Financing and commercialisation of cleantech innovation

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Europäisches Patentamt
European Patent Office
Office européen des brevets

European Investment Bank

Foreword

The global shift towards sustainability has brought the green transition to the forefront of the European agenda, with the EU Green Deal leading the way. If Europe is to be climate-neutral by 2050, then our industries must be transformed in this process. Innovation in new, cleaner technologies is pivotal in this context to reshape Europe's economy and ensure its sustained competitiveness, requiring ingenuity and investment.

With this study, the European Investment Bank (EIB) and the European Patent Office (EPO) have teamed up to offer key insights into Europe's position in the global race for innovation in clean and sustainable technologies. This study focuses on companies that are commercialising novel patented technologies, thereby shedding light on the central players of the European Union's cleantech ecosystems. It benchmarks them against their peers in other European countries and the United States, using the combined expertise of the EIB and the EPO to document their financing and patenting profiles.

Patent protection is key for companies that invest in innovation. As the patent office for Europe, the EPO provides high quality patents to protect innovation in up to 39 member states (including all 27 EU member states). It is at the forefront of technological progress, classifying and publishing millions of patent documents in a wide range of fields. Importantly, patents benefit not only large multinational companies, but smaller firms and even university research. This report clearly shows that they are critical assets for smaller cleantech companies to attract investors and raise funding (EPO-EUIPO, 2023), with a view to commercialising new technology.

In the European Union, innovative firms suffer from a lack of suitable finance, which limits companies' ability to grow. Cleantech innovators are not an exception. Underdeveloped capital markets are part of the explanation, with the EU financial sector being largely bank based. The European Investment Bank Group, comprising the European Investment Bank (EIB) and the European Investment Fund (EIF), is at the forefront in terms of addressing this challenge. As the world's largest multilateral financing institution, the EIB Group lent nearly EUR 88 billion around the world in 2023 alone, with more than half of it going to climate action and environmental sustainability. The EIB Group supports a diverse spectrum of players, from startups to well-established corporations, through mechanisms ranging from loans and guarantees to banks, direct financing and guarantees, seed capital, venture capital support, to strategic venture debt for small and medium-sized enterprises (SMEs). With the aim of closing the scale-up financing gap, the EIB Group has launched the European Tech Champions Initiative (ETCI), a fund of funds managed by the EIF, and the EIB Scale-Up Initiative (ESI), with a focus on quasi-equity products.

The findings presented in this study confirm the relevance of focusing on European cleantech innovators as a coherent cohort. European firms that commercialise patented technology typically aim to scale up from their domestic market to the EU single market. Since June 2023, they have been able to use the broad geographic protection offered by the Unitary Patent for that purpose. As European cleantech innovators clearly see their future in the EU market, a well-functioning single market and coherent regulation emerge as crucial assets to exploit the full potential of the European Union in cleantech innovation.

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List of abbreviations

4IR	Fourth Industrial Revolution
CAGR	Compound annual growth rate
CATI	Computer-assisted telephone interviews
CAWI	Computer-assisted web interviews
CCMTs	Climate change mitigation technologies
Cleantech	Clean and sustainable technologies
CPC	Cooperative Patent Classification
CRMA	Critical Raw Materials Act
EIB	European Investment Bank
EIBIS	EIB Investment Survey
EIF	European Investment Fund
EPO	European Patent Office
ESI	European Scale-Up Initiative
ETCI	European Tech Champions Initiative
GHG	Greenhouse Gas
ICT	Information and communication technology
ICTSD	International Centre on Trade and Sustainable Development
IP	Intellectual property
IPFs	International patent families
IPO	Initial public offering
IPR	Intellectual property right
IRA	Inflation Reduction Act
NZIA	Net-Zero Industry Act
PROs	Public research organisations
R&D	Research and development
RTA	Revealed technological advantage
SME	Small and medium-sized enterprises
UNEP	United Nations Environmental Programme
UP	Unitary Patent
UPC	Unified Patent Court
VC	Venture capital

List of countries

EU	European Union
AT	Austria
BE	Belgium
CZ	Czech Republic
DK	Denmark
ES	Spain
FI	Finland
FR	France
IE	Ireland
IT	Italy
NL	Netherlands
Other EPO member states	Member states of the European Patent Organisation that are not part of the EU27, AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK.
CH	Switzerland
P. R. China	People's Republic of China
RoW	Rest of world
R. Korea	Republic of Korea
UK	United Kingdom
US	United States

Executive summary

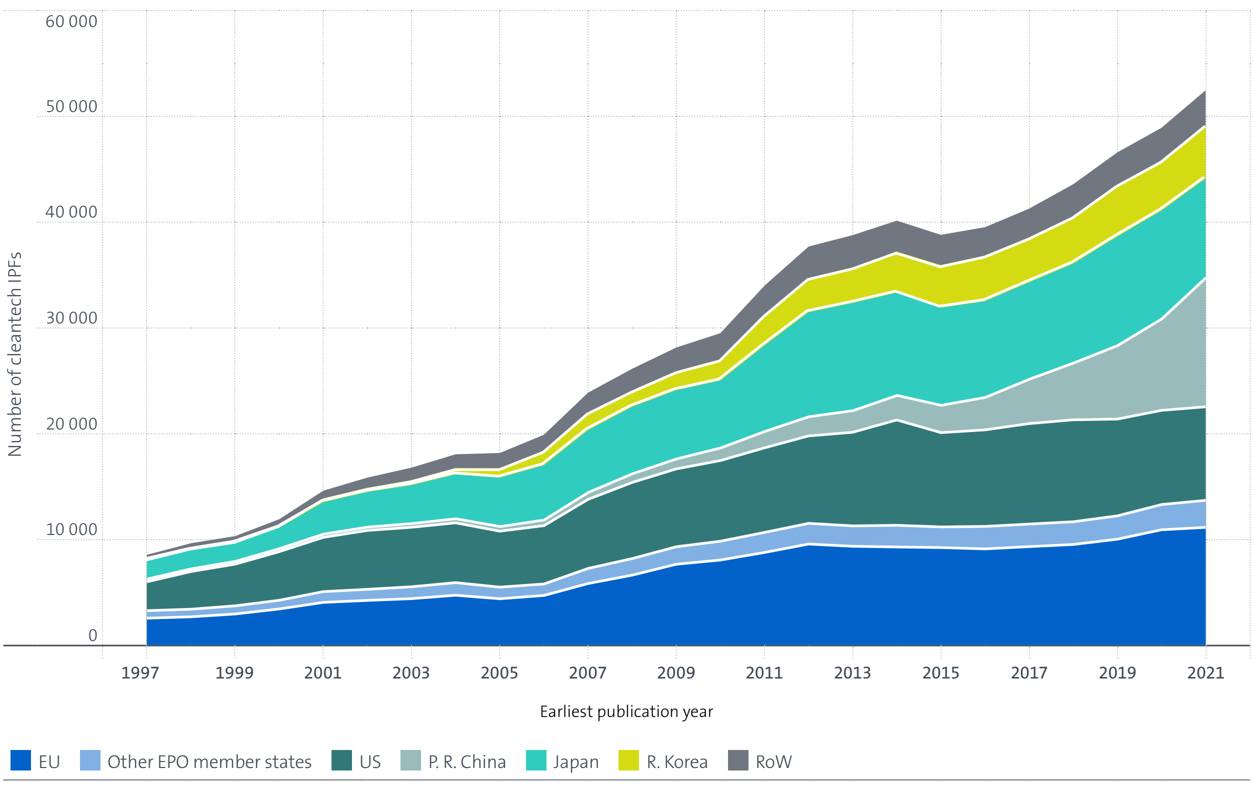
1. The transition to a cleaner, more sustainable economy is fuelling a race for innovation in which Europe is among the main contenders.

Over the past 25 years, the innovation landscape has been significantly enriched. There are now over 750 000 international patent families (IPFs) in clean and sustainable technologies worldwide, which represent nearly 12% of all IPFs. Remarkably, IPFs in clean and sustainable technologies grew faster than overall patenting activity during this period. There are two distinct phases of acceleration in cleantech patenting: 2006–2012, driven mainly by the EU and Japan, contributing 27% and 26% of the total increase in IPFs; and 2017–2021, led by China (comprising 70% of the surge in IPFs applications during this period), followed by the EU (16%).

The EU and other European countries are spearheading the wave in green innovation, together accounting for almost 27% of cleantech IPFs globally for the period 2017–2021, ahead of Japan (21%), the US (20%) and China (15%). China's rapid catch-up highlights its emerging role in the global sustainability effort, reflecting a vibrant and competitive landscape in clean and sustainable technologies.

Figure E1

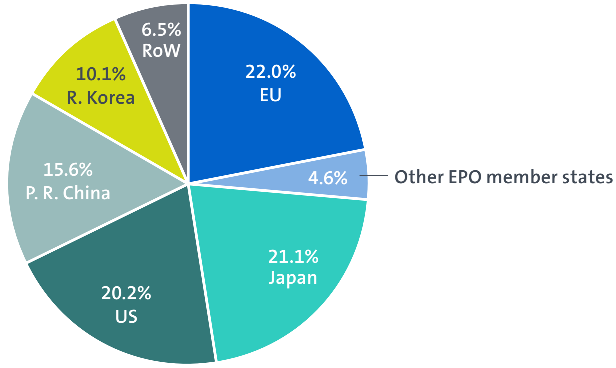
Trends in IPFs in clean and sustainable technologies, 1997–2021



Source: EPO

Figure E2

Share of cleantech IPFs, 2017–2021



Source: EPO

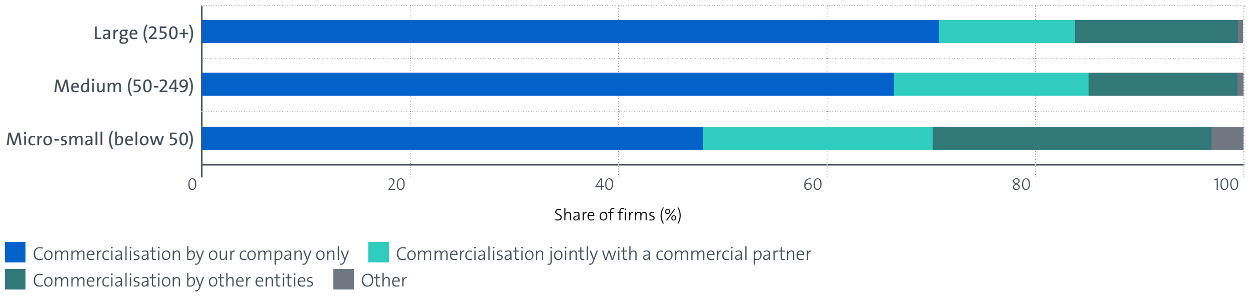
2. Patents support the commercialisation of clean and sustainable technologies.

Although more than three-quarters of international patent families in clean and sustainable technologies in the EU and US are filed by very large companies, the large majority of firms patenting in this field have fewer than 5 000 employees. The analysis of this report focuses on those firms, as they are very important for dynamic ecosystems in cleantech and more likely to face challenges when navigating through the innovation, patenting and industrialisation landscape.

Patents in clean and sustainable technologies serve the purpose of commercialisation for firms with less than 5 000 employees. In the EU, companies with less than 5 000 employees have already commercialised around 60% of the technologies for which they filed patent applications in the period 2011–2022, with an additional 28% nearing market launch. Size matters for commercialisation strategies. Around two-thirds of the technologies developed by medium and large firms (between 50 and 5 000 employees) are commercialised by the patent owner alone. Micro and small firms (fewer than 5 000 employees) instead take a more collaborative approach, with nearly half commercialising the technology either jointly with a commercial partner or with other entities. Registering a patent matters for external collaboration and financing, particularly for smaller firms. Among firms that have filed patent applications, the smallest ones emphasise most the importance of patents for setting up external partnerships, conducting technology transfers and attracting investors.

Figure E3

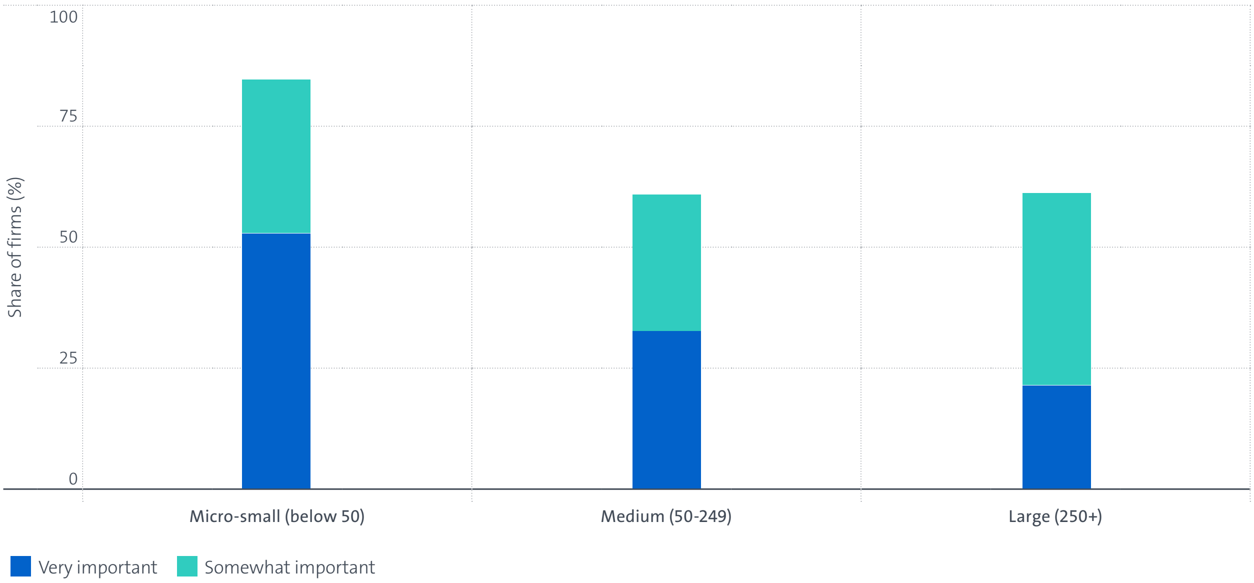
EU - Commercialisation of clean and sustainable technologies



Source: Cleantech Survey

Figure E4

EU - Role of patents for external partnerships and transfer of clean and sustainable technologies



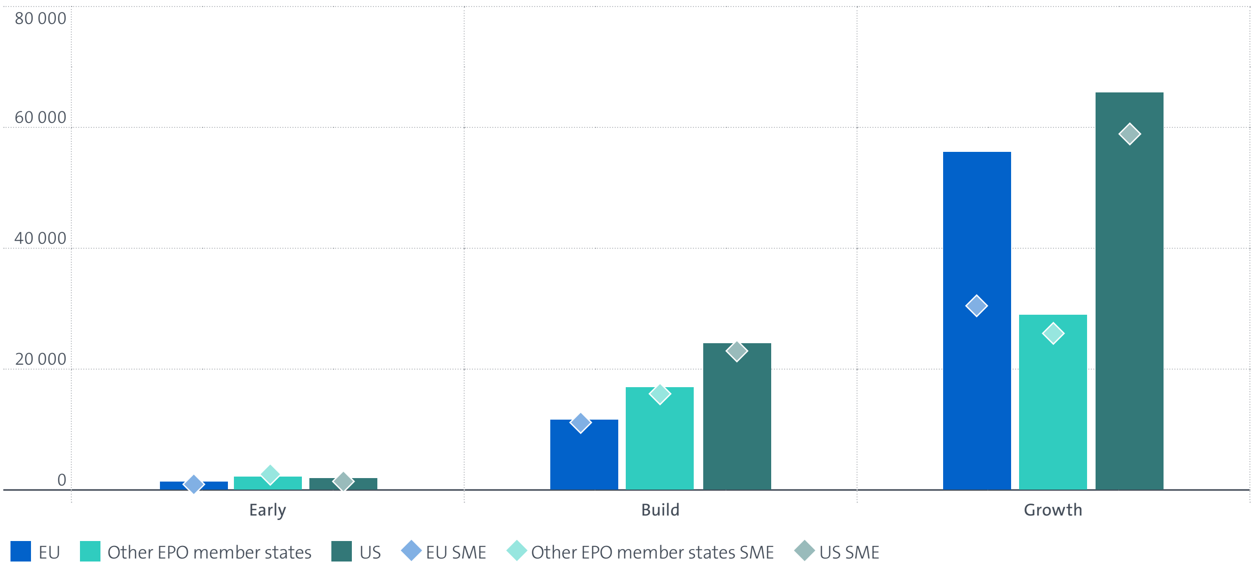
Source: Cleantech Survey

3. Funding disparities between EU and US firms are confirmed in the case of cleantech.

The capacity of firms to scale up differs substantially across regions, with innovative firms in the EU facing a financing gap versus US firms. In this respect, EU cleantech innovators are not an exception, even if the market appetite for cleantech is increasing. EU cleantech innovators are not able to raise as much significant funding as their US counterparts in all stages of growth. The median funding amount is considerably smaller than in the US, while the amounts raised at different stages increase much faster in the US than in Europe. Ultimately, EU cleantech innovators are more likely to depend on debt finance to finance their cleantech activities. By contrast, equity plays an important role as a supplementary source of external finance in the US and, to some extent, in other EPO member states.

Figure E5

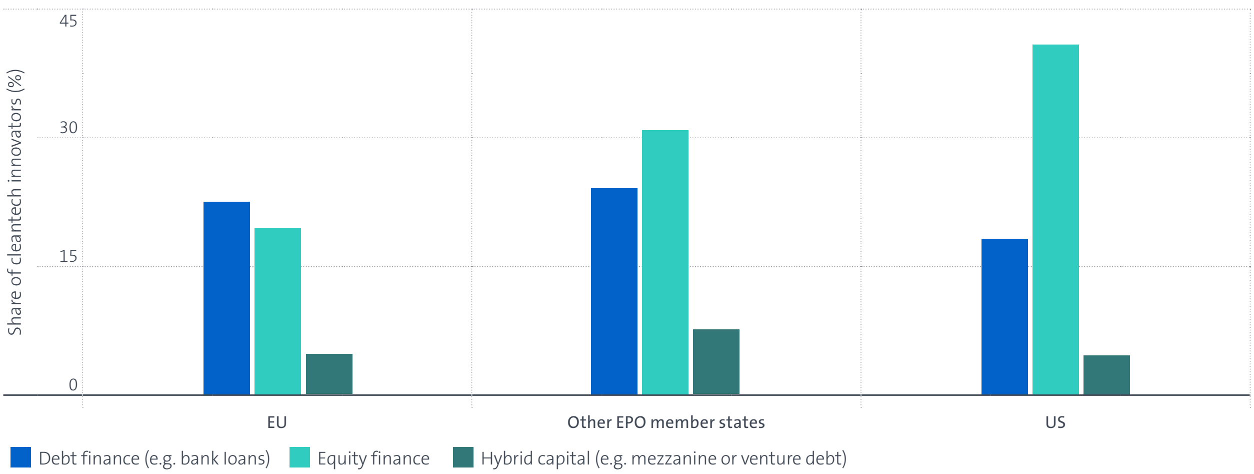
Funding received by firms at different growth stages, funding amount in USD (median), 2013–2023



Source: Crunchbase

Figure E6

Use of different forms of external finance for cleantech activities



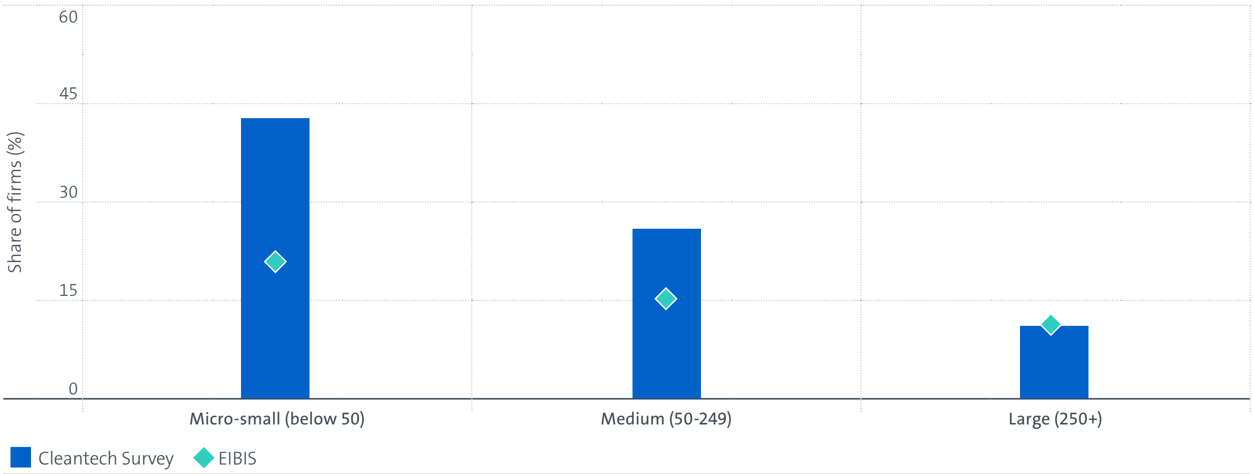
Source: Cleantech Survey

4. When looking at barriers to the commercialisation of clean and sustainable technologies, access to finance emerges as a particularly severe challenge for smaller companies.

Over 30% of EU companies identify lack of finance as a significant barrier to the commercialisation of clean and sustainable technologies. While only 12% of large companies report financing as a hurdle, 43% of micro and small companies face difficulties, indicating a more acute problem within this segment compared to the average SME in the EU (as per the European Investment Bank Investment Survey). Against this backdrop, small cleantech innovators seeking to commercialise patented technologies call for access to funding. Patents emerge as an asset for them, with the majority considering them very important in attracting venture capital (VC) investors or providing collateral for debt.

Figure E7

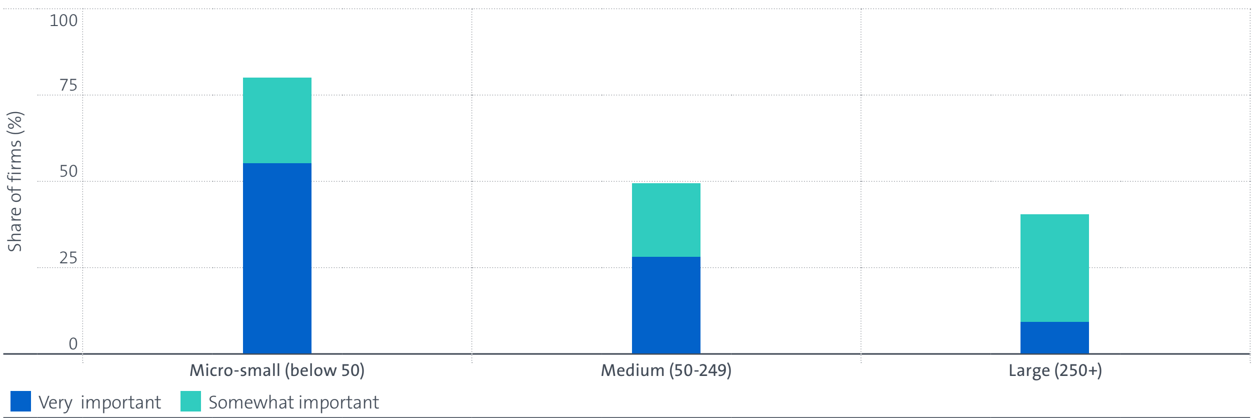
EU - Lack of finance as a major obstacle for the commercialisation of clean and sustainable technologies



Source: Cleantech Survey and EIB Investment Survey (EIBIS) 2023

Figure E8

EU - Applicants' view on the role of patents in raising funds and attracting investors



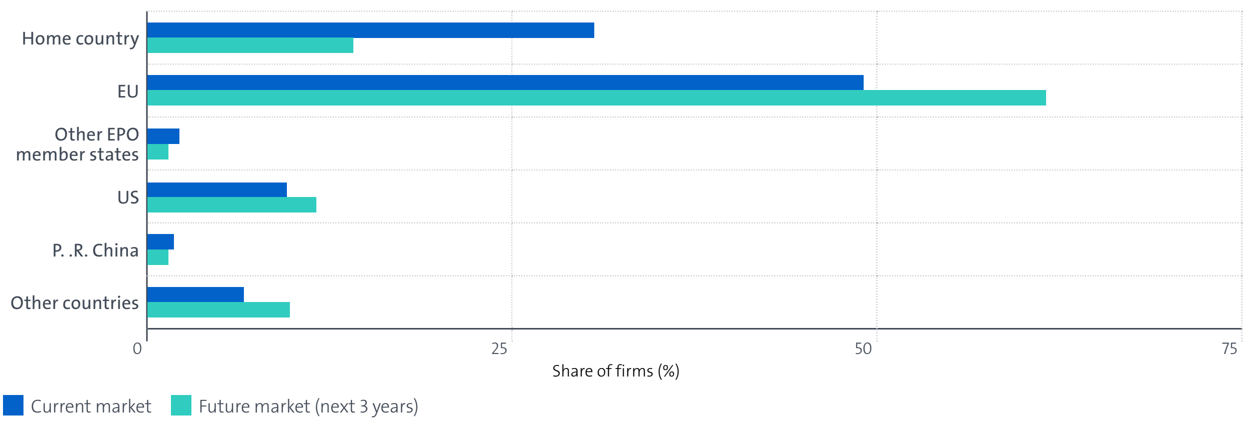
Source: Cleantech Survey

5. The EU single market is a key catalyser for scaling clean and sustainable innovation

EU cleantech innovators remain primarily focused on EU markets for their growth. Even though 29% of EU companies currently prioritise their national market, 61% view the EU as their key market for the future. Scaling up in Europe is not without challenges. Whereas small businesses mention access to finance as their priority in bringing new technology to market, a total of 43% and 55% of medium and large companies respectively cite consistent regulation in the EU as the main way to foster commercialisation.

Figure E9

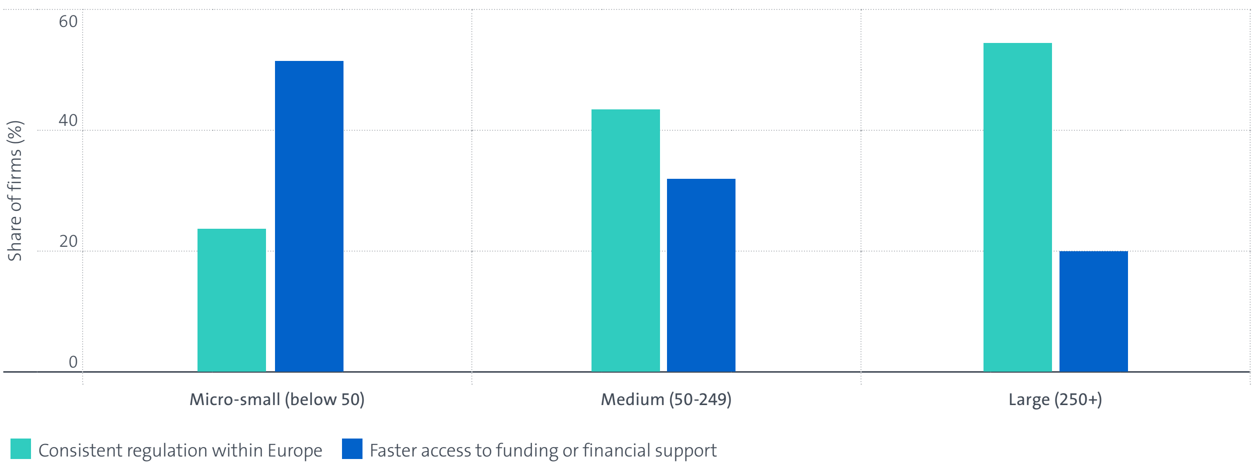
Current and future primary sales market for EU cleantech innovators



Source: Cleantech Survey

Figure E10

EU - Consistent regulation within the EU and fast access to funding are considered important for supporting innovation in cleantech



Source: Cleantech Survey

6. Navigating challenges: scaling up innovation and regulatory consistency

Europe is at the forefront of global net-zero ambitions, with a leading position at the frontier of cleantech patents. However, global competition is strong, and preserving Europe's lead requires effort.

Cleantech in Europe faces the usual funding gap that characterises innovation on the continent. Firms rely mostly on debt rather than equity finance and thus face issues in scaling up, with less finance at all different stages of growth.

The EU market remains the key focus for EU cleantech innovators and their favoured option to scale up. The importance of the EU single market is confirmed by the call for consistent and robust regulations, particularly by larger firms. This is an important feature in the context of an emerging market, where Europe has shown its ambition. Although the EU has already invested significant effort, continued focus on integration and improvement in regulatory clarity remains essential, for European cleantech innovators to derive the full benefits from the sheer scale of the single market.

Patents are a means for European cleantech companies to secure their technological lead. They are also proving to be important assets for commercialising new technologies, building partnerships and attracting funding, especially for small cleantech companies. The recent creation of the Unitary Patent opens up promising perspectives in this respect. By allowing cost-efficient access to uniform patent protection in 17 EU member states, it is a significant step towards addressing the need for harmonisation expressed by European cleantech innovators, thereby enabling further progress in technology commercialisation and IP-based finance on a truly European scale.

1. Introduction

As the world embarks on a transformative transition to a low-carbon and sustainable future, innovation is emerging as a critical frontier where economic growth and environmental responsibility intersect. The European Union (EU) is at the forefront of this transition, with the ambition reconfirmed by the European Green Deal – a comprehensive initiative launched by the European Commission in December 2019. This landmark commitment aims to achieve climate neutrality by 2050 while promoting a circular economy. The Green Deal Industrial Plan aims to boost the competitiveness of Europe's net-zero industry and accelerate the transition to climate neutrality through four key pillars: a simplified regulatory environment, faster access to finance[1], skills development and open trade for resilient supply chains. This transformative agenda puts clean and sustainable technologies (cleantech) at the heart of Europe's economic, industrial, and environmental strategies.[2]

The EU's competitiveness in cleantech faces intricate challenges in a complex geopolitical and economic context. The United States, recognised for its leadership in advanced digital technologies (see EPO-EIB, 2022), has also set its sights on supporting cleantech, notably through the Inflation Reduction Act (IRA) enacted in August 2022. Beyond the transatlantic dynamic, China has shown rapid progress in cleantech innovation and industrialisation, particularly in battery production and electric vehicles. At the same time, China exercises significant influence over critical raw material supply chains and key components for green technologies.

Against this backdrop, this report documents the long-term and short-term patenting trends in cleantech by covering a wide range of different technology fields that enhance energy efficiency, leverage sustainable resources, decrease pollution and waste, and combat climate change's negative effects. Patent data illustrate the geographical distribution of patenting activity in cleantech and identify the main contributors, with Europe at the forefront. The analysis shows that very large corporations contribute the most to cleantech patenting; however, most of the innovators are businesses with fewer than 5 000 employees.

Based on a new full-scale survey of cleantech innovators, this study provides a comprehensive inventory and assessment of EU companies with fewer than 5 000 employees that innovate in cleantech. These innovation-driven businesses typically rely on recombining existing technologies or leveraging emerging technologies rooted in science and advanced engineering that offer significant advances over those currently in use. As a result, they also often face higher upfront R&D investment costs, a combination of technology and market risks, and a longer transition period from research to actual industry applications. Patent protection is instrumental in securing the legal exclusivity needed to develop and bring new technology to market.

The study documents the profiles of European cleantech innovators across the EU and benchmarks them against their counterparts in the US, as well as other member states of the European Patent Organisation that are not part of the EU. To this end, it exploits a holistic set of indicators spanning the business and IP strategies, development trajectories, funding and financial performance of the firms. Throughout the analysis, particular attention is paid to plans to grow and commercialise cleantech and the factors impacting their ability to fulfil those plans. Furthermore, cleantech innovators are compared with the firms interviewed in the EIB Investment Survey (EIBIS), highlighting the obstacles they face compared with their peers. These findings should offer policymakers, business decision-makers and investors insights into the specific challenges of bringing new clean and sustainable technology to market within Europe.

The report begins with an overview of global cleantech patenting trends based on an analysis of international patent families (IPFs), based upon patent data. It looks at the geographical distribution of cleantech and recent developments in individual technologies. Subsequently, this report presents the results of a survey, conducted on firms applying for clean and sustainable patents in the past 10 years and having less than 5000 employees. More specifically, it examines the current status of cleantech innovators in terms of deployment and commercialisation of their technologies. The results of the survey also allow to illustrate the R&D activities, investment prospects,

1 In support of the Commission's Green Deal Industrial Plan, the EIB expanded its REPowerEU package from EUR 30bn to EUR 45bn in July 2023 and expects to mobilise more than EUR 150bn of investment in renewable energy, energy efficiency and innovative technologies between 2022 and 2027.

2 The Net-Zero Industry Act (NZIA) and the Critical Raw Materials Act (CRMA) are follow-up initiatives to the European Green Deal Industrial Plan. The NZIA is designed to enhance the production of clean technologies within the EU, while the CRMA aims to fortify domestic supply chains and bolster international agreements on critical materials. These initiatives are integral to ensuring a successful green transition.

and funding profiles of the firms surveyed, along with the structural barriers they face and their preferred policy support. To complement the analysis on access to finance, the report also builds upon Crunchbase and PitchBook Inc. data. Finally, the report also features several case studies of European companies showcasing how they financed and commercialised their clean and sustainable technologies and the role that patents played during their business journeys. A case study discusses the experience of the EIB Group (EIB and EIF) in supporting innovation and cleantech innovation, as well as the industrialisation of clean and sustainable technologies.

2. Cleantech patenting overview

Patents are essential in the domain of clean and sustainable technologies, as they provide legal protection for innovations, thereby encouraging further research and development in this critical area. The analysis of patent applications offers valuable insights into trends, technological advancements, and key players within the sector of clean and sustainable innovation. Such examination is instrumental to understanding the trajectory of environmental solutions and the entities contributing to these advancements. The analysis in this chapter is based on international patent families (IPFs).

An IPF refers to a set of patent applications filed in multiple countries to protect the same invention. They serve as a good metric for evaluating the global impact and recognition of technological innovations because they demonstrate an inventor's or a company's intention to expand their market and protect their invention on an international scale. All cleantech IPFs for technologies described in Box B are identified based on patent classification and the technical content of patent documents.

Box A: Patents and patent metrics

Patents support innovation, competition and knowledge transfer

Patents are exclusive rights that can only be granted for technologies that are new, inventive and industrially applicable. High-quality patents are assets that can help to attract investment, secure licensing deals and provide market exclusivity. Inventors pay annual fees to maintain those patents that are of commercial value to them. Once they lapse, the technical information in them becomes free for everyone to use. A patent can be maintained for a maximum of 20 years.

In exchange for these exclusive rights, all patent applications are published, revealing the technical details of the inventions within them. Patent databases therefore contain a wealth of technical information, much of which cannot be found in any other source, which anyone can use for their own research purposes. The EPO's free Espacenet database contains over 150 million documents from over 100 countries and comes with a machine translation tool in 32 languages. Most of the patent documents in Espacenet are not in force, so the inventions are free to use. The legal status of a patent document can easily be checked within Espacenet.

Patent metrics

The identification of patent applications related to different clean and sustainable technologies was carried out using knowledge of the EPO's expert patent examiners, together with scientific publications and studies published by various consultants and international organisations. This in-house knowledge has been built up over many years of working within the different technology fields and collected via networks of technology specialists within the EPO.

Published international patent families (IPFs) are used in this study as a uniform metric to measure patenting activity in the different categories of clean and sustainable technologies. Each IPF identified as relevant is assigned to one or more clean and sustainable technology fields, depending on the technical features of the invention.

Each IPF covers a unique invention and includes patent applications targeting at least two countries. More specifically, an IPF is a set of applications for the same invention that includes a published international patent application, a published patent application at a regional patent office, or published patent applications at two or more national patent offices. It is a reliable proxy for inventive activity because it provides a degree of control for patent quality by only representing inventions for which the inventor considers the value sufficient to seek protection internationally.

The reference year used for all statistics in this report is the earliest publication year of each IPF, which is usually 18 months after the first application within the patent family. The dataset was further enriched with information about the applicants for IPFs. In particular, data was retrieved from Bureau van Dijk's ORBIS database, Crunchbase, and other sources, and was used to harmonise and consolidate applicant names and identify their type.

2.1 Patenting trends in clean and sustainable technologies

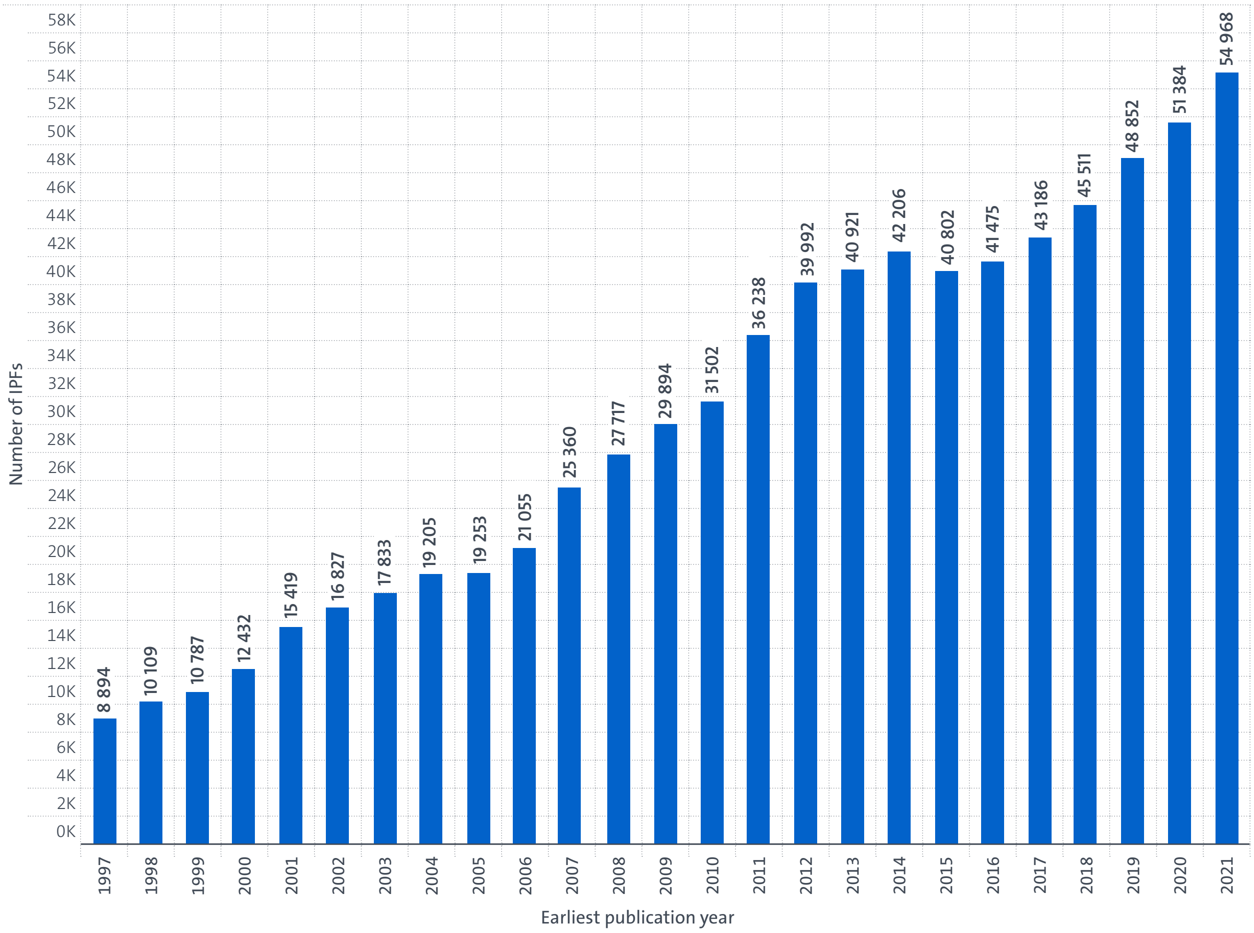
Innovation in cleantech has been very dynamic over the last few decades, as evidenced by the trends in IPFs (Figure 1). The 25-year period from 1997 to 2021 witnessed the publication of over 750 000 IPFs related to clean and sustainable technologies, representing nearly 15% of all IPFs published in 2021, from just under 8% of global inventions in 1997.

Over the last two decades, there have been two periods of marked acceleration in cleantech. Activity in clean and sustainable technology patents has accelerated rapidly since the mid-1990s. While there were less than 10 000 IPFs in 1997, this number had increased to almost 40 000 by 2012, outpacing the growth rate of total patenting activity (Figure 2). This period was marked by clean and sustainable technologies representing about 14.5% of all inventions by 2012, highlighting their increased significance in the global innovation landscape.

Between 2012 and 2016, the annual filings of IPFs in cleantech plateaued at around 40 000. This stagnation was followed by a resurgence from 2017 onwards, as evidenced by a robust compound annual growth rate (CAGR) of 6.2%, which was more than twice as fast as the overall growth rate of IPFs across all technologies. Almost 244 000 IPFs were filed in the last five years of this period, indicating a heightened focus on sustainability. In 2021 alone, nearly 55 000 clean and sustainable inventions, or almost 15% of all technological inventions globally, were disclosed to the public, demonstrating a nearly 33% increase compared to five years prior. This not only reflects the sector's resilience but also its critical role in driving forward the agenda of environmental sustainability through technological innovation.

Figure 1

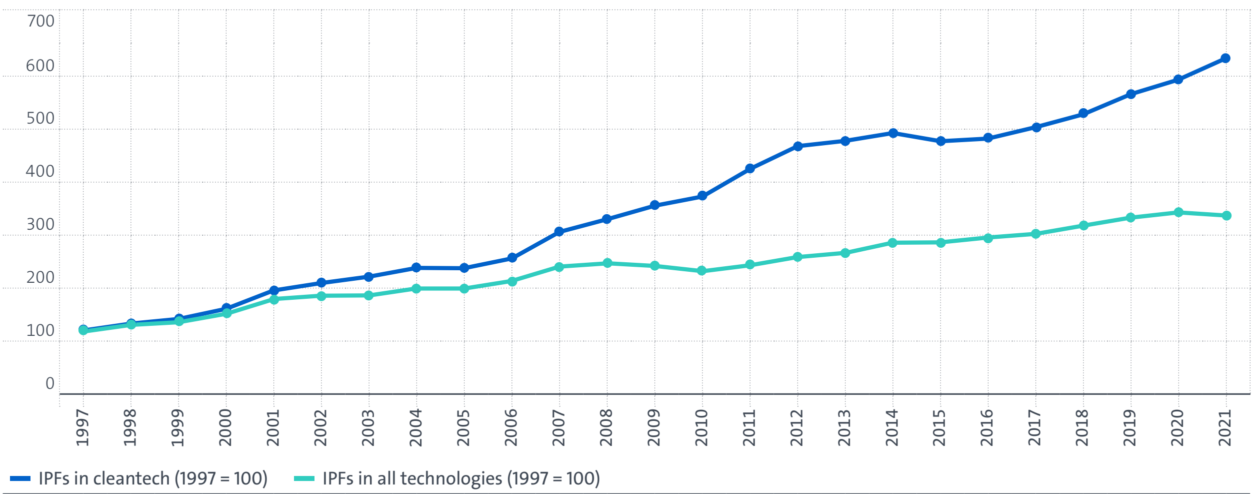
Trends in IPFs in cleantech worldwide, 1997–2021



Source: EPO

Figure 2

Comparative growth trends of IPFs in cleantech versus IPFs in all technologies, 1997–2021



Source: EPO

Box B: Clean and sustainable technologies

Clean and sustainable technologies, often referred to as cleantech or green tech, encompass a broad range of processes, products, and services that aim to reduce or eliminate negative environmental impacts. These technologies are designed to improve energy efficiency, utilise sustainable resources, protect the environment by reducing pollution and waste, and help deal with the adverse effects of climate change. This study is based on the analysis of international patent families (IPFs) that have received a Y02/Y04S classification tag, or have been identified as related to plastic recycling or alternatives to plastics, as described in EPO (2021), or climate-friendly hydrogen technologies, as described in EPO-IEA (2023).

The Y02/Y04S tagging scheme has been developed by the EPO and external partners, such as the United Nations Environmental Programme (UNEP) and the International Centre on Trade and Sustainable Development (ICTSD), to facilitate the identification and retrieval of patent documents related to climate change mitigation technologies (CCMTs). It forms the state-of-the-art methodology for the identification of clean and sustainable technologies (Veefkind et al., 2012) and is continually updated to reflect advancements in technology and changes in the field of climate change mitigation. It consists of the following technology fields:

Low-carbon energy (Y02E):[3] Technologies for the reduction of greenhouse gas emissions, related to energy generation, transmission or distribution, including energy generation through renewable energy sources, combustion technologies with mitigation potential, biofuels, and energy storage technologies.

CCMTs related to transportation (Y02T):[4] Climate change mitigation technologies related to road transport, aeronautics or air transport, and maritime or waterways transport

CCMTs in manufacturing (Y02P):[5] Climate change mitigation technologies in any kind of industrial processing or production activity, including the agri-food industry, agriculture, fishing, ranching and the like.

CCMTs related to buildings (Y02B):[6] Climate change mitigation technologies related to buildings, e.g., housing, house appliances or related end-user applications.

Adaptation to climate change (Y02E):[7] Technologies that allow adapting to the adverse effects of climate change in human, industrial (including agriculture and livestock) and economic activities.

CCMTs in information and communication technologies (ICT) (Y02D):[8] ICT, whose purpose is to minimise the use of energy during the operation of the involved ICT equipment.

Smart grids (Y04S):[9] Systems integrating technologies related to power network operation, communication or information technologies for improving the electrical power generation, transmission, distribution, management or usage.

CCMTs related to waste and wastewater treatment (Y02W):[10] Technologies for wastewater treatment and solid waste management.

Carbon capture and storage (Y02C):[11] Technologies related to the capture, storage, sequestration or disposal of greenhouse gases such as nitrous oxide, methane, or carbon dioxide.

In addition to the technologies covered in the Y02/Y04S tagging scheme, this study also incorporates two other clean and sustainable technologies:

Plastic recycling and alternatives to plastics:[12] Technologies enabling a circular economy for plastics – from the recovery of post-consumer plastic waste to the various processes available for its recycling – and alternative plastic materials which encompass bio-based, biodegradable and compostable plastics, as well as plastics designed for easier recycling.

Hydrogen-related technologies:[13] Technologies with the potential to decarbonise hydrogen production, hydrogen storage, distribution and transformation technologies, and technologies related to end-use applications of hydrogen.

The field of clean and sustainable technologies includes a range of different technologies. **Low-carbon energy technologies, encompassing renewable energy generation and energy storage solutions like batteries, stand out as the predominant cleantech sector** (Figure Box B1 and Figure Box B2). Despite a fluctuation in growth rates, with a robust expansion leading up to 2012, followed by a decline, the sector rebounded with a CAGR of nearly 6% between 2017 and 2021 (Figure Box B3). From 2017 to 2021, this field accounted for over 78 000 IPFs, representing 32.1% of all IPFs in cleantech.

Inventions focusing on clean and sustainable mobility solutions ranks as the second-largest field, with over 47 000 IPFs filed between 2017 and 2021 (Figure Box B2). Plastic recycling and the development of alternatives to plastics closely follow, with over 46 000 IPFs. Interestingly, in the early 2000s, the field of plastic recycling and alternatives to plastics was at the forefront of clean technology, surpassing even low-carbon energy in the number of filings. This sector has seen steady yet modest growth, with a CAGR of 4.4% from 2017 to 2021 (Figure Box B3), culminating in over 10 000 IPFs in the year 2021. Conversely, the pace of innovation in clean transportation technologies has decelerated in recent years, with a CAGR of 1.8% between 2017 and 2021, making it one of the slowest-growing cleantech sectors.

3 Based on Cooperative Patent Classification (CPC) scheme Y02E. Energy creation using nuclear energy (Y02/E30) has not been considered.

4 Based on Cooperative Patent Classification (CPC) scheme Y02T.

5 Based on Cooperative Patent Classification (CPC) scheme Y02P.

6 Based on Cooperative Patent Classification (CPC) scheme Y02B.

7 Based on Cooperative Patent Classification (CPC) scheme Y02A.

8 Based on Cooperative Patent Classification (CPC) scheme Y02D.

9 Based on Cooperative Patent Classification (CPC) scheme Y04S.

10 Based on Cooperative Patent Classification (CPC) scheme Y02W.

11 Based on Cooperative Patent Classification (CPC) scheme Y02C.

12 See EPO 2021, Patents for tomorrow's plastics: Global innovation trends in recycling, circular design and alternative sources.

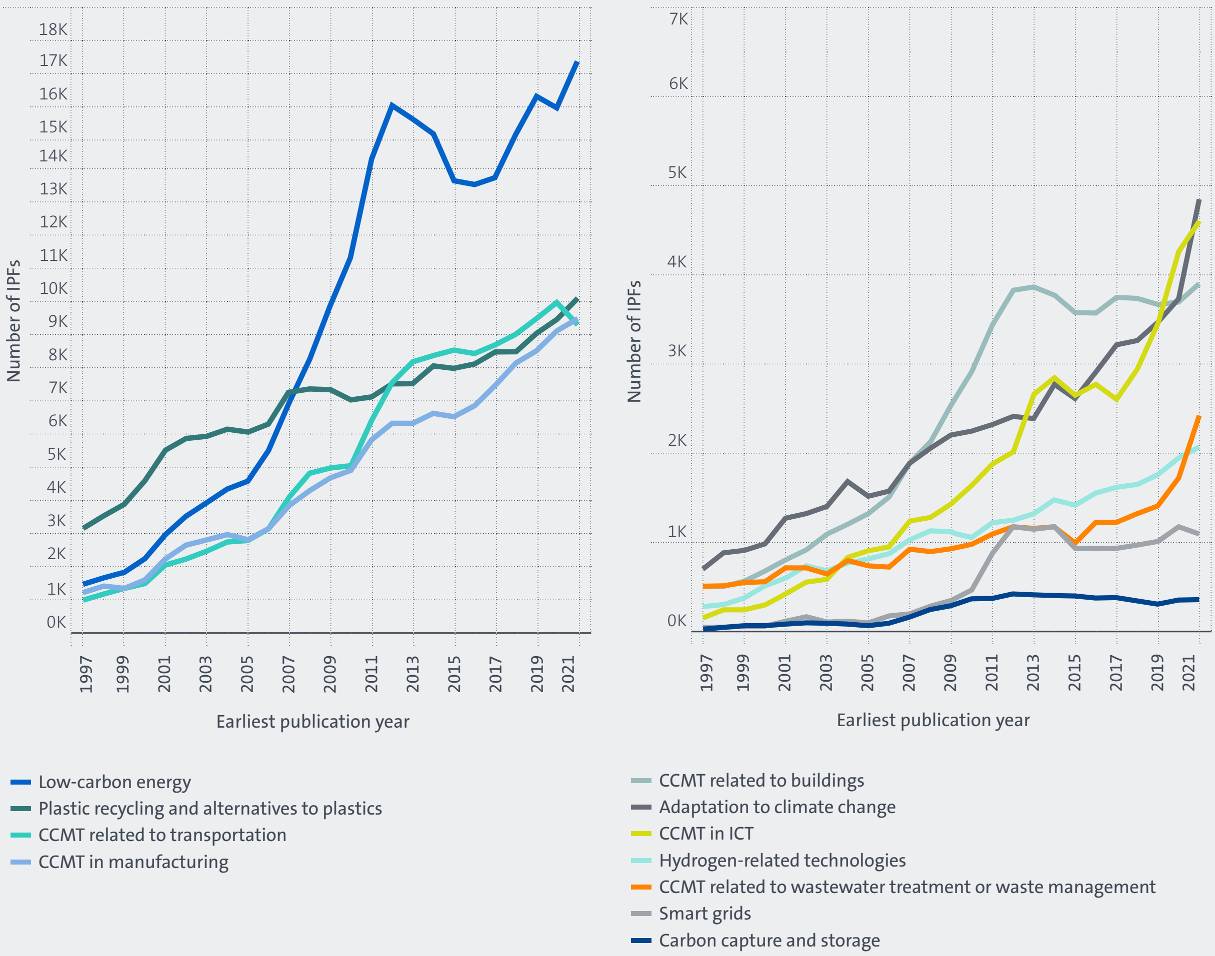
13 Only climate-friendly hydrogen-related technologies have been considered, see EPO-IEA 2023, "Hydrogen patents for a clean energy future: A global trend analysis of innovation along hydrogen value chains"

Innovations in clean and sustainable manufacturing have also been significant, with more than 43 000 IPFs between 2017 and 2021, reaching over 9 500 IPFs in 2021 alone. Other notable areas include clean tech solutions related to buildings, ICT, and adaptation to climate change, each with around 18 000 IPFs between 2017 and 2021. However, these fields have displayed varying growth patterns; while innovation in building-related technologies has stagnated, ICT has surged forward with a CAGR of 15%, the second largest of all fields. Climate change adaptation technologies have also experienced strong growth between 2017 and 2021.

The smaller sectors within clean and sustainable technologies, with less than 10 000 IPFs between 2017 and 2021, are climate-friendly hydrogen-related technologies, wastewater treatment and waste management, smart grids, carbon capture and storage. Wastewater treatment and waste management technologies have emerged as the fastest-growing of all technology fields, with a CAGR of nearly 18%. Meanwhile, carbon capture and storage technologies have seen stable filing numbers, with approximately 400 IPFs annually over the last decade (Figure Box B1). Growth rates for climate-friendly, hydrogen-related technologies and smart grids have been modest, slightly below the overall average.

Figure Box B1

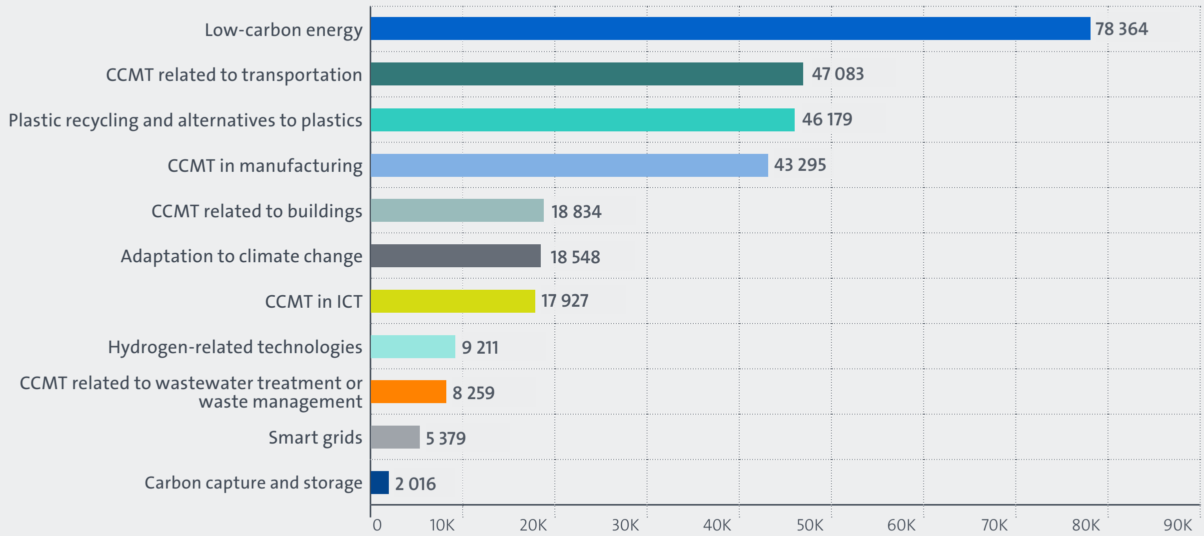
Trends in IPFs in different clean and sustainable technologies, 1997–2021



Source: EPO

Figure Box B2

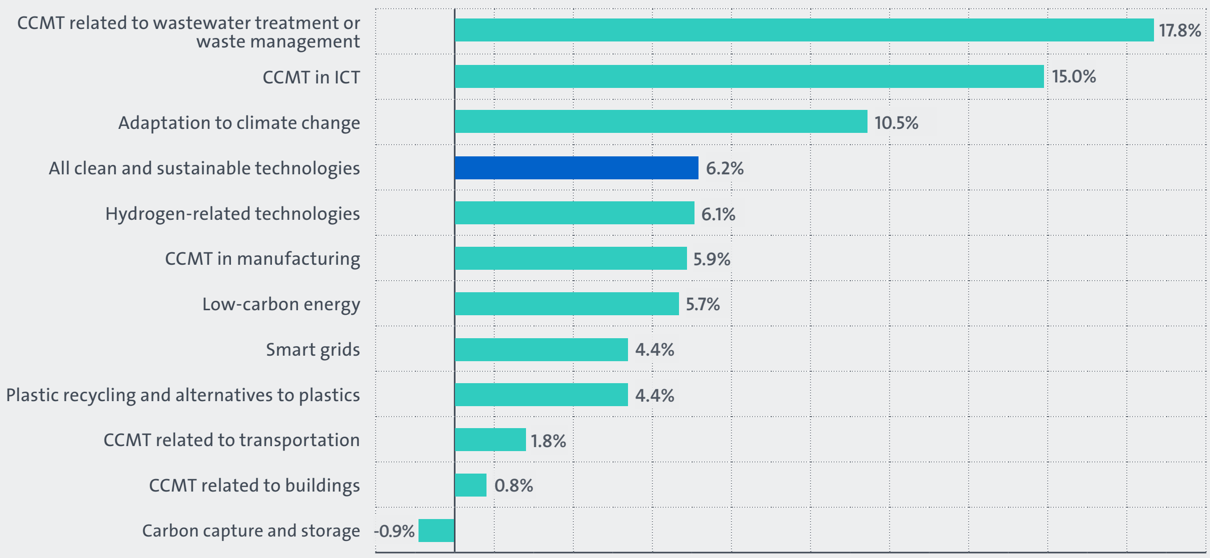
Number of IPFs in different clean and sustainable technologies, 2017–2021



Source: EPO

Figure Box B3

CAGR in different clean and sustainable technologies, 2017–2021



Source: EPO

2.2 Geographical distribution of cleantech innovators

Europe is a significant contributor to the advancement of cleantech.[14] Between 2017 and 2021, the EU was responsible for nearly 52 000 IPFs, accounting for 22% of all IPFs in this field (Figure 4). The annual number of IPFs from EU applicants even increased from just over 9 000 in 2016 to more than 11 000 in 2021 (Figure 3).

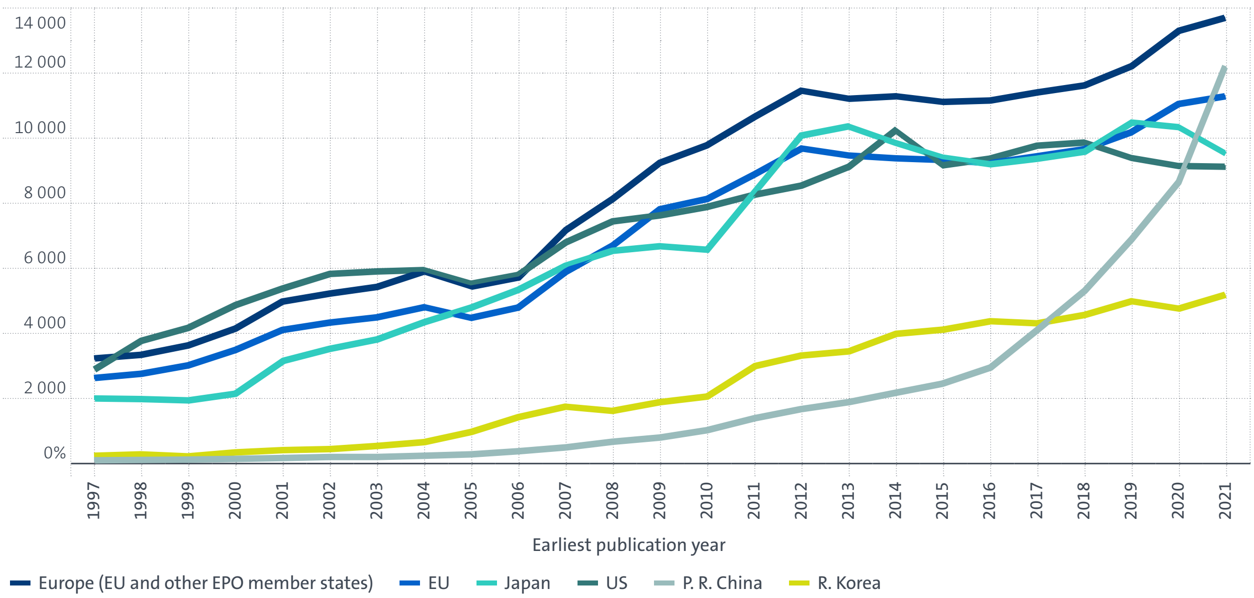
The revealed technological advantage (RTA) index is a measure of a country's specialisation in clean and sustainable innovation relative to its overall capacity for innovation across all technologies.[15] An RTA greater than one suggests a country's focus in a specific technological area. **The EU, with an RTA of 1.1 in the period 2017–2021, indicates a strong specialisation in clean and sustainable technologies.** This specialisation has even grown in recent years (Figure 6).

Europe's commitment to cleantech innovation extends beyond the EU, with other member states of the European Patent Organisation (EPO) contributing an additional 10 000 IPFs, or 4.6% of all IPFs in this field, between 2017 and 2021 (Figure 4). This collective effort positions Europe as a powerhouse of clean and sustainable innovation, holding almost 27% of the global share. Germany stands out within Europe as the largest single contributor, accounting for nearly 37% of Europe's IPFs, followed by France and the UK with 14.5% and 8.5%, respectively (Figure 5a). All three countries have an RTA above one, showing their specialisation in clean and sustainable technologies in the period 2017–2021. However, Denmark, with an RTA exceeding two, has by far the most specialised IPF portfolio of all top cleantech innovating countries in Europe (Figure 5b).

Outside of Europe, Japan and the US are significant players, with 21.1% and 20.2%, respectively, though their annual contributions have plateaued in recent years at around 10 000 IPFs per year (Figure 3 and 4). Notably, both countries have seen a decline in their RTA further below one, indicating a decrease in specialisation in clean and sustainable technologies (Figure 6).

Figure 3

Trends in IPFs in cleantech by country of origin, 1997–2021



Source: EPO

14 Europe in this report refers to all 39 member states of the European Patent Organisation. All 27 EU Member States are also members of the EPO. Other EPO member states include countries such as the United Kingdom, Switzerland, Norway, Türkiye, and others.

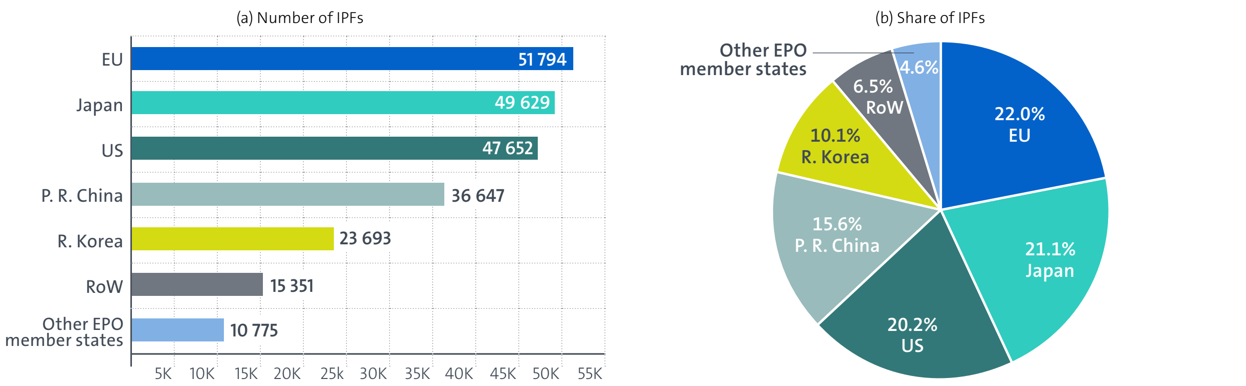
15 The revealed technological advantage (RTA) is defined as a country's share of IPFs in a particular field of technology divided by the country's share of IPFs in all fields of technology in a certain period.

China, with a share of 15.6%, has shown remarkable growth in cleantech in recent years, with the annual number of IPFs surging from just over 4 000 in 2017 to more than 12 000 by 2021, even surpassing the EU's contribution in that year. This rapid growth is mirrored in China's increasing RTA, which rose from 0.7 to over 1 in the same period, signalling a growing focus on clean and sustainable technologies.

R. Korea, with a share of 10% of IPFs in cleantech, also demonstrates the highest level of specialisation in the period 2017-2021, though its RTA has declined from its peak in 2018. Nevertheless, R. Korea's annual contributions to clean and sustainable technologies have grown from just over 4 000 in 2017 to over 5 000 in 2021.

Figure 4

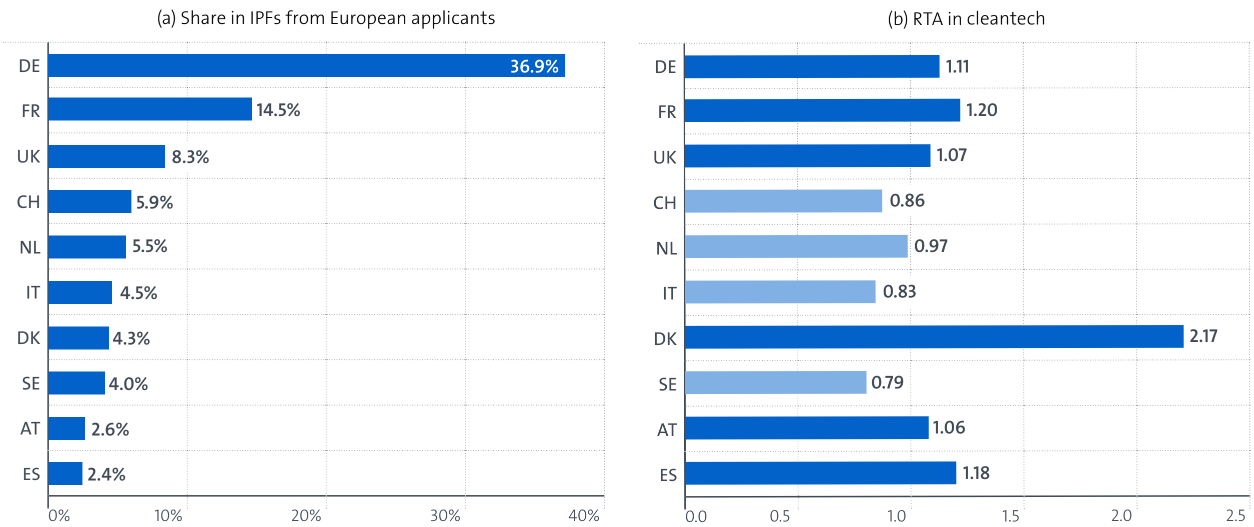
Number and share of IPFs in cleantech by country of origin, 2017–2021



Source: EPO

Figure 5

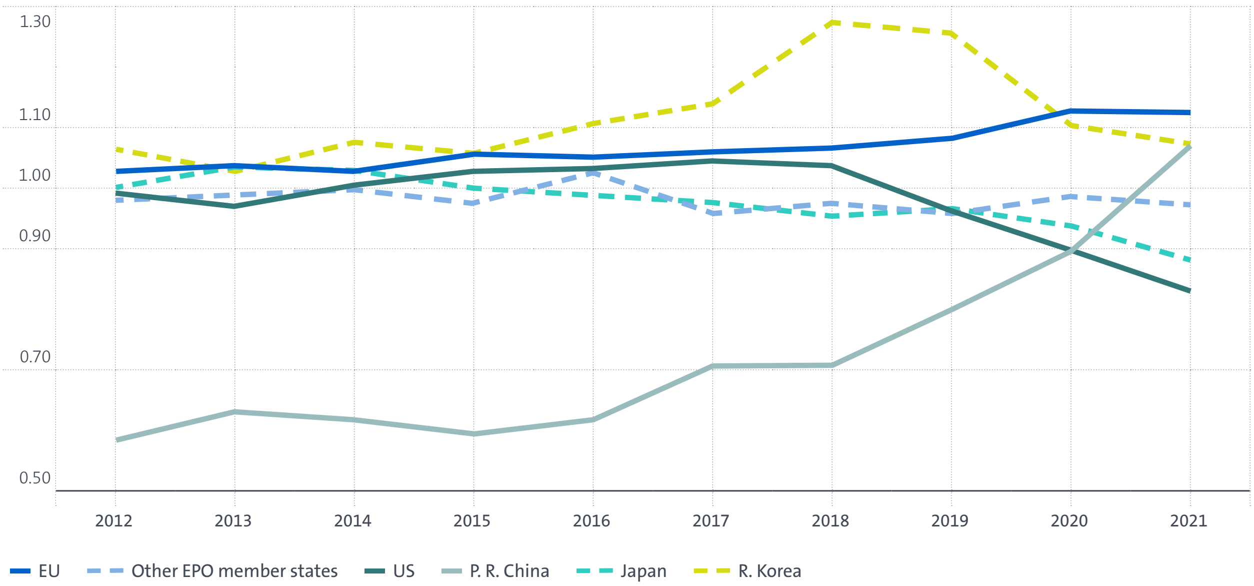
Share of IPFs in cleantech from European applicants by country of origin and their RTA in cleantech, 2017–2021



Source: EPO

Figure 6

Trends in RTA in cleantech by country of origin



Source: EPO

EU applicants have a strong position in CCMTs related to transportation, one of the major cleantech fields, and in wastewater treatment and waste management, contributing 28.3% and 27.2% of all IPFs in these technology fields, respectively (Figure 7). IPFs in the sectors of wastewater treatment and hydrogen-related technologies are among the fastest-growing, with the EU also making a notable recovery in low-carbon energy innovation, the largest cleantech domain, after a decline between 2012 and 2016 (see Annex 1). The EU exhibits, on the other hand, a lower focus in CCMTs related to ICT compared to other regions, with only a 7.8% share and thus also the lowest specialisation.

US applicants lead in the smallest cleantech technology domain, namely carbon capture and storage technologies, with their share reaching nearly 30%. US applicants also contribute more on plastic recycling and alternatives to plastics (27.4%) and climate change adaptation technologies (27.2%). Yet, their contribution to the largest technology field, namely low-carbon energy, is relatively low at 13.0%. Wastewater treatment and waste management, and hydrogen-related technologies, were the main growth areas of US applications, while other fields either stagnated or experienced a decline in IPFs.

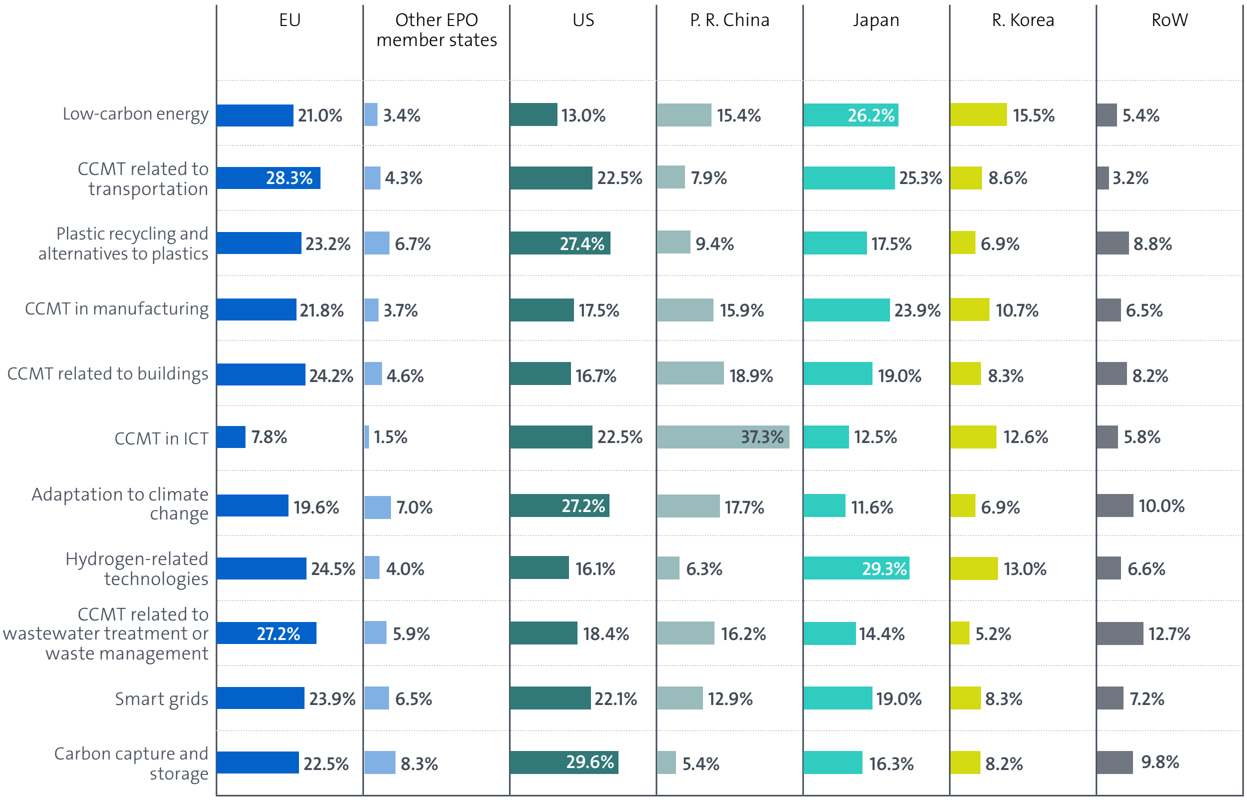
Japan distinguishes itself in hydrogen-related technologies (29.3%) and low-carbon energy (26.2%), showcasing its leadership in these areas. However, its involvement in CCMTs in ICT (12.5%) and climate change adaptation technologies (11.6%) is comparatively lower. The most remarkable growth for Japan has been in CCMTs related to wastewater treatment and waste management in the recent period.

Chinese applicants dominate the field of CCMTs in ICT, commanding over 37% of all IPFs in this category between 2017 and 2021. Despite smaller shares in hydrogen-related technologies (6.3%) and carbon capture and storage (5.4%), IPFs from Chinese applicants surged across all domains of clean and sustainable technologies, indicating a broad and aggressive innovation strategy.

Korean applicants exhibit high contributions in CCMTs in ICT (12.6%), hydrogen-related technologies (13.0%) and low-carbon energy technologies (15.5%), with their participation in wastewater treatment and waste management being the least, at 5.2%.

Figure 7

Share by clean and sustainable technology field by country of origin, 2017–2021



Source: EPO

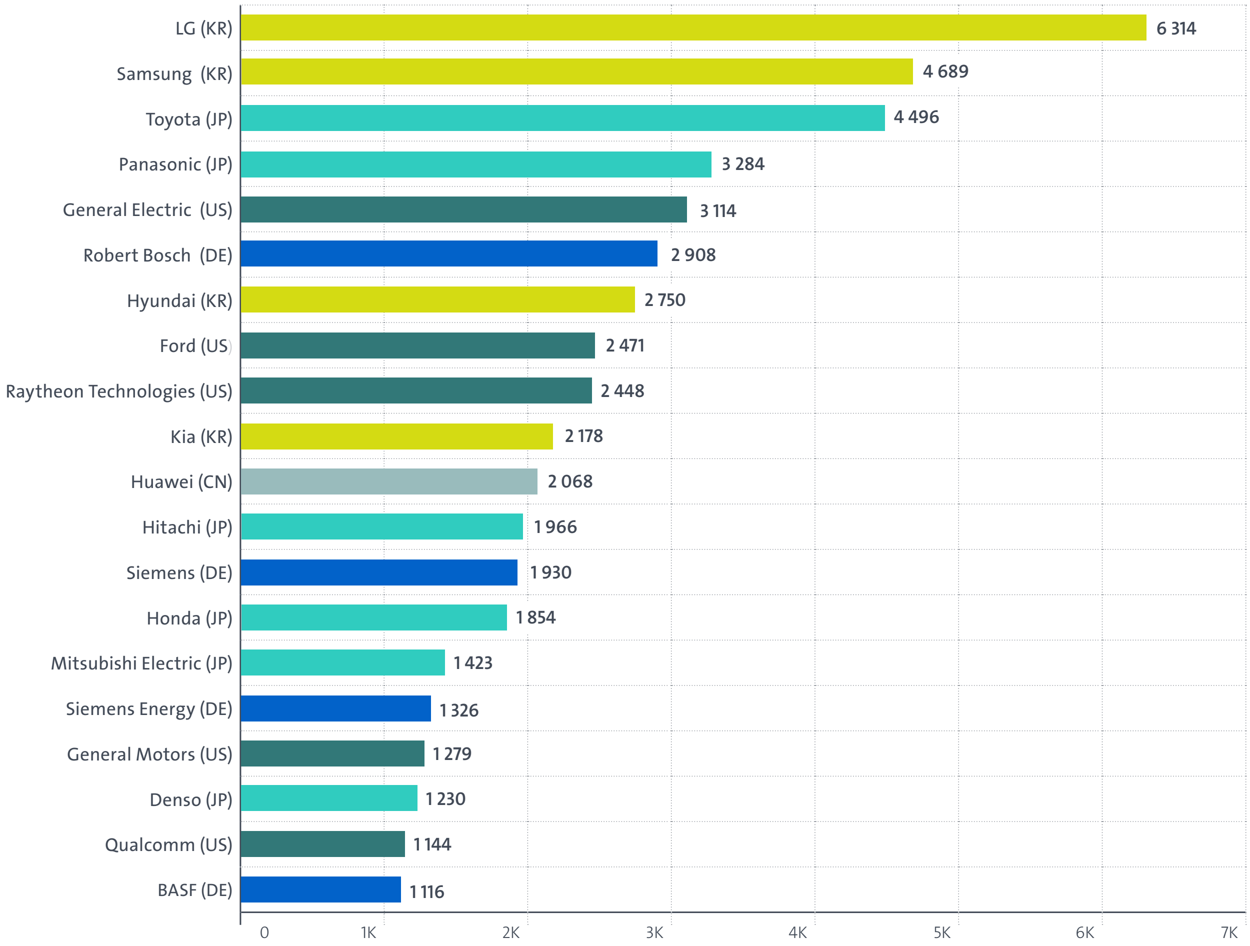
2.3 Top patent applicants and size distribution of cleantech innovators

The list of the top 20 applicants in cleantech for the period 2017-2021 includes companies from R. Korea, Japan, the US, China and Europe. In the period 2017–2021, with over 6 000 IPFs, LG, one of four Korean companies among the top ten, has contributed the most to clean and sustainable technologies (Figure 8). The main focus of its activities was on low-carbon energy technologies, but also CCMTs related to manufacturing and buildings.

With over 4 000 IPFs, the Korean company Samsung, which has large shares in low-carbon energy IPFs and CCMTs in ICT is the second largest contributor, closely followed by the Japanese company Toyota, the biggest contributor in CCMTs in transportation. The only European company among the top ten is the German company Robert Bosch, a strong contender in CCMTs in transportation and low-carbon energy technologies. Together with Siemens, Siemens Energy, and BASF there are four German companies among the top 20. There are three US companies among the top ten, General Electric, placed 5th, Ford (8th), and Raytheon Technologies (9th) and another two, General Motors and Qualcomm, among the top 20. The only Chinese company among the top 20 applicants is Huawei (11th), which is the clear leader in CCMTs in ICT.

Figure 8

Top 20 applicants in clean and sustainable technologies, 2017 –2021



Source: EPO

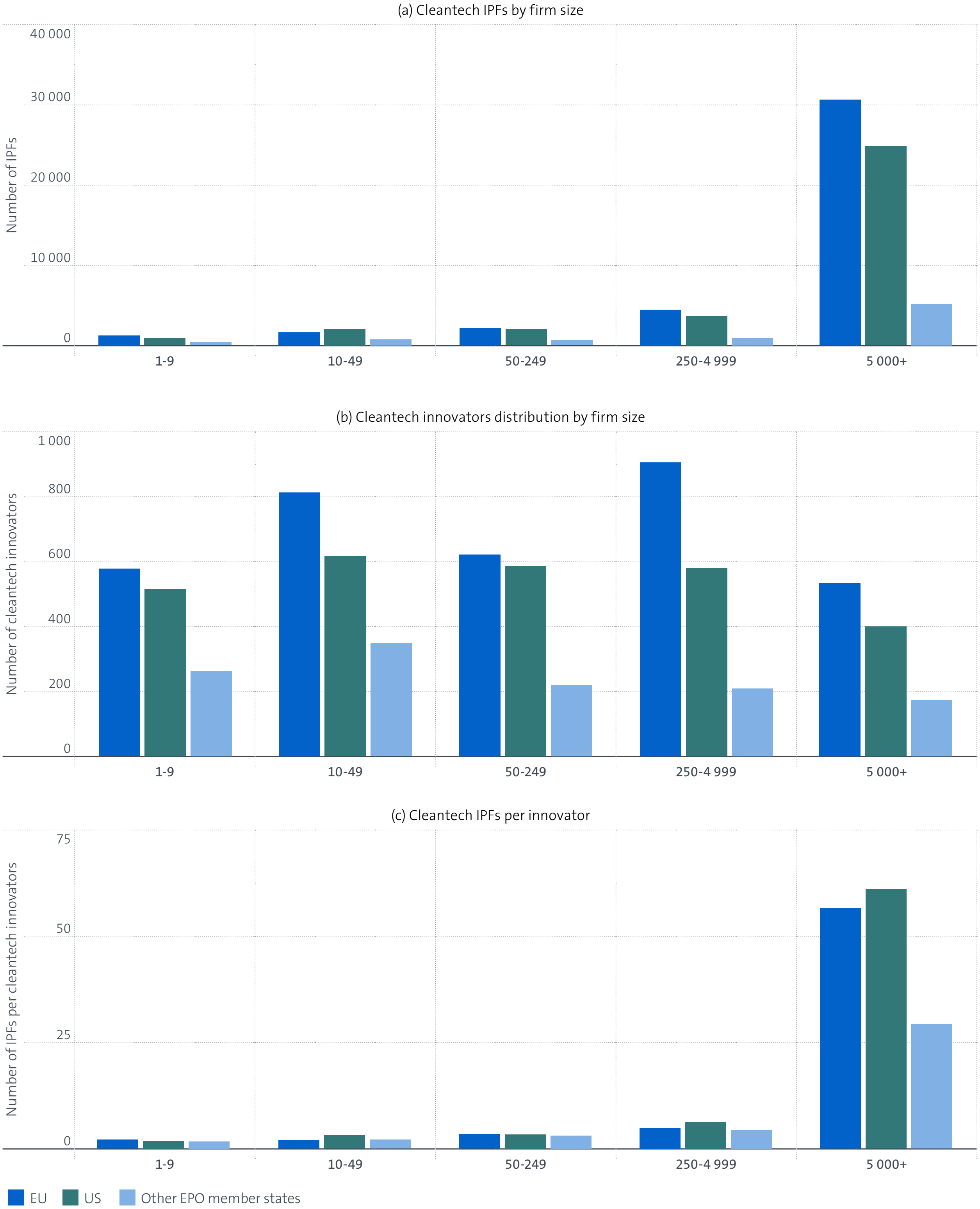
Approximately three out of four cleantech IPFs from European or US companies, excluding those from universities, hospitals, public research organisations, or individual inventors, are submitted by a very large company with more than 5 000 employees (Figure 9). Yet, these very large enterprises only represented less than 15% of all corporate applicants. Indeed, the remaining quarter of all corporate IPFs belonged to small and medium-sized enterprises (SMEs) and companies with less than 5 000 employees.[16]

The subsequent sections are based on firms with fewer than 5 000 employees. This size segment accounts for 24% of clean and sustainable technology IPFs but is of high relevance for several reasons. First, with 86%, it encompasses most cleantech innovators in Europe. Second, this group of firms is particularly relevant for creating dynamic innovation ecosystems, as smaller firms have an advantage in producing radical and disruptive innovations (see Kolev et al., 2022). Third, very large firms produce lower quality inventions but have greater commercialisation capabilities (Arora et al., 2023), which points to potential gains associated with the transfer of inventions from smaller to larger firms through technology markets, a phenomenon that we study in detail. Finally, smaller firms setting out to commercialise their own inventions in product markets, rather than licensing them to larger established firms, typically encounter greater obstacles worth studying.

16 For 15% of the corporate applicants matched to Crunchbase, information about the number of employees was not available. This missing information was retrieved through LinkedIn.

Figure 9

Distribution of cleantech IPFs and their company applicants by number of employees, 2017–2021



Note: Information on the number of employees is based on the matching of patent applicant data with Crunchbase and LinkedIn databases. For IPFs with European applicants and US applicants, 78% and 76% were, respectively, successfully matched. IPFs with universities and public research organisations as applicants are not presented.

Source: EPO

Case study: Neste (Finland)

Company:	Neste
Headquarters:	Espoo, Finland
Founded:	1948
No. of employees:	5 200
Products:	Sustainable fuels and renewable feedstock solutions for various polymers and chemical industries

Headquartered in Finland, Neste manufactures sustainable fuels and renewable feedstock solutions tailored for a wide range of applications in the polymers and chemicals industries. The company was first established as a state petrol company in 1948 but switched its focus to renewables in the mid-1990s. Neste began investing in renewable diesel production and, as part of its strategy, has committed to helping customers reduce their greenhouse gas emission, end crude oil-refining and achieve carbon neutral production. Intense research and development in circular innovation is underpinned by a strong patenting culture within the organisation.

Sustainable solutions

An International Energy Agency (IEA) report estimates that the global transport sector emits approximately 7.3 billion tonnes of CO_2 a year – 20% of global CO_2 emissions. The report also found that 30% of these emissions are caused by medium-to-heavy lorries and aviation. Addressing this challenge, Neste uses its proprietary NEXBTL platform and associated processes to transform various renewable fats and oils into sustainable products. Among these solutions is Neste MY Renewable Diesel, which is compatible with all diesel engines and can potentially reduce greenhouse gas emissions by 75–95% over the fuel's life cycle compared to fossil diesel. In addition, Neste MY Sustainable Aviation Fuel is a direct replacement for fossil jet fuel. When used without blending, this fuel has the potential to decrease emissions by up to 80% over its life cycle compared to fossil jet fuel.

To manufacture its renewable products, the company sources a broad range of raw materials from around the world, including animal fat waste, used cooking oil and vegetable oil residues. A multi-step process transforms waste and residues into pure hydrocarbons. First, impurities are removed before a catalytic process converts oils and fats into hydrocarbons. Later, a process called hydro isomerisation rearranges the atoms, forming a product less likely to solidify. The resulting fuel is suitable for cold atmospheric conditions and ensures smooth operation in engines, including those of airplanes and cars.

Creating a research culture

The Neste team first applied for a patent related to its NEXBTL process during their initial research in the 1990s. When the company's first patent on the platform was granted in 1996, it signalled a significant shift and to this day, the patent is considered a milestone in the company's history. Since then, Neste has continually expanded its portfolio with patents covering various manufacturing and purification methods, as well as the chemical composition of the end products.

With some 2 000 granted patents, IP is deeply integrated into operations from an early stage of technology development. Around a quarter of its workforce is dedicated to research, product development and engineering. In 2022, Neste's research and development expenditure reached EUR 85 million.

Fuelling a growing industry

In 2007, Neste began producing renewable diesel in Porvoo, Finland. Within only four years, the company had established additional manufacturing facilities in Singapore (2010) and in Rotterdam, the Netherlands (2011). Neste MY Renewable Diesel is now available in Belgium, Estonia, Finland, Latvia, Lithuania, Sweden, Germany, the Netherlands and the United States (California and Oregon), while MY Sustainable Aviation Fuel is used by airlines such as KLM, Lufthansa and American Airlines, and cargo carriers including DP-DHL, Amazon PrimeAir and UPS.

Further reading:
European Inventor Award 2023: meet the team

3. Commercialisation of clean and sustainable technologies through the lens of the Cleantech Survey

The remaining chapters of this report are based on results from a novel survey of cleantech innovators with less than 5 000 employees (hereafter referred to as the Cleantech Survey), complemented by an analysis of cleantech innovators based on Crunchbase.

The Cleantech Survey is a novel survey of cleantech innovators with less than 5 000 employees. Results from interviews with 604 companies, of which 81 are from the US and 524 from EPO member states, provide insights into the technology profiles and business profiles of cleantech innovators. Where possible and appropriate, the results are compared to those from the 4IR survey of small and medium-sized enterprises (SMEs) that are patenting in the area of technologies for the Fourth Industrial Revolution (EIB-EPO, 2022) and the latest EIB Investment Survey (EIBIS).

The cleantech survey is based on a sample of 4 848 corporate applicants from member states of the European Patent Organisation and 3 576 from the US that filed for at least one patent application in cleantech in Europe or the US between 2011 and 2022. These companies were identified through a matching of patent applicants with company-level information from Crunchbase.[17]

This chapter provides insights into the commercialisation of the selected cleantech technology associated with the patent application and the role that IP plays in supporting business development.

17 The matching was first performed for European and US applicants of cleantech IPFs. IPFs published between 2011 and 2022, with European applicants and US applicants, excluding those with universities and public research organisations as applicants, 73% and 71%, respectively, were successfully matched to Crunchbase. The matching was further expanded to applicants of a random sample of cleantech patent families with only one national patent application. This was necessary to ensure a sufficiently high number of operating companies with less than 5 000 employees for the survey.

3.1 Stage of commercialisation of cleantech innovation

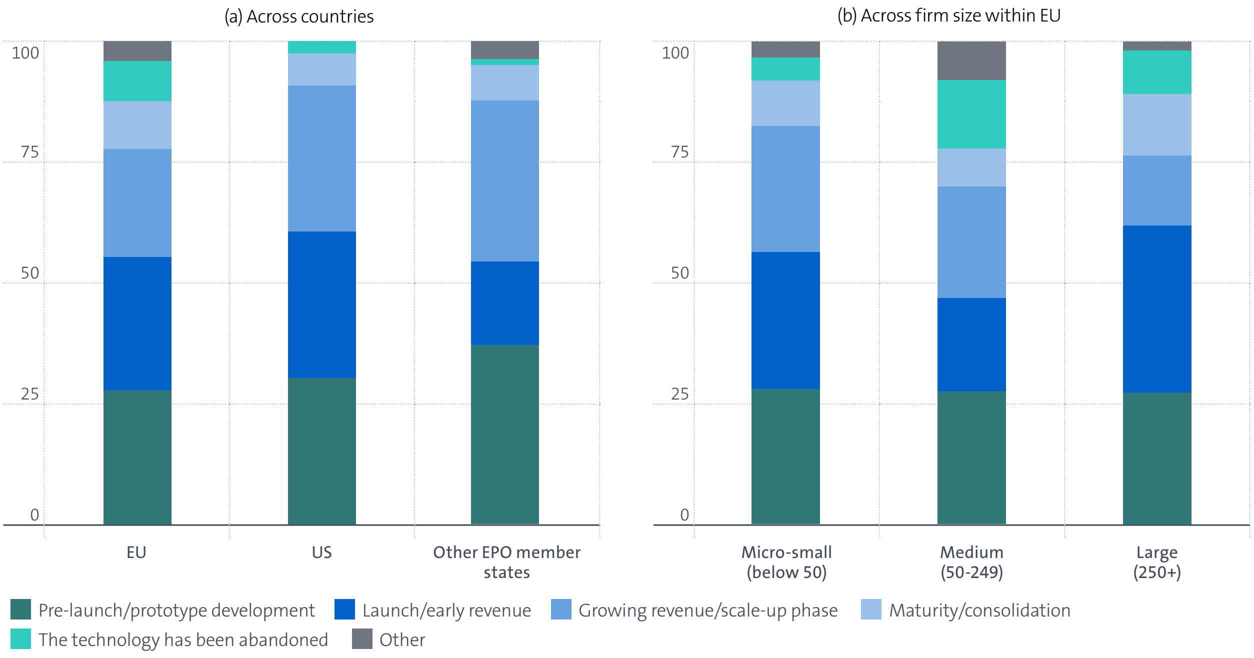
Around half of clean and sustainable technologies from EU innovators are at a launch or early revenue stage, some 22% are at scale-up stage and another 10% are already mature or consolidating (Figure 10). Within the EU, 28% of cleantech innovators report that their patented technology is at the launch or early revenue stage, and 22% state that it is at the growing revenue stage. The gap between the EU and the US seems to emerge for the scale-up phase, with 22% of cleantech innovators in the EU indicating they are at this stage compared to 30% in the US. The proportion of firms that report having abandoned the patented technology they were asked about is very low, but slightly higher in the EU, at around 8%, compared with around 2.7% in the US and around 1.2% in other EPO member states. The share of companies stating that their technology is at pre-launch or prototype development phase is hovering around 30% across all regions, with the lowest share in the EU (at 28%).

The share of EU cleantech innovators with a technology in the prototype stage is roughly similar across different firm sizes, at around 27%. Larger firms have a slightly higher share of early revenue phase technologies (34%) than micro-small firms (28%). In contrast, the share of firms with technology in the growing revenue and scale-up phase is slightly lower for large firms than for micro-small or medium-sized companies. On the other hand, the proportion of technologies in the maturity or consolidation phase is slightly higher among larger enterprises than among small innovators.

It should be noted that medium and larger firms have a higher share of firms declaring that they have abandoned the technology, compared to micro-small firms.

Figure 10

More than half of clean and sustainable technologies are at launch or scale-up stage



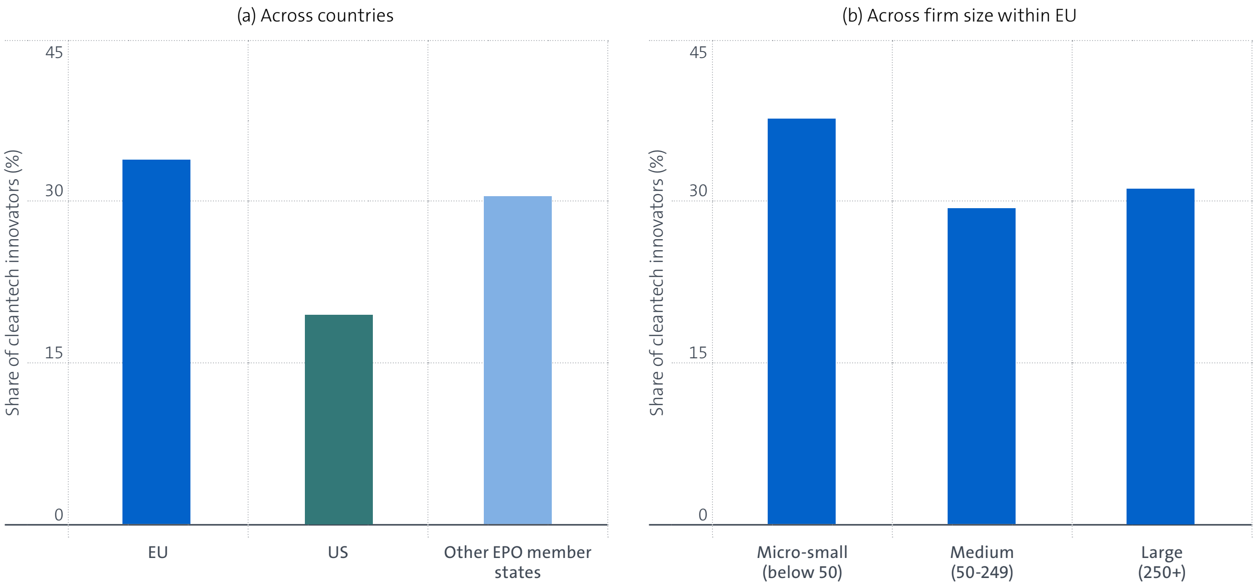
Question: What is the current status of the technology?

Source: Cleantech Survey

Almost a third of cleantech innovators report that the technology was developed in collaboration with other organisations, including other companies, universities and public research organisations (PROs). Specifically, 34% of cleantech innovators in the EU report collaborations, a figure that is close to the 30% reported by firms in other EPO member states (Figure 11). This is slightly higher than in the US, where around 20% of cleantech innovators report collaborative development efforts. **Smaller firms are more likely to develop the technology in collaboration with others:** around 38% of micro and small companies report that their clean and sustainable technology was developed in collaboration with other organisations, compared to around 30% of medium-sized and larger enterprises.

Figure 11

Compared to the US, smaller EU firms are more likely to develop clean and sustainable technologies in collaboration with other organisations



Question: Was the technology developed in collaboration with other organisations?

Source: Cleantech Survey

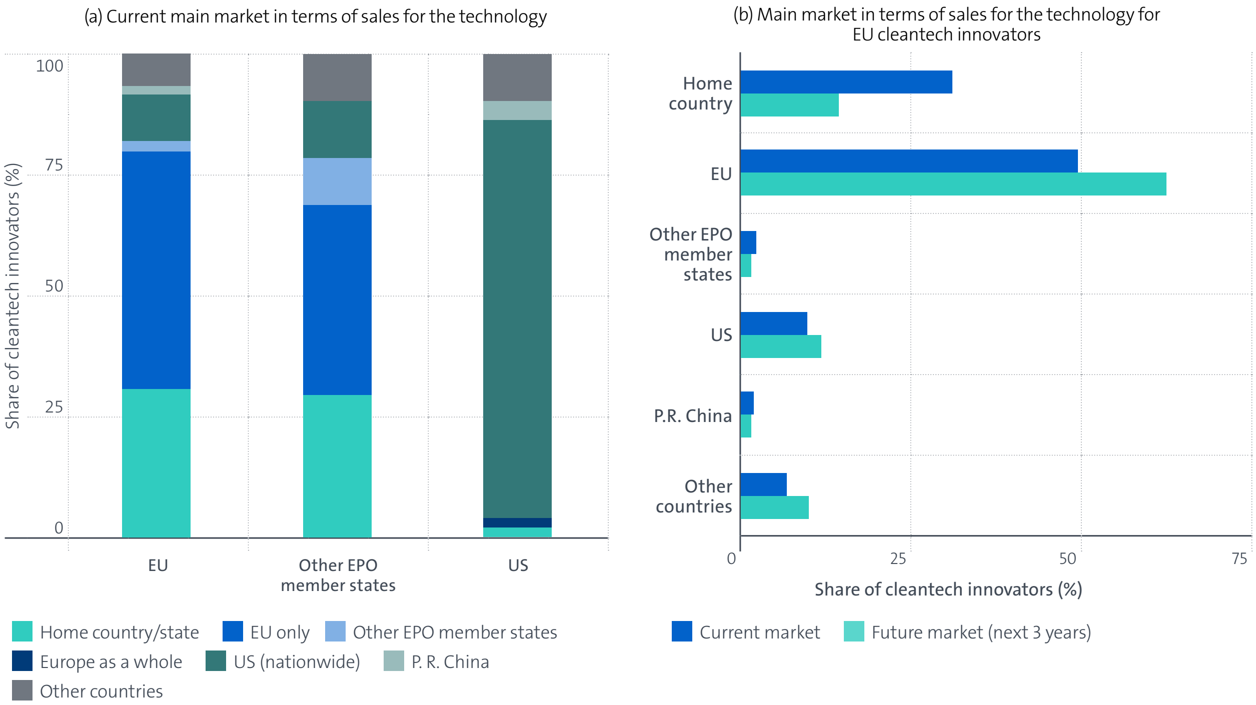
3.2 Market for the commercialisation of cleantech innovation

Around half of EU cleantech innovators report that the EU single market is already the main market for their technology (Figure 12a). However, a significant proportion (29%) also see their home country as their main market and around 10% mainly target the US. Cleantech innovators from other EPO member states have a similar geographical market focus, even though a smaller share of companies (around 39%) focus on the EU single market compared to their EU counterparts. These findings on market focus are relatively similar to those of 4IR SME innovators as documented in the EIB-EPO (2022) report.

In the US, on the other hand, 82% of cleantech innovators consider the US itself as the primary market for their technology. Virtually no US cleantech innovator (2%) focuses solely on their home state. **Only a small fraction (around 2%) of US companies identify Europe as the main market for their technology.** Other markets, such as China (4%) or the rest of the world (10%), also remain peripheral for US cleantech innovators, even if the focus on these regions is higher than the focus on the EU.[18]

Figure 12

Geographical markets for clean and sustainable technologies



Note: Panel (a): "Europe as a whole" includes both EU only and Other EPO member states and it is asked only to the US sample. To the EU and the other EPO member states, EU only and Other EPO member states are asked separately. "Other countries" refers to countries not included under the other labels.
Note: Panel (b): Future corresponds to the next three years, whereas current refers to 2022. Only EU firms are considered.
Question: In 2022, which of the following regions was the main market in terms of sales for the technology? Please rank the following geographical markets in order of strategic priority for the commercialisation of the technology in the next three years.

Source: Cleantech Survey

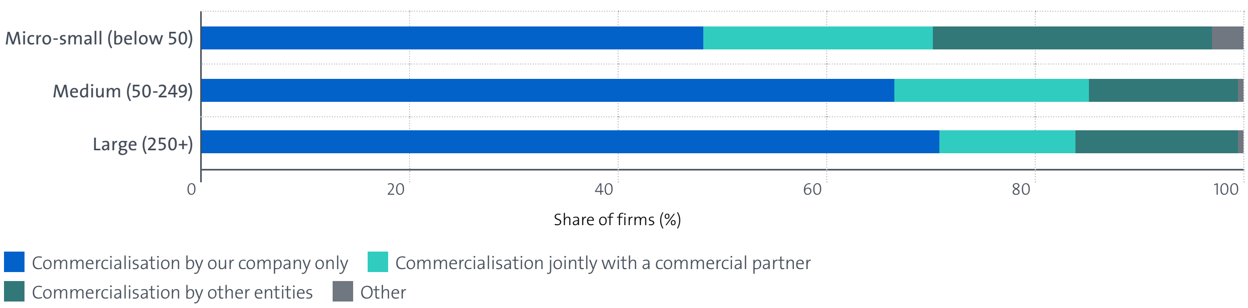
18 These figures are also relatively similar for US 4IR SMEs, with 87% focusing exclusively on the US market, around 7% on the European market, and less than 1% on P.R. China and 3% on the rest of the world (EIB-EPO, 2022).

Looking forward, EU firms are mostly European focused. Only 14% of EU firms consider their national market as the main strategic priority for the commercialisation of their technology in the next three years, showing their intention to scale. **Growth plans are primarily focused on the EU market, with approximately 62% of EU cleantech innovators considering it their strategic priority (Figure 12b).** The US market is the priority for only around 12% of EU cleantech innovators in the coming years. The Chinese market is reported as the main market by a small proportion of firms (less than 2%).

European micro-small innovators tend to rely on commercial partners for the commercialisation of their technology. A significant proportion (48%) of these micro-small cleantech innovators opt for commercialisation strategies jointly with a business partner, or through other entities, via licensing, selling or other forms of technology transfer (Figure 13). In contrast, self-commercialisation is the predominant choice for medium and larger enterprises, with 66% and 71%, respectively, adopting this approach. This is also in line with the finding that micro-small cleantech innovators are more likely to develop their technology in collaboration with other organisations.

Figure 13

EU smaller innovators are more likely to rely on commercial partners to commercialise clean and sustainable technologies



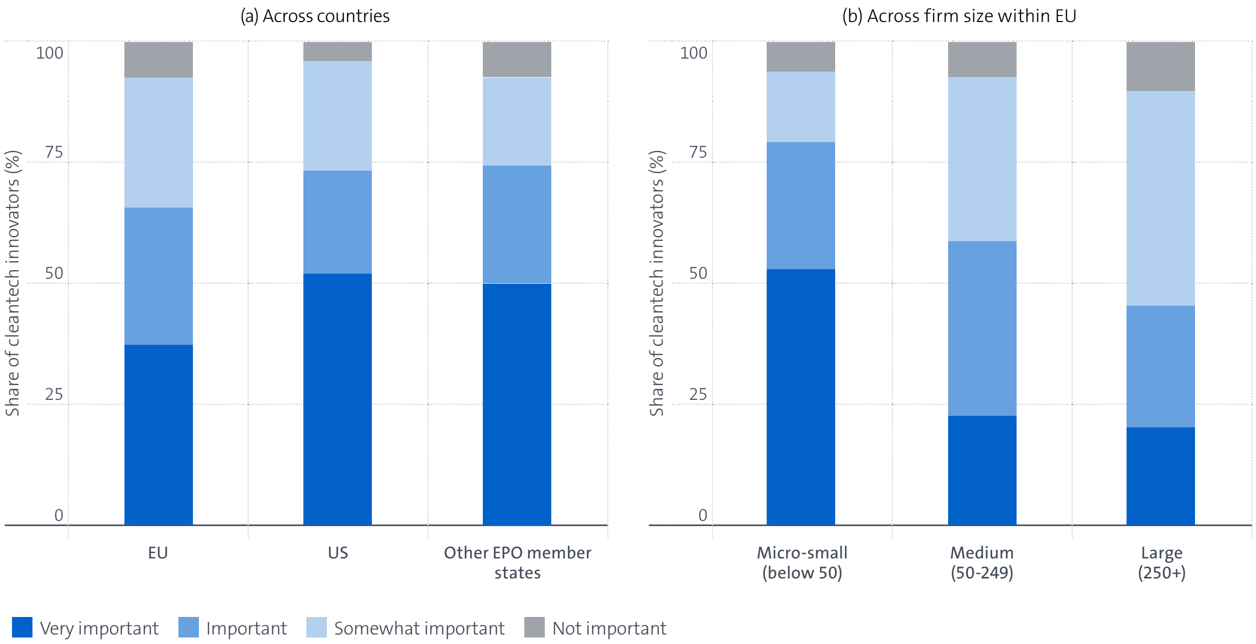
Note: Only EU firms considered. Firms with no commercialisation plans were excluded. Firms with more than one commercialisation option are assigned equal probability for each option.
Question: How is the technology commercialised or how do you plan to commercialise it? Select all categories that apply.

Source: Cleantech Survey

Looking ahead, clean and sustainable technologies are considered to be highly relevant for the companies. Almost three-quarters of the respondents indicated that the technology in focus is either very important or important for their business plans over the next three years (Figure 14). Within the EU, more than half (53%) of micro-small firms that have developed a clean or sustainable technology say that it will be very important for their business over the next three years, compared with 23% of medium-sized and 20% of large firms.

Figure 14

Clean and sustainable technologies are particularly important for smaller firms



Question: How important is the technology to your company's business plans over the next three years?

Source: Cleantech Survey

3.3 Role of patent protection for cleantech innovation

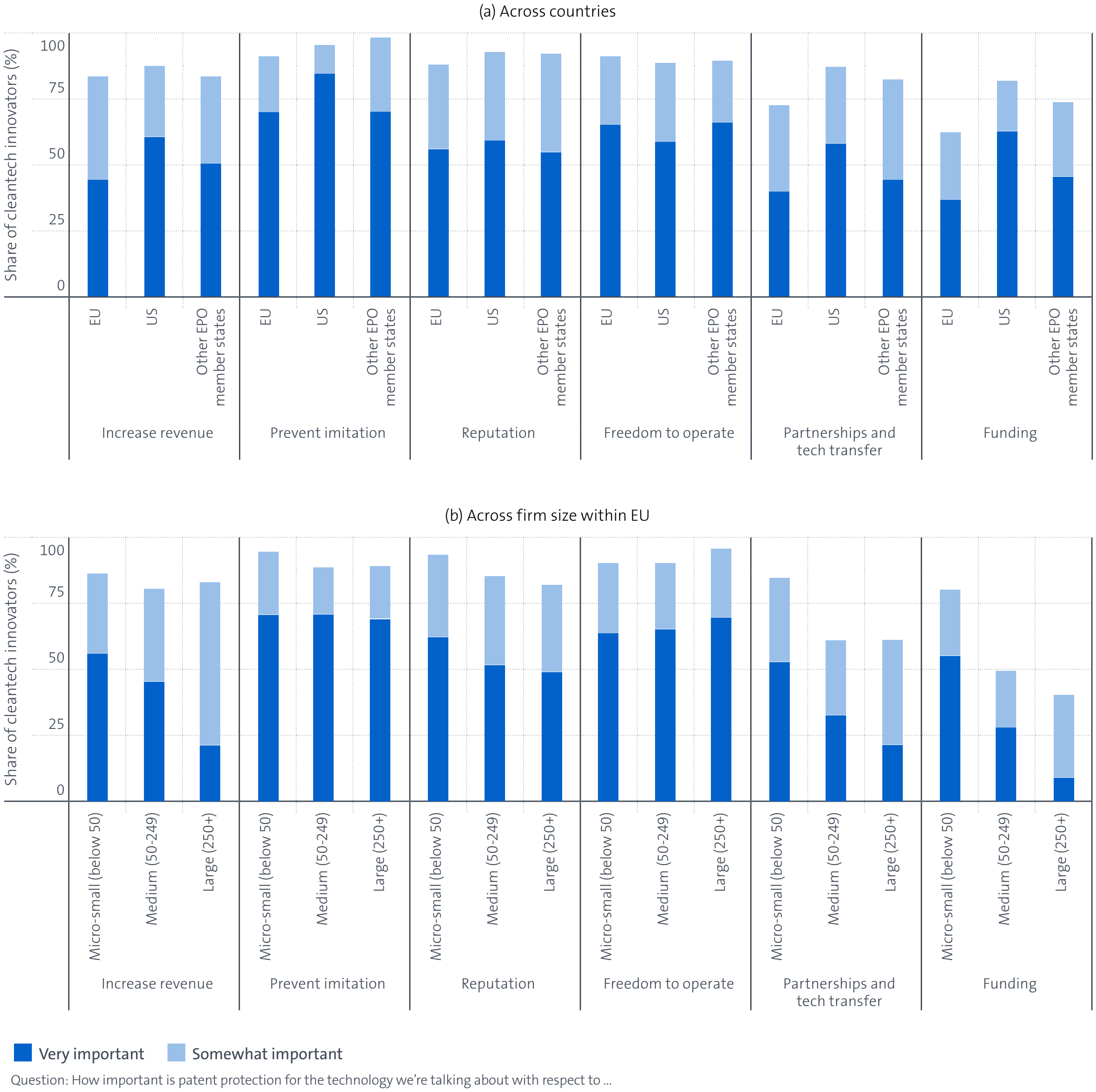
In the field of cleantech innovation, securing IP rights has strategic importance for bringing technologies to market. **The role of patents in preventing imitation is cited as one of the most critical by firms** (Figure 15). More than 70% of EU cleantech innovators deem the prevention of imitation as very important. This sentiment is echoed by approximately 84% of US firms and around 70% of firms in other EPO member states.

For EU cleantech innovators, freedom to operate (67%) and reputational benefits (57%) are also considered very important. Interestingly, only 43% of EU cleantech innovators see patents as very important for increasing revenues, and only 37% see them as very important for securing funding. This is in contrast to their US counterparts, 63% of whom consider patents to be crucial for funding and 60% for increasing revenues. However, this is driven by the dominance of companies of smaller size among US respondents.

Smaller firms are more likely to consider the role of patent protection as very important for increasing revenue and facilitating access to financing. More than half of micro-small EU cleantech innovators see patents as very important for revenue generation, for example through licensing or selling of the technology, compared to only around 20% of their larger counterparts. Furthermore, 54% and 57% of micro-small firms consider IP rights as highly important in securing funding and facilitating tech transfer, respectively, compared to only 9% and 21% among large firms. This is in line with the result that micro-small cleantech innovators tend to rely on commercial partners for the commercialisation of their technology (Figure 13).

Figure 15

Main roles of patent protection for cleantech innovators



Question: How important is patent protection for the technology we're talking about with respect to ...

Source: Cleantech Survey

Box C: Expedient proceedings for cleantech patent applications

European climate legislation requires EU countries to reduce greenhouse gas emissions by at least 55% by 2030, and the aim is to make the EU climate neutral by 2050. Clean and sustainable technology inventions have a key role to play in this context, as they can make an important contribution to reach that goal and mitigate climate change.

A number of patent offices around the world allow for expedient procedures for patent applications relating to cleantech. Such expedient procedures for cleantech applications are currently available, among other countries, in Australia, Brazil, Canada, P. R. China, Israel, Japan, R. Korea, Malaysia, United Kingdom and the United States. Eligibility requirements vary from country to country and also differ in scope. The acceleration of proceedings may relate to all stages of the patent grant procedure or be limited to a specific action. In most countries, an express request by the applicant is required to expedite the procedures, and in some the number of admissible requests is limited. A special fee may be charged, although most countries that offer such expedient procedures for cleantech applications do not require the payment of a fee. Some of the patent offices offering this type of acceleration report that the average duration of applications under these procedures is around 12 months from filing to grant. Other offices report that the time can be reduced by 50% or to just a few months.

The EPO does not offer specific expedient procedures for cleantech applications. However, the EPO has developed a specific classification that includes areas related to specific clean energy technologies. These are subclasses Y02C (greenhouse gases- capture and storage/sequestration or disposal) and Y02E (greenhouse gases - emissions reduction technologies related to energy generation, transmission, or distribution). Applications in this area may be accelerated on request under the programme for accelerated prosecution of European patent applications (PACE), which is available in all technology areas and allows for faster search and examination (see the notice from the EPO dated 30 November 2015, OJ EPO 2015, A93; for PACE requests filed before 1 January 2016 see also OJ EPO 2010, 352). A PACE request may be filed only once during each stage of the procedure, i.e. search and examination, and for one application at a time. In addition, there are also additional ways to expedite the grant procedure at the EPO, which is also available for applications for clean and sustainable technologies (see OJ EPO 2015, A94).

Case study: Skeleton Technologies (Estonia)

Company:	Skeleton Technologies
Headquarters:	Tallin, Estonia
Founded:	2009
No. of employees:	251–500
Products:	Ultracapacitors, ultracapacitor modules and full energy storage systems

Skeleton Technologies is a start-up that develops, manufactures and sells ultracapacitor energy storage cells, modules and systems. Ultracapacitors, also known as supercapacitors, are energy storage devices that offer high power density and rapid charging/discharging capabilities, unlike batteries that provide higher energy density for longer-term energy storage. Skeleton's breakthrough innovation tweaks the properties of a carbon material called curved graphene, which significantly enhances the power and energy density of ultracapacitors. Established in 2009, the Estonian company has built a robust intellectual property (IP) portfolio to protect its technology throughout the value chain. Skeleton also ensures that employees are cross-trained and understand IP and its role in research and development.

Ahead of the curve

Skeleton's cell modules and storage systems are produced with curved graphene, a nanomaterial with several advantages over the activated carbon commonly used by other manufacturers. The material is synthesised via a process that enables optimum pore size distribution and fine-tuning of pore size. As a result of tweaking the properties of curved graphene, Skeleton's ultracapacitors offer enhanced power and energy density, enabling devices that can deliver and store energy quickly.

The ultracapacitor cell modules are designed to be integrated into customers' products, providing high-power density energy storage solutions. These modules can be used in various applications, including heavy transportation, rail, pulse power supply, regenerative power, peak assistance in power grids and industry. Manufactured entirely in Europe, Skeleton's curved graphene has a high chemical purity and is free of the toxic materials often used in similar technologies. This not only ensures reliability, but also helps to limit the environmental impact of the company's ultracapacitors.

Growing business, evolving IP

Skeleton manufactures its ultracapacitors for various industries and uses its patent portfolio to maintain a competitive advantage through the business-to-business value chain. The performance of curved graphene is Skeleton's unique selling point and therefore vital to protect against reverse engineering and copying.

The company's IP strategy has evolved as the business has grown. Initially, the company wanted to establish a patent portfolio and sought patent cover for the process of synthesising a new material with a hexagonal graphene structure. The strategy later expanded to Skeleton's cell modules and storage systems, and the company also began to analyse patent information, which helped to identify trends, potential competitors and gaps in the market. Skeleton then established a clear process for IP creation and management. As part of this process, the company cross-trains its employees in IP, business and science. The company continues to align research and development with its IP strategy, aiming to record and evaluate knowledge, and link short-term research aims with long-term IP opportunities.

Skeleton's patent portfolio comprises 15 patent families and is geared towards key markets in Europe (Germany, France, the UK and Estonia), as well as the US. While the company aims to broaden its cover, the cost of constantly applying for multiple new patents can limit these ambitions. The company has expressed a keen interest in the Unitary Patent and Unified Patent Court [19], which won't fundamentally change its IP strategy but will enable it to consider broader protection and streamlined enforcement at a lower cost.

Setting the standard

Skeleton works closely with its customers to adapt its components to meet customer needs. This collaboration enables the company to bolster internal knowledge by learning from its partners. Skeleton may also need to share sensitive know-how with external collaborators, making patents a key condition for safely disclosing information. In addition, collaboration could help Skeleton gain a competitive edge in the future, particularly in the relatively new ultracapacitor market. By presenting a united front and pooling resources, Skeleton and its collaborators can influence future regulatory standards, with patented inventions adding authority to negotiations.

Further reading: Graphene draws on the capacity for energy storage (case study: PDF)

19 Unitary Patents make it possible to get patent protection in up to 17 EU Member States by submitting a single request to the EPO, making the procedure simpler and more cost effective for applicants. The Unified Patent Court (UPC) is an international court set up by participating EU Member States to deal with the infringement and validity of both Unitary Patents and European patents, putting an end to costly parallel litigation and enhancing legal certainty.

4. Financing cleantech innovators

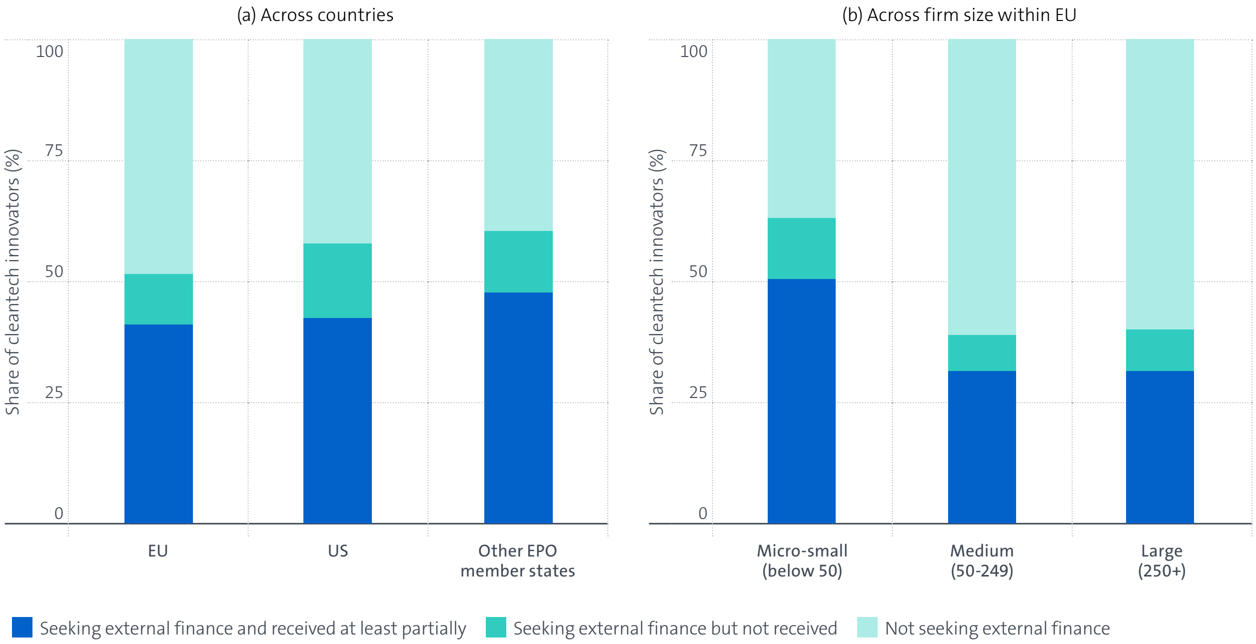
This chapter provides information on the financial conditions of cleantech innovators, using results of the Cleantech Survey, complemented by analysis based on Crunchbase.

4.1 Investment finance for cleantech innovators: evidence from the Cleantech Survey

The results of the Cleantech Survey show that **around 50% of EU innovators are actively seeking external funding for their clean and sustainable technologies (Figure 16).** Eighty percent were able to secure at least part of it. These statistics are broadly in line with their counterparts in the US and other EPO member states. **Zooming in on the EU,** 63% of micro-small cleantech innovators seek external finance, compared with around 40% of medium-sized and larger enterprises. The proportion of enterprises that have sought and secured at least some of the funding they needed (among those seeking external finance) remains relatively constant across enterprise sizes.

Figure 16

Smaller cleantech innovators are more likely to seek external sources to finance their cleantech activities



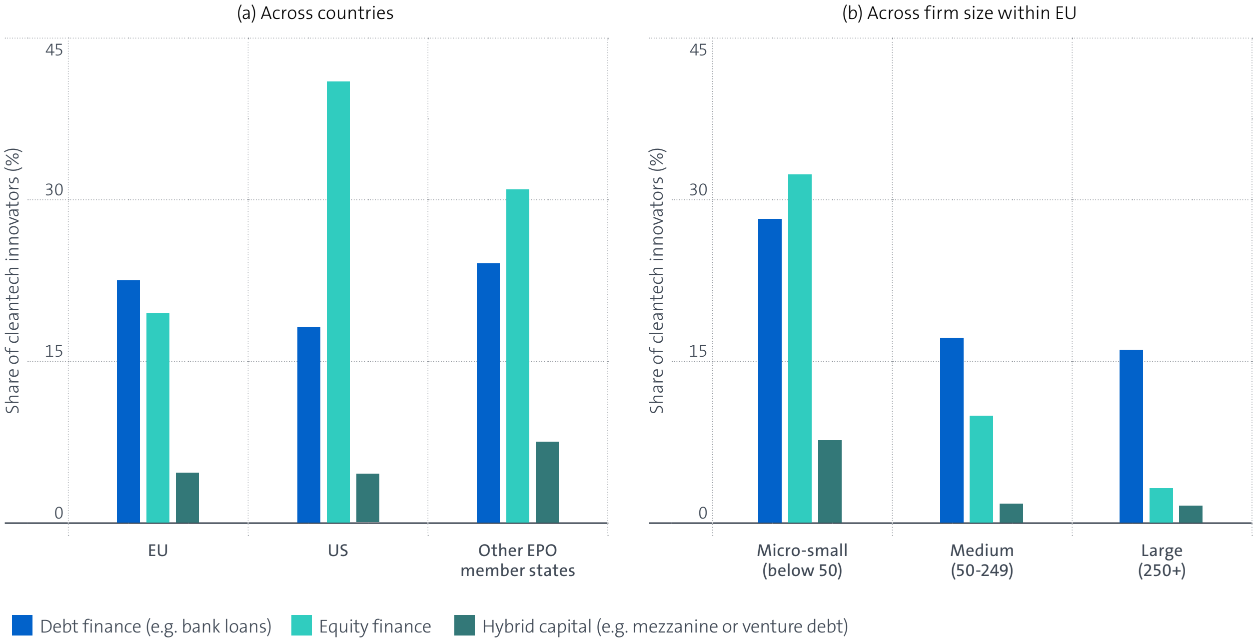
Question: Did your company seek any external finance in 2022 to fund your business activities related to clean and sustainable technologies? If yes, did you receive (at least part of) the external finance you applied for in 2022 to fund your business activities related to clean and sustainable technologies?

Source: Cleantech Survey

In terms of financial instruments, US firms (41%) and those based in other EPO member states (30%) are more likely to have received external finance in the form of equity finance than debt finance and hybrid capital (Figure 30). **EU cleantech innovators are almost equally likely to have received external finance in the form of debt (23%) and equity (19%) in 2022.** Micro-small cleantech innovators in the EU are more likely to have received equity finance than their larger counterparts. In fact, 33% of micro-small enterprises financed their clean and sustainable activities in 2022 through equity finance, compared to 10% of medium firms and only 3% of larger firms with more than 250 employees. It is also noteworthy that **larger cleantech innovators within the EU demonstrate a stronger inclination towards debt financing** over equity financing.

Figure 17

US firms and smaller EU innovators are more likely to use equity to finance their cleantech activities



Base: All cleantech innovators.
Question: Did your company seek any external finance in 2022 to fund your business activities related to clean and sustainable technologies? Was any of the external finance in 2022 in the form of ... ?

Source: Cleantech Survey

4.2 Financing gaps between EU and US: a focus on equity

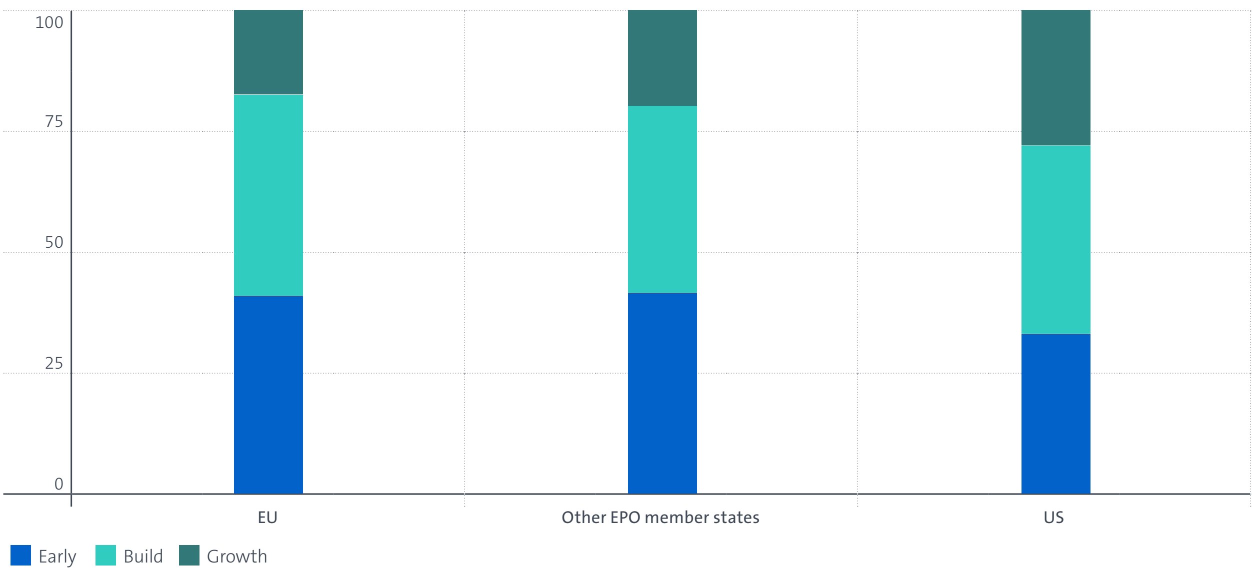
As noted in the previous section, EU cleantech innovators are almost equally likely to have received external financing in the form of debt and equity, unlike their US counterparts who lean more towards equity. This bias towards debt is more pronounced for larger EU cleantech innovators. This trend reflects well-established financing patterns over the life cycle of a firm. Young start-ups are often attracted to equity financing because of its risk-sharing nature and the absence of immediate repayment obligations. This is particularly the case when they lack collateral or may not yet be generating sufficient revenues for debt financing (bank loans or bonds), which require regular interest and principal repayments.

This section explores the use of equity finance at different stages of a startup's lifecycle, including the early stage (pre-seed, angel, seed and crowdfunding), build stage (Series A/B) and growth stage (Series C and beyond). It mainly uses Crunchbase data to shed light on the funding gaps between the EU and the US, particularly in the context of later-stage equity financing.

Compared to the US, the EU has a lower share of cleantech innovators in the growth phases and a higher share in the early stages (Figure 18). This reflects differences in the capacity for cleantech innovators to scale up in the different regions.

Figure 18

Share of firms by funding stage, 2013–2023



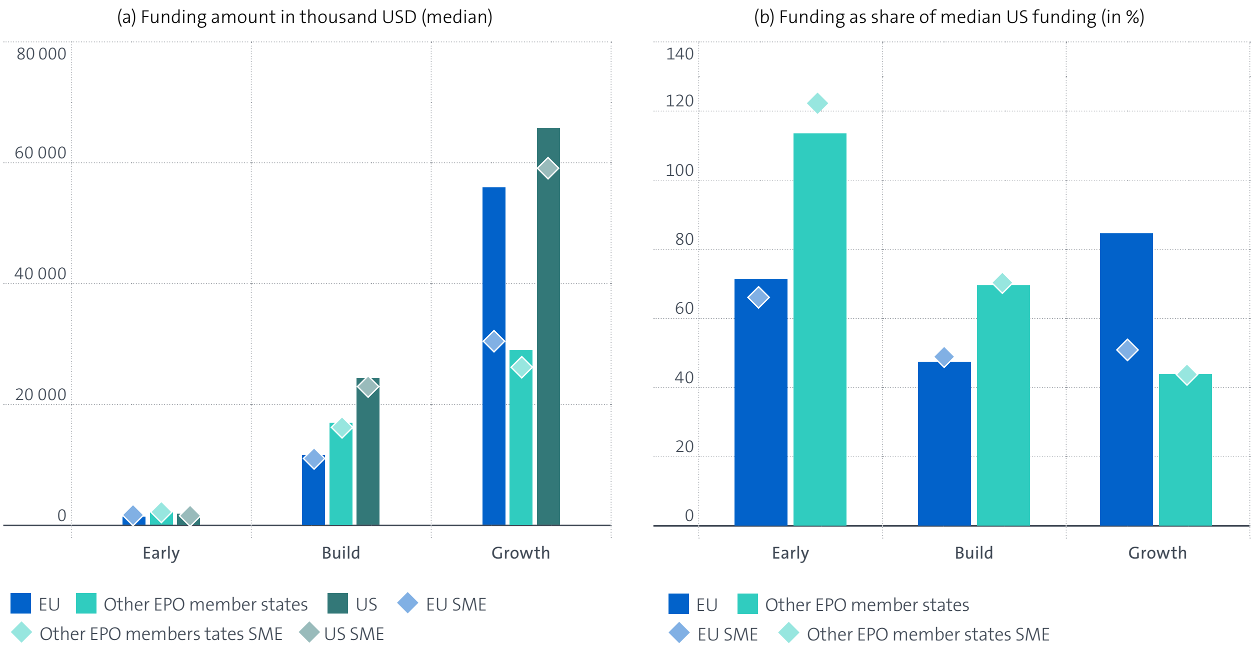
Base: All operating companies, funding rounds announced before 2013 were dropped from the analysis.
Note: Early stage comprises the following types of funding: angel, convertible note, equity crowdfunding, pre-seed, product crowdfunding, seed. Build phase comprises the following types of funding: series a, series b. Growth stage comprises the following types of funding: series c, series d, series e, series f, series g, series h, series i, series j, private equity.

Source: Crunchbase

In addition, EU firms raise less funding at later stages than their US counterparts, especially in the build phase. **The median funding amount is significantly smaller in the EU than in the US.** The amount of funding raised at different stages increases much faster in the US than in Europe (Figure 19). The funding gap between cleantech innovators in the EU and the US is smallest in the growth and early phases and largest in the build phase. **This gap between the EU and US in later-stage funding is particularly severe for smaller companies.** This reflects differences in the capacity for cleantech innovators to scale up in the different regions. For a more comprehensive overview on scale-ups, focusing on an alternative subset of companies active in cleantech, see Box E.

Figure 19

Funding received by fund stages, 2013–2023



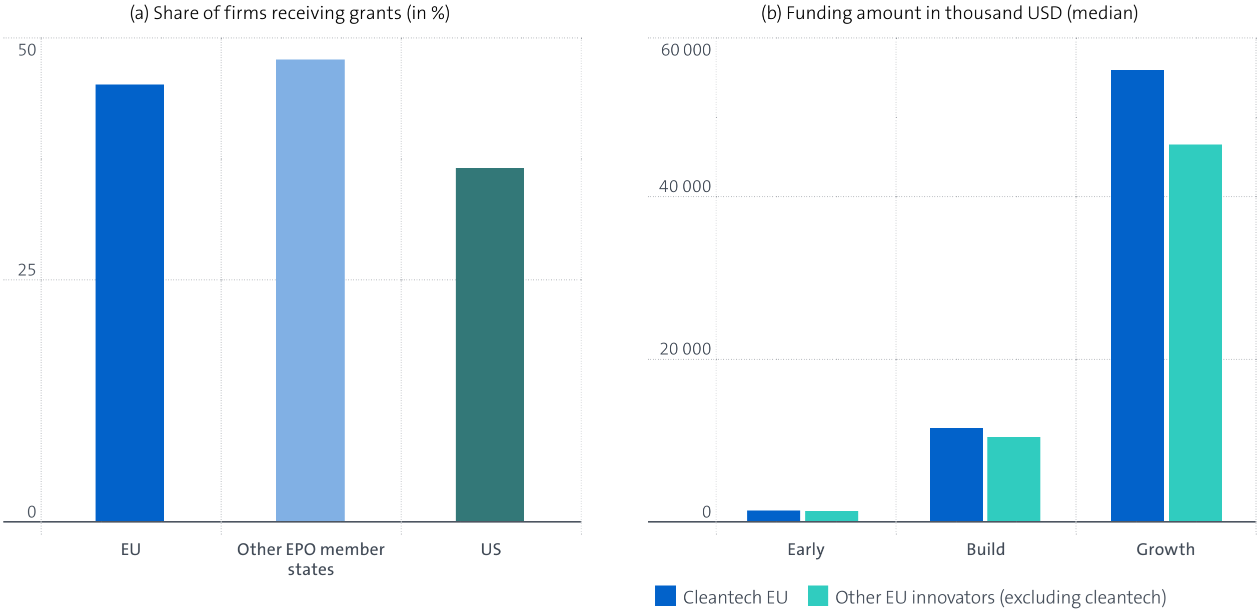
Base: All operating companies, funding rounds announced before 2013 were dropped from the analysis.

Source: Crunchbase, author's calculation

In addition to the amount raised, there is a difference in the funding mix between the EU and the US. The reliance on grants tends to be higher in Europe than in the US (Figure 20a). About 40% of EU cleantech innovators mention that they received grants, compared to 33% in the US. This suggests that public support in the EU can be quite effective in closing the early-stage funding gap, but perhaps less to help firms scale up in the build and growth phases. When comparing median funding received per stage, cleantech companies tend to receive higher median amounts, especially in later growth stages, than the other, non cleantech innovators (Figure 20b). Complementing this finding, the analysis in Box E suggests a relatively stronger performance of the EU compared to the US in this sector within the VC market.

Figure 20

Grants and funding of cleantech innovators versus other innovators, 2013–2023



Base: All operating companies, funding rounds announced before 2013 were dropped from the analysis.

Source: Crunchbase

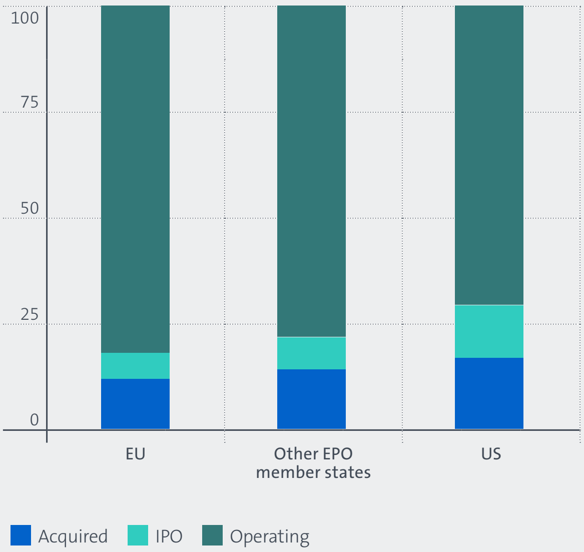
Box D: Exit strategies of cleantech innovators

Next to growing and remaining operational, different exit strategies play a crucial role for companies in navigating their growth journey strategically. This Box focuses on acquisitions and initial public offerings (IPOs), only two of several exit routes, including among others secondary sales to other financial investors but also liquidation. Of all cleantech innovators identified in Crunchbase, US companies are most likely to have been acquired or to have gone through an IPO (Figure Box D1).

Companies with promising innovations are often acquired by other start-ups or larger companies. European cleantech innovators are more often acquired by US companies than vice versa (Figure Box D2). This confirms the findings for 4IR SMEs (EIB-EPO, 2022) and also resonates findings by the EIF (2023) VC Survey 2023, indicating that a large share of EU exits is outside the EU. This is a reason for concern given that the destination of exit matters. Focusing on greentech markets, a recent report from EIF (2022) shows that a strong exit environment has a positive impact on investors and entrepreneurial activity. In addition, there is a strong relationship between VC activity, the exit environment and innovative performance (for an overview, see EIF, 2021). This suggests that a thriving exit environment is key for the success of companies and the business appetite of investors, start-ups as well as established market players.

Figure Box D1

US firms are more likely to have been acquired and to have gone through an IPO

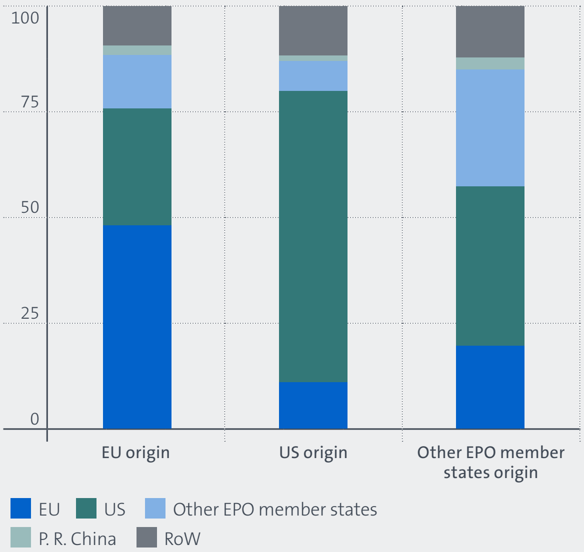


Base: All companies.

Source: Crunchbase

Figure Box D2

EU firms are more likely to be acquired by US companies than vice versa



Base: Exit events, only the last exit event is kept for each company

Source: Crunchbase

Box E: PitchBook VC activities related to greentech [20]

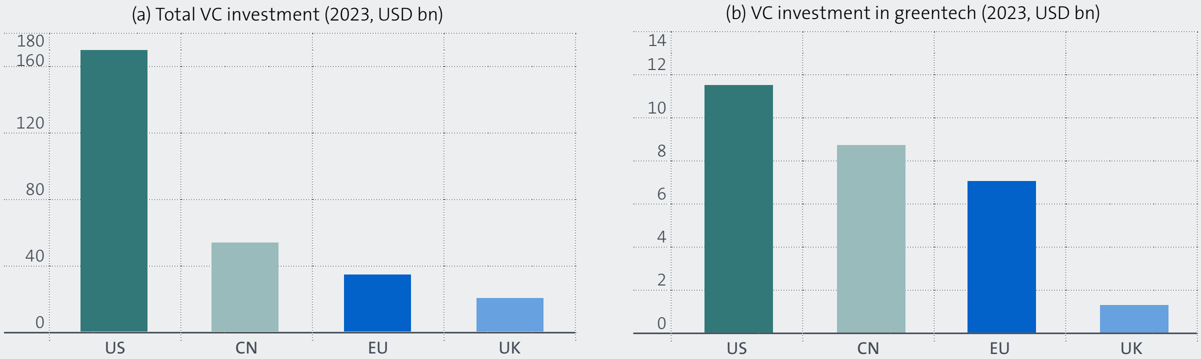
Venture capital (VC) plays an important role in the financing of innovation for the green transition. The green transition needs breakthrough innovation and technological disruption to achieve its ambitious objectives. To accomplish these objectives, startups, traditionally the innovative engine for growth, have an important role to play. Even though incumbents have a larger share of patent applications, VC-backed startups are often involved in the most groundbreaking and widely cited innovations. For example, the surge in VC-finance for renewable energy technologies in the early 2000s was accompanied by a rising share of patenting by startups.

VC investment in greentech in the EU is remarkably high relative to the US. The EU VC market is still small relative to that in the US and the UK, when considering differences in population and GDP. On the contrary, as a unique example, VC investment in greentech in the EU is comparable in size to that in the US (Figure Box E1). This sector also remained relatively resilient in 2022 and 2023, when the tightening of financing conditions led to a swift readjustment in VC financing globally.

The gap in VC market activity between the EU and the US is less pronounced in the greentech sector compared to the overall market. As shown in Figure E2, the density of VC-backed firms in greentech, measured as the number of greentech companies per million inhabitants, is approximately half in the EU relative to the US, while it is a third for all sectors. In terms of volume of VC investment per capita, the EU is less than a third behind the US in the greentech sector. However, in the overall market, the EU's per capita VC investment is only one eighth of that of the US. This underlines the relatively stronger performance of the EU in greentech within the VC market.

Figure Box E1

Comparison on the size of the VC market

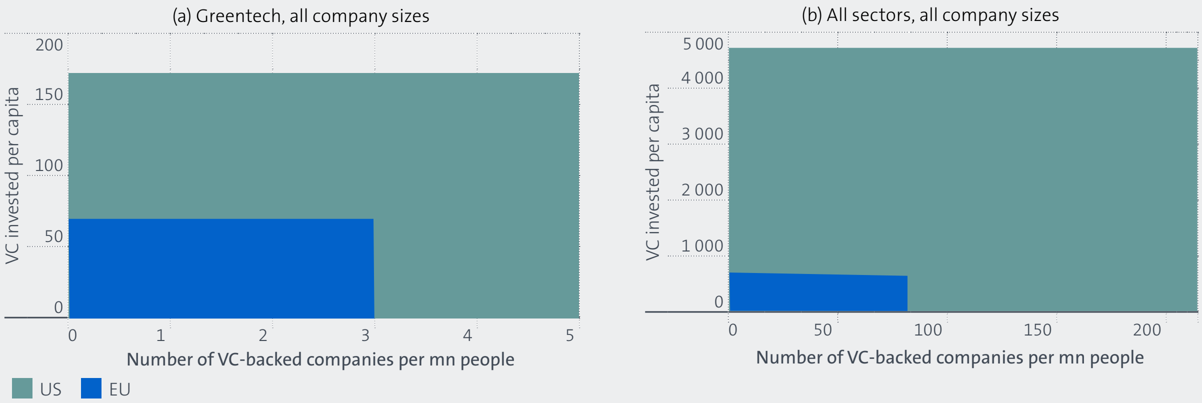


Note: Data has not been reviewed by PitchBook analysts.

Source: Fratto et al. (forthcoming) using PitchBook Inc. data.

Figure Box E2

The EU-US gap in the VC market is smaller for greentech than for all sectors



Note: Data has not been reviewed by PitchBook analysts.

Source: Fratto et al. (forthcoming) using PitchBook Inc. data.

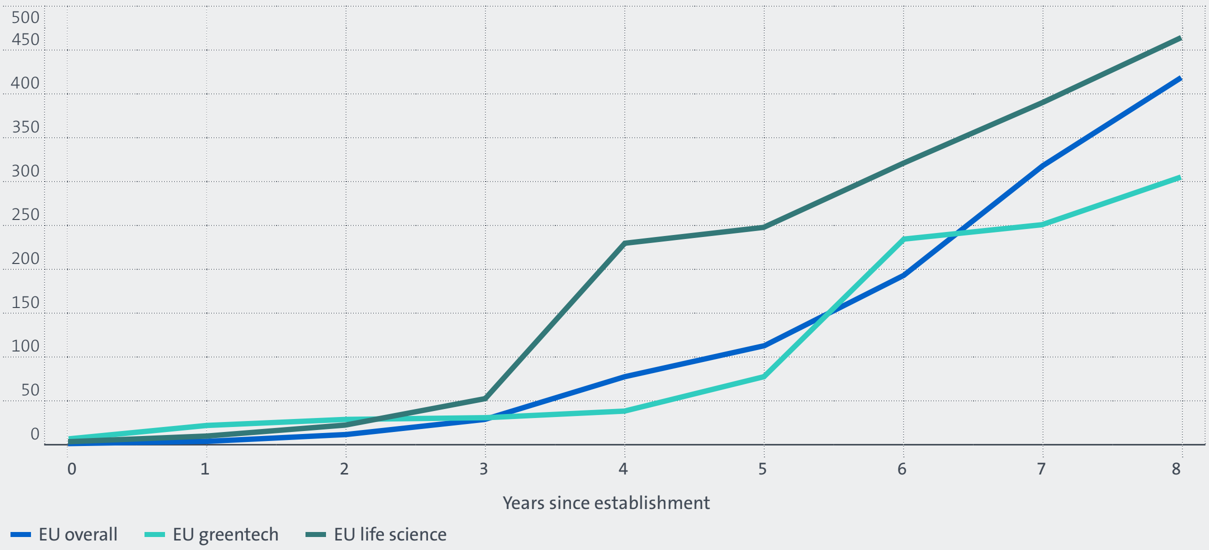
20 The selection of greentech sectors with PitchBook data differs slightly from the cleantech sectors listed in Box B. The greentech selection is based on selected industry segments, supplemented by the use of specific keywords in the description of the business activity. Industry segments are filtered as follows: Energy > Energy Services > Energy Storage, Energy > Smart Grid, Energy > Carbon Capture, Energy > NextGeneration Battery Technology, and Energy > Hydrogen Energy. Keywords and their variants employed for the selection of greentech encompass: "renewable energy", "smart grid", "hydrogen", "green hydrogen", "decarbonisation", "wastewater treatment", "plastic recycling", "insects feed", "battery", "circular economy", "clean transportation", "green transportation", "solar energy", "smart metering", "lithium recycling", and "fertilizer alternative".

The greentech sector in the EU benefits from robust research and a strong domestic demand, driven also by an ambitious decarbonisation agenda. In addition, the demand for renewable energy in the EU has steadily increased over the past years, thanks in part to the European Green Deal, with one of the most ambitious carbon neutrality objectives in the world. Similarly, policy initiatives such as RePowerEU and the Critical Raw Materials Act have accelerated the transition to green energy and sustainable supply chains. These factors help explain why a disproportionately large share of greentech VC investment is directed towards EU firms. Energy storage, circular economy, and AgTech are particularly promising areas of development.

Greentech companies face even higher financing constraints than other innovative companies. Asymmetric information on the novelty and technical complexity of the projects, a longer time-to-market, and a higher capital-intensity result in a suboptimal level of financing available to greentech firms. Technological risks, regulatory risks, and an uncertain future demand for their output further increase financing costs. Despite being more capital-intensive than companies in other sectors, European scale-ups in greentech only raise on average USD 307bn, 27% less than other European scale-ups, and 34% less than scale-ups in life sciences, another capital-intensive sector (Figure Box E3). The limited access to capital is partly offset by a higher reliance on public grants, part of the European Union's net-zero agenda.

Figure Box E3

Cumulative funding raised by EU scale-ups (average, USD mn)



Note: Data has not been reviewed by PitchBook analysts.
Strongly balanced panel including all companies with at least one deal between 2013 and 2023, with a market valuation of between USD 500mn and USD 10bn, and which were established between 2000 and 2013.

Source: Fratto et al. (forthcoming) using PitchBook Inc. data.

To be successful, the VC model must adapt to the specific needs of the greentech industry. To support the green transition, innovation requires deep pockets, technical expertise, and the ability to navigate a complex regulatory environment and fierce competition from incumbents domestically and abroad. VC financing remains of paramount importance for the sector as it combines large amounts of unutilised capital with a propensity to take on risky projects and financial expertise. However, identifying areas in the supply chain in which VC can be more impactful will be important. For example, while electricity transmission operators constitute natural monopolies, the components used in their daily activities constitute a much more dispersed market, more open to technological disruptions.

Box F: EIB Group support for clean and sustainable technologies

Start-ups and scale-ups are important drivers of innovation. They develop groundbreaking technologies and deploy them to the market, improving competitiveness and fostering economic growth. Yet, innovative firms are also among the firms most affected by a lack of access to finance at different stages of their life cylce. Asymmetric information between borrowers and lenders limits start-ups' capacity to attract patient capital that allows them to turn innovative ideas into viable products. At later stages, a lack of access to finance also hampers firms' capacity to grow in size and scale up production. With the aim of supporting innovative firms, the EIB Group, consisting of the European Investment Bank (EIB) and the European Investment Fund (EIF), is present throughout companies' lifecycles, by providing funding through a range of financial instruments, including equity and debt, loan guarantees, venture capital, and risk sharing facilities.

With the aim of closing the scale-up financing gap, the EIB Group has launched two initiatives contributing to the deployment of innovative technologies: the European Tech Champions Initiative (ETCI), a fund of funds managed by the EIF, and the EIB Scale-up Initiative (ESI), with a focus on quasi-equity products. The ETCI has an aggregate commitment of EUR 3.25 bn, from six Member States and the EIB, and aims to channel much needed late-stage growth capital to promising EU innovators, thus reinforcing EU strategic autonomy and competitiveness. Through the ESI and the venture debt programme, the EIB has issued more than EUR 6bn since 2015 in the form of quasi-equity instruments (long-term debt with equity features), often serving as the lead investor and signalling investment quality to the market. The ESI closely matches the existing venture debt product with two key differences: larger ticket sizes and lower return requirements. EIB staff's research shows that EIB venture debt enabled larger start-ups to grow 33% more and crowd in 2.5 times more debt finance than unsupported similar firms. Overall, with this support, the EU aims to spur innovation, drive growth, and foster the ecosystem, hoping to become home to ten tech giants by 2030.

The EIB Group is also committed to expanding investments in strategic sectors, including innovation in net-zero technologies and resource efficiency. Key examples include the financing of Northvolt's gigafactory in Sweden, Europe's first circular battery production gigafactory and the first globally outside Asia. The EIB has partnered to finance Northvolt from an early stage in 2018, supporting the roll-out of its demonstration line with a EUR 52mn loan supported by the European Union's InnovFin programme, followed soon after by a EUR 350mn loan to support the financing of Europe's first domestic gigafactory for lithium-ion battery cells. The latest EIB lending package is just above USD 1bn (EUR 942.6mn), including a USD 400mn guarantee under the European Commission's InvestEU programme and USD 500mn from the Swedish National Debt Office (Riksgälden). The EIB's capacity for project appraisal and the ability to structure with unmatched terms and conditions on the commercial market has brought significant added value, closing a large financing gap but also crowding-in other financiers.

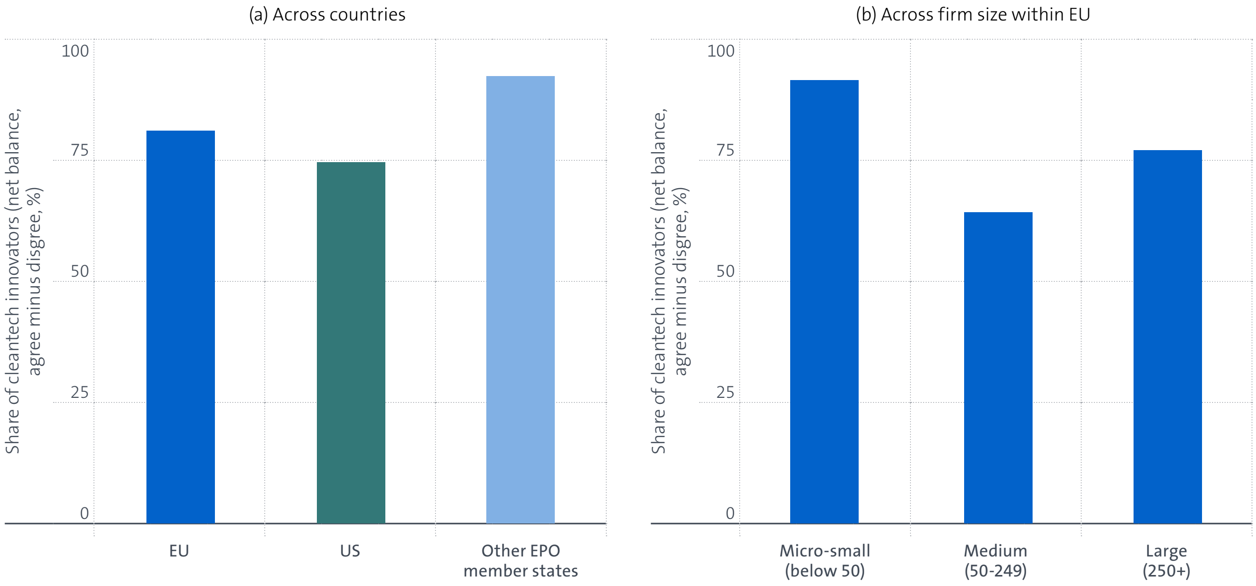
4.3 The role of intellectual property as a financing enabler for cleantech innovators

Patents and other IP rights are essential for smaller cleantech innovators as they help to raise capital and finance innovation.[21] Patent information also makes it easier for investors to assess the quality of a firm's innovation, thereby reducing information asymmetries. It may give a company a competitive advantage and make it more profitable. Furthermore, patent rights can be detached from the business and liquidated during financial hardship, thereby enhancing the company's residual value in the event of insolvency or bankruptcy.

According to the Cleantech Survey, around 75% of cleantech innovators in both the EU and the US report that IP strategies are relevant to their investors (Figure 21). This figure is even higher, at 92%, for firms located in other EPO member states. When looking at the size of firms within the EU, micro and small firms especially report that their IP strategy is relevant to their investors, with over 90% of them confirming this view, compared to 64% for medium-sized companies and 77% of large firms.

Figure 21

IP is relevant for investors



Question: To what extent do you agree or disagree with the following statements about financing the development or commercialisation of clean and sustainable technologies: "Investors pay attention to intellectual property (including patents)"?

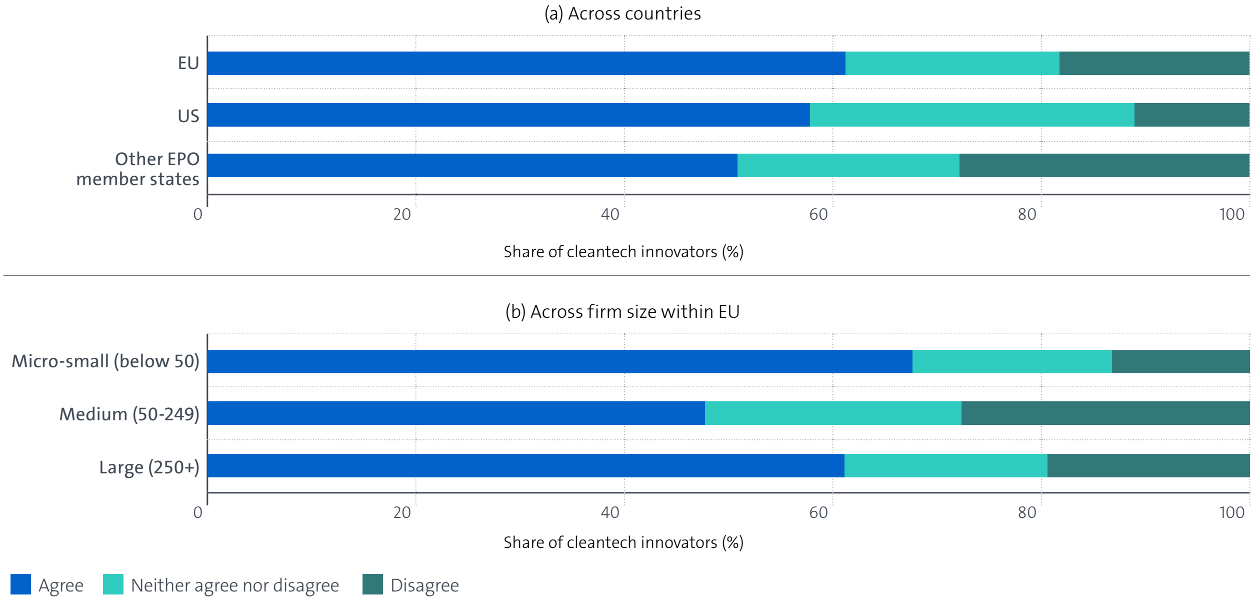
Source: Cleantech Survey

21 See a recent EPO and EUIPO joint report on how IP helps European start-ups to raise finance (EPO-EUIPO, 2023).

IP may serve as collateral for loans or as a backing for equity investments, facilitating access to finance. After having invested in IP, around 61% of cleantech innovators in the EU, 58% in the US and 51% in other EPO member states agreed that their IP is considered as collateral by investors (Figure 22). Conversely, only 18% in the EU, 11% in the US and 28% in other EPO member states disagreed with this statement. Micro-small cleantech innovators in the EU were the most likely to consider that IP can be used as collateral by investors, with almost 68% of these firms agreeing, followed by larger firms at 61% and medium firms at 48%. At the same time, the rate of disagreement was highest among medium firms at 28%, compared with only 13% of micro-small firms and 19% of larger ones.

Figure 22

IP is seen as collateral by investors



Question: To what extent do you agree or disagree with the following statements about financing the development or commercialisation of clean and sustainable technologies: "Our intellectual property is considered to be collateral by investors"?

Source: Cleantech Survey

Case study: Orcan Energy (Germany)

Company:	Orcan Energy AG
Headquarters:	Munich, Germany
Founded:	2008
No. of employees:	65
Products:	Waste heat power generators using the Organic Rankine Cycle (ORC) process

Orcan Energy is a renewable energy company spun out of the Technical University of Munich (TUM) in Germany. Established in 2008, Orcan offers components for heat power generators that convert waste heat into electricity using the Organic Rankine Cycle (ORC). The company made a pivot from technology provider to product sales-oriented business early on, taking up the challenge of developing and installing standalone products. With their products integrated into the installations of large industry players in Europe, Orcan began to eye the Asian market, culminating in a joint venture with a Chinese partner and investment fund. Their patent portfolio, initially acquired from TUM, helped them obtain funding, cement key strategic partnerships and ultimately enable market entry into Asia.

Breaking new ground in an established field

The company's roots lie in a programme for university-based startups. As part of this government-backed programme, a research group developed a compact and cost-efficient ORC system to recover waste heat from combustion engines. The ORC follows a similar process to a steam engine, in which heat energy (in the form of steam) is converted into electrical energy. However, unlike traditional steam engines, an ORC system uses an organic fluid that has a lower boiling point than water. With the right fluid, an ORC system can generate power using lower temperature heat sources, for example, industrial processes or biogas, solar or geothermal plants.

Today, Orcan constructs its heat power generators using standard industry components. Through intensive research and development, the company has adapted these standardised components to make its generators cheaper, simpler and easier to maintain. Their modular units can be installed directly wherever excess heat is generated, helping companies in the cement, oil and gas, power generation and marine sectors reduce costs and meet sustainability targets.

Entering new markets with patent protection

For Orcan, patents are essential to prevent the reverse engineering and copying of their components. The company's ever-growing portfolio includes 23 patent families and more than 100 granted patents. As part of its strategy, Orcan opts for broad geographic protection for key patents covering the basic technology. The company also emphasises patent cover based on where its customers and competitor production sites are located.

Patents and intellectual property rights are entwined in Orcan's business development, guiding their expansion plans. China is intensely focussed on improving its environmental sustainability and reducing its oil dependence. In addition, the country offers a promising potential customer base, as many industries there rely on diesel or natural gas generators. However, entering China presented several legal and cultural barriers, heightened by Orcan's inexperience in Asia.

After considering its options, Orcan set up a joint venture including a licensing agreement with an established business partner in China. The exclusive licence enables the venture to manufacture, market and maintain Orcan's patented products in Asia and Africa. As part of the agreement, Orcan cannot directly sell in these regions. However, third-parties may purchase Orcan products, incorporate them into their own products, and then sell the resulting combinations in Asia and Africa.

While core products are currently produced in Germany and sent to China, the venture manufactures less critical components. Once completed and tested, units are then shipped to customers and installed by the partner in China. In the future, the venture aims to produce a larger quantity of components as well as more complex components.

Further reading: Recycling waste heat to cool down the planet (case study: PDF)

5. Navigating cleantech innovation in the EU: balancing progress and challenges

The previous chapter provided an overview of the financial landscape for cleantech innovators. In order to better understand the playing field of European companies, this chapter provides a further deep-dive into the unique characteristics, strengths and constraints of cleantech innovators.

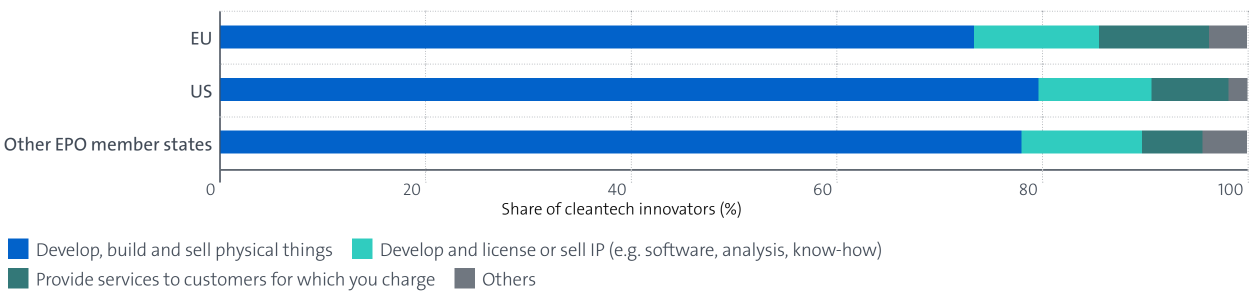
5.1 Business profiles of cleantech innovators

Most cleantech innovators report that they are involved in manufacturing activities, which include the design, production and sale of physical products. Some 73% of EU firms are involved in such manufacturing activities. Another 12% state that they create and sell, or license, intellectual property to generate revenue and around 11% that they provide services to customers (Figure 23). Compared to US and other EPO member states, the EU companies seem less likely to be involved in manufacturing activities and focus slightly more on services.

Within the EU, large cleantech innovators are more likely to report being involved in manufacturing. Eighty-four percent of large cleantech innovators are involved in the design, production or sale of physical products, compared to 76% of medium enterprises and around 66% of micro and small enterprises (Figure 24). This is higher than what was reported by innovators that develop technologies for the 4th Industrial Revolution (4IR) in the EIB-EPO (2022) report. Less than half of 4IR innovators with 250 or fewer employees (SMEs) report being involved in manufacturing themselves. Smaller cleantech innovators (fewer than 250 employees) are more likely than their larger counterparts to develop, license and sell IP and provide services to their customers.

Figure 23

Business models of cleantech innovators

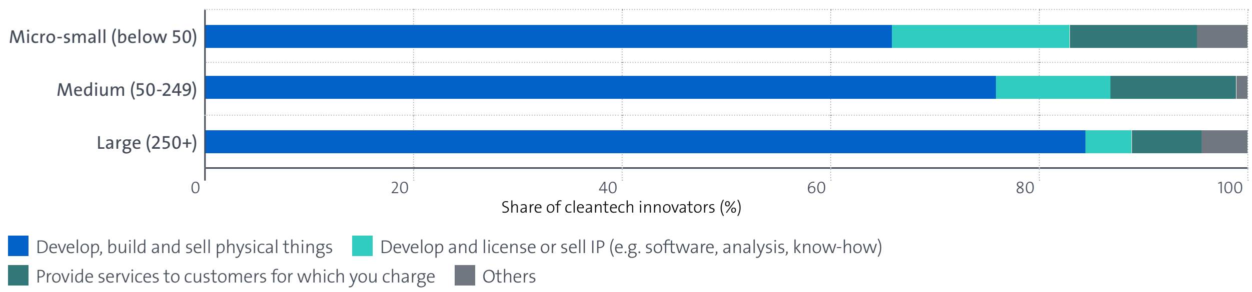


Question: What is your company's main activity? Do you ...

Source: Cleantech Survey

Figure 24

Within the EU, larger cleantech innovators are more likely to be involved in manufacturing



Question: What is your company's main activity? Do you ...

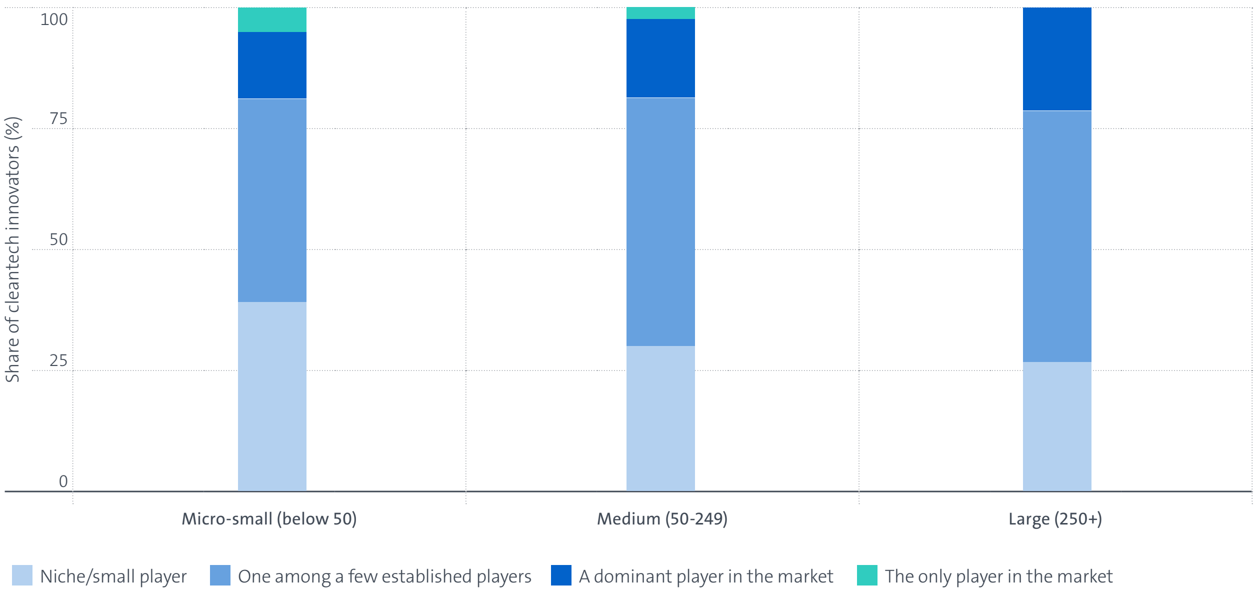
Source: Cleantech Survey

5.2 Market position and investment activities of EU cleantech innovators

More than half of cleantech innovators report having successfully built up a robust and competitive market position. In the EU, most companies state that they are established players in their market (47%). About one third (33%) identify themselves as a niche or small player, another 16% state they are a dominant player and only 3% are the only players in their respective market. Firm size seems to be positively correlated with being one of the few established players or having a dominant market position (Figure 25). Conversely, **smaller firms, especially micro-small ones, are more likely to report being the only player in the market, thus creating new markets or occupying niche markets.**

Figure 25

Market and competitive position of EU cleantech innovators



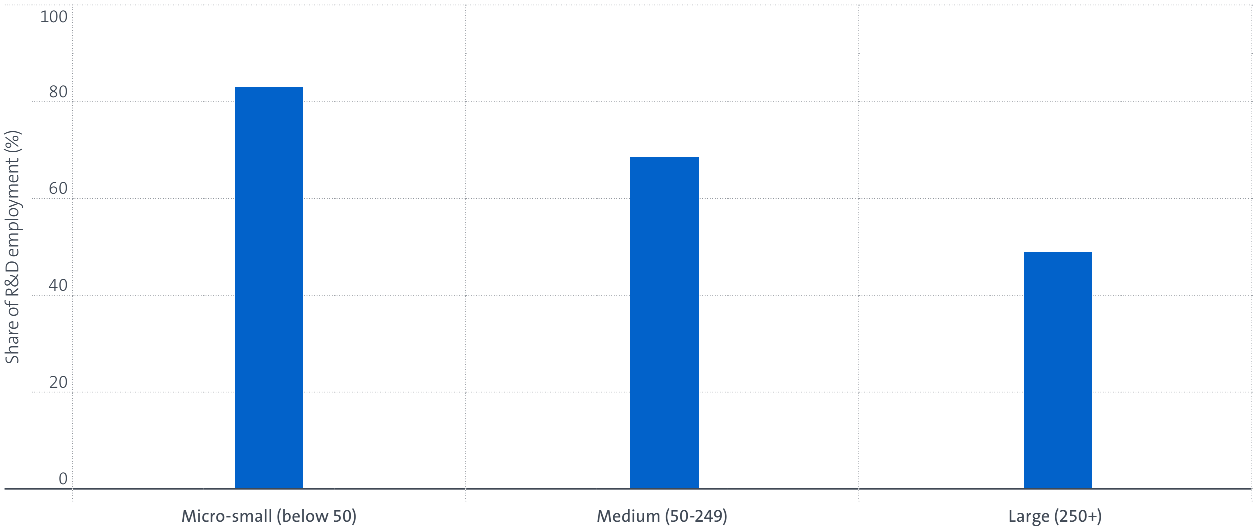
Note: Only EU cleantech innovators considered.
Question: Which of the following describes your company's business activities related to clean and sustainable technologies? Please select only one.

Source: Cleantech Survey

Cleantech innovators employ a large share of R&D employees dedicated to advancing clean and sustainable technologies. Micro-small companies report having, on average, 83% of R&D employees involved in R&D activities related to cleantech. For medium and large firms, this share is lower, at 68% and 50%, respectively (Figure 26).

Figure 26

EU - R&D employment share in clean and sustainable technologies by size



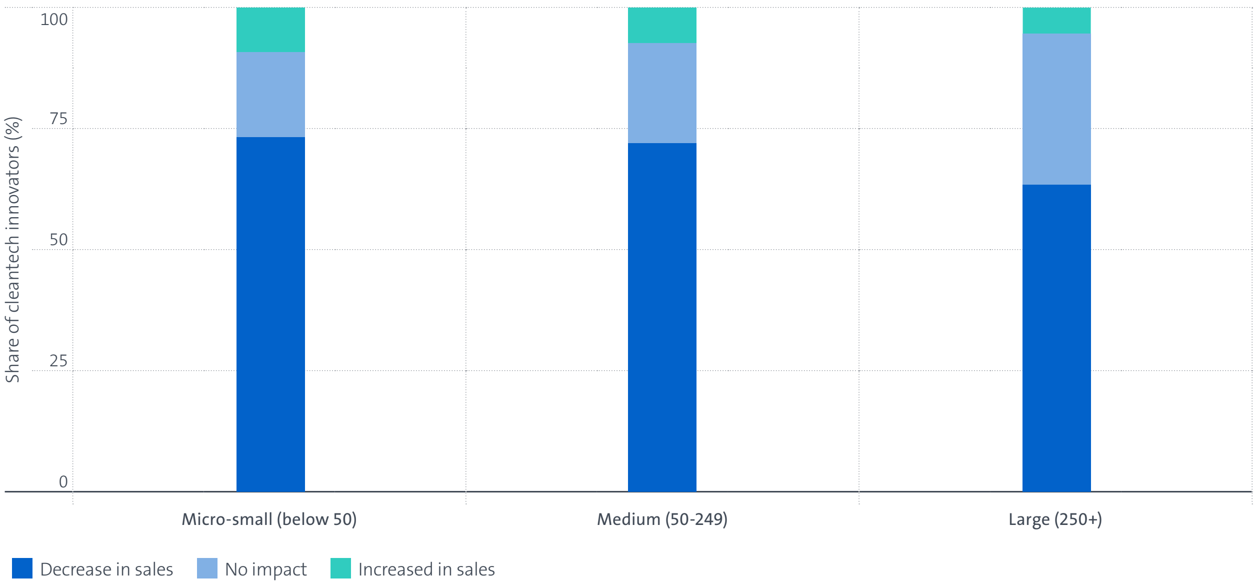
Note: Only EU firms considered.
Questions: What is the approximate share of people who are involved in R&D activities related to clean and sustainable technologies out of all the people currently working on R&D activities at your company?

Source: Cleantech Survey

The vast majority of EU cleantech innovators consider that their sales would have decreased if they had not invested in clean and sustainable technologies (Figure 27). This is especially the case for micro-small and medium companies, as approximately three out of four cleantech innovators assert this. Even though they may have a broader portfolio of projects, the proportion of large companies indicating that their sales would have declined without investments in clean and sustainable technologies remains substantial (64%). This underscores the importance of cleantech investments for these companies.

Figure 27

EU - Expected impact of NOT having invested in clean and sustainable technologies



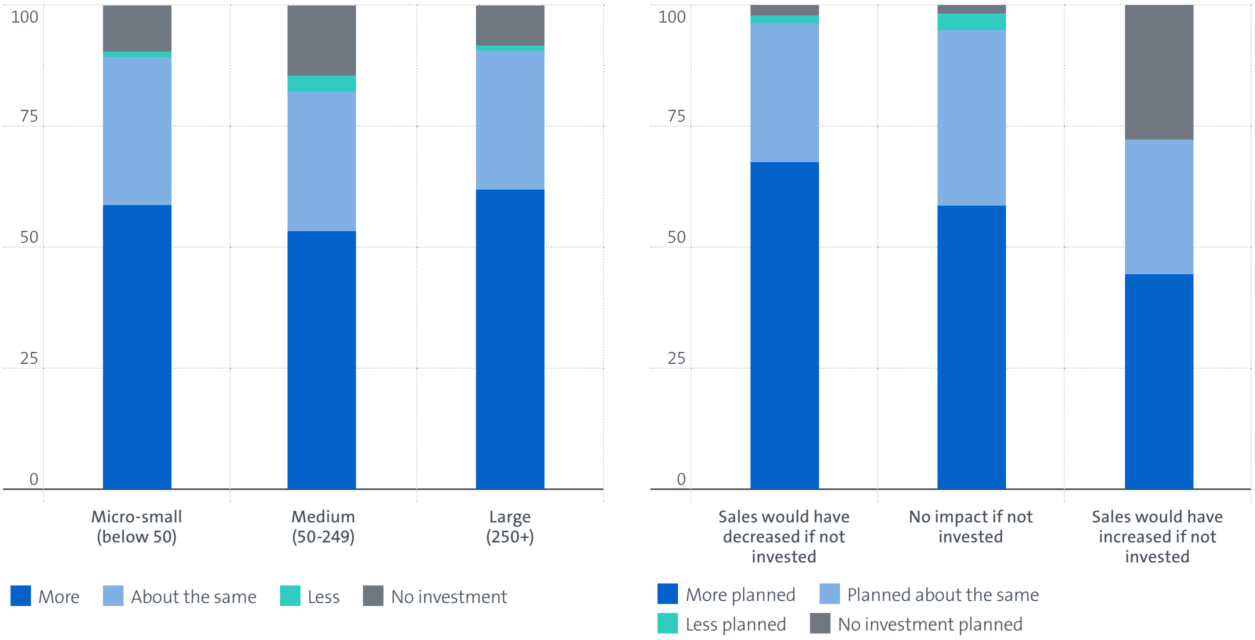
Note: Only EU firms considered. "Decreased" embodies both "decreased substantially" and "decreased slightly"; "increased" includes both "increased substantially" and "increased slightly".
Question: If your company had never invested in clean and sustainable technologies, what impact would that have had on your company's overall level of sales in 2022?
Sales would have ...

Source: Cleantech Survey

More than half of cleantech innovators are actively planning to further increase their investment in R&D related to clean and sustainable technologies in the next three years (Figure 28). About 30% report that they will invest the same amount, while less than 2% plan to invest less. In particular, EU firms who reported that their sales would have decreased or stayed the same without having previously invested in clean and sustainable technologies are planning to expand their cleantech investments in the future.

Figure 28

EU - Expected R&D investment in clean and sustainable technologies in the next three years



Note: Only EU firms considered.
Questions: In the next three years, do you expect your company to invest more, less or about the same in R&D related to clean and sustainable technologies? If your company had never invested in clean and sustainable technologies, what impact would that have had on your company's overall level of sales in 2022? Sales would have ...

Source: Cleantech Survey

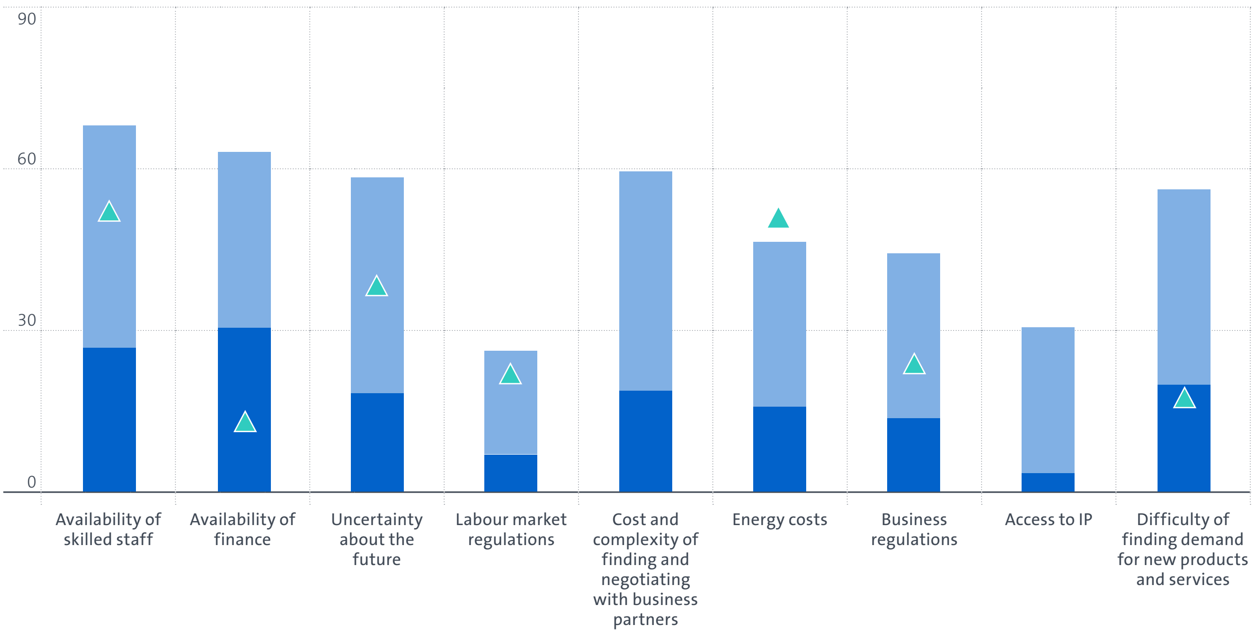
5.3 Structural barriers for EU cleantech innovators

Structural barriers affect the growth prospects of cleantech innovators. **EU cleantech innovators report a lack of finance and a shortage of staff with the necessary technical skills as the main challenges to their activities (Figure 29)**. Specifically, 30% of EU cleantech innovators cite financial constraints as a major hurdle, followed by 27% reporting a lack of staff with the right skills as a major impediment for their business activities related to clean and sustainable technologies. One out of five firms report that difficulty finding demand for their new products and services related to these technologies is a major concern, while the uncertainty, cost and complexity of finding and negotiating with business partners are major concerns for slightly less than a fifth of cleantech innovators.

Compared to cleantech innovators, the broader set of non-financial corporates surveyed in the EIB Investment Survey (EIBIS) seem to face similar barriers for their investment activities. One major difference stands out: compared to all firms covered in EIBIS as well as the innovative companies identified in EIBIS, **cleantech companies in the EU are much more likely than other (innovative) companies to consider that the lack of finance is an obstacle to their activities.** Cleantech innovators tend to complain less about other factors, however, such as labour market regulations or energy costs. Nevertheless, the lack of skills, the lack of demand for their products or services, and uncertainty also remain important obstacles for cleantech innovators.

Figure 29

EU - Lack of skills and lack of finance are the obstacles most cited by cleantech innovators



Note: Only EU firms considered. Only major obstacles were reported for EIBIS. Information on cost and access to IP are not available in EIBIS.
Question: Thinking about your company's business activities related to clean and sustainable technologies, to what extent is each of the following an obstacle?

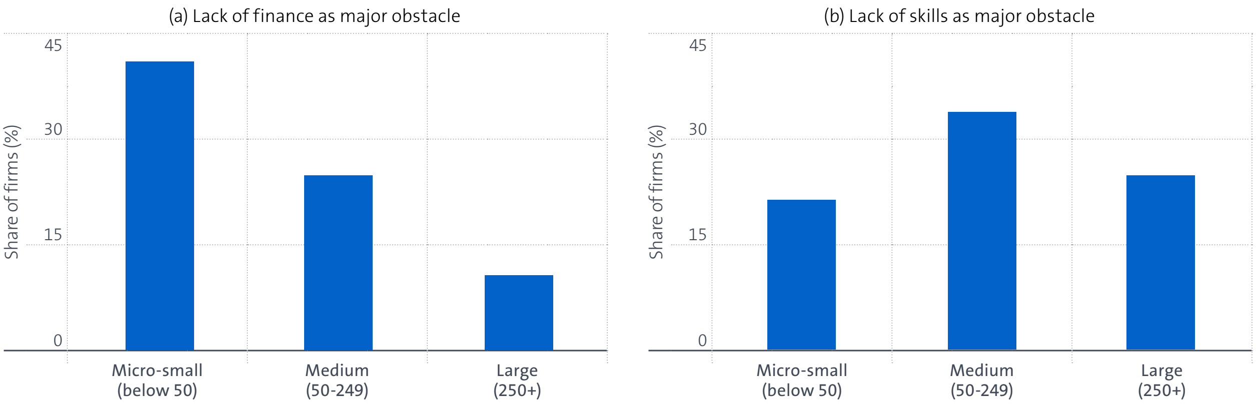
Source: Cleantech Survey, EIBIS 2023

Among cleantech innovators, the **micro-small ones are more likely than larger firms to identify lack of finance as a major obstacle**. This underscores that the lack of finance disproportionally poses a challenge for micro-small cleantech companies (Figure 30). In contrast, medium-sized cleantech innovators are more likely than their small counterparts to highlight skill gaps as a major challenge.

Cleantech innovators report that a lack of skills mainly lead to delays in bringing technologies to the market, followed by a failure or delay in scaling up and a failure or delay to enter new markets (Figure 31). Overall, a lack of finance has more important implications for smaller companies, especially by leading to a delay in bringing technologies to the market and a failure or delay in scaling up. A lack of skills on the other hand mainly seems to impact larger companies by causing a failure to or a delay in scaling up and entering new markets.

Figure 30

Financing is considered the main barrier by small cleantech innovators, and skills shortage by medium-sized ones

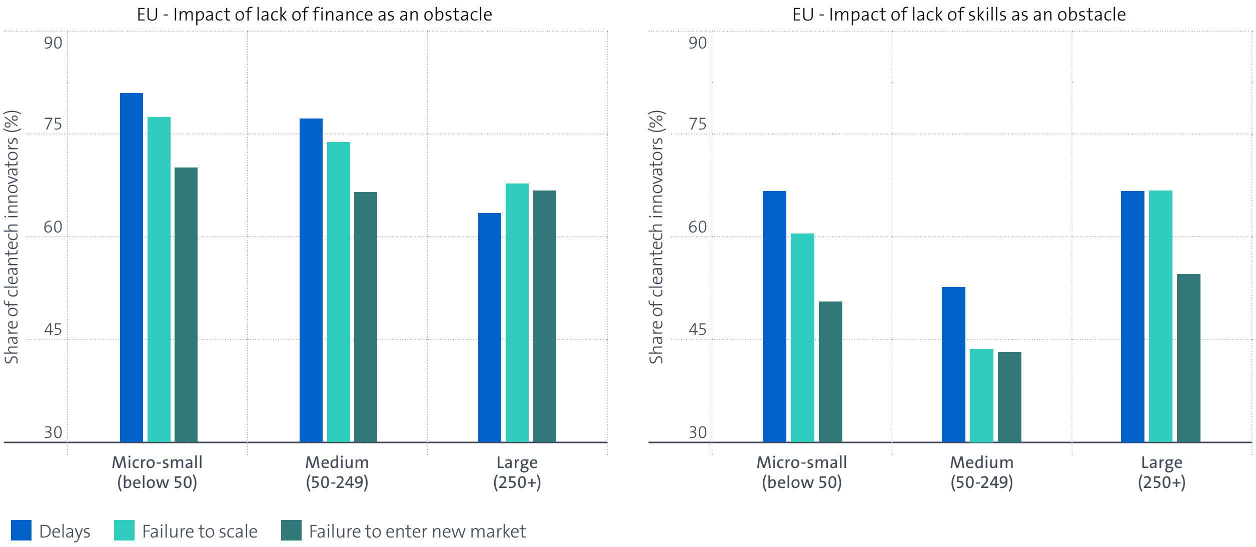


Note: Only EU firms reporting lack of finance (panel a) and lack of skills (panel b) as major obstacles were considered.
Question: Thinking about your company's business activities related to clean and sustainable technologies, to what extent is each of the following an obstacle?

Source: Cleantech Survey

Figure 31

Lack of finance and lack of skills have a significant negative impact on business activitiess



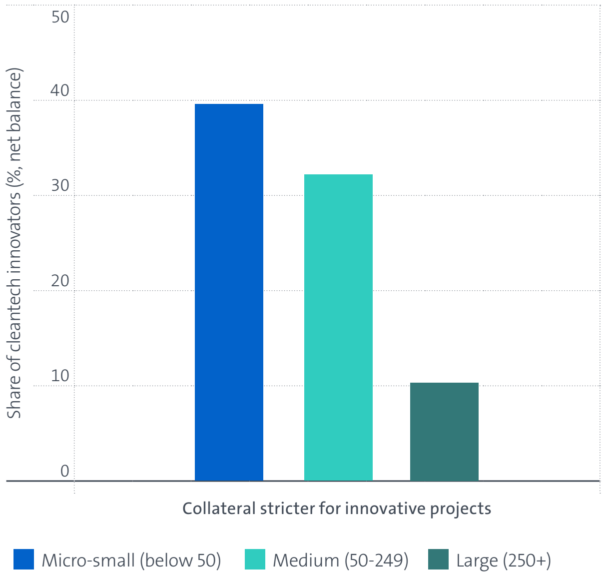
Note: Only EU cleantech innovators facing lack of finance/skills as an obstacle considered.
Question: You mentioned availability of staff with the right skills as an obstacle to your business activities related to clean and sustainable technologies. Has this caused one or more of the following?

Source: Cleantech Survey

Asked about financing the development or commercialisation of clean and sustainable technologies, on balance, **cleantech innovators are more likely to agree than disagree that collateral requirements for innovative projects are stricter** (Figure 32). Interestingly, **micro-small firms perceive more stringent conditions for their innovative projects than larger companies.** This resonates with earlier findings that smaller firms generally face greater financing obstacles.

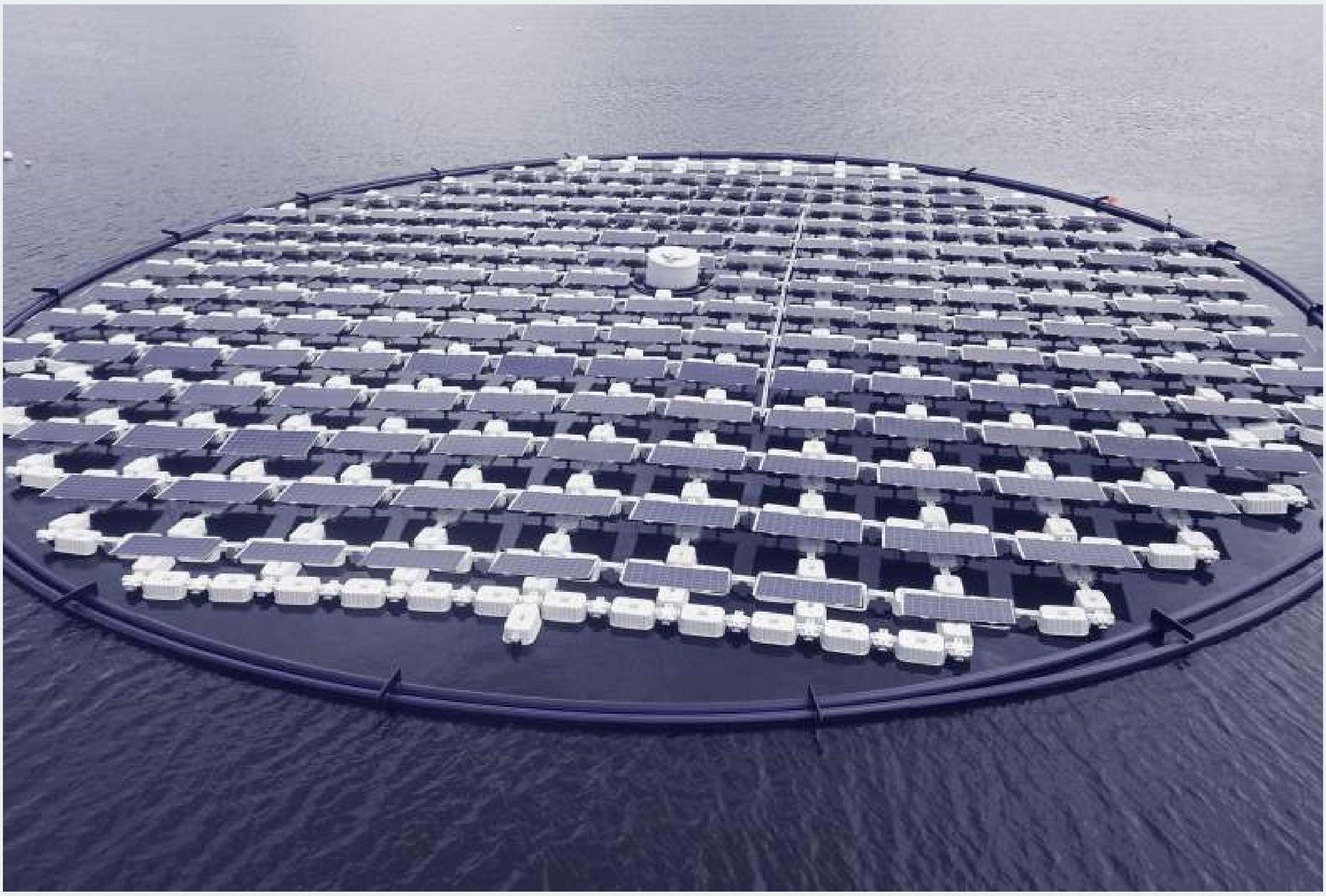
Figure 32

EU smaller cleantech innovators perceive more stringent collateral conditions for innovative projects



Question: To what extent do you agree or disagree with the following statements about financing the development or commercialisation of clean and sustainable technologies: "The collateral required for external finance is stricter for innovative projects"?

Source: Cleantech Survey



Case study: SolarisFloat (Portugal)

Company:	SolarisFloat Ltd.
Country:	Portugal
Founded:	2016
No. of employees:	10
Products:	Modular floating solar islands

The global demand for renewable energy is encouraging research in solar innovation, driving advances in fields such as materials science, nanotechnology, photovoltaic (PV) cell design and energy storage. Based in Portugal, SolarisFloat has developed Protevs, a system that enables an island with photovoltaic solar panels to rotate while the panels themselves can also be tilted. This floating island tracks the sun's movements throughout the day and can capture up to 40% more energy compared to stationary solutions. While SolarisFloat aims to commercialise Protevs, it contracted an external team of engineers to design and implement the system. Intellectual property rights formed a key part of contract negotiations and the agreement between SolarisFloat and its innovation partners.

Bringing a bright idea to life

While rotating panels had been successfully installed on land, few engineers had taken up the technical challenge of implementing a similar system on water. Waves, wind, currents, changes in water levels and weather conditions need to be factored into the design, as does the challenge of maintaining the system and the use of materials that can withstand exposure to water and UV radiation. To speed up research and development, SolarisFloat contracted a team of researchers at the Institute of Science and Innovation in Mechanical and Industrial Engineering (INEGI) in Porto.

The INEGI team developed a system featuring an onboard control and 180 tiltable photovoltaic panels in a circular island of about 38 metres in diameter. The island slowly rotates around a central point powered by electric motors, following the sun during the day before returning to its original position at night. Designed for lakes and reservoirs, the system is fixed in place by an outer ring moored with cables and anchors of flexible length, enabling it to move with water levels. The system is made from 100% recycled materials, with components built to withstand a wide variety of environmental conditions.

Currently, Europe is the largest market for the system. SolarisFloat also has partners in India and has an eye on South America, where Brazil is home to some of the world's largest dams. Floating solar power plants could potentially supply 80% of the country's energy if they were to cover 8% of the area in its 165 largest dams.

Partnership peace of mind

With climate change at the forefront of policy agendas, governments worldwide are offering incentives, subsidies, grants and research funding to support the transition to clean energy. This support is further underpinned by private sector investment. The marketplace for solar technologies is thus highly competitive, with multiple companies trying to gain a foothold. In crowded markets, a patent may help a company differentiate itself from a competitor. A strong patent portfolio can be a competitive advantage, highlighting research and development efforts to potential investors and partners.

For collaborative projects, patents and other intellectual property rights serve another vital function. SolarisFloat is part of the jp.group, a Portuguese business group operating in over 70 countries. Furthermore, the company has contracted various partners and worked with several teams, each of which contributed to the development of Protevs. Patents formed part of the earliest project discussions, and enabled the collaborators to define ownership rights and responsibilities while ensuring each party's contribution was recognised. In this agreement, the INEGI engineers are named inventors in the patents. SolarisFloat has retained ownership of the intellectual property and will use its patents to safeguard and monetise the system.

Further reading:
European Inventor Award 2022: meet the finalists

6. Unlocking cleantech innovation: the need for policy support

Fighting climate change stands as one of the critical imperatives of our time. At its heart lies the unwavering commitment to reducing greenhouse gas emissions, mitigating climate change and securing a resilient future for generations to come. Cleantech innovators will develop groundbreaking technologies that promise to revolutionise this landscape. Cleantech innovation demands substantial investment, spanning research and development up to commercialisation. However, the previous section has shown that their path is fraught with challenges, particularly in the realms of access to finance.

When asked about the one type of support that would most encourage them to continue to innovate in clean and sustainable technologies, **faster access to funding and consistent regulation within Europe are most frequently mentioned by EU cleantech innovators** (Figure 33).

Some noteworthy differences emerge when focusing on EU cleantech innovators in different size classes. **For micro-small firms, the most favoured type of support is faster access to funding**, as indicated by over half (51%) of firms surveyed. This is in line with the lack of finance cited as a major obstacle for these firms. While faster access to funding is also a priority for medium and large firms, it is less pronounced, with 32% and 20% respectively citing this as the most requested support.

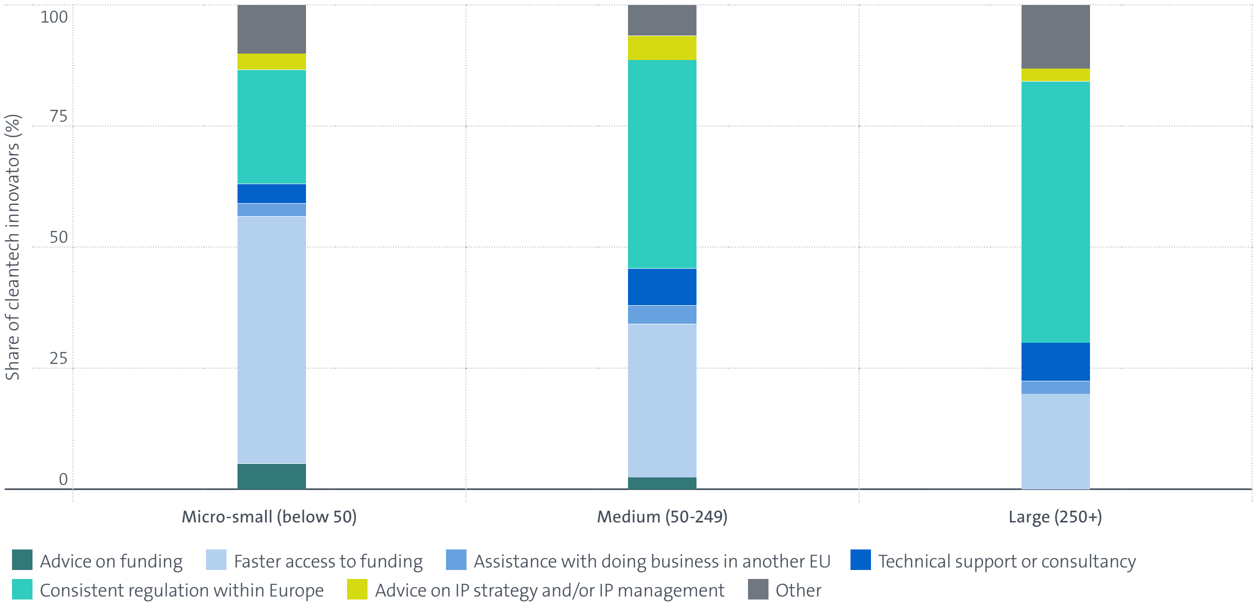
This study shows that a lack of access to finance can lead to a delay in bringing technologies to market, and a failure or delay in scaling up or entering new markets. The need for faster access to funding for innovative companies is grounded in some well-known market failures. Investments related to R&D and innovation are often very capital-intensive, with a high share of sunk costs. Once the investment is made, it is largely irreversible, making projects inherently risky since their potential benefits are perhaps not appropriable. In addition, given that knowledge is not tangible, it is difficult to own it.

Larger EU firms are most likely to identify consistent regulation within Europe as the most beneficial type of support, with 54% in agreement (Figure 33). This is echoed by 43% of medium firms and 23% of micro-small firms. They emphasise the importance of consistent and long-term regulation to incentivise the development of new technologies. Limiting market fragmentation, including in terms of standards and regulations, can help the cleantech sector to develop fruitfully.

Technical assistance or consultancy is reported as a policy priority by 8% of large and medium-sized firms, and 4% of micro-small firms. Advice on IP strategy and/or IP management is reported by 3 to 5% of EU firms. Support in the form of assistance in doing business in another EU country seem to be a less important priority, with only between 2 to 4% of firms across all size categories expressing this as their preferred type of policy support.

Figure 33

Preferred type of support: Micro-small cleantech innovators prefer fast funding while larger firms favour EU-wide consistent regulation



Note: EU cleantech innovators.
Question: Which one type of support would most encourage you to innovate further in clean and sustainable technologies? Select one category only.

Source: Cleantech Survey

Selected quotes from interviewees:

"Too many different standards and laws for the use of renewable energies (in the EU)."

"Legislations (in the EU) are very different."

"(There is a) lack of funding to grow the business."

"(We need) faster access to funding and advice on IP strategy."

"(We want) consistent regulation within Europe but also simplification of those (rules)."

"EU is currently in a global leadership position (in our technology area), but it must support the scale-up to build the industry here."

Box G: Inflation Reduction Act (IRA) – overview and potential impacts

The Inflation Reduction Act (IRA), is one of the most recent pieces of US industrial policy, expected to have significant impact on cleantech sectors.[22] This Box provides an overview of the IRA and discusses the potential reactions of cleantech innovators based on the Cleantech Survey.

Overview

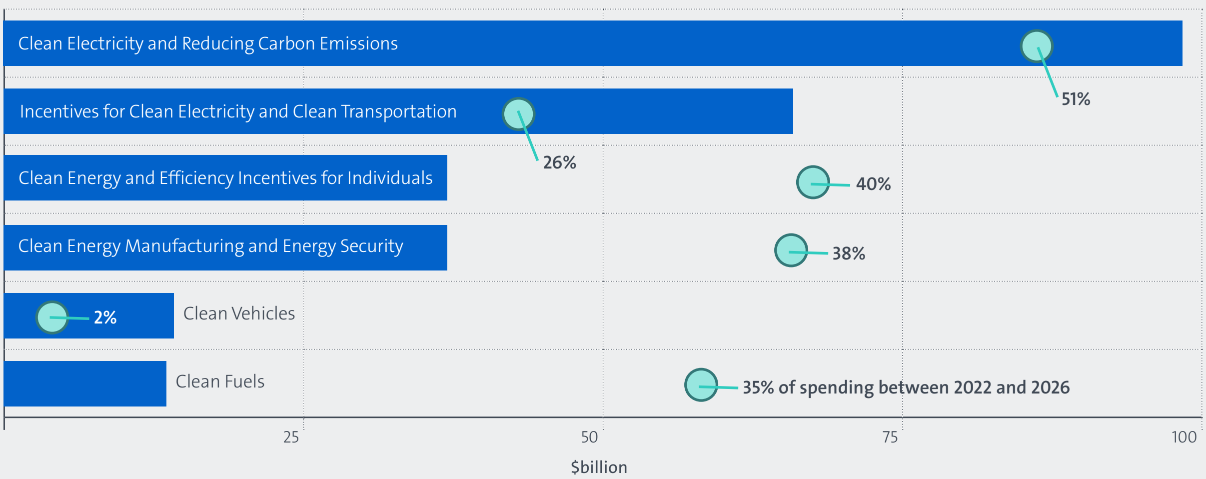
The Inflation Reduction Act is a broad package, both in scope and financial power, putting the United States back on track towards its climate targets. The IRA represents a substantial move to mobilise private sector funding for green technologies in the United States and beyond. The IRA increases the likelihood that the United States will achieve its 2030 target of reducing GHG emissions by 50–52% below 2005 levels as part of the Paris Agreement.[23] The IRA's funding is estimated to reach a total fiscal cost of USD 392bn, with substantial tax credits, mostly expiring in 2032, and capital to expand the US Department of Energy's lending capacity by USD 348bn.[24]

IRA support is visible and clear to the targeted sectors and provided in a way to limit the administrative burden on beneficiaries. The IRA relies heavily on tax credits for net-zero industrial manufacturers. By primarily relying on tax credits (70% of the IRA's funding), directly available to corporates and households, the IRA delivers cuts to production costs and subsidies to manufacturers quickly and in a predictable way. The substantial remaining part of IRA funding is aimed at financing large-scale infrastructure and scaling up of clean energy investments through US Department of Energy loans. Much effort has been made to clarify eligibilities and the application process in the first year. However, the IRA loan programmes are more complex to access and require that firms become familiar with the provisions and transaction process as the product is new to the market. Small US firms with high-growth potential, and which invest in green innovation key to net zero transformations, are more likely to receive grants than large innovative firms.

Despite its appeal to manufacturers of net-zero solutions, delays in the IRA's implementation, uncertainty around future funding, as well as China's dominant position on green supply chains, cast a shadow on the overall impact in terms of US environmental objectives and the competitiveness of domestic industries. The IRA aims at reducing production costs and enhancing the United States' ability to compete with China and to a lesser extent the European Union. But the IRA implementation is showing signs of delay, linked to challenges faced in the United States, particularly the high cost of financing and cost of inputs, weaknesses in nascent supply chains in certain sectors, ageing infrastructure (for example electrical transmission lines), and cumbersome regulations that have led to delays or cancellations of some planned investments. While the European Union shares these same challenges, early indications are that offshore wind and renewable energy projects are being even held back more in the United States than in the European Union due to these capacity constraints. Moreover, the IRA tax credits require continued fiscal support from US Congress. Difficult debt ceiling negotiations impose a degree of uncertainty on the availability of financing going forward.

Figure Box G1

Direct Spending on Energy Security by Thematic Area, 2022-2031



Source: Congressional Budget Office (2022) Estimated Budgetary Effects of H.R. 5376, the Inflation Reduction Act.

22 Since the IRA came into force in August 2022, there has been a boom in US manufacturing activity in the wind, solar and battery storage sectors. IRA trackers from the American Clean Power Association (ACP) show that 117 new utility-scale clean energy manufacturing facilities were announced in the first 18 months (75 weeks) of the IRA. These projects represent USD 421 billion in investment and are expected to create an additional 42 000 manufacturing jobs. For more details, see Clean Energy Investing in America | ACP (cleanpower.org) (accessed on 21 February 2024).

23 Recent estimates suggest that the United States is still expected to fall short of the Paris Agreement target, but the IRA is estimated to drive US emissions to 32–42% below 2005 levels in 2030 compared to 24–35% without the IRA (Rhodium Group).

24 The IRA's fiscal costs range from USD 392bn in the most conservative estimate (CBO, September 2022) to USD 1.2tn according to Goldman Sachs.

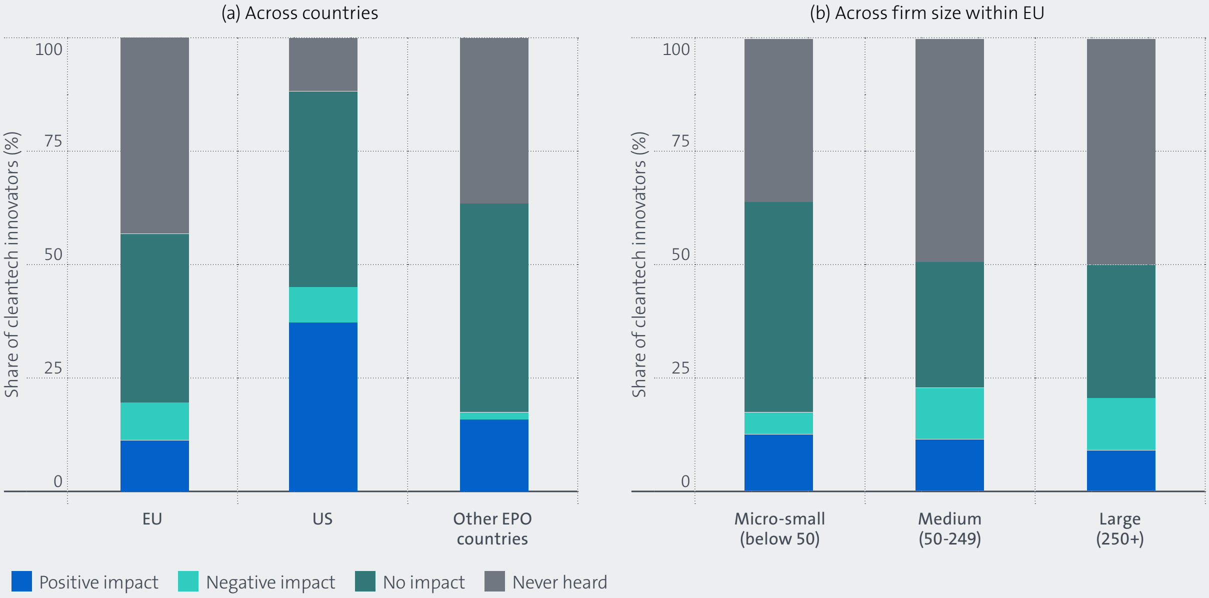
Potential impacts and reactions of cleantech innovators

The Cleantech Survey shows that **US cleantech innovators are clearly more aware of the IRA and tend to view it more positively than their EU counterparts**. At the time of the interviews (April–October 2023), around 90% of US-based cleantech innovators indicated that they were aware of the IRA, compared to around 60% of innovators in the European Union and other EPO member states (Figure Box G2). Furthermore, 37% of US cleantech innovators perceive the IRA as having a positive impact on their business, a view shared by only 11% of their EU counterparts and 16% of cleantech innovators in other EPO member states. A significant proportion of firms in the EU and other EPO member states, 38–46%, and the United States, 43%, report no impact by the IRA on their business.

Within the European Union, **smaller innovators tend to have a more positive view of the IRA than their larger counterparts.** Around 65% of EU micro-small cleantech innovators are aware of the IRA, with 12% viewing it positively and only 5% negatively. In contrast, awareness of the IRA drops to around 50% among medium and large cleantech innovators, with a balanced share having a negative (12% for both size classes) and positive perception (11% for medium and 9% for large cleantech innovators).

Figure Box G2

US cleantech innovators show a higher awareness and more positive perception of the IRA compared to their EU counterparts



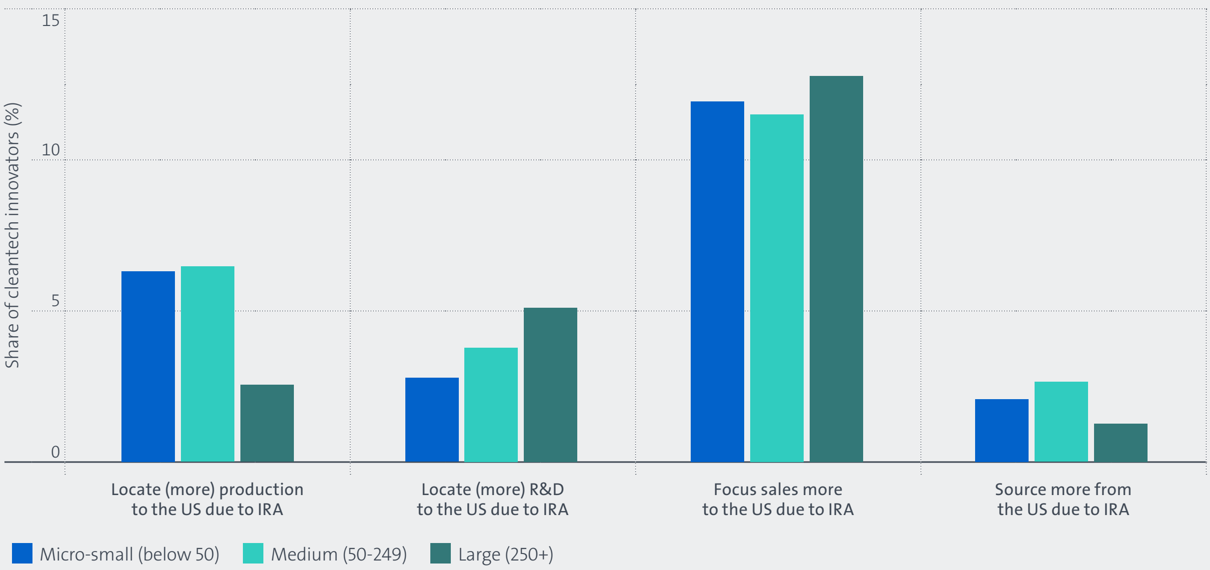
Questions: Is the US Inflation Reduction Act impacting your business related to clean and sustainable technologies?

Source: Cleantech Survey

Only a fraction of EU firms are reacting to the IRA with active strategies. Around 12% of micro-small innovators indicate that they are currently increasing their sales focus towards the United States or have plans to do so (Figure Box G3). These figures are relatively stable across firm sizes, with around 12-13% of medium and larger innovators indicating a similar reponse. Only a fraction of firms in the European Union are considering (more) production or (more) R&D activity in the United States.

Figure Box G3

EU - Measures taken or planned as a response to the US Inflation Reduction Act



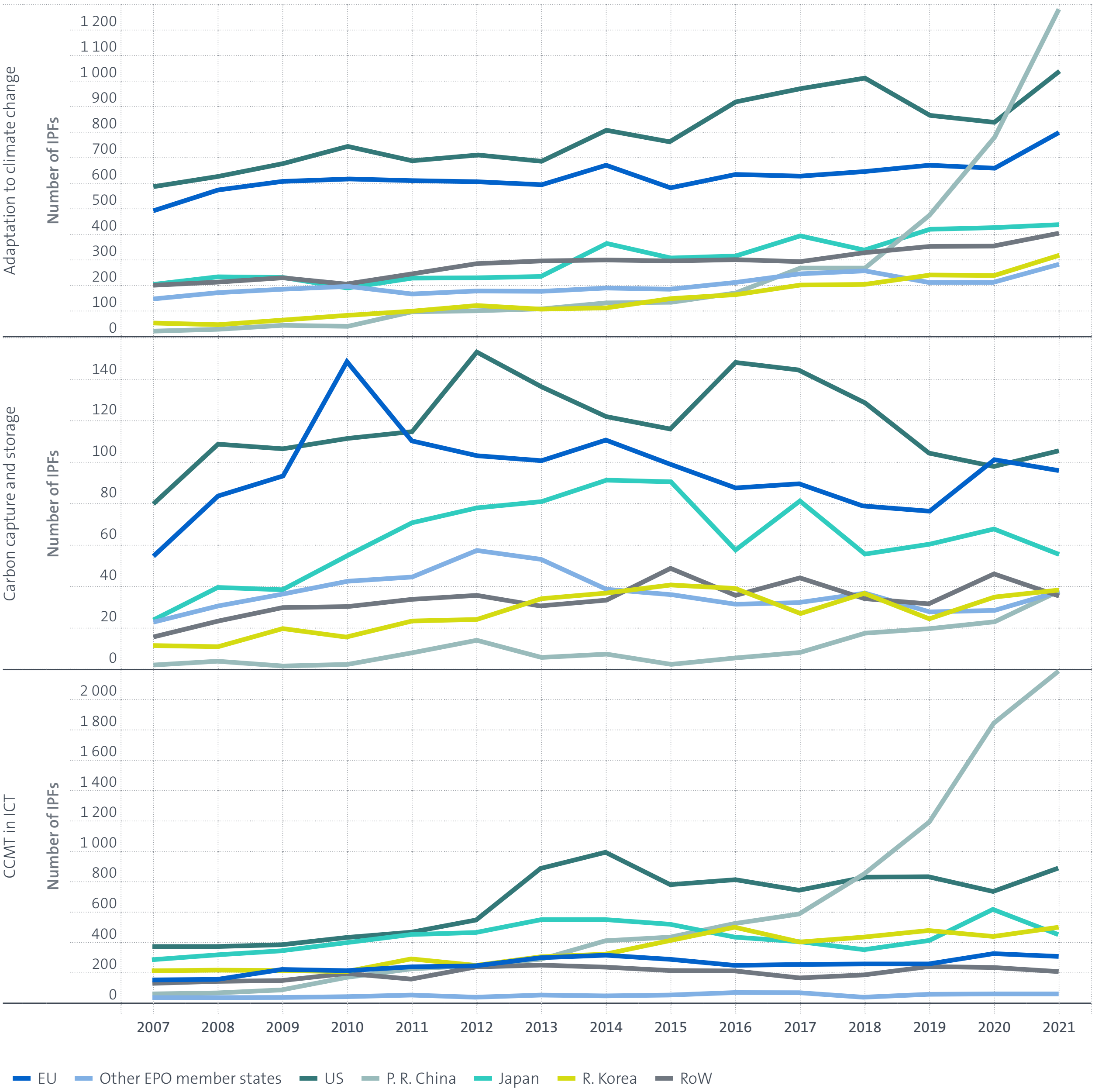
Note: All EU cleantech innovators considered.
Questions: Is the US Inflation Reduction Act impacting your business related to clean and sustainable technologies? Since the US Inflation Reduction Act is impacting your business related to clean and sustainable technologies, are you taking, or do you plan to take any of the following measures?

Source: Cleantech Survey

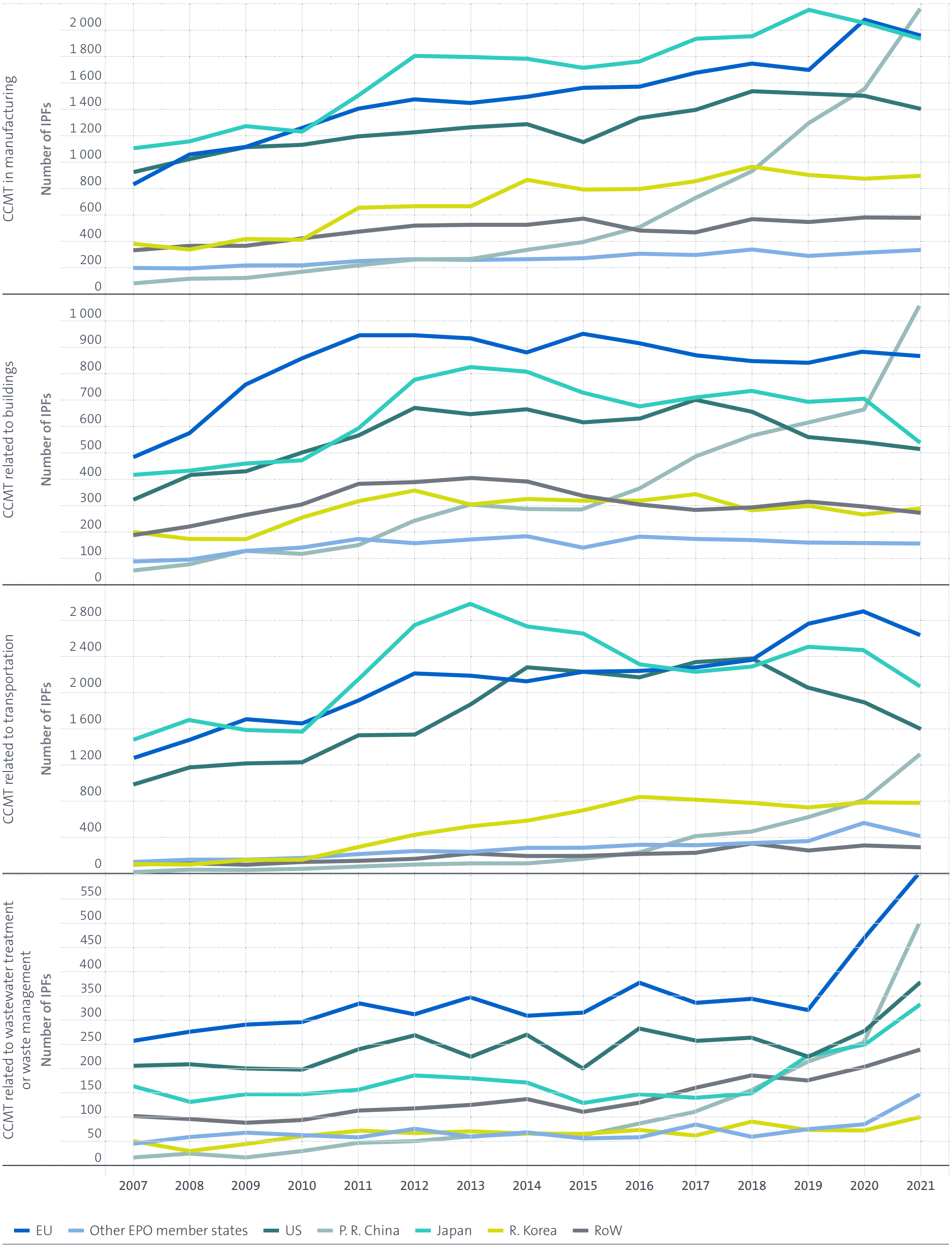
ANNEX 1: Patenting trends and specialisation in individual clean and sustainable technology fields

Figure A1

Trends in IPFs in clean and sustainable technologies by technology field and country of origin, 1997–2021



Source: EPO


CCMT in manufacturing
Number of IPFs
2 000
1 800
1 600
1 400
1 200
1 000
800
600
400
200
0
CCMT related to buildings
Number of IPFs
1 000
900
800
700
600
500
400
300
200
100
0
CCMT related to transportation
Number of IPFs
2 800
2 400
2 000
1 600
1 200
800
400
0
CCMT related to wastewater treatment or waste management
Number of IPFs
550
500
450
400
350
300
250
200
150
100
50
0
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
EU
Other EPO member states
US
P. R. China
Japan
R. Korea
RoW

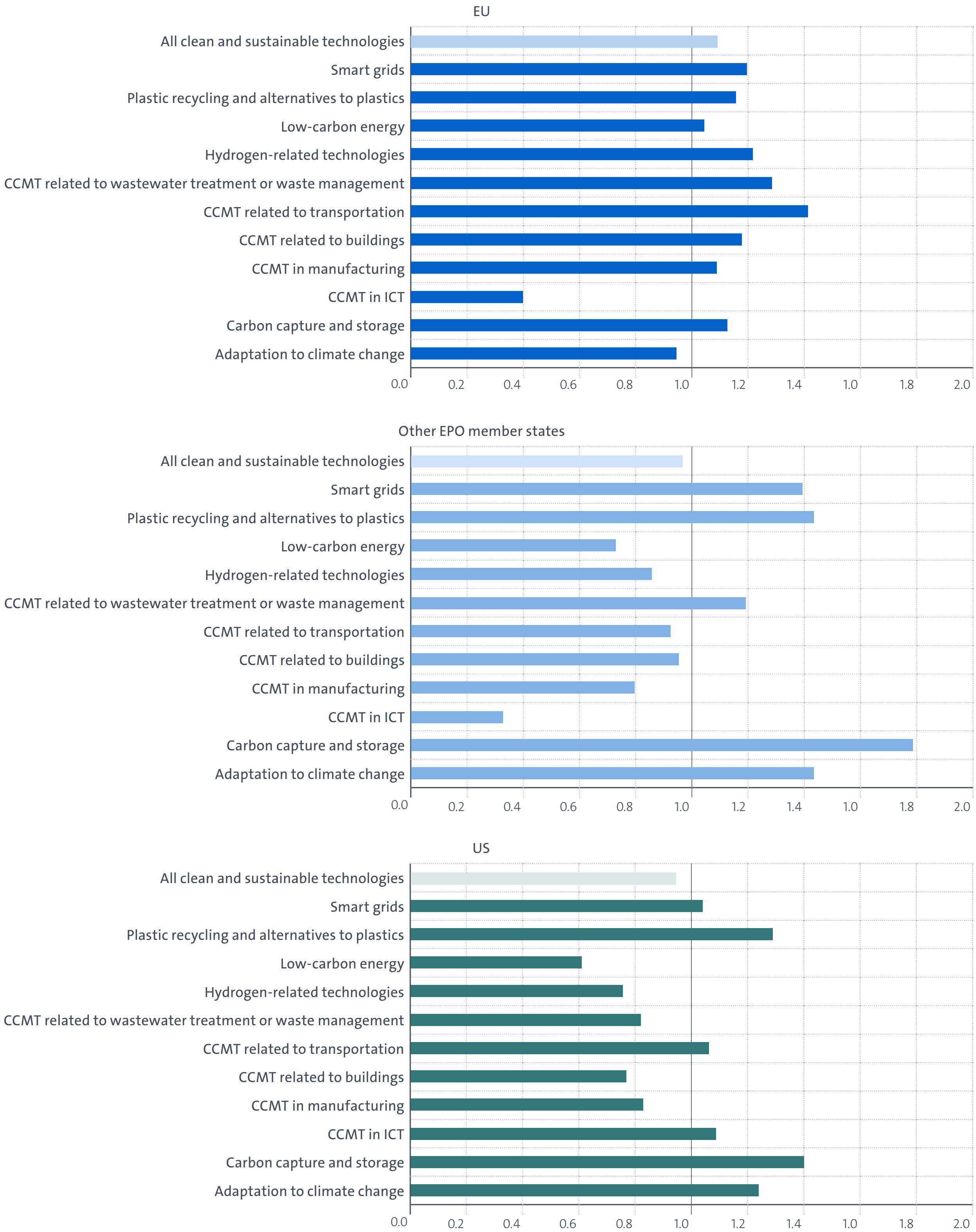
Source: EPO


Hydrogen-related technologies
Number of IPFs
550
500
450
400
350
300
250
200
150
100
50
0
Low-carbon energy
Number of IPFs
4 500
4 000
3 500
3 000
2 500
2 000
1 500
1 000
500
0
Plastic recycling and alternatives to plastics
Number of IPFs
2 400
2 000
1 600
1 200
800
400
0
Smart grids
Number of IPFs
350
300
250
200
150
100
50
0
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
EU
Other EPO member states
US
P. R. China
Japan
R. Korea
RoW

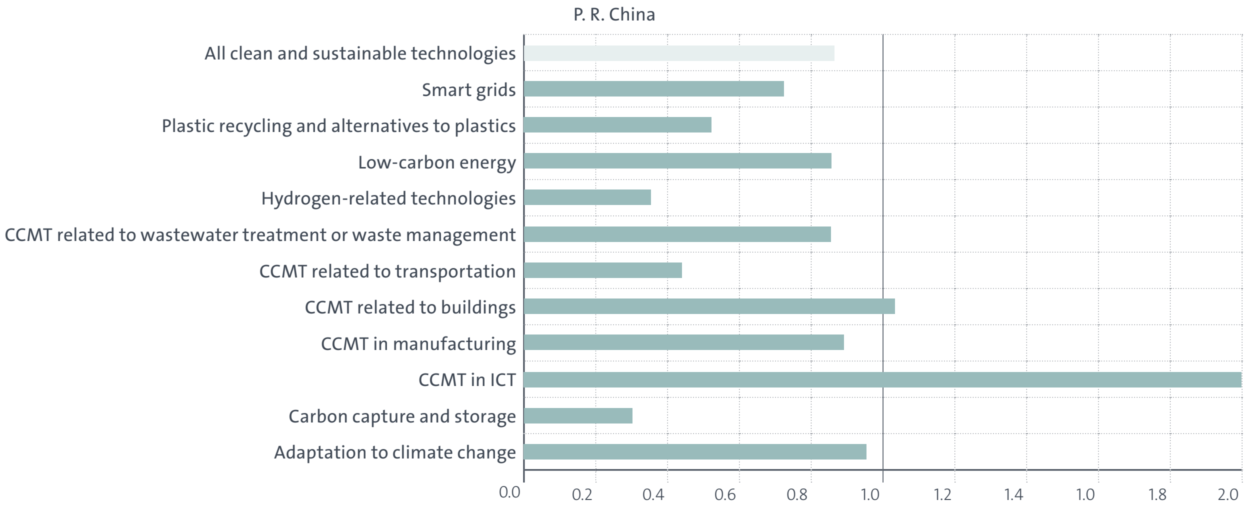
Source: EPO

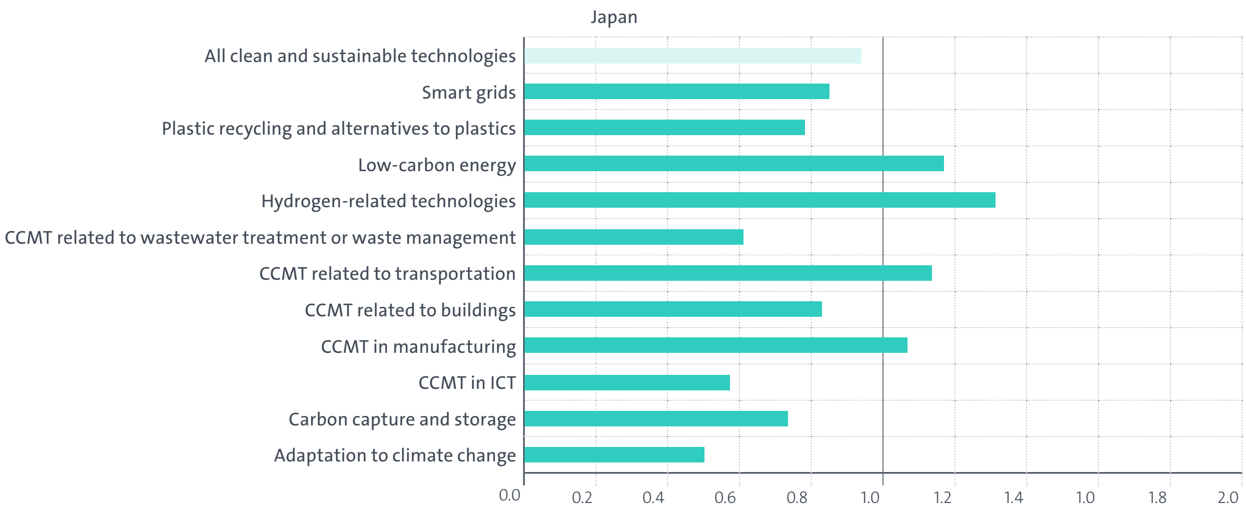
Figure A2

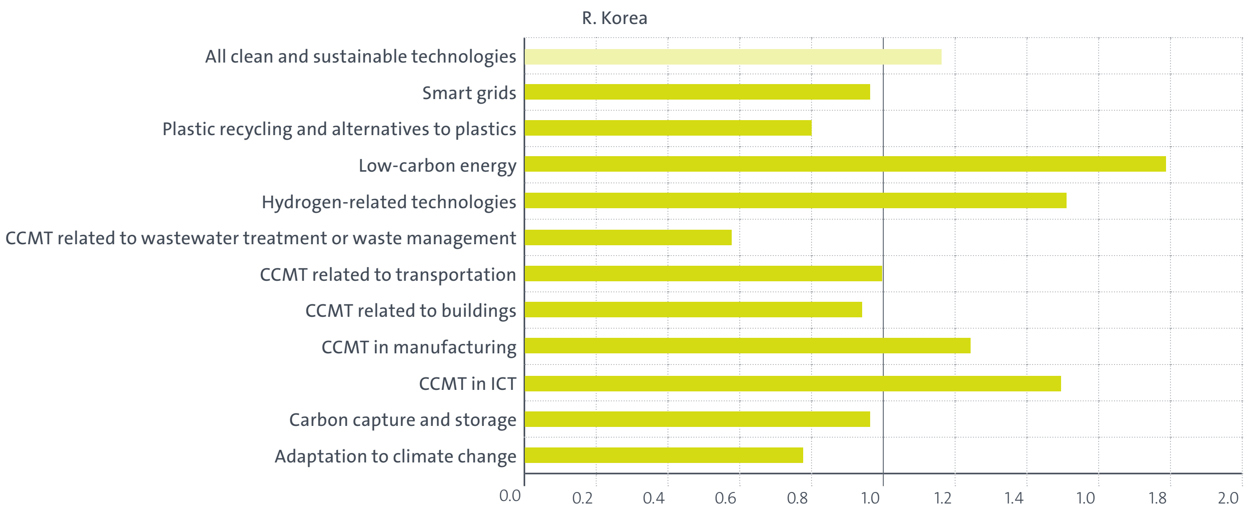
RTA in clean and sustainable technologies by country of origin and technology field based on IPFs, 2017–2021



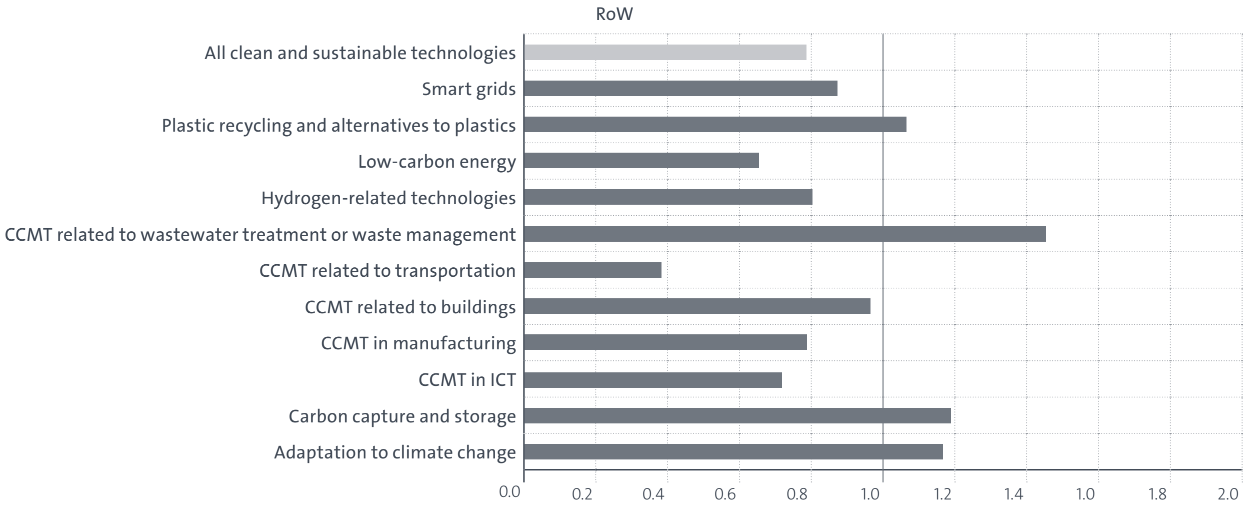
Source: EPO


P. R. China
All clean and sustainable technologies
Smart grids
Plastic recycling and alternatives to plastics
Low-carbon energy
Hydrogen-related technologies
CCMT related to wastewater treatment or waste management
CCMT related to transportation
CCMT related to buildings
CCMT in manufacturing
CCMT in ICT
Carbon capture and storage
Adaptation to climate change
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.0
1.8
2.0


Japan
All clean and sustainable technologies
Smart grids
Plastic recycling and alternatives to plastics
Low-carbon energy
Hydrogen-related technologies
CCMT related to wastewater treatment or waste management
CCMT related to transportation
CCMT related to buildings
CCMT in manufacturing
CCMT in ICT
Carbon capture and storage
Adaptation to climate change
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.0
1.8
2.0


R. Korea
All clean and sustainable technologies
Smart grids
Plastic recycling and alternatives to plastics
Low-carbon energy
Hydrogen-related technologies
CCMT related to wastewater treatment or waste management
CCMT related to transportation
CCMT related to buildings
CCMT in manufacturing
CCMT in ICT
Carbon capture and storage
Adaptation to climate change
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.0
1.8
2.0

Source: EPO


RoW
All clean and sustainable technologies
Smart grids
Plastic recycling and alternatives to plastics
Low-carbon energy
Hydrogen-related technologies
CCMT related to wastewater treatment or waste management
CCMT related to transportation
CCMT related to buildings
CCMT in manufacturing
CCMT in ICT
Carbon capture and storage
Adaptation to climate change
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.0
1.8
2.0

Source: EPO

ANNEX 2: Cleantech Survey methodologies

Box H: Crunchbase and EIBIS

Crunchbase

Crunchbase is a commercial database that provides information on companies worldwide, focusing on the startup ecosystem, venture capital funding, and other business activities. It provides insights into company financials, team members, and industry trends, making it a valuable tool for investors, entrepreneurs, and market researchers.

EIBIS

The European Investment Bank Investment Survey (EIBIS) is a unique survey, conducted annually by the European Investment Bank (EIB) since 2016, providing details on the investment and financing decisions of EU non-financial corporates (including SMEs, mid-caps and very large firms). Each year, the EIBIS completes about 12 000 interviews with EU firms. Since 2019, it has also included about 800 companies in the United States, providing a valuable benchmark to understand the similarities and differences in investment and financing patterns between the European Union and the United States.

Cleantech Survey

The objective of this survey was the collection of information regarding the commercialisation of clean and sustainable technologies by surveying target people from companies in Europe (EPO member states) and the United States that applied for a patent application between 2011 and 2022 for inventions in at least one of the 11 pre-defined technical areas.

The survey mode was designed to take into account different preferences and cultural behaviour in certain regions and countries by offering a choice of survey method, namely CATI (computer-assisted telephone interviews) and CAWI (computer-assisted web interviews).

To optimise the distribution of interviews across countries, a target quota was defined for the United States and Europe.

Questionnaire design

The questionnaire was designed to collect information about certain aspects of the technology related to the patent application and its commercialisation, as well as the companies' investment in R&D, financing and obstacles related to clean and sustainable technologies.

The survey languages were defined as English, German and French.

To evaluate the survey questionnaire, questions had to be tested under real interview conditions. For this reason, pilot interviews were conducted to test:

- whether the wording of the questions worked in practice
- if the questions were clear, and whether any explanatory notes or briefings were needed for the interviewers
- the interview length

Pilot interviews began on 4 April 2023 and ended on 21 April 2023. After evaluation of these pilot interviews, the questionnaire was modified and approved for the general fieldwork.

Survey programming

A master version was programmed first and underwent a two-step check. The first step was to test the survey logic for errors, as follows:

- question routing
- display logic
- rotation/randomisation

Test interviews were conducted covering the different routes through the survey and texts to be displayed. The logic and data capture were checked and any errors corrected. After starting the fieldwork, or approximately after 30 full interviews had been conducted, the logic and data capture under real conditions were checked again.

After the master version was released, it was used as a template to ensure that the English, German and French translated versions all had the same technical structure. Each language version was then programmed separately and reviewed by native speakers, with corrections being made where necessary. After all checks had been completed, the English, German and French surveys were released for the start of fieldwork.

Sampling

Sampling is the process of selecting a subset of the population for data collection, based on a study's objective(s) and the population.

For this study, the population consisted of companies that, firstly, have filed at least one application in pre-defined technical areas at the EPO. The time span for the filing year of the applications in the population was defined as the years from 2011 to 2022. Furthermore, the regional location of the applicant companies in the population were defined as Europe (EPO member states) and the United States and the size of the companies was limited to 5 000 employees.

For the sampling, an extraction of the applicant companies was provided by the EPO, based on the above population definition. It resulted in N = 8 424 applicant companies altogether, where N = 4 848 were EPC countries and N = 3 576 were companies from the United States.

Additionally, all related patent applications that fell under the defined technical areas were extracted and linked to the applicant companies in the population. Depending on the number of linked applications for each applicant company, a maximum of three applications were selected. The applications selected were used during the fieldwork to clarify to the respondents the technical field in focus, which was the subject of the survey.

Finally, N = 6 003 applicant companies (sampling units) were selected and processed during fieldwork for the collection of interview data, 3 275 in Europe and 2 728 in the United States.

The processed applicant companies were selected randomly within the strata of country/country groups, along with the number of applications of the company and the current status of the company (operating, initial public offering, acquired).

For the quota stratification, the targeted number of interviews in the fieldwork were projected as N = 600 for EPC countries and N = 200 for the United States. A lower expected response/completion rate and a limited number of applicant companies in the population were taken into account when setting the disproportionally lower interview target number for the United States.

Table A1

Population by country/country group and the targeted number of interviews

Country/country group	Target (N)	Population (N)
BeNeLux[1]	600	367
France		695
Germany and Austria		1 045
Italy		392
Scandinavia[2]		715
Spain		218
Switzerland		365
United Kingdom and Ireland		912
Other EPO member states		139
Total Europe		**4 848**
United States	200	3 576
Total	**800**	**8 424**

1 Belgium, Netherlands, Luxembourg
2 Denmark, Finland, Norway, Sweden

Fieldwork

Fieldwork started on 4 April 2023, with pilot interviews completed first in order to test the questions with real respondents. The fieldwork was closed on 12 October 2023.

The sampling data were divided across the different language versions of the survey software. A database sample management was used to manage sample control, monitoring and operator management.

For fieldwork management, each unit of the sampling was assigned into assembled batches by the strata of country/country group, the number of applications of the company and the current status of the company. The batches were processed sequentially, after a batch became exhausted. The sample units were selected at random within each batch. Therefore, all units within a batch were initially equally likely to be selected to be contacted for the first time. Depending on the current outcome of the latest contact attempt, the units were either put on a list to be automatically contacted or reminded again, an appointment was made to call or write an email to the target person of the specific company, or the operator noted that the companies were not to be contacted again (e.g. because they had declined to participate). This automatic procedure determined when a company was suggested to be re-contacted if a previous contact had not produced a definitive result.

The automatic re-suggestion maximised use of the sampling and compensated at least partly for significant fluctuations in the likelihood of a response between the different country/country group strata.

Experience shows that the most successful method of contacting companies differs between geographical regions and even between countries. Whereas in the US an approach by telephone is unlikely to result in a potential contact with a target person, an approach by email is generally much more promising. By contrast, in Europe, a contact approach by telephone is often more successful. For this reason, a mixed methodology for both Europe and the US, using both CATI and CAWI, was employed.

During the fieldwork, N = 6 003 applicant companies were processed.

Table A2

Processed sampling units by country/country group

Country/country group	Target (N)	Processed sampling units (N)	Population (N)
BeNeLux[1]	600	205	367
France		500	695
Germany and Austria		881	1 045
Italy		190	392
Scandinavia[2]		372	715
Spain		165	218
Switzerland		222	365
United Kingdom and Ireland		618	912
Other EPO member states		122	139
Total Europe		**3 275**	**4 848**
United States	200	2 728	3 576
Total	**800**	**6 003**	**8 424**

1 Belgium, Netherlands, Luxembourg
2 Denmark, Finland, Norway, Sweden

Net sample

The net sample resulted in N = 658 interviews.

Table A3

Interviews conducted by country/country group

Country/country group	Target (N)	Interviews (N)	Processed sampling units (N)	Population (N)
BeNeLux[1]	600	30	205	367
France		31	500	695
Germany and Austria		272	881	1 045
Italy		17	190	392
Scandinavia[2]		68	372	715
Spain		33	165	218
Switzerland		32	222	365
United Kingdom and Ireland		47	618	912
Other EPO member states		39	122	139
Total Europe		**569**	**3 275**	**4 848**
United States	200	89	2 728	3 576
Total	**800**	**658**	**6 003**	**8 424**

1 Belgium, Netherlands, Luxembourg
2 Denmark, Finland, Norway, Sweden

The completion rate (calculated by processed sample units, divided by conducted interviews) was lowest at 3.3% in the US. The most frequent problem in the US was the low email response rate combined with relatively unsuccessful telephone contact attempts. Higher completion rates were achieved in Europe, ranging from 6.2% in France up to a very respectable 30.9% in Germany and Austria.

The mean length of all interviews conducted was 15 minutes (outliers having been discarded from this calculation).

Data preparation and validation

Once the fieldwork was finished, open text data were scanned, and the captured data were checked for:

- completeness
- conditional logic
- consistency – whether the answers given by a respondent are consistent, and closer analysis of any inconsistent interviews, which were removed from the data if necessary
- plausibility – whether the answers given by a respondent are plausible, and closer analysis of any implausible interviews, which were removed from the data if necessary

In addition, an evaluation of the question TS08: *Which of the following larger technology fields does the technology relate to?* was performed together with the description of the relevant patent applications in order to exclude companies whose technology is clearly not related to clean and sustainable technologies. Overall, 56 companies were excluded from the final sample, resulting in a total final sample of 604 companies, of which 81 were from the US and 524 from EPO member states.

Table A4

Cleantech Survey data, by country group

	Number of observations	Percentage
EU (Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Spain, Sweden)	434	73.2%
US	77	13.0%
Other EPO member states (Iceland, Norway, Switzerland, UK, Türkiye)	82	13.8%

Table A5

Cleantech survey data, by firm size

	Number of observations	Percentage
Micro-small (fewer than 50 employees)	211	48.6%
Medium (50–249 employees)	113	26.0%
Large (250+ employees)	110	25.4%

ANNEX 3: Technology fields in the Cleantech Survey

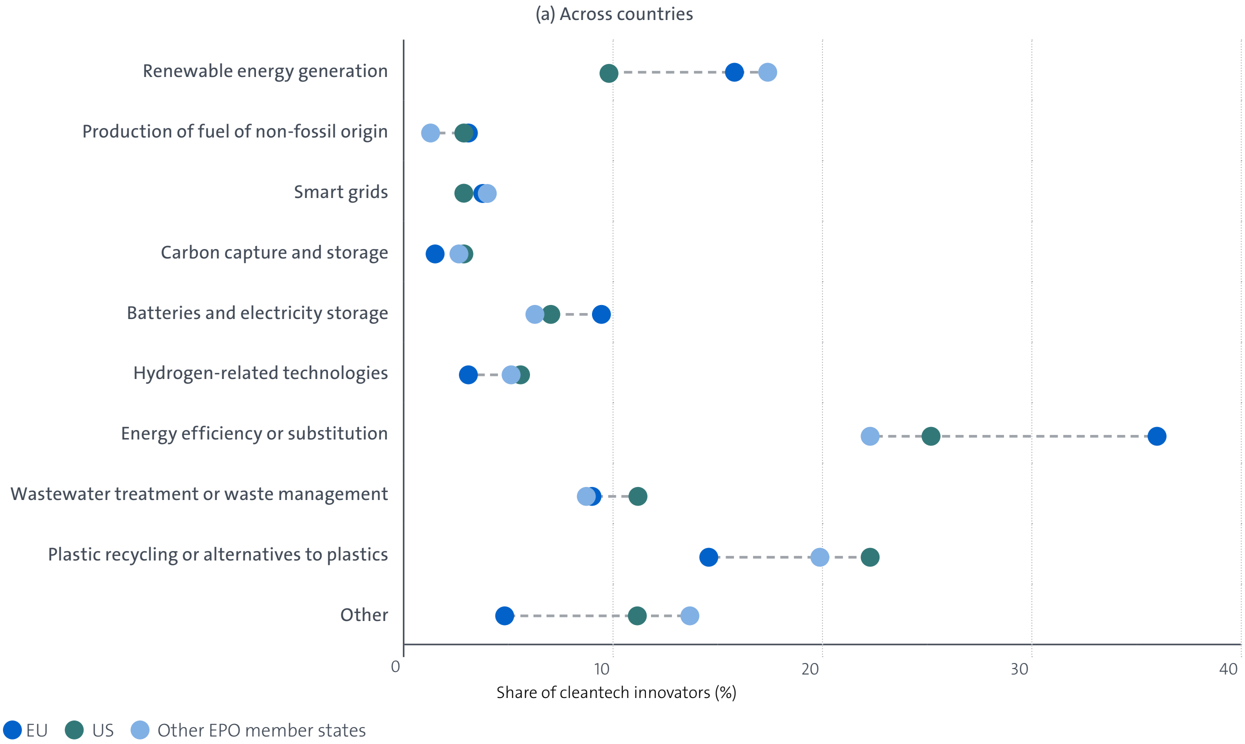
The importance of different technology fields reported by firms in the Cleantech Survey is well aligned with the overall patent trends in different clean and sustainable technologies (see Chapter 2). Asked to focus on the patent application they selected for the interview, **energy efficiency or substitution emerges as the most cited technology field**, cited by 36% of EU cleantech innovators (Figure 11). This is also the most common technology field for companies in the US (25%) and other EPO member states (22%), albeit to a lesser extent than in the EU.[25]

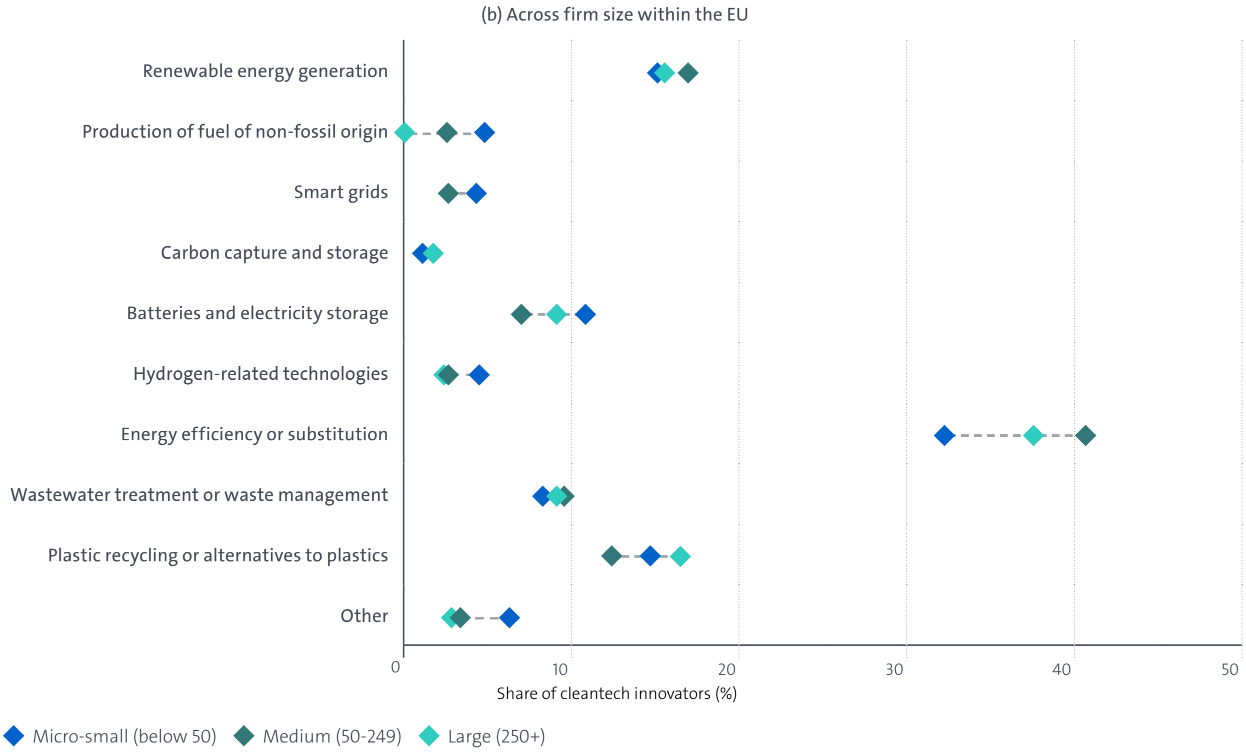
Renewable energy production and plastic recycling or plastic alternatives are also cited by a large share of companies. Batteries and electricity storage technologies are the focus of around 9% of EU cleantech innovators, compared to 7% in the US and 6% in other EPO member states. Approximately 3% of cleantech innovators in the EU and 6% in the US report hydrogen-related technologies as the focal technology field of their cleantech invention. Carbon capture and storage is less mentioned as the main technology field, cited by fewer than 2% of firms within the EU and almost 3% of cleantech innovators in the US.

25 It was agreed to present the technology distribution based on the survey results and not the patent classification, since an invention can be assigned to different patent classes based on the technology description, but it was important to understand which is the main technology field according to the interviewed company.

Figure A3

Energy efficiency or substitution is the most common technology focus of cleantech innovators





Question: Which of the following larger technology fields does the technology relate to

Source: Cleantech Survey

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