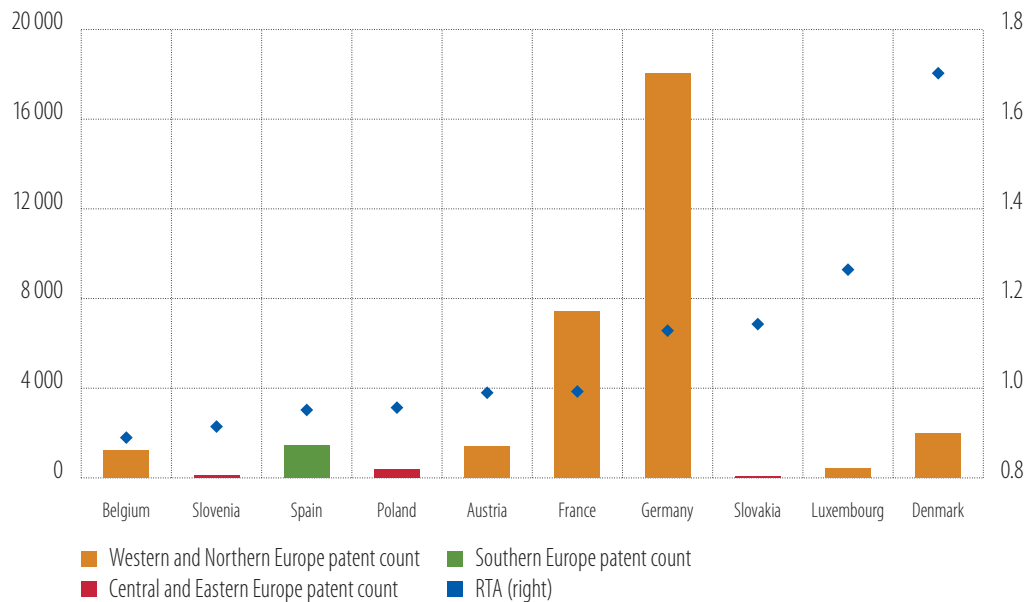
Note: The light lines show the count of green patents (right axis) and the dark lines show the share of green patents in the total domestic patent portfolio (left axis).

Patenting activity in Germany and France stands out, while Denmark, Luxembourg and Slovakia specialise the most in developing green technologies. Overall, above-average patenting is concentrated on a handful of countries with a revealed technological advantage (RTA) above 1 (Figure 23). Most of these top European players focus on innovations related to energy generation, transmission and distribution, and to transport and mobility, except for Denmark, which focuses mainly on energy generation, and Luxembourg, which is mainly active in environmental management innovations.

Europe is strongest in electrification, energy efficiency, and transport and mobility. Not only does Europe have the most internationally oriented climate-related patents in these areas (more than China and the United States), but it has also seen the highest increase in patenting in these domains compared to other regions over the past decade. A large number of innovations are needed in these domains given that energy-intensive industries, together with the transport and mobility, accounted for almost half of total emissions in 2018. To assess Europe's performance in some of these key domains, this chapter builds on the methodology of Haščič and Migotto (2015) to classify the patented inventions (see Table 2).

Figure 23

Advantage in green patenting across the EU members (left axis: count of patents related to climate change; right axis: RTA), 2013-2018



Source: Authors' calculations based upon PATSTAT (PCT) data in collaboration with ECOOM.

Note: The RTA (revealed technological advantage) index is the share of green patents in the country portfolio relative to the share of green patents in Europe. Only countries with a sufficient number of green patents are shown in the graph. The index was calculated for the time period 2013-2018.

Table 2

Different patent domains in climate change mitigation

Climate change mitigation	Including
The transport and mobility sector and its enabling technologies	Road transport; enabling technologies in transport such as electric vehicle charging and application of fuel cell and hydrogen technology to transportation
Electrification and its enabling technologies	Electrification technologies; supporting technologies in the energy sector; energy efficiency in buildings
Capture, storage, sequestration or disposal of greenhouse gases	Carbon capture or storage; capture or disposal of greenhouse gases other than carbon dioxide

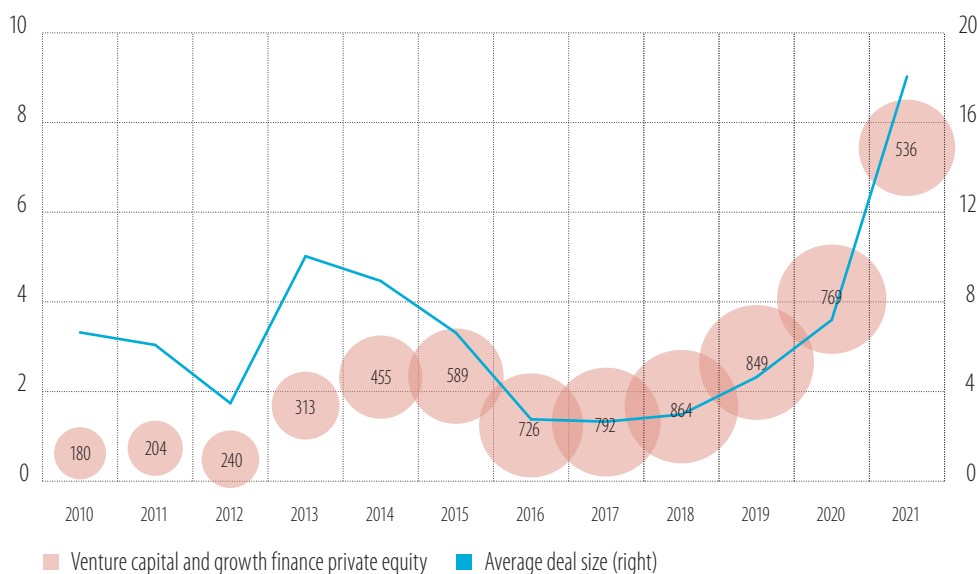
The EU greentech sector¹¹

Supporting innovation among firms focusing on green technologies is a key element of Europe's net-zero emissions strategy. By lowering the cost of greenhouse gas abatement or pollution reduction, greentech innovation can ensure the European Union reaches climate neutrality in a cost-efficient manner. Moreover, innovation can help EU firms to adapt to the reality of an altered climate, for example through the introduction of new crop management or irrigation techniques in agriculture, better weather forecasting technologies, or advances in the field of disease control.

¹¹ The analysis in this section is based on the EIF's European Small Business Finance Outlook. For more detailed information about the data this section is based on, please see Kraemer-Eis et al. (2021).

Financing for greentech innovation has been on the rise in recent years (Figure 24). After a minor setback from 2013 to 2016, venture capital and private equity investments in European greentech companies increased sharply from 2017 onwards, reflecting growing societal concerns about the environment and sustainability, and the increased focus of EU policymakers on private financing as a catalyst for the green revolution.

Figure 24
Innovation finance for European greentech companies (left axis: EUR billion), **venture capital and private equity in the EU27*** (right axis: EUR million)



Source: Kraemer-Eis et al. (2021), based on Pitchbook.

Note: *The bubble surface area indicates annual number of deals in the venture capital and growth finance private equity sphere.

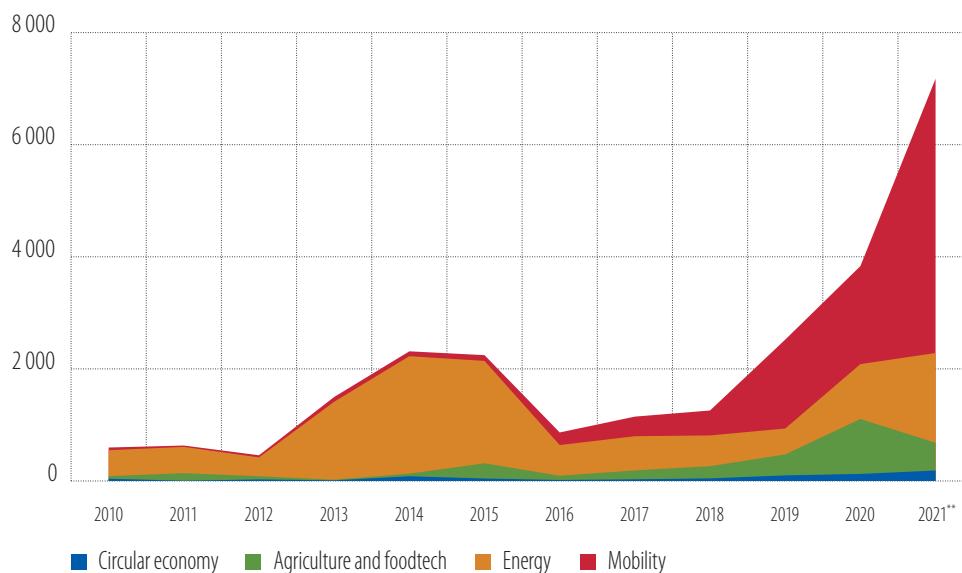
**Incomplete yearly total at the time of data extraction (18 October 2021).

From the third quarter of 2015 until 2021, about half of total investments (venture capital and scale-up) in European greentech flowed to firms focused on mobility and transport solutions (Figure 25). These solutions included electric vehicles, electric vehicle batteries, e-scooters, IT platforms for shared micro-mobility solutions, hydrogen power technologies with applications in transport, electric vehicle technology in the aviation industry, etc.

Another 35% of money invested went to companies working on green energy applications. These businesses are focusing on renewable energy infrastructure (wind farms, solar power generation plants) or equipment (such as photovoltaic panels), new-generation nuclear energy, biogas production, etc. Sustainable food and agritech made up 13% of green tech investments in the EU27 greentech sector (insect-based protein production, sustainable soy production, internet of things technology for vertical farming systems, etc.). Companies active in the circular economy, focusing mostly on waste management and recycling technology, made up 3% of investment.

Investments in European greentech ecosystem are increasingly focused on mobility solutions in recent years. Investments in mobility and transport greentech drove the investment growth, with mobility accounting for nearly 70% of investments during the first three quarters of 2021. This is a welcome trend, considering that decarbonising the transport sector will likely be one of the most challenging aspects of Europe's net-zero emissions plan. Mobility has lagged behind in Europe's sustainability revolution, and current technological developments will ensure that cutting emissions in the transport sector in the next decade will not be too costly.

Figure 25
Trends in the EU greentech ecosystem (EUR million)*



Source: Kraemer-Eis et al. (2021), based on Pitchbook.

Note: * Totals do not perfectly coincide with the volumes represented in Figure 24, as a limited number of deals were not categorised under any of the four categories and were therefore omitted from the analysis. Moreover, the classification method was not designed to construct mutually exclusive categories, leaving open the possibility of a minor degree of overlap.

** Incomplete year data extracted at the time of writing (19 October 2021).

The European Union's path to lower carbon emissions: electrification, energy efficiency, transport and mobility

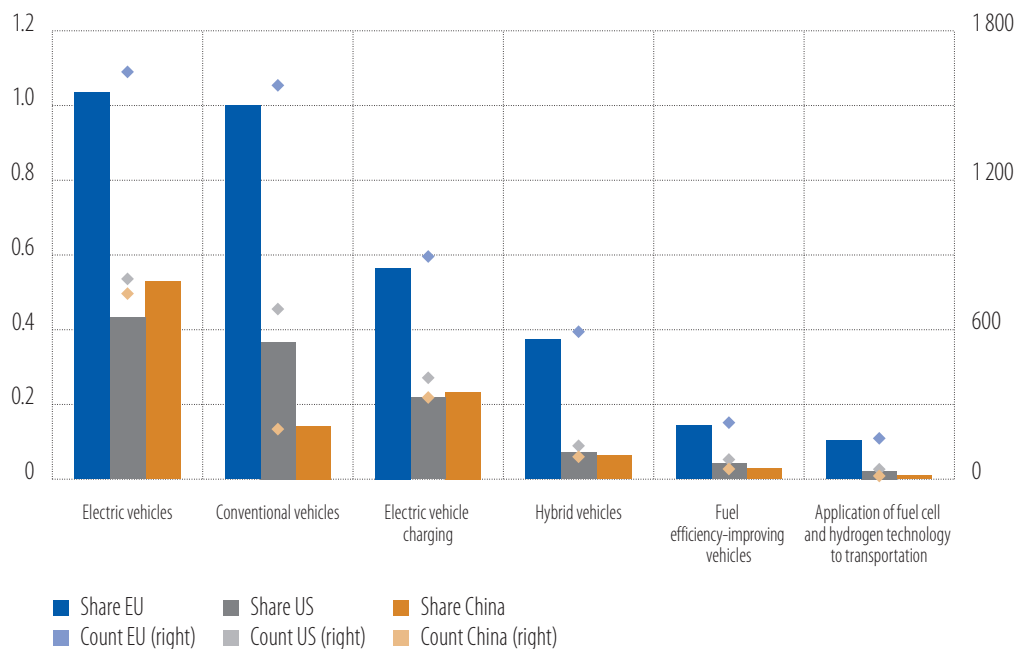
Just as it is leading in overall international patent applications for climate change technologies, Europe is also ahead in transport and mobility, as well as in innovations related to electrification and energy efficiency. Europe is at the forefront of international patenting in these areas, in absolute patent counts and in the share these patents make up of the total domestic portfolio. However, China is rapidly catching up and is intensifying its international presence, especially in inventions related to energy efficiency (see discussion in Chapter 2).

When it comes to transport and mobility, the main focus is currently on electric vehicles, an evolution that goes hand in hand with EU priorities (see Box C in Chapter 5). Still, transport and mobility continue to account for 24% of direct carbon emissions, and the sector needs a radical shift to clean energy (International Energy Agency (IEA), 2020b). Figure 26 shows that Europe is not only prioritising development in electric cars, but is also investing in the charging technologies.

The green premium being paid for investments in electric vehicles and tightening emissions regulations are actually spurring innovation in conventional vehicles. The European Commission's Fit for 55 package targets a 55% reduction in carbon emissions by 2030. In that aim, the Commission will soon introduce new, stricter Euro7 emissions performance targets. These targets are putting pressure on car manufacturers to further improve the internal combustion engine while at the same time investing in electrification. Electric vehicles also come with a green premium, although that premium does not fully compensate for the convenience of conventional vehicles when it comes to autonomy or fuelling time.

Figure 26

Climate change mitigation technologies related to transport and mobility (left axis: patent share in %; right axis: patent count), 2017-2019



Source: Authors' calculations based upon PATSTAT (PCT) data in collaboration with ECOOM.

Note: The diamonds show the count of climate change mitigation technologies related to transport and mobility (right axis); the bars show the share of patents in the respective total domestic patent portfolio for the climate change mitigation technologies related to transport and mobility (left axis).

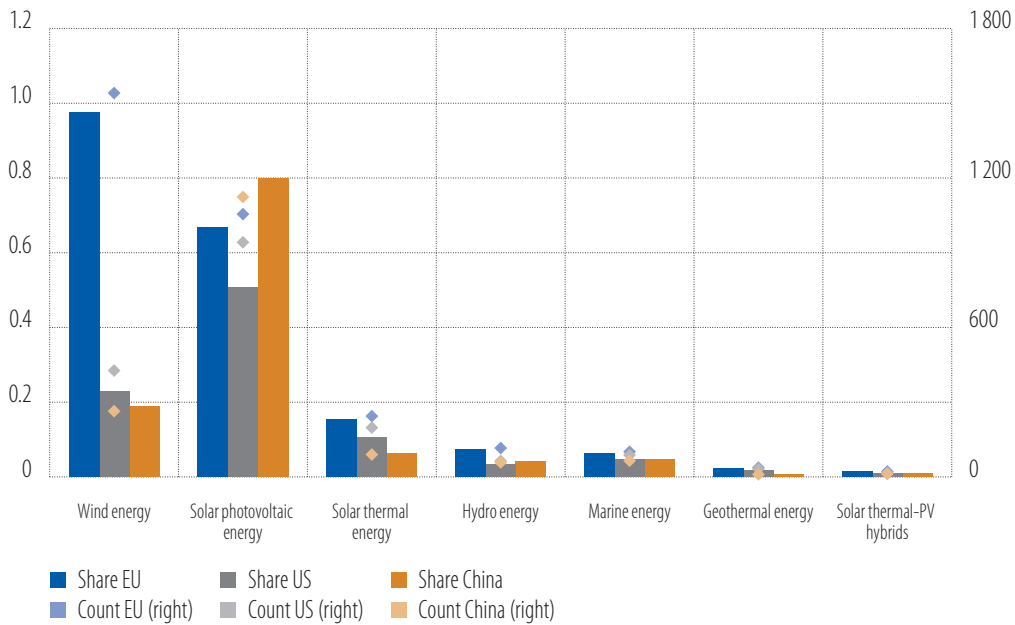
Some of the technologies developed in the transport and mobility sector are closely related to energy efficiency. When it comes to fuel efficiency, electric vehicles or hydrogen technology, innovation is highly dependent on advances in the energy sector. If coal or other polluting fuels are used to generate the electricity needed to charge electric cars, for example, then climate objectives will be hard to achieve.

Europe seems to have a competitive advantage in innovations in wind energy, but not necessarily for solar. Patents in electricity generation are focused on two key technologies: wind and solar photovoltaic energy. While Europe is establishing its presence in the wind technologies, China remains the major force in solar power.

All three of the European regions are intensively developing smart grid and energy storage technologies. These technologies are key to advancements in the energy sector (Figure 27). Europe and China are ahead of the United States when it comes to innovation in both areas.

The world is still largely focused on technologies that are fairly well established, while technologies such as hydrogen require further development. As pointed out by Gates (2021), hydrogen technologies could be a valid alternative for storing electricity. Recent rises in oil and gas prices and the arising energy shortages have called into question Europe's focus on intermittent renewable energy sources. Against this backdrop, it seems even more important to follow the recommendation of the Intergovernmental Panel on Climate Change (2021) and the IEA (2019, 2020) to shift the focus towards a different set of technologies — including hydrogen — that could make it possible to store electricity coming from renewable energy for later use. Nevertheless, as Figure 28 shows, while Europe is putting considerable effort into developing hydrogen technologies, those technologies remain in their infancy.

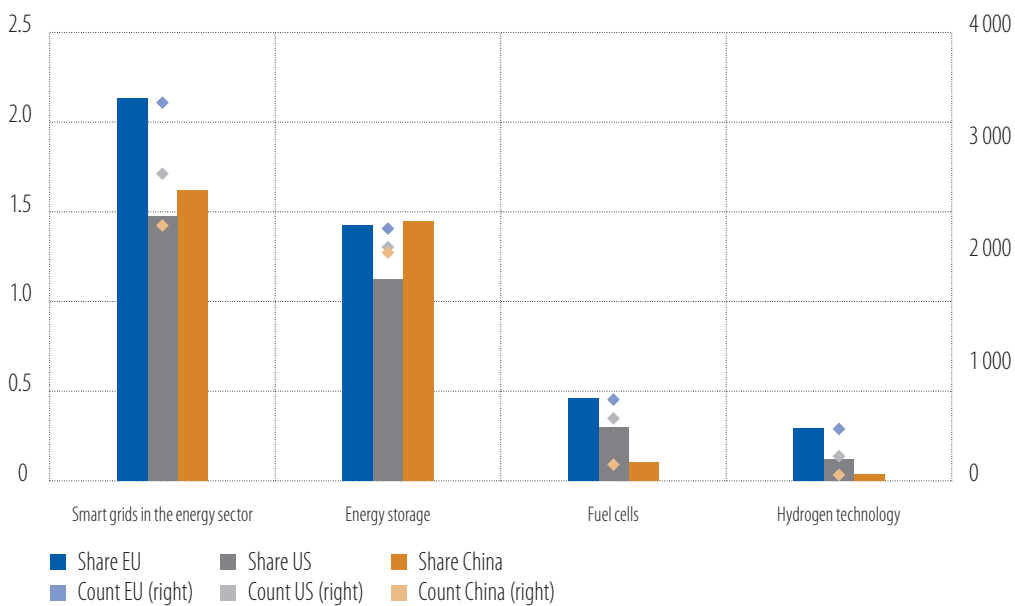
Figure 27
Climate change mitigation technologies related to electrification
(left axis: patent share in %; right axis: patent count)



Source: PATSTAT (PCT) data prepared in collaboration with ECOOM.

Note: The bars show the share of climate change mitigation technologies related to electrification in the total domestic patent portfolio (in %), the dots show the count of these patents in the respective region. PV stands for photovoltaic.

Figure 28
Climate change mitigation technologies supporting electrification
(left axis: patent share in %; right axis: patent count)



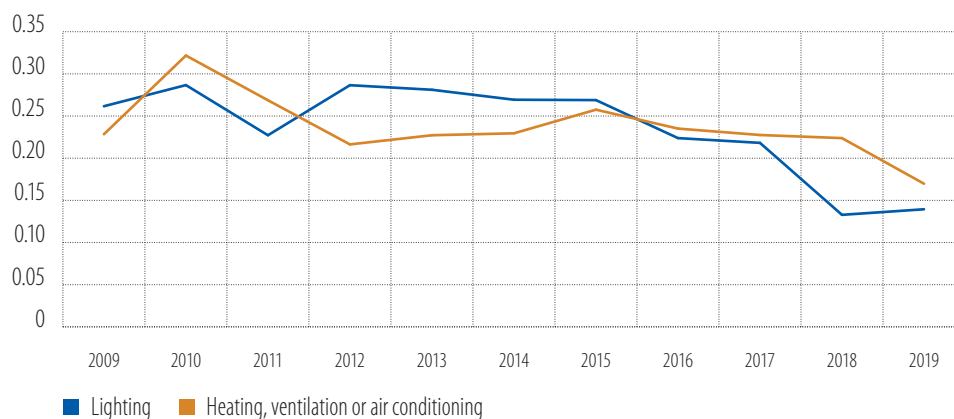
Source: Authors' calculations based upon PATSTAT (PCT) data in collaboration with ECOOM.

Note: The bars show the share of climate change mitigation technologies supporting electrification in the total domestic patent portfolio (in %), the dots show the count of these patents in the respective region.

While hydrogen can help to address the critical energy challenges, its production still depends to a large extent on fossil fuels. Very versatile in nature and easy to store, hydrogen is still almost entirely produced by fossil fuels, mainly natural gas. Nevertheless, hydrogen is often considered as a solution to store energy produced out of electricity, thereby saving renewable energy in peak hours that could otherwise be lost. This could ensure that Europe's bet on wind energy will pay off in the future, and improve the match of energy supply with demand.

Policymakers could also play a critical role in fostering innovations in underdeveloped energy applications. For example, despite the massive energy consumption of buildings (40% of final energy consumption), European patenting for energy efficiency in buildings is at best stagnating (Figure 29). The European Commission plans to introduce a new, separate emissions trading system to cover emissions from fuels in road transport and buildings (European Commission, 2021). Whether the new trading system will create a spur for innovation is yet to be seen, but previous trends suggest that similar policies could stimulate new technologies (see Chapter 8 in EIB, 2021 and Calel and Dechezleprêtre, 2016). Higher fuel prices could also boost innovation. For example, using patent data, Aghion et al. (2016) focused on the car industry, showing that higher fuel prices boost innovation in low-carbon technologies while curbing innovation in high-carbon ones.

Figure 29
Climate change mitigation technologies addressing building energy efficiency improvements in lighting and heating in the European Union (% of energy efficiency patents in total portfolio), 2009-2019

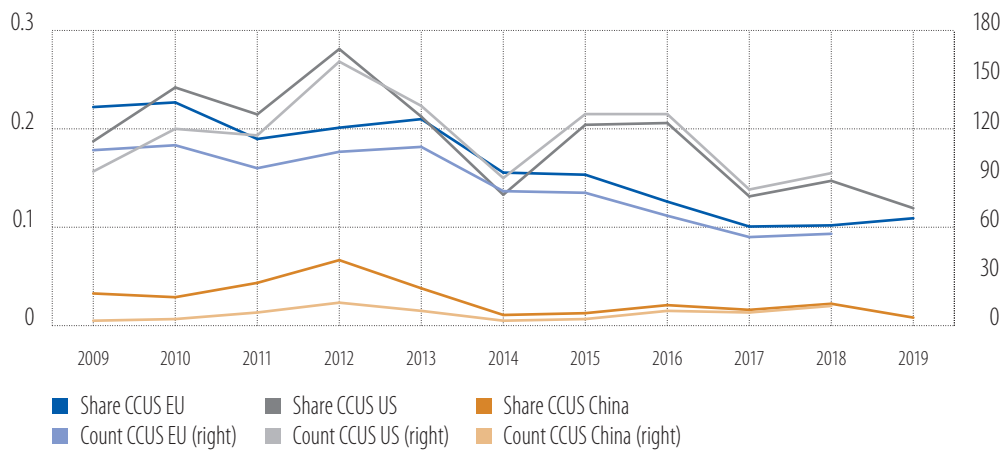


Source: Authors' calculations based upon PATSTAT (PCT) data in collaboration with ECOOM.

Other green approaches: capture, storage, sequestration or disposal of greenhouse gases

A different approach, such as the exploitation of carbon capture, utilisation and storage (CCUS) technologies, could play an important role in meeting global energy and climate goals. The most recent IPCC (2021) report puts capture and storage technologies at the heart of its proposed solutions, and the IEA (2021) also stresses the importance of these technologies.

While carbon capture and storage technologies are being deployed with increasing regularity, the technologies are still not living up to their full potential (IEA, 2021) — more innovation is needed. CCUS could tackle emissions from existing infrastructure and from the most polluting industries, supporting the production of low carbon hydrogen and, more ambitiously, removing carbon from the atmosphere. Nevertheless, more innovation is needed — and fast — to deploy these technologies against a ticking clock.

Figure 30
Technologies related to carbon capture and storage (left axis: % of patents in total portfolio; right axis: patent count), 2009-2019


Source: Authors' calculations based upon PATSTAT (PCT) data in collaboration with ECOOM.

Innovation in carbon capture and storage is moving very slowly, and the current trend shows a decline in patenting (Figure 30). The decline in patenting contrasts with the increased deployment of these technologies across regions and applications (IEA, 2021). In spite of greater momentum, larger-scale technological development is still required to make this technology commercially viable and ready for wider deployment.

However, as with climate change innovation in general, market prices do not factor in the potential environmental benefits of these technologies. The incentives for private market players to invest in these type of technologies — without clear rewards and high risks — are very low (Popp, 2019). The lack of incentives for the development of these technologies has led to less-than-optimal levels of green investment. Policy support could help rectify the situation.

In addition, growing consumer and market pressure could motivate firms to further develop technologies such as carbon capture and storage and hydrogen. A large share of firms react to consumer preferences, market demand, energy prices and cost savings. These findings are supported by the trend in patent applications and fossil fuel prices discussed in Chapter 8 of EIB (2021) and the patent trends observed in building energy efficiency.

Even if firms devote resources to green technologies, finding funding for energy innovations — and climate innovation in general — is challenging, especially for smaller firms. Due to the novelty of these technologies, the high risk of their benefits spilling over into other industries and high upfront costs, these technologies often have difficulty attracting financing. The often experimental nature of green innovations exacerbates the problems (Nordhaus, 2009; Rodrik, 2014; Popp, 2019).

For most newer technologies, the surrounding infrastructure would need to be adjusted or sometimes changed completely. Infrastructure plays a major role in the application of hydrogen, carbon capture and storage or any other type of technology. If these technologies are to achieve their full potential, existing infrastructure must be adjusted and new infrastructure built.

Conclusions and policy implications

This is the make-or-break decade for avoiding the adverse effects of climate change. Europe has shown leadership, committing to a net-zero economy by 2050 and integrating this commitment into its policies with the European Green Deal and the Fit for 55 legislative package. The EU Taxonomy will also improve transparency on sustainable investments, making them more attractive. This leadership is critical, not least because it provides clarity for firms, households and public authorities on the way ahead, limiting uncertainty.

While the pandemic stalled in climate investment, the road to recovery presents an opportunity to act and to contribute to regional and international climate objectives. The ambitious European Green Deal set out long- and short-term decarbonisation targets and a comprehensive set of measures for aligning the incentives of different players to the green transition. Resources are also being made available. The European Union's comprehensive recovery strategy — which encompasses dedicated climate resources — could be the much-needed push that accelerates the response to the climate emergency and contributes to the region's pledge to become the first carbon-neutral continent by 2050.

Firms are waking up to the reality of what climate change and the green transition mean for them. The EIBIS suggests that 58% of European and 63% of US firms are vulnerable to physical climate risks. Larger firms are more aware of the need to adapt to a low-carbon future, as are firms in low-carbon sectors (which are more inclined to see opportunities) and firms in brown sectors (which are more inclined to see risks). Small firms and firms in transition sectors — the bulk of firms in the European Union — tend to be unaware of the challenges ahead.

European businesses still need to understand what the climate transition means for them, if they are to invest, adapt and thrive in the new era. Firms face new reporting requirements on carbon emissions and sustainability. They also now need to understand their exposure to the risks of the climate transition and climate change itself. Though delayed by the pandemic, climate investments are set to grow, but they need to increase massively. Some 43% of EU firms have recently invested in mitigation or adaptation, while 47% plan to do so (compared with 28% investing and 40% planning to do so in the United States).

Clarity about Europe's plans and technical capacity are essential for firms to make investments in a timely and appropriate way. Interventions deemed "the most helpful" by firms include EU and national-level clarity on climate policy (29%), advice on financial support (18%) and technical support (17%). Greater clarity will help all economic sectors to avoid underestimating the benefits of climate investment. In addition, guidance on finding adequate finance support could encourage them to take on the upfront investment costs and overcome the limited availability of finance, which are obstacles to climate investment. Similarly, technical support would counter the limited availability of skilled staff.

Adopting green management practices — including hiring dedicated climate staff, setting and reporting climate targets or conducting energy audits — acts as a catalyst for climate investment. EIBIS results suggest that SMEs are lagging behind large firms in areas such as green management practices and adaptation investment, suggesting a need for targeted intervention. This support could then be directed at enhancing a firm's ability to adapt to the transition and improving its green capabilities (through technical support and skills training). Increasing technical capacity is also key to increasing municipalities' climate awareness and investment.

The push for greater disclosure of climate-related information is also important to guide and encourage investments in a carbon neutral future. Businesses' investors, customers and other stakeholders are demanding greater transparency and more disclosure of climate change risks. This demand has become so strong that businesses failing to disclose their climate change risks could jeopardise their reputations. In parallel, poor disclosure can lead to poor investment decisions, stranded assets, and the continuation of trade practices that contribute to climate change. Firms need to provide reliable, comparable and meaningful sustainability data. This information will enable institutional investors and banks to incorporate

long-term sustainability risks into their decision-making and to redirect finance towards sustainable investments.

Given that a substantial share of investment is going towards sustainable activities and growing evidence of a greenium in EU corporate bonds, a clear and reliable public framework for green bonds is needed. To this end, the Green Bond Standard needs to be adopted throughout the European Union. Therefore, the standard needs to be made mandatory for newly issued green bonds within a reasonable time period. Until the Green Bond Standard becomes mandatory, it should be encouraged at the European Union and national level by public policies that favour bonds complying with the standard.

The climate transition is a major economic opportunity for Europe, but Europe will only be able to seize it by building on its early lead in green innovation. Market leadership in emerging green technologies might bring economic benefits on a scale comparable with the United States' dominance of the digital domain. For now, Europe is in a lead position. As research and development in these technologies accelerate, Europe will be well placed to maintain its lead, but nothing can be taken for granted. Europe is particularly strong in electric vehicles and charging, wind power, smart grids, fuel cells and hydrogen technology, where its share of recent patents is greater than the United States and China combined. In the areas of solar photovoltaic generation and energy storage, patenting levels by the United States, European Union and China are similar. Moreover, while the United States continues to dominate digital innovation, followed by China, Europe has taken an early lead in patents that combine green and digital technologies.

Policy intervention is needed for clean technologies to be created, developed and rolled out with sufficient speed and at the appropriate scale. It is especially important that the policy instruments — carbon pricing, regulation and public support for clean R&D — are deployed simultaneously and in a coordinated manner, as major synergies could be exploited. Such intervention is needed to overcome inertia among investors and consumers and to stimulate demand for innovative green technologies. A coordinated push could increase firms' appetite for taking risks in the development of technologies (such as hydrogen and carbon capture and storage) that are necessary for Europe to reach carbon neutrality.

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