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Office européen des brevets

Innovation in water-related technologies

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Foreword

Water is one of our most precious resources. Yet under the increasing impact of climate change, society now faces major challenges not only in terms of water supply, but also of flooding. At one extreme, 2.2 billion people lack access to safe drinking water, as UNESCO reports in their latest Water Development Report. Droughts are becoming more severe and persistent on a global scale. At the other extreme, devastating floods are increasingly frequent and destructive. Technological innovation on both fronts, to improve water supply where it is lacking or threatened, and to provide protection against water-related hazards, is thus critical and urgent.

The EPO, with its comprehensive patent databases, is well positioned to shed light on the innovation landscape surrounding these topics. We are hopeful that our work will be useful and valuable for everyone with a stake in water, be they inventors, researchers, policymakers or the general public.

The results of our study on water-related technologies convey a mixed message: while these technologies are steadily advancing, often supported by new or changing regulations, more needs to be done to meet the challenges we face. Europe is an innovation powerhouse in this regard, with applicants from the EPO's 39 member states accounting for 40% of all international patent families concerning water-related technologies and exhibiting a fairly high level of specialisation. This is encouraged by policy measures and the evolution of the regulatory framework in Europe and worldwide. Several European countries actively promote research and innovation in the water sector through targeted policies. At the same time, other countries outside Europe like Australia, India and Israel – all particularly exposed to threats of water shortages and flooding – are also showing the way in leveraging technology to address those challenges.

This study benefited from a dedicated technology platform that we built to run in Espacenet and which is freely accessible: "Innovation in water technologies" is designed to empower innovators in the field. It allows researchers to explore more easily the rich technical information in patents and identify the latest advances and cutting-edge developments, as well as discover opportunities for further research. Moreover, the new "water" filter in our Deep Tech Finder will facilitate the identification of promising startups.

Both the study and the platform were developed in the framework of the EPO's Observatory on Patents and Technology, which was established in 2023 to further enable and foster collaboration with the EPO's stakeholders. This allowed EPO experts to work together with fourteen national patent offices in our member states and a further national patent office in one of our validation states; namely Austria, Bulgaria, Cyprus, the Czech Republic, Finland, France Germany, Italy, Monaco, the Netherlands, Slovenia, Sweden, Türkiye, the United Kingdom and Morocco.

I hope you find the study and the platform interesting and gain new insights into these important and urgent topics.

António Campinos
President, European Patent Office

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List of abbreviations

AI	Artificial intelligence
ARIPO	African Regional Intellectual Property Organization
DTF	Deep Tech Finder
EAPO	Eurasian Patent Organization
EPA	Environmental Protection Agency
EPO	European Patent Office
EU	European Union
EWA	European Water Association
GCCPO	Patent Office of the Cooperation Council for the Arab States of the Gulf
ICT	Information and communication technology
IPFs	International patent families
NIDIS	National Integrated Drought Information System
NOAA	National Oceanic and Atmospheric Administration
OAPI	African Intellectual Property Organization
PFAS	Per- and polyfluoroalkyl substances
PROs	Public research organisations
R&D	Research and development
RTA	Revealed technological advantage
USDA	US Department of Agriculture
UN SDGs	United Nation's Sustainable Development Goals
WISE	Water Information System for Europe
WFD	Water Framework Directive

List of countries

AT	Austria
AU	Australia
CA	Canada
CH	Switzerland
CN	P.R. China
DE	Germany
ES	Spain
FI	Finland
FR	France
IL	Israel
IN	India
IT	Italy
JP	Japan
KR	R. Korea
NL	Netherlands
RoW	Rest of world
SA	Saudi Arabia
SE	Sweden
SG	Singapore
UK	United Kingdom
US	United States

1. Executive summary

According to the United Nations (United Nations, 2024), 2.2 billion people lacked access to safely managed drinking water as of 2022, while 3.5 billion lacked safely managed sanitation services. The situation is projected to worsen significantly by 2050 if current trends persist. In addition, droughts and floods regularly cause deaths, leading to billions in economic losses every year and affecting hundreds of million people. This study relies on patent information to provide insights into trends in innovation in water-related technologies aimed at addressing these critical challenges. It also focuses on new solutions to improve water access and management, as well as resilience to extreme weather events.

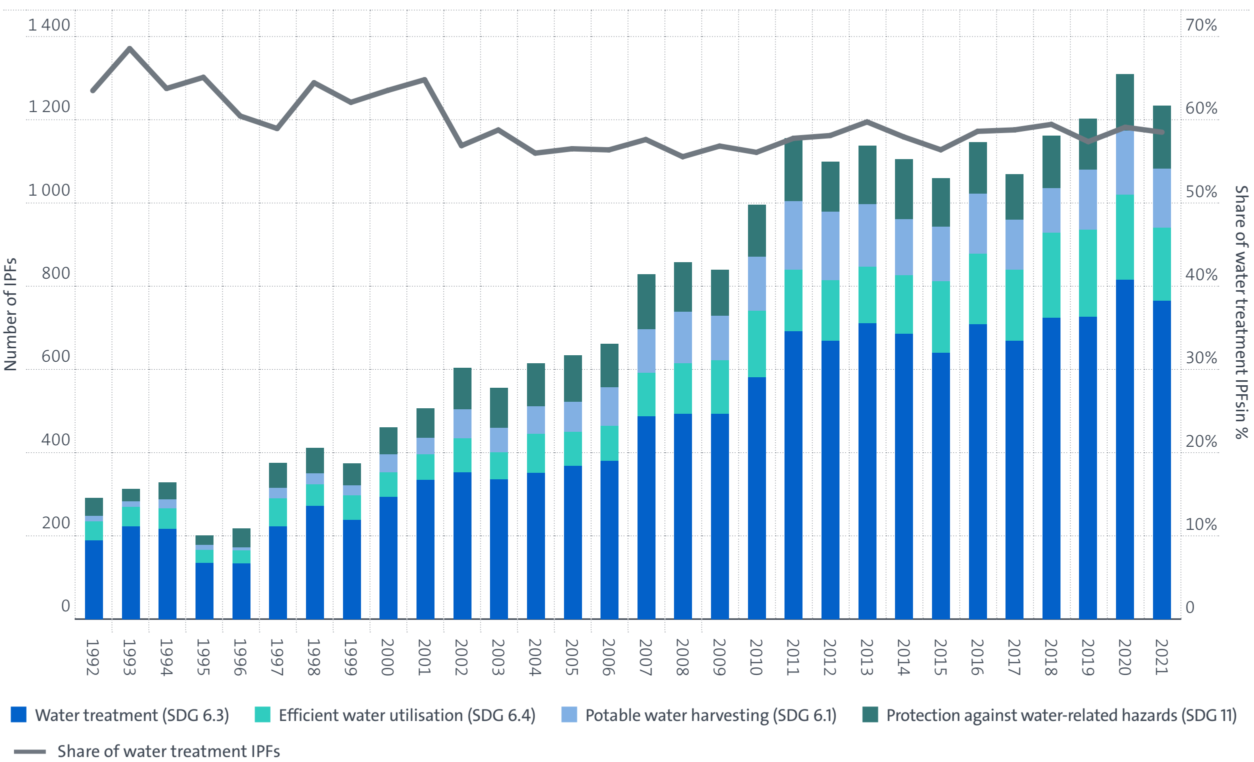
1. A small, but growing technology field

With 22 372 or 0.33% of all international patent families (IPFs) filed worldwide between 1992 and 2021, water-related technologies constitute a relatively small area of the global innovation landscape. In a context of climate change and increasing water scarcity, however, they are critically important. Innovation in these technologies increased almost fourfold in thirty years, from 300 annual IPFs in the early 1990s to over 1 200 in the 2020s, often driven by new regulations or changes to existing regulations. This growth aligns with the overall rate of patenting activity over that period, yet it lags behind the pace of many other clean technology sectors.

Innovation in water-related technologies is dominated by water treatment, which represents a stable share of about 60% of all IPFs. IPFs in water treatment are mainly focused on waste water and sludge treatment, and particularly on tertiary water treatment technologies such as disinfection and the removal of micropollutants. Over the past decade, however, the fastest growth has been seen in the number of IPFs in efficient water treatment, especially technologies related to the automation and control of water treatment operations. IPFs in other fields are fairly equally distributed between efficient water utilisation, potable water harvesting and protection against water-related hazards.

Figure E1

Growth in IPFs in water-related technologies, 1992–2021



Source: EPO

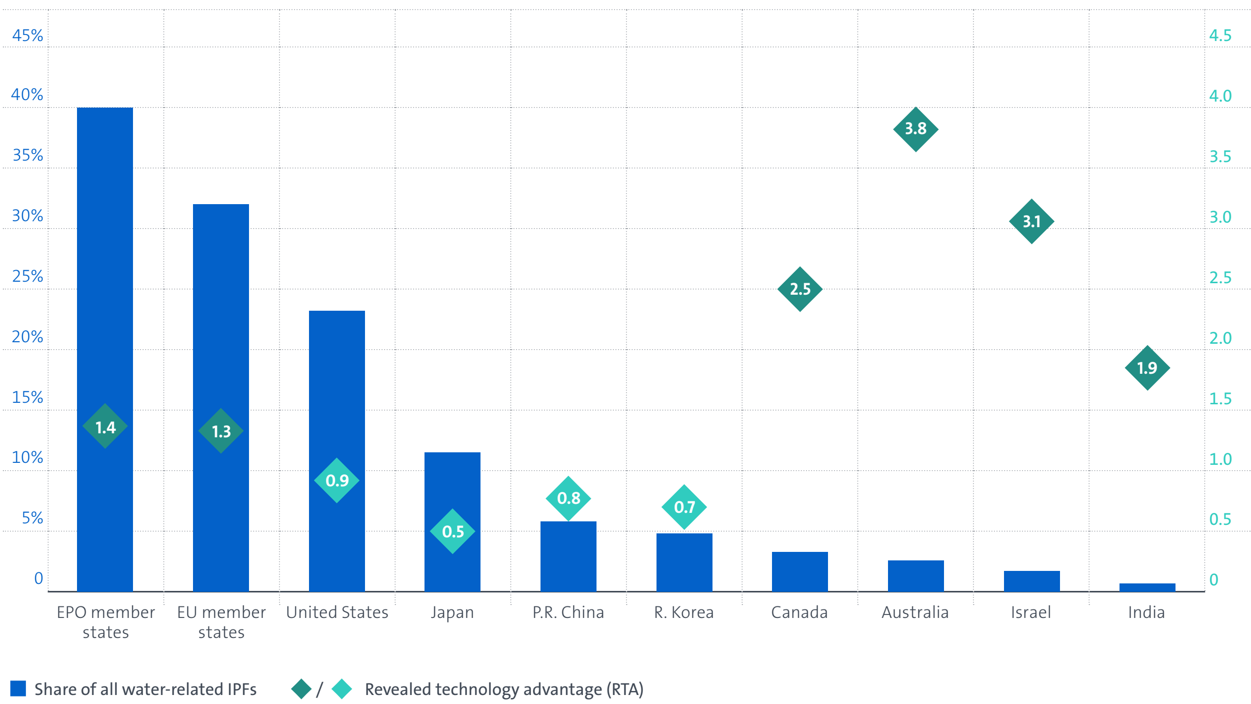
2. Europe is at the forefront of innovation in water-related technologies

European countries play a major role in fostering innovation in water-related technologies. They contributed 40% of all IPFs in this sector between 1992 and 2021 and hold leading positions in all water technology fields. Europe is the only global innovation centre exhibiting a comparatively high level of specialisation in water-related technologies, with an RTA[1] index of 1.4 from 1992–2021, intensifying to over 1.5 in recent years. While Germany, France and the UK are Europe's leading countries in terms of number of water-related IPFs, Spain stands out with a high level of specialisation in those technologies.

Beyond Europe, the US is the second major innovation centre in water-related technologies, but does not show a clear specialisation pattern, whereas Japan, R. Korea and P.R. China show a lack of specialisation in those technologies. However, other countries, including Australia, Canada, Israel and India emerge with relatively high degrees of specialisation (RTA>1) denoting a local prioritisation of innovation in water-related technologies.

Figure E2

Share of IPFs and specialisation in water-related technologies by region, 1992–2021



Source: EPO

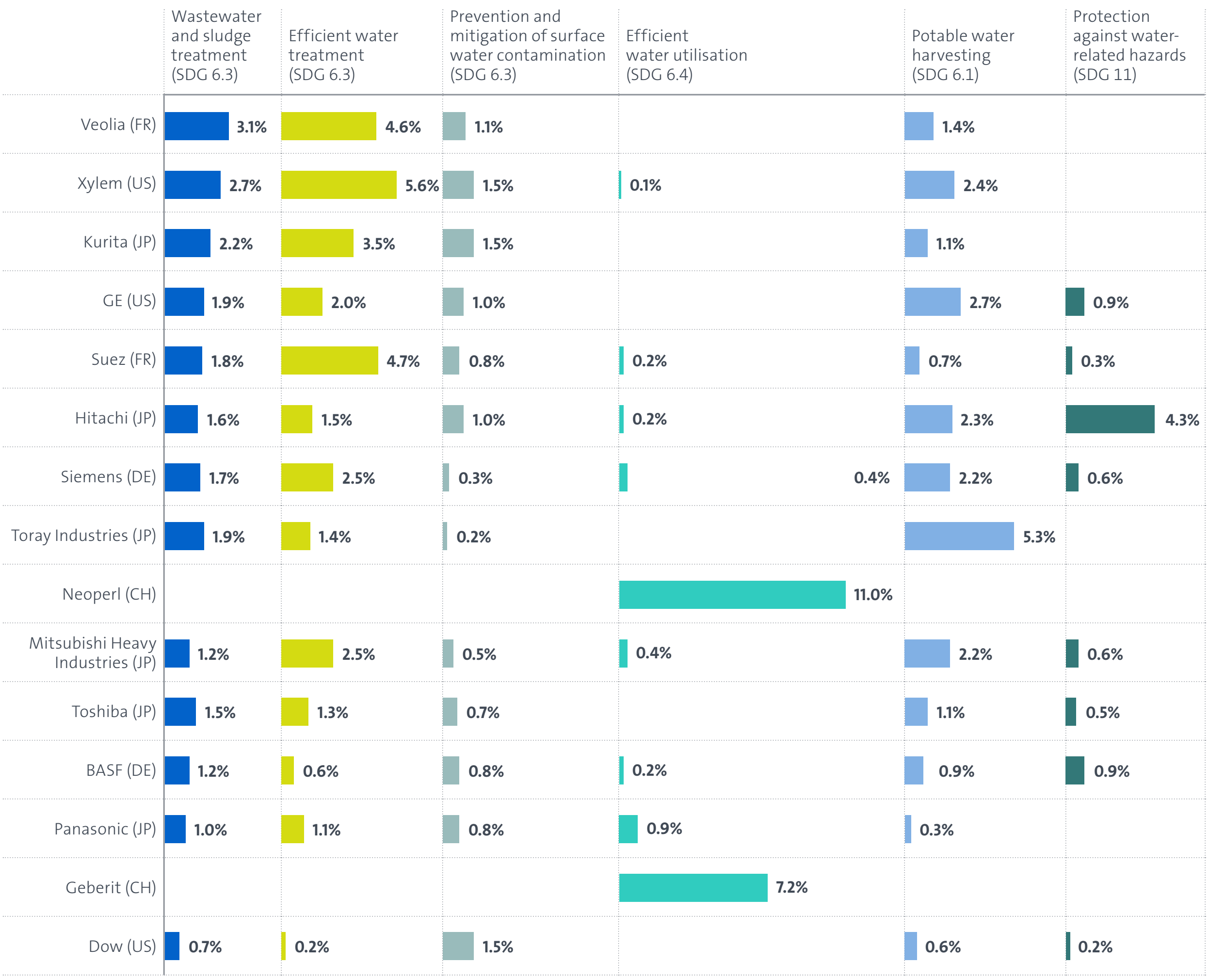
1 The RTA index indicates a country's specialisation in terms of water-related innovation relative to its overall innovation capacity. It is defined as a country's share of IPFs in a particular field of technology divided by the country's share of IPFs in all fields of technology. An RTA above one reflects a country's specialisation in a given technology.

3. All top 15 applicants are private enterprises, most of which are headquartered in Europe

Veolia, a diversified French company, tops the list with over 200 international patent families (IPFs) from 1992 to 2021, closely followed by two players predominantly active in the water industry, the US-based Xylem and Japan's Kurita. Europe has six companies among the top 15 applicants, followed by Japan, also with six, despite its low overall level of specialisation. The primary focus of the top companies has been in water treatment technologies. The majority of the leaders in water-related technologies are large conglomerates that are active in many different industries, who saw a peak in their IPFs in the period 2012–2016, followed by a decline in the next five years. The Swiss companies Neoperl, a drinking water specialist, and Geberit, a sanitary product provider, are notable exceptions with a strong specialisation in efficient water utilisation technologies.

Figure E3

Profiles of top 15 applicants in water-related technologies, 1992–2021



Note: The Figure indicates the share of IPFs in each field originating from the respective top applicants.

Source: EPO

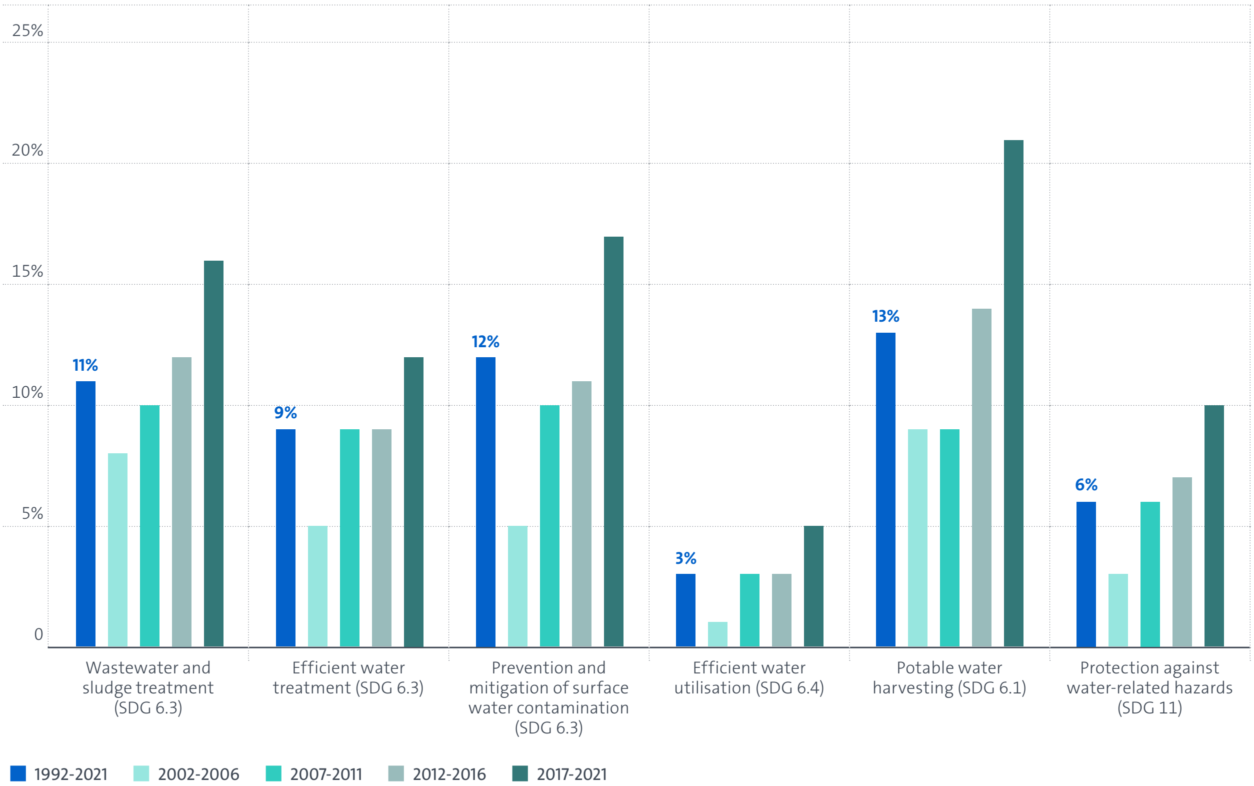
4. Significant and growing role of universities and PROs

Universities and public research organisations (PROs) are increasingly contributing to water-related technology innovations, from under 5% of all IPFs in the 1990s to 14% by 2017-2021. A closer analysis of their inventions suggests that this trend is in a large part driven by efforts to address growing water challenges, such as potable water harvesting or the prevention and mitigation of surface water contamination, where the contribution of industry innovators to date has remained limited. Potable water harvesting emerges as the field with the highest share of IPFs from universities and PROs, increasing to over 21% in the most recent five-year period.

Most of the growth in academic contributions is observed in P.R. China and R. Korea. Chinese universities and PROs accounted for 26% of all the IPFs originating in China in the period 1992–2021, the highest share of all countries, while contributions in Europe and the US are still below 10%. Although contributions from public research institutions are very important, such high shares in China point to differences in institutional frameworks and a market for water innovation that is possibly still developing in China compared to other major innovation centres.

Figure E4

Trends in shares of IPFs contributed by universities and PROs by technology field, 1992–2021



Source: EPO

2. Introduction

Water scarcity and management have emerged as pivotal challenges, reflecting a broader global crisis that threatens sustainable development, environmental conservation and the well-being of societies. According to the OECD, over 40% of the global population resides in areas facing water stress[2], with water demand projected to increase by 55% within the next three decades.[3] In its most recent publication, the United Nations confirms that as of 2022, 2.2 billion people worldwide lacked access to safely managed drinking water, with four out of five of these individuals residing in rural areas (see United Nations, 2024). The situation is equally dire in terms of sanitation, with 3.5 billion people lacking safely managed sanitation services. The OECD predicts that if current trends persist, an estimated 240 million individuals will lack any access to clean water by 2050, while 1.4 billion people will not even have access to basic sanitation facilities. As the global population burgeons, surge in demand for water is placing immense pressure on this vital resource.

However, it is not only access to clean water that poses a significant challenge. The management and sustainability of water resources are equally critical to ensuring long-term water security and resilience against the impact of climate change. According to the IPCC (2023), approximately half of the global population faces severe water scarcity for at least part of the year, with some regions experiencing it throughout the entire year. Between 2002 and 2021, droughts affected over 1.4 billion people, caused over 21 000 deaths and led to almost EUR 160 billion in economic losses (United Nations, 2024).[4] Over the same period floods resulted in nearly 100 000 deaths, affected 1.6 billion people and caused over EUR 770 billion in economic losses.

In Europe, the majority of citizens perceived water quality and quantity as pressing issues within their countries as long as 15 years ago.[5] This concern has probably been exacerbated by climate change, which influences the availability, quality and quantity of water, potentially leading to increased water scarcity and poverty, but also to more water hazards created by extreme weather events.

Such developments have profound implications for food security, the environment, human health and the socio-economic and political stability of regions worldwide. Europe's struggle with water scarcity already affects approximately 29% of its territory and 30% of its population annually, with Southern Europe experiencing most water stress conditions.[6] Recent events, such as Italy's state of emergency in drought-affected northern regions, underscore the severity of water scarcity, posing significant risks to agriculture and food security.

According to the European State of the Climate 2022 report, climate projections suggest a potential 40% reduction in river flow in southern and southwestern Europe, intensifying concerns over widespread water insecurity. In recent years, droughts have significantly impacted nearly all regions of the EU, affecting critical systems such as agriculture, water supply, energy, river transport and ecosystems (Rossi, L. et al., 2023). At the same time, flood risk may increase significantly due to climate change and continued development in flood-prone areas over most countries in Central and Western Europe, exacerbating the impact on human health, the environment and the economy in these regions (Dottori, F. et al, 2023).

2 According to the European Environment Agency, water stress occurs when demand for water exceeds the amount available during a certain period or when poor water quality restricts its use. Water stress causes the deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.). See https://www.eea.europa.eu/help/glossary/eea-glossary/water-stress for further details.

3 OECD, "Addressing water scarcity, so the world doesn't get thirsty", https://www.oecd.org/en/about.html#:~:text=The%20OECD%20is%20working%20to,management%20is%20inclusive%20and%20effective.

4 Using EUR/USD exchange rate as of June 2024.

5 European Commission, "Majority of Europeans believe quality and quantity of water is a serious problem", https://ec.europa.eu/commission/presscorner/detail/en/IP_09_446.

6 European Environment Agency, 2023, "Water scarcity conditions in Europe (Water exploitation index plus)", https://www.eea.europa.eu/en/analysis/indicators/use-of-freshwater-resources-in-europe-1?activeAccordion=546a7c35-9188-4d23-94ee-005d97c26f2b.

Likewise, the United States has been grappling with recurring drought conditions across various regions, posing significant challenges to water availability and management. To address this issue, the federal government has implemented several policies and initiatives aimed at enhancing drought resilience and water conservation efforts. The National Integrated Drought Information System (NIDIS) serves as a centralised drought monitoring and early warning system, providing crucial data and information to stakeholders. Additionally, the Environmental Protection Agency (EPA) supports water efficiency programmes like WaterSense, promotes aquifer recharge practices, and offers guidance for water utilities on drought response and recovery.[7] The US Drought Monitor, a collaborative effort between federal agencies, provides a comprehensive overview of drought conditions nationwide, supporting decision-making and resource allocation.[8] Furthermore, federal agencies like the US Department of Agriculture (USDA) and the National Oceanic and Atmospheric Administration (NOAA) offer various support programmes, including direct payments, insurance, cost-share assistance and loans, to assist farmers and ranchers during drought periods.[9]

Political leaders are increasingly recognising the pressing need to address water-related challenges. In Spain, severe drought has moved to the forefront of political debate, underscoring the urgent need for action in areas experiencing extreme water stress. Efforts like the EIT Water Scarcity Programme, which supports innovative solutions to alleviate water scarcity in Southern Europe, are being implemented to boost knowledge, foster entrepreneurship, and promote strategies that minimise water waste, enhance efficiency, and bolster resilience to climate change.[10] Germany sets a precedent with its successful management of Lake Constance's water quality through comprehensive pollution reduction strategies, showcasing a model for sustainable water use with new technologies.[11]

At the heart of EU water policy is the Water Framework Directive (WFD), established under the European Green Deal, a legislative instrument that provides the main framework and objectives for water management in Europe. The WFD's ambitious goals aim to secure clean, high-quality bathing water, ensure universal access to safe drinking water, effectively manage flood risks, protect and conserve groundwater and marine waters and tackle pollution from nitrates in agriculture and chemicals in surface waters. It also focuses on improving urban wastewater treatment, promoting efficient water reuse and addressing the challenges of water scarcity and droughts.

However, addressing water-related challenges entails significant costs, highlighting the critical need for technology advances in water supply, treatment and protection. Water-related innovation is vital for the sustainable management and efficient use of one of our most critical resources, supporting the health, food security, and economic activities of global societies. Innovation related to water spans a broad spectrum of technologies, systems and processes aimed at improving water management, treatment and distribution for various uses, including drinking, agriculture, industrial applications and environmental conservation.

Such innovation is crucial for ensuring sustainable water management and includes advanced filtration systems, wastewater treatment technologies, smart water management leveraging the Internet of Things and AI, desalination techniques, as well as infrastructure designed to mitigate the impact of water-related disasters. Furthermore, innovation such as the development and investment in urban and agricultural infrastructure and improvements in water efficiency are essential for adapting to changing climate conditions and ensuring the sustainability of water resources.

7 EPA, "Drought Resilience and Water Conservation" https://www.epa.gov/sites/default/files/2016-06/documents/epa_drought_technical_brief_may_2016.pdf.

8 US Drought Monitor: https://droughtmonitor.unl.edu/About/AbouttheData/DroughtClassification.aspx.

9 Congressional Research Service, "Drought in the United States: Science, Policy, and selected Federal Authorities", https://droughtmonitor.unl.edu/About/AbouttheData/DroughtClassification.aspx

10 EIT Manufacturing, co-founded by the European Union, "Water Scarcity", https://www.eitmanufacturing.eu/what-we-do/cross-kic-transversal-activities/water-scarcity/.

11 Euronews.green, in partnership with European Commission, "Freshwater for all: Europe faces up to the challenge", https://www.euronews.com/green/2023/05/16/freshwater-for-all-europe-faces-up-to-the-challenge.

This publication on patenting trends in water technologies aims to shed light on the latest developments, along with the key actors and contributors in water-related innovation. It is based on the identification of relevant patent documents in water-related technology domains such as potable water harvesting, wastewater and sludge treatment, efficient water treatment and utilisation and protection against water-related hazards. Such mapping is possible thanks to the expertise of EPO patent examiners in collaboration with experts from national patent offices of EPO member states. Based on this mapping, the study seeks to provide evidence on trends and patterns in water technology development and support the EU's efforts to achieve sustainable water management and conservation goals.

This study is structured as follows: section 3 discusses the societal and economic aspects of water and sets out a methodology to study trends in water-related technologies based on patent data. Section 4 provides an overview of the main patenting trends in water-related technologies, its geographic distribution and its main contributors, while section 5 presents further in-depth analysis of individual water-related technologies. This study also presents three case studies of companies developing and commercialising water-related technologies in Europe, which were finalists in the EPO's European Inventor Award or featured in the EPO's innovation case study series.[12 13]

12 The European Inventor Award is one of Europe's most prestigious innovation prizes. Launched by the EPO in 2006, the award honours individuals and teams, who have come up with solutions to some of the biggest challenges of our time. Read more here: https://www.epo.org/en/news-events/european-inventor-award.

13 This EPO innovation case study series is a collection of case studies that reveals how innovators can make better use of the IP system to create value. The SME and technology transfer case studies that make up the series showcase technology commercialisation across Europe in a wide range of industries and innovation ecosystems and by applying a range of business models. See https://www.epo.org/en/learning/learning-resources-profile/business-and-ip-managers/innovation-case-studies.

Box 1: 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 the patent 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 in them. Patent databases therefore contain a wealth of technical information – much of which cannot be found elsewhere – and which anyone can use for their own research purposes. The EPO's free Espacenet database contains almost 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.

Box 2: EPO Observatory on Patents and Technology and the Deep Tech Finder

In October 2023 the EPO launched the Observatory on Patents and Technology, which serves as a vital digital hub for transparent and informed debate on innovation. The Observatory offers comprehensive insights into emerging technology trends and fostering a collaborative environment for IP professionals and stakeholders from industry, finance and academia. The objective of the Observatory is to democratise innovation to create a safer, smarter, more sustainable world and to provide an expanding collection of digital tools, in-depth analyses and studies, alongside interactive online seminars and discussions, leveraging the EPO's extensive patent data and expertise.

The Observatory has launched the Deep Tech Finder (DTF), a digital platform designed to make it easier to find and analyse startups in European Patent Organisation member states that have filed European patent applications. Tailored to companies, investors, researchers and other participants in the innovation ecosystem, this innovative and free tool offers advanced search capabilities based on various industry and technology parameters, enabling users to pinpoint emerging ventures with the potential to launch new technologies on a European scale. The Deep Tech Finder will enable the identification of European startups that have filed patent applications for water-related technologies.

Leveraging the EPO's extensive patent information, the tool offers detailed insights into the development of inventions in specific technological fields and their protection using the European patent system. This enhances the assessment of both innovation trends and the scope of intellectual property protection in the deep tech landscape.

The EPO, in collaboration with ten national patent offices in Europe, has also developed a new free online platform "Water-related technologies". The platform contains 77 search queries that can be run in Espacenet with little or no prior experience. These queries provide access to technical information contained in patents, which describe the most recent advances in water-related technologies and can support scientists and researchers in finding inventive solutions.

CASE STUDY: Royal HaskoningDHV and the Delft University of Technology

Partners	Royal HaskoningDHV and the Delft University of Technology
Country	The Netherlands
Products	Aerobic granular sludge technology to treat wastewater
Technology field	Wastewater and sludge treatment (SDG 6.1)

Urban wastewater is treated before being discharged into rivers. Traditional treatment processes rely on bacteria to remove pollutants and, as a final step, these bacteria are separated from the treated water. This approach relies on the formation of flocs, or a small, loosely clumped mass of particles. Scientists at the Delft University of Technology have developed a new approach that has since been applied in wastewater treatment facilities worldwide. Their innovative Nereda technology trains bacteria to form granules that settle rapidly, allowing for faster and more efficient separation from the treated water. Nereda offers 20-30% energy savings, uses up to four times less space, and reduces chemical usage by over 80% compared to many existing systems. Its scalability and retrofit capability make it an attractive long-term option for municipalities.

Success through perseverance

In 1988, Mark van Loosdrecht became an associate professor at the Delft University of Technology (TUD) and worked on the CIRCOX airlift reactor for industrial wastewater. He studied bacterial growth and was able to observe and predict the conditions under which bacteria agglomerate and form granules. This became the basis of the Nereda technology.

In a Nereda reactor, purifying biomass grows naturally as compact aerobic granular sludge through a simple three-step cycle, giving it excellent settling properties. An important feature of the granules is the co-existence of aerobic and anaerobic zones, enabling a wide variety of biological processes to occur simultaneously, such as nitrification, denitrification and biological phosphate removal.

However, the path from hypothesis to product was not straightforward due to academic scepticism, early challenges in proving feasibility and the competing technologies.

Despite these hurdles, the technology was well advanced by 1999 and caught the eye of the Dutch Foundation for Applied Water Research (STOWA) and consultancy firm DHV. Merle de Kreuk then joined the project and further developed the technology as part of her PhD thesis.

STOWA funded technological and economic evaluations, culminating in a pilot plant in Ede in 2003. The team received further grants to scale up from the laboratory to real-life conditions and by 2005, DHV branded the process as Nereda, creating a trademark. Royal HaskoningDHV, STOWA, TUD and six Dutch water boards set up the National Nereda Research Program (NNOP) to develop the technology for municipal applications. With backing from various national innovation funds, NNOP helped to launch the first full-scale municipal plant in the Netherlands in January 2012.

Research and commercialisation: varying roles for IP

The collaboration between Royal HaskoningDHV and TUD highlights the varying ways in which academia and the private sector may use IP. Universities use patents and IP to attract industry interest and secure research funding, while maintaining academic freedom for publication. By contrast, firms use patents and IP to establish market leadership, protect commercial interests and generate revenue through licensing and sales, often prioritising practical application and competitive advantage over academic dissemination.

Today, Royal HaskoningDHV provides Nereda-based systems directly to customers in the Netherlands and the UK. In other regions, it partners with dedicated licensees. The company offers Nereda plants in various contract setups, including total solutions, design-build solutions and out-licensing under specific conditions.

You can find more information on the European Inventor Award 2012 finalist at: https://www.epo.org/en/news-events/european-inventor-award/meet-the-finalists/mark-van-loosdrecht-merle-krista-de-kreuk.

3. Water and innovation

This section outlines the scope of this study by describing the relation of water technologies to the global UN Sustainable Developments Goals (UN SDGs) and their economic impact. It presents a full cartography of water-related technologies and provides examples of relevant technologies.

3.1 Key water challenges

According to the Sustainable Developments Goals Report 2023, 2.2 billion people did not have safe access to clean water, 3.4 billion people lacked adequate sanitation services and an estimated 42% of household wastewater was not treated in 2022. Additionally, 18.2% of countries experienced water stress. Sustainable Development Goal 6 (SDG 6) aims to ensure the availability and sustainable management of water and sanitation for all by 2030. This goal encompasses a broad spectrum of targets designed to address the global water crisis. They focus on improving water quality, increasing water-use efficiency and ensuring equitable access to drinking water and sanitation services. Key goals include achieving universal and equitable access to safe and affordable drinking water, ending open defecation, substantially increasing water-use efficiency across all sectors and implementing integrated water resources management at all levels.

Critical components in the pursuit of achieving SDG 6 are technologies related to water treatment (SDG 6.3), potable water harvesting (SDG 6.1) and efficient water utilisation (SDG 6.4). These technologies address key aspects of SDG 6 by improving access to clean water, enhancing water quality and promoting the efficient use of water resources. Water treatment technologies - including advanced methods like reverse osmosis, nanofiltration and ultrafiltration - play a vital role in removing contaminants from water, making it safe for human use and preventing diseases. If they are powered by renewable energy, it can further contribute to sustainable water management by reducing reliance on non-renewable energy sources and minimising environmental impact. Potable water harvesting technologies offer innovative solutions for accessing clean water in areas with limited conventional water sources, thereby expanding water availability. Water conservation and optimisation technologies can enhance water-use efficiency across all sectors. These technologies include advanced irrigation systems, such as drip and smart irrigation, which deliver water directly to plant roots, minimising waste and maximising efficiency, but also water-saving solutions in faucets and toilet cisterns.

Although water is crucial for life, people and the economy, it can also have a dangerous impact, leading to catastrophic events. Water-related disasters have dominated the list of natural disasters over the past 50 years, accounting for 70% of all deaths related to such events.[14] The frequency of water-related hazards has increased over the past 20 years, with flood-related disasters rising by 134% since 2000 (WMO, 2021). These disasters not only cause loss of life but also have a significant negative economic impact. For instance, floods have killed over 250 000 people since 1980 and caused over USD 1 trillion in damage, accounting for about 40% of natural catastrophe losses (Marsh McLennan, 2021). Therefore, it is not only important to ensure access to clean water and sanitation, but also to develop and implement technologies that protect society and infrastructure from water hazards. Technologies such as dune restoration or creation, cliff stabilisation, erosion prevention, flood management, flood prevention and the monitoring and controlling of floods and hurricanes, as well as the construction of dams, are crucial for mitigating the impacts of water-related disasters and safeguarding communities and support SDG 11 by enhancing urban resilience and safety, thereby making cities safer, more sustainable, and disaster-resilient.

14 See https://www.worldbank.org/en/topic/waterresourcesmanagement

3.2 Cartography of water-related technologies

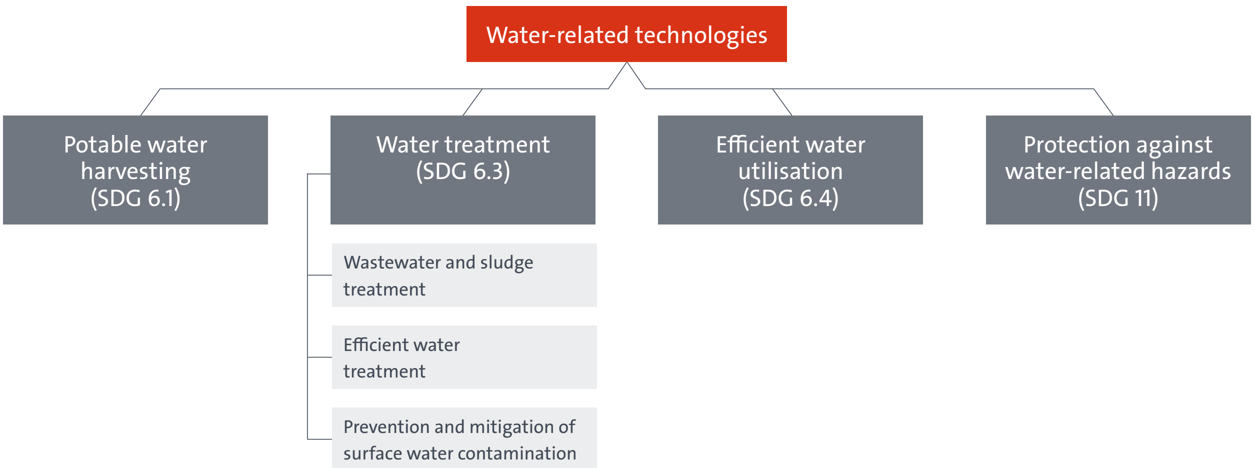
Water-related technologies encompass a broad spectrum of systems, processes and tools designed to manage, treat and distribute water for various applications, including drinking, agriculture, industrial use and environmental conservation. These technologies aim to enhance water quality, improve efficiency in water use and ensure sustainable water resource management. As a result, they have the potential to contribute to UN SDG 6: ensure availability and sustainable management of water and sanitation for all. Additionally, water-related technologies include innovations for protecting against water as a hazard such as flood prevention systems, early warning systems for extreme weather events, and infrastructure designed to mitigate the impact of water-related disasters. As such, they can also contribute to SDG 11: make cities and human settlements inclusive, safe, resilient and sustainable. The cartography of water-related technologies is divided into six different technology fields (Figure 1).

Water treatment (SDG 6.3): The three technology fields related to water treatment are wastewater and sludge treatment, efficient water treatment and the prevention and mitigation of surface water contamination. They have the potential to contribute to SDG 6.3 improve water quality, wastewater treatment and safe reuse.

— **Wastewater and sludge treatment:** This technology field encompasses various methods and systems designed to manage and treat wastewater and sludge effectively. This field includes biological wastewater treatment, which can be centralised, decentralised or operated in batch processes. A critical area within biological wastewater treatment is the advanced removal of phosphorus and nitrogen, essential for preventing eutrophication and maintaining water quality. Additionally, the field involves the utilisation and valorisation of biogas produced during the treatment process, converting it into energy or other valuable products. The treatment of sludge, which is a byproduct of wastewater treatment, involves biological, mechanical and thermal methods to reduce its volume and potential environmental impact, either by making the sludge suitable for disposal or by making valuable products from it. Furthermore, tertiary wastewater treatment focuses on disinfection and the removal of contaminants of emerging concern, such as endocrine disruptors, per- and polyfluoroalkyl substances (PFAS), and pharmaceuticals, ensuring that the treated water is safe for discharge or reuse.

Figure 1

Overview of water-related technologies



Source: EPO

— **Efficient water treatment:** This technology field encompasses the integration of renewable energy sources, energy-efficient processes and advanced control strategies to optimise water treatment operations. This includes the use of photovoltaic modules or wind turbines as autonomous power supplies for mobile water treatment installations, which can purify wastewater or produce potable water from seawater and are typically mounted on trailers, vessels, or barges. Energy recovery applications, such as pressure recovery devices in reverse osmosis systems, are also a key component, allowing the recapture and reuse of energy employed in the treatment process. Additionally, the optimisation of water treatment processes using advanced control strategies and data analysis involves the implementation of artificial intelligence, neural networks and other sophisticated technologies to automate and enhance the efficiency of water treatment operations. These innovations collectively contribute to more sustainable and cost-effective water treatment solutions.

— **Prevention and mitigation of surface water contamination:** This technology field encompasses methods and equipment designed to prevent and clean up oil spills and microplastics, ensuring the protection of aquatic environments. This includes technologies for treating ballast and bilge water from ships, which can transport invasive species and pollutants, as well as systems to prevent algal growth that can lead to harmful algal blooms. Advanced techniques such as sedimentation, flotation and the use of magnetic microsubmarines are employed to remove contaminants, while proactive measures like oil spill booms and skimmers are used to contain and clean up spills effectively

Potable water harvesting (SDG 6.1): Potable water harvesting encompasses a diverse array of technologies aimed at collecting and purifying water from various sources - including atmospheric humidity, open bodies of water, rainwater, snow, ice and groundwater wells - to make it safe for human consumption. These technologies range from simple rainwater catchment systems and fog nets to more complex desalination processes and groundwater extraction methods, each tailored to harness specific water sources. The field integrates advanced filtration, chemical treatment, and ultraviolet disinfection techniques to ensure the harvested water meets drinking water standards, addressing the critical need for accessible, clean water in various environments.

Efficient water utilisation (SDG 6.4): Efficient water utilisation encompasses a range of solutions aimed at conserving water, ensuring efficient supply and optimising water use across various sectors. This includes water-saving solutions such as advanced irrigation methods and devices, as well as smart irrigation systems that provide controlled water delivery in agriculture and urban settings. Additionally, it involves technologies for leakage reduction and detection in water storage and distribution systems, which are crucial for minimising water loss and ensuring the integrity of water supply networks. Water-saving measures in everyday use, such as efficient sanitary fixtures and appliances, as well as the use of grey- and rainwater, also play a significant role in reducing water consumption. Furthermore, the protection and restoration of water resources is addressed through measures like the installation of saltwater barriers, the protection of rivers and the safeguarding of water reservoirs by detecting and reducing leaks.

Protection against water-related hazards (SDG 11): Protection against water-related hazards encompasses solutions designed to mitigate the destructive power of water-related hazards. This includes draining storm water, disposing it into the ground or regulating the run off of storm water into equalising tanks, as well as coastal protection measures such as the construction and maintenance of dunes and cliffs to prevent water erosion and manage flood risks. Protective structures are categorised into hard structures, like dams and seawalls, which provide physical barriers against water and vegetated structures like artificial reefs and seaweed plantations, which enhance natural resilience and reduce wave energy. Additionally, forecasting technologies play a crucial role, employing risk analysis, storm forecasting, and hurricane or flood forecasting to predict and prepare for extreme weather events. These integrated approaches ensure the comprehensive protection and management of water hazards, safeguarding communities and ecosystems.

Box 3: Patent metrics

Patent applications related to the different water-related technologies were identified drawing on the advanced knowledge of the EPO's expert patent examiners and experts from national patent offices in Europe, together with scientific publications and studies published by various consultants and international organisations. This knowledge has been built up over many years of working within the different technology fields and collected via networks of technology specialists within and outside of the EPO.

Published international patent families (IPFs) are used in this study as a uniform metric to measure patenting activity in the various categories of water-related technologies. Each IPF identified as relevant for water-related technologies is assigned to one or more technology sectors, or fields of the cartography, 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.[15] 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 usually is 18 months after the first application within the patent family.

The dataset was further enriched with information about the applicants of the IPFs. In particular, complementary data was retrieved from Bureau van Dijk's ORBIS database, Crunchbase and other available internet sources, and was used to harmonise and consolidate applicant names and identify their type.

15 The regional patent offices are the African Intellectual Property Organization (OAPI), the African Regional Intellectual Property Organization (ARIPO), the Eurasian Patent Organization (EAPO), the European Patent Office (EPO), and the Patent Office of the Cooperation Council for the Arab States of the Gulf (GCCPO).

CASE STUDY: Orbital Systems

Company	Orbital Systems
Headquarters	Malmö, Sweden
Founded	2012
No. of employees	100
Products	Water and energy saving solutions for homes and businesses
Technology field	Efficient water utilisation (SDG 6.4)

Over 2 billion people lack access to safe drinking water, with rapid urbanisation, population growth and climate change driving water scarcity. According to a United Nations progress report on its Sustainable Development Goals (SDGs), 18.2% of renewable freshwater resources were withdrawn in 2020. While this global water-stress level seems safe, several SDG regions had values exceeding 25%, placing them at risk. The same report identifies wastewater management and water-saving technologies as vital in ensuring that water demand does not exceed the available supply. Since 2012, Orbital Systems has developed solutions to reduce water and energy consumption, including the world's first closed-loop shower.

Down to Earth

In 2012, NASA and Sweden's Lund University collaborated on the Journey to Mars project. At the time, Mehrdad Mahdjoubi and his colleagues began to wonder whether it would be possible to establish the same living standard on Mars as on Earth. The team knew that water scarcity would be a major obstacle, requiring smart resource management.

Their research culminated in the Oas, a closed-loop shower system that uses 80% less energy and 90% less water by filtering and recycling the same five litres of water. The shower features sensors that analyse water quality and use conductivity as a reference point. This approach is used in nuclear power plants, as contaminants make water more conductive. The system measures conductivity against the reference point every 20 seconds and automatically flushes water too contaminated to be purified.

The remaining water is purified by passing through two stages: a micron filter, which removes larger particles like hair and dirt; and a UV irradiation stage, which neutralises microorganisms including bacteria and viruses. Once purified, the water passes through a heater on its way to the shower head, then through the shower head to the drain where it is collected and circulated again. As the water temperature drops only a few degrees between the drain and the shower head, very little energy is used to re-heat it.

Scaling up

Mahdjoubi founded Orbital Systems in 2012 to commercialise the invention. The company joined the startup incubator Minc in Malmö and a year later installed its first prototype. Following pre-seed and first seed investment round, Orbital scaled up prototype production and had installed showers across 18 countries and five continents by the end of 2016.

Funding, product development and patenting have been hallmarks of the company's growth. By the time the European Investment Bank awarded EUR 15 million in funding in 2019, Orbital had built up a patent portfolio of over 100 patents. With Mahdjoubi at the helm, the company continues to draw high-profile backers such as the Amazon Alexa Fund and the Swedish Energy Agency.

The Orbital Shower can be installed or retrofitted in all bathrooms, from private residences to hotels, spas and recreational facilities. Several hotel chains have installed the closed-loop shower and it is gaining popularity with property developers building sustainable housing. One of Orbital's earliest installations was at Malmö football club, where Mahdjoubi played in the under-21 league.

You can find more information on the finalist of the European Inventor Award 2018 finalist at: https://www.epo.org/en/news-events/european-inventor-award/meet-the-finalists/mehrdad-mahdjoubi

4. Water-related patents: an overview

Using the concept of IPFs as an indicator, this section highlights the innovation activity in water-related technologies over the 30-year period from 1992 to 2021. It details the contributions of individual countries, as well as the leading applicants from both the private sector and academic research institutions.

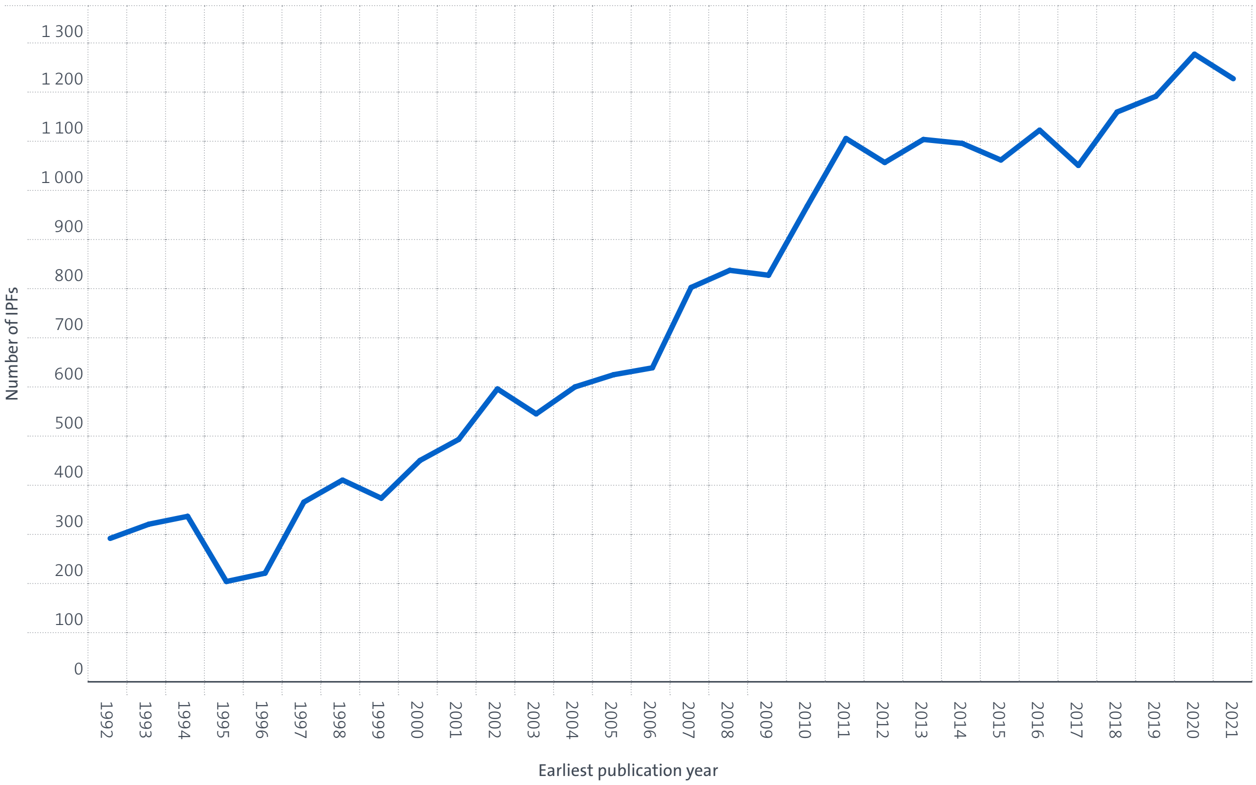
4.1 General patenting trends

From the early 1990s, when there were around 300 IPFs filed annually in this domain, a gradual increase can be seen in innovation in water-related technologies (Figure 2). By 2011, the number of IPFs had risen to over 1 100 each year and remained at this level until 2017. This pattern has also been observed in other clean technology sectors, as reported in EIB-EPO (2024). Growth subsequently resumed, reaching a peak of nearly 1 300 IPFs in 2020. The growth trajectory of IPFs in water-related technologies mirrors overall growth in patenting activity worldwide, suggesting that it expanded at a rate consistent with general technological development (Figure 3), yet slower than many other clean technology sectors (EIB-EPO, 2024). Despite this growth, with 22 372 IPFs between 1992 and 2021, the sector accounts for only 0.33% of all IPFs filed globally during the same period, indicating a relatively small yet specialised technological area.

As reported in Figure 4, innovation in water-related technologies is dominated by water treatment (SDG 6.3), which represents a stable share of around 60% of all IPFs. IPFs in water treatment are mainly focused on waste water and sludge treatment, although the number of IPFs in efficient water treatment has seen the fastest growth in the past decade. IPFs in other fields are fairly equally distributed between efficient water utilisation, portable water harvesting and protection against water.

Figure 2

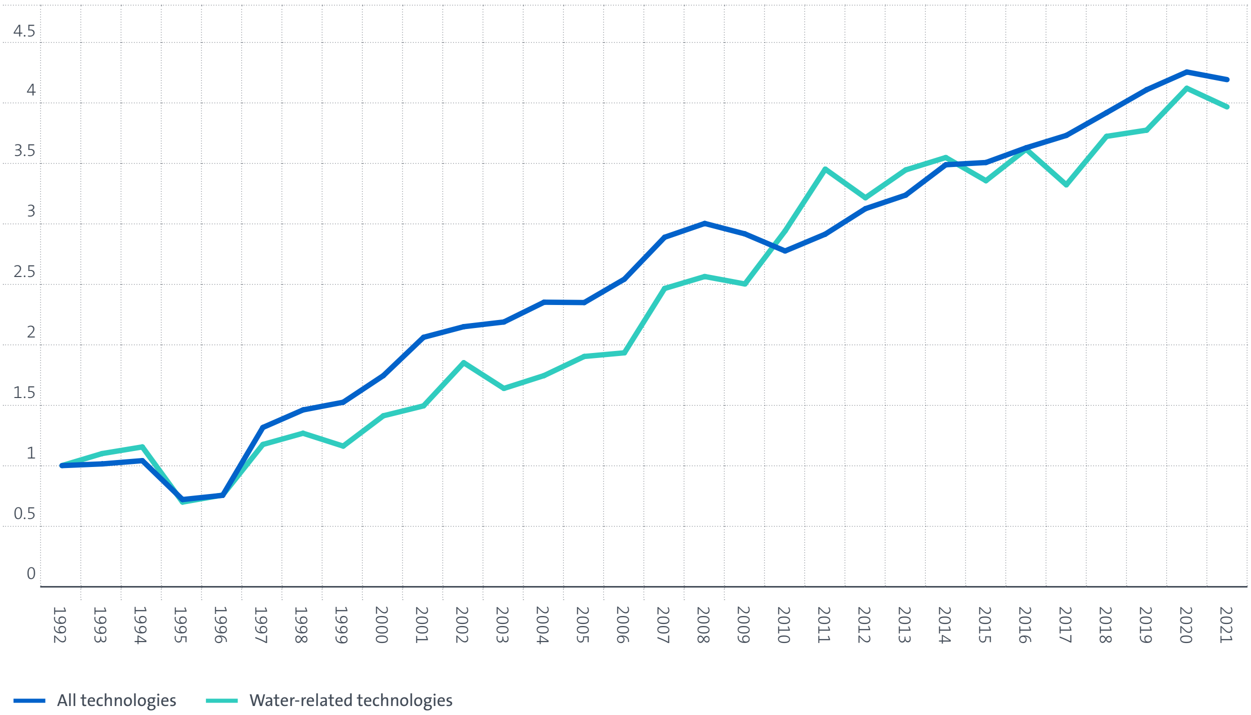
Trends in IPFs in water-related technologies, 1992–2021



Source: EPO

Figure 3

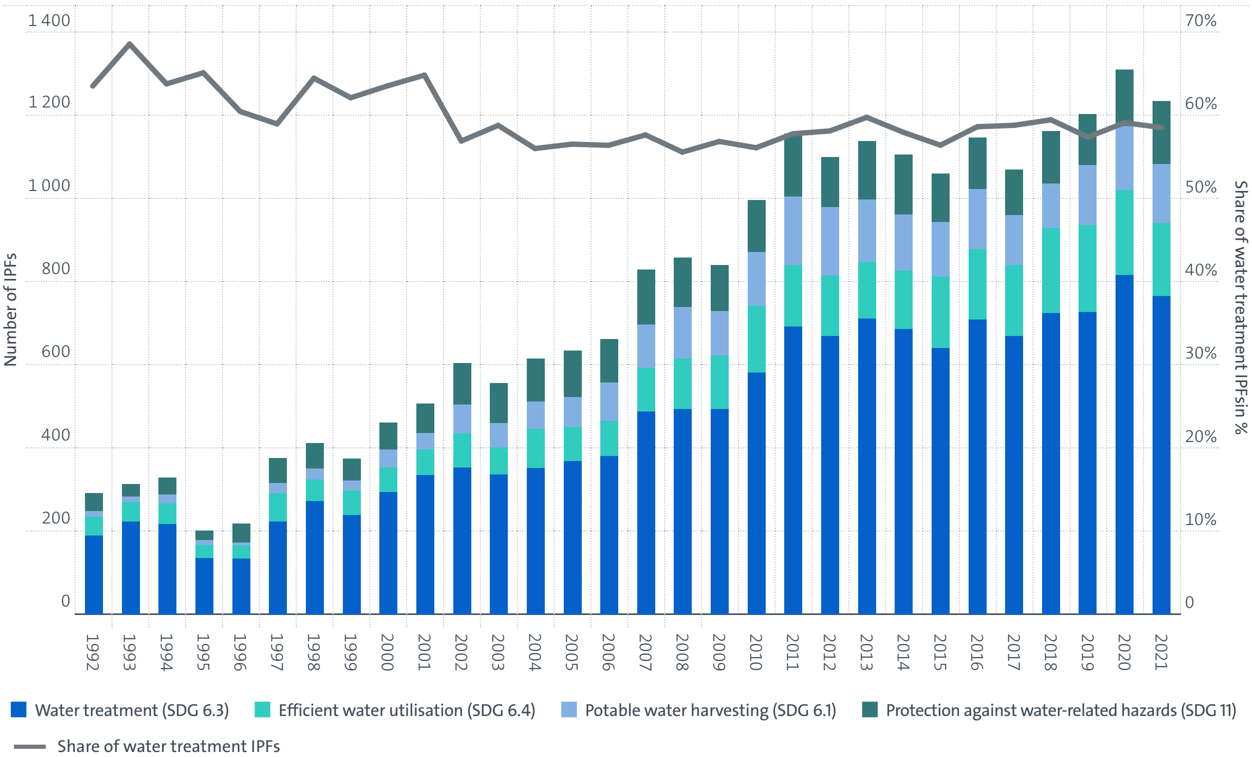
Growth in IPFs in water-related technologies compared to IPFs in all technologies, 1992–2021 (base 1 in 1992)



Source: EPO

Figure 4

Growth in IPFs in water-related technologies, 1992–2021



Source: EPO

4.2 Geography of water-related patenting activity[16]

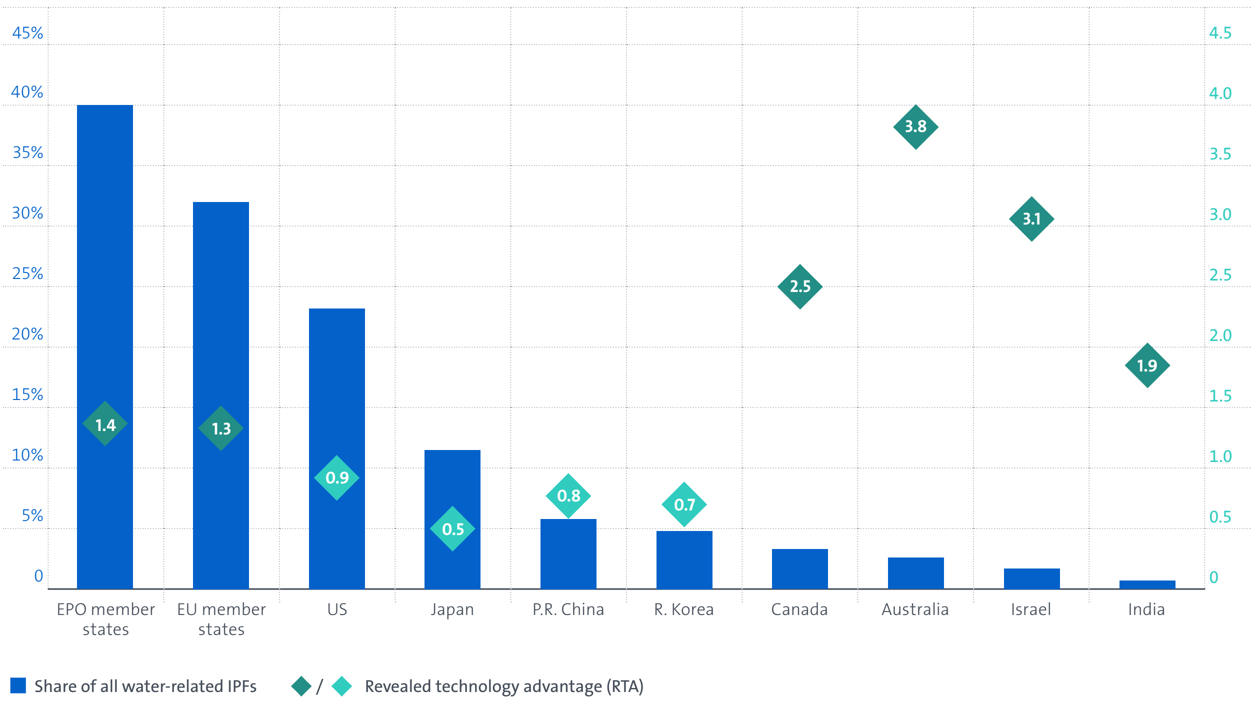
European applicants from EPO member states significantly impacted the field of water-related technologies, contributing almost 8 200 IPFs between 1992 and 2021 (Figure 5), which represents 40% of all IPFs in this sector. Over the decades, the annual contribution from these European applicants has seen a steady increase, growing from fewer than 200 IPFs per year in the 1990s to about 400 IPFs in recent years. Within Europe, the 27 EU countries accounted for 6 543 IPFs over the 30-year period, while other EPO member states added another 1 642 IPFs. Germany was a standout among them, responsible for 2 373 IPFs, or 29% of Europe's total and 36.3% of the EU's contributions, making it the holder of the second-largest water-related IPF portfolio worldwide (Figure 7). France was next, securing its position as the second largest contributor in Europe with just over 1 000 IPFs and ranking it fifth globally.

The United Kingdom followed, with 863 IPFs, making it the third largest contributor in Europe and seventh worldwide.

The US, with 4 750 IPFs, or 23% of the total, made the largest contribution to water-related innovation by any individual country, showing a consistent increase from less than 100 per year in the 1990s to around 300 by 2020. However, a noticeable decline occurred in 2021 when the number dropped by 20% to 234 IPFs. Japanese applicants, with just under 2 400 IPFs recorded over the 30-year period, ranked as the third highest contributor to water-related technologies, trailing slightly behind Germany. Initially, Japan's contributions were on an upward trajectory, peaking in 2014 with 184 IPFs. However, there was subsequently a marked decline, with annual filings dropping to fewer than 100 IPFs from 2017 onwards. Chinese contributions to the sector amounted to 1 192 IPFs between 1992 and 2021. Notably, Chinese involvement was minimal prior to 2011. From 2011 to 2017,

Figure 5

Contributions to IPFs and specialisation in water-related technologies by region, 1992–2021



Note: The RTA index indicates a country's specialisation in terms of water-related innovation relative to its overall innovation capacity. It 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. An RTA above one reflects a country's specialisation in a given technology.

Source: EPO

16 Information on the country of applicant was not available for approximately 9% of all IPFs. An analysis of the country of the first filing within the patent family suggests that it should not have a major impact on the overall country applicant distribution.

the annual number of IPFs from China hovered at around 50, but this figure surged to nearly 200 IPFs in 2021, positioning China as the second largest contributor for that year, just behind the US.

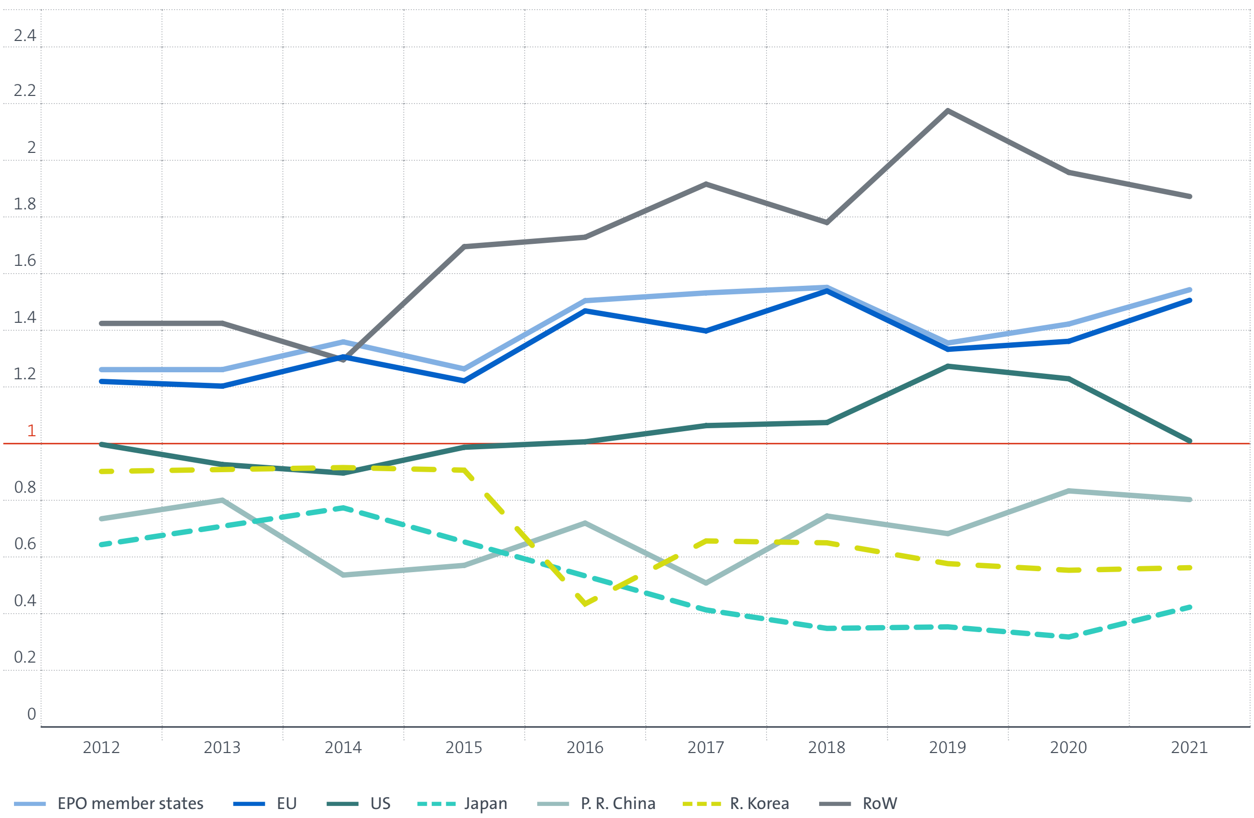
Interestingly, countries outside the top innovation centres – Europe, the US, China, Japan, and R. Korea – have also contributed a significant share of water-related innovation in recent decades. These countries accounted for 14%, or 2 904 IPFs between 1992 and 2021. Their combined contribution peaked in 2019 at just under 200 IPFs, but has since declined gradually to 170 IPFs in 2021. Canada emerged as the largest contributor with 672 IPFs, followed by Australia with 541 IPFs and Israel with 349 IPFs, highlighting a robust yet diverse global interest in advancing water-related technologies.

To assess a country's performance in water-related technologies, it is important to view its contributions in terms of its overall innovation activity across all technologies. The revealed technological advantage (RTA) index is used as a measure of a country's specialisation in water-related innovation. It relates a country's or a region's contribution to IPFs in water-related technologies to its IPFs across all technologies over a certain time period.[17] An RTA greater than one suggests a country's specialisation in a specific technological area.

Among the leading global innovation centres, Europe, and specifically the EU, has demonstrated the strongest specialisation in water-related technologies, with an RTA exceeding 1.3 for the period 1992–2021 (Figure 5). This specialisation has intensified in recent years, rising to over 1.5 (Figure 6). Conversely, the other four major

Figure 6

Trends in RTA by region, 2012–2021



Note: The RTA index indicates a country's specialisation in terms of water-related innovation relative to its overall innovation capacity. It 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. An RTA above one reflects a country's specialisation in a given technology.

Source: EPO

17 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.

innovation centres – the US, Japan, R. Korea, and P.R. China – recorded an RTA below one throughout the 30-year period in question. However, the specialisation in water-related technologies in the US and China has seen significant growth over the past decade, with the US surpassing an RTA of 1 and China approaching 0.8. In contrast, R. Korea and Japan have experienced a further decline in their specialisation in this sector in recent years.

Outside of Europe, the major contributors – Australia, Canada and Israel – exhibit exceptionally high levels of specialisation in water-related technologies. Their RTA values range from 2.5 to 3.8, underscoring their significant focus and expertise in this area of innovation.

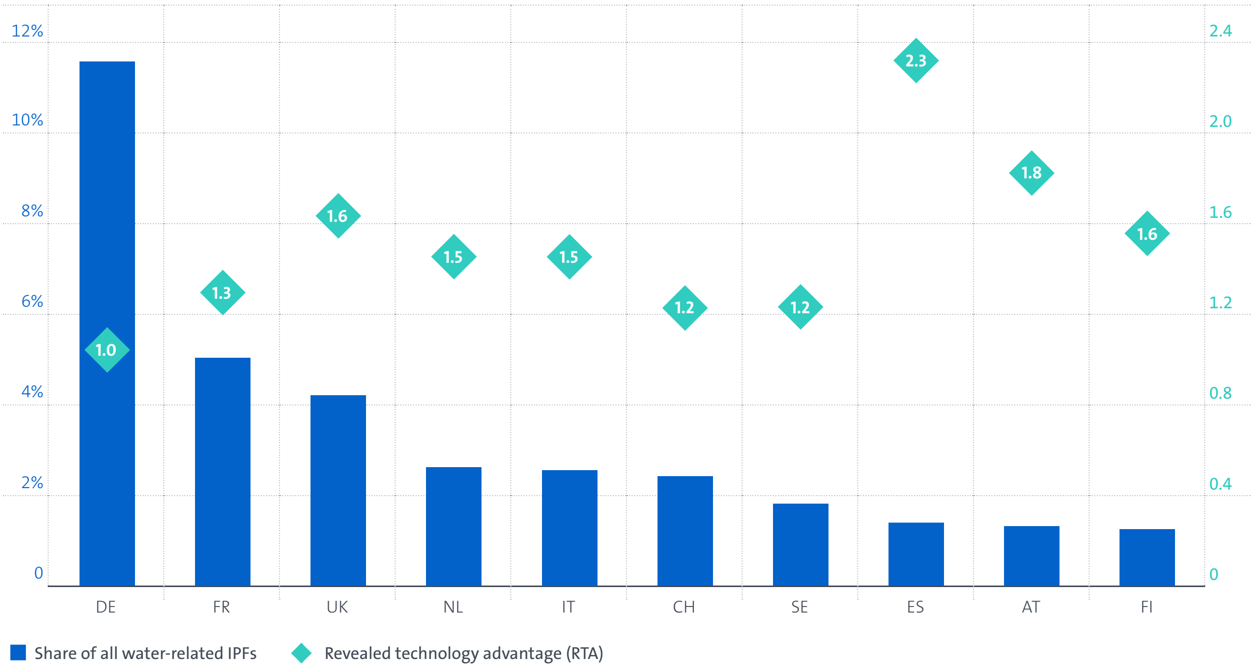
Within Europe, Spain leads in specialisation in water-related technologies, boasting the highest RTA at 2.3, followed by Austria (1.8) (Figure 7), the UK and Finland, with an RTA of around 1.6. Both Italy and the Netherlands, each with an RTA of 1.5, also show high levels of specialisation. Despite being the largest European contributor, Germany's RTA is just above 1, but below the European average in this sector.

4.3 Top applicants[18]

Veolia, a French company specialised in water and waste management, emerged as the leading applicant in water-related technologies, filing over 200 IPFs from 1992 to 2021 (Figure 8).[19] It was closely followed by Xylem, a US water technology provider with 202 IPFs, and Kurita, a Japanese enterprise that provides solutions to water industries with 155 IPFs. The primary focus for these companies is on water treatment technologies (Figure 9). Despite Japan's relatively low specialisation in water-related technologies overall, it has six companies among the top 15 applicants. Hitachi leads in water

Figure 7

Share of IPFs and specialisation in water-related technologies in selected EPO member states, 1992–2021



Note: The RTA index indicates a country's specialisation in terms of water-related innovation relative to its overall innovation capacity. It 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. An RTA above one reflects a country's specialisation in a given technology.

Source: EPO

18 The company structures as of 2024 has been taken into account, considering mergers, acquisitions and divestures to the best degree possible. For example, the US Filter corporation had been acquired by Veolia in 1999, subsequently sold to Siemens in 2004. Siemens water technologies (Evoqua), on the other hand, was acquired in 2014 by a private equity firm and rebranded as Evoqua which was taken over by Xylem in 2023.

19 In 2022, Veolia completed the acquisition of parts of Suez. This merger has been taken into account as reflected in the most recent applicant information available in the patent register.

protection technologies, while Toray Industries stands out in potable water harvesting. Besides Xylem, the US has only two other major applicants in this field, namely General Electric (GE) and Dow.

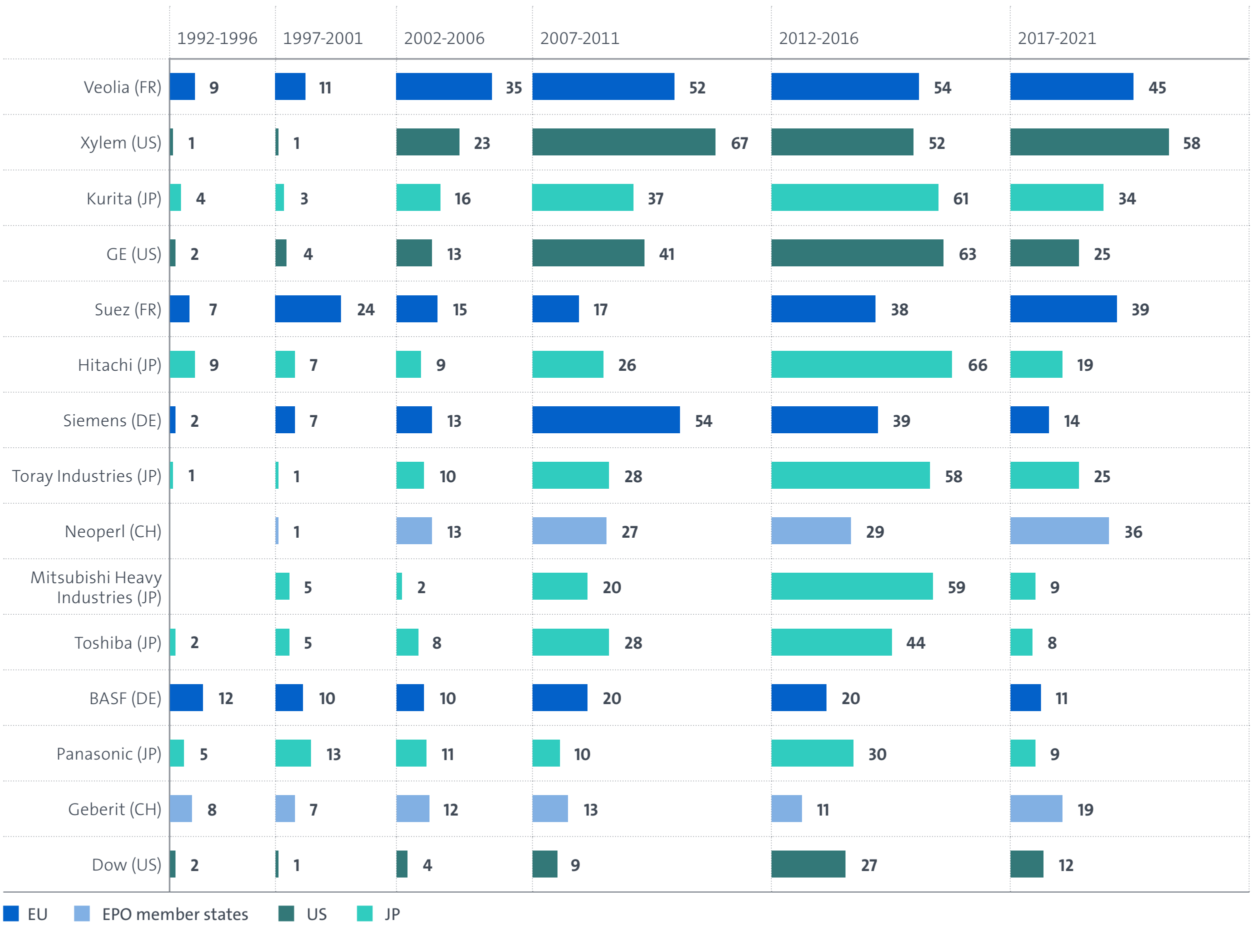
European companies, with six entities, are the most represented within the top applicants, as is Japan. France contributes two major companies: Veolia and Suez, both notable for their significant involvement in efficient water treatment. Germany is represented by Siemens and BASF, while Switzerland boasts Neoperl and Geberit, both leaders in efficient water utilisation which collectively hold almost 20% of IPFs in this technology field.

The majority of these top 15 companies are large conglomerates that are active in many different industries and published most of their IPFs between 2012 and 2016, with a marked decline in the subsequent five-year period (Figure 10). However, Xylem, Neoperl, a specialist in drinking water solutions and Geberit, a sanitary product provider, were exceptions to this rule. By maintaining or increasing their contributions during this time, they contributed to the field of water conservation and efficient water use that saw the most significant growth in IPFs between 2012–2016 and 2016–2021 (Figure 16).

Between 1992 and 2021, around 9% of all water-related IPFs were filed by universities or public research organisations (PROs). As illustrated in Figure 10, this share has steadily increased over time – from under 5% in the 1990s to 14% in the period 2017–2021. This underscores the evolving role of academic institutions in innovation ecosystems, particularly in the context of addressing global water challenges. Universities and PROs are increasingly engaging in partnerships with private

Figure 8

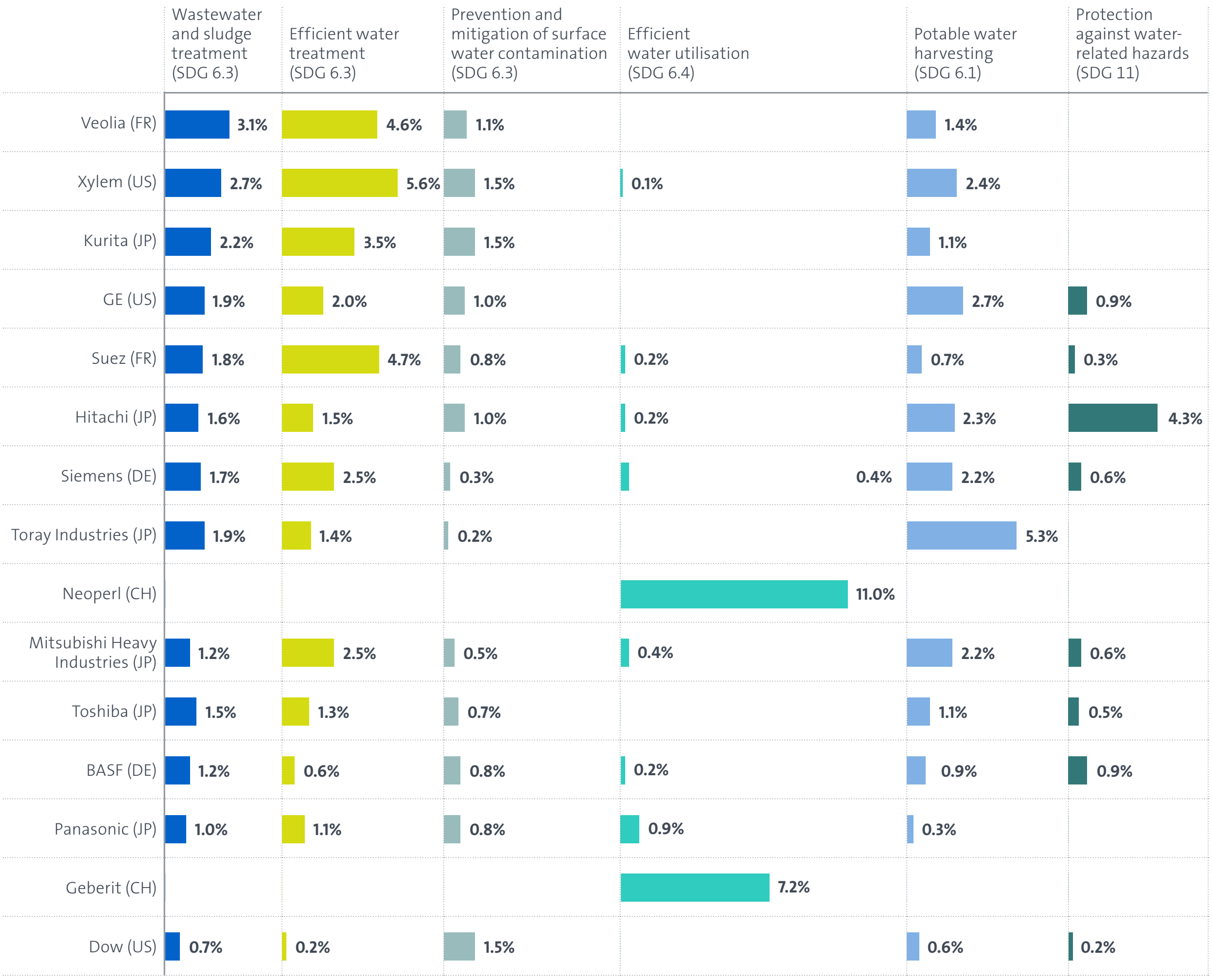
Trends in IPFs of top 15 applicants in water-related technologies, 1992–2021



Source: EPO

Figure 9

Technology profiles of top 15 applicants in water-related technologies, 1992–2021



Note: The percentages represent the proportion of each applicant's contributions within each technology field.

Source: EPO

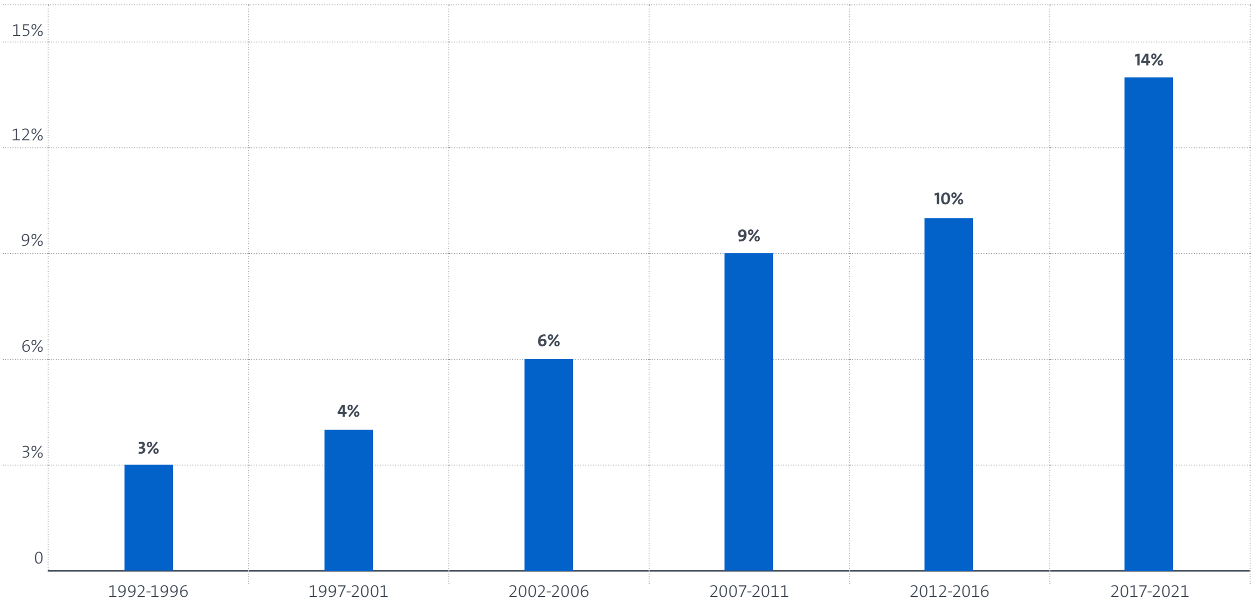
companies to co-develop technologies that address specific water challenges. This collaborative approach not only accelerates the development of innovative solutions but also facilitates the transfer of knowledge and technology from academia to industry.

Another significant factor contributing to the trend is the supportive policy and regulatory environment in Europe and other regions worldwide. Many European countries, for instance, have been proactive in implementing policies that encourage research and innovation in the water sector. The European Commission's support for water research and innovation, as part of Horizon Europe, exemplifies this trend.[20] The increasing focus on sustainable development and environmental goals, such as the UN SDGs, has also encouraged universities and PROs to engage more actively in patenting water-related technologies.

20 See https://research-and-innovation.ec.europa.eu/research-area/environment/water_en.

Figure 10

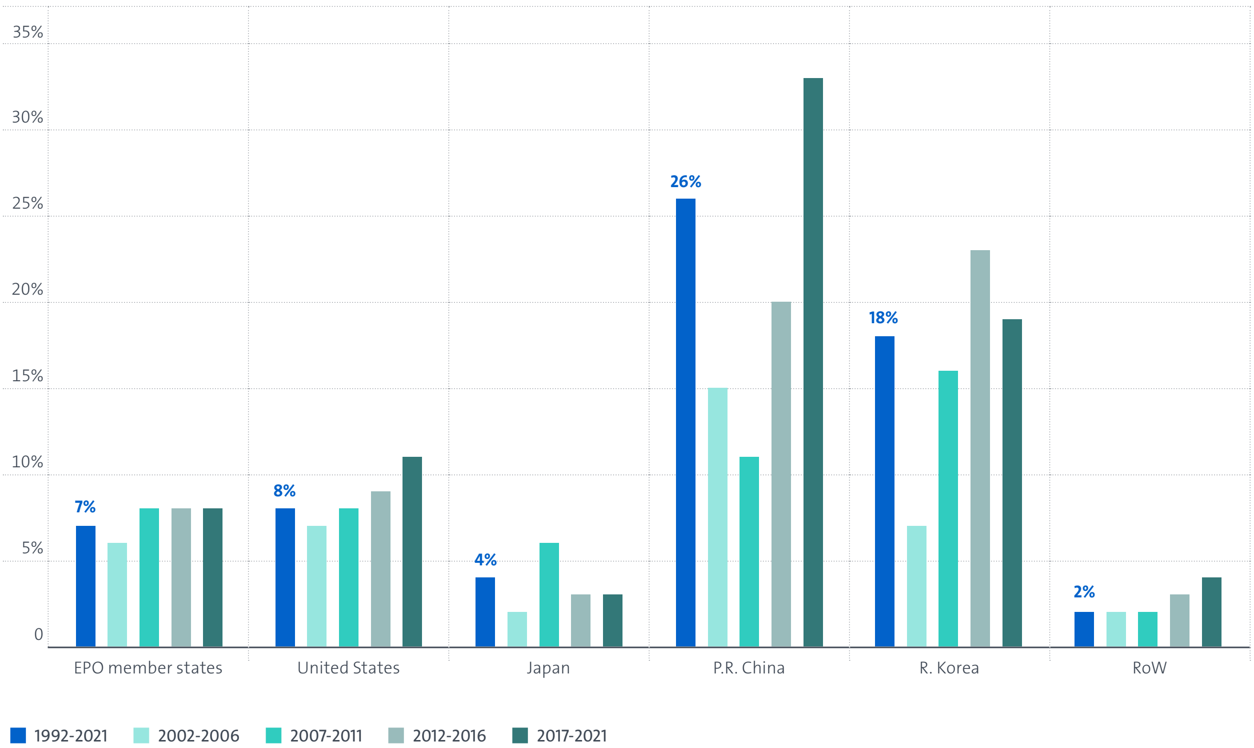
Trends in shares of IPFs contributed by universities and PROs, 1992–2021



Source: EPO

Figure 11

Share of IPFs contributed by universities and PROs by region, 1992–2021



Source: EPO

The European Green Deal with its Water Framework Directive (WFD) and efforts like the EIT Water Scarcity Programme have placed a premium on innovations that can address water scarcity, pollution and the impact of climate change. Universities and PROs are at the forefront of developing technologies that contribute to these goals.

While contributions from universities and PROs have grown across most countries and regions, the fastest growth has occurred among Chinese applicants. As shown in Figure 11, P.R. China leads with a significant 26% of all IPFs attributed to academic institutions from 1992 to 2021, which marked the highest share globally, and even increased to 33% in 2017–2021. Public innovators play a more significant role in the development of eco-innovations in the water sector in China compared to Europe. This contrast can be attributed to differences in institutional frameworks, such as the role of public planning and public involvement in water innovation, as well as a relatively less mature green market in China (see Abbritta Moro et al., 2018). By contrast, Japan and other world regions recorded the lowest contributions from universities and PROs, with only 4% and 2% respectively.

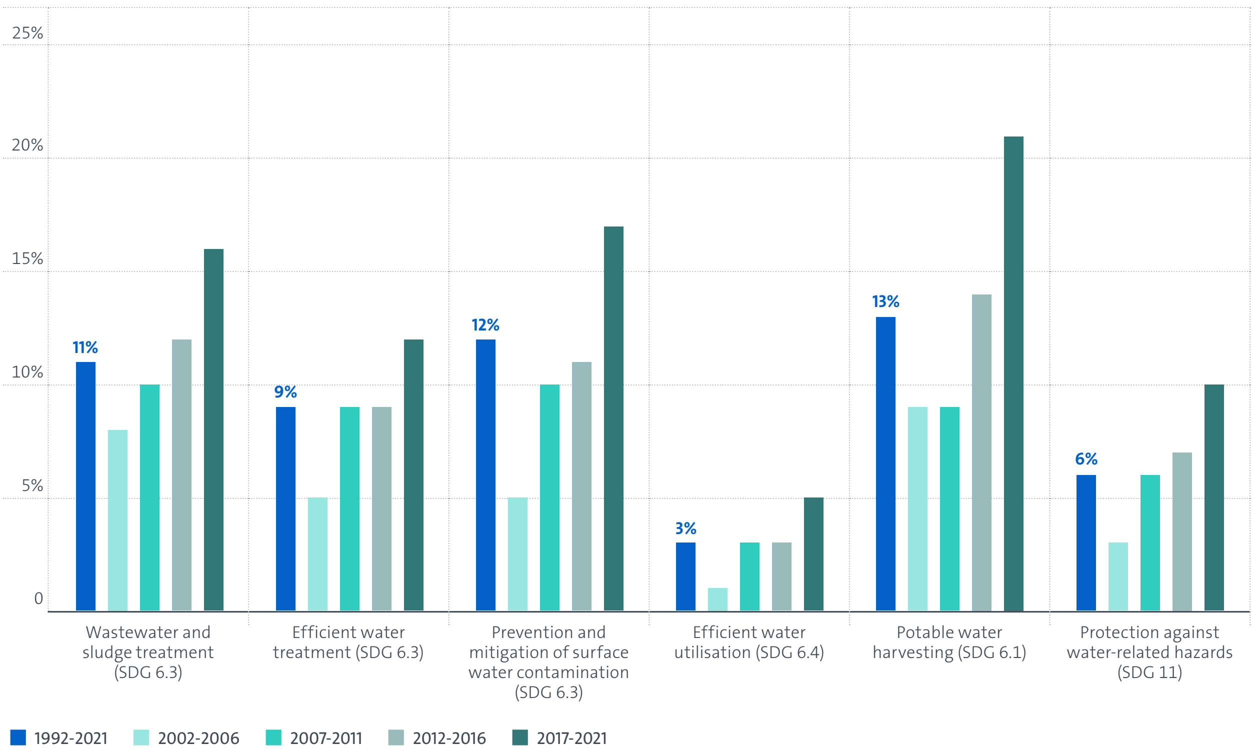
Contributions from the US and Europe were higher, at 8% and 7% respectively. However, during the period from 2017 to 2021, these figures have risen to 10% for the US and over 8% for Europe, indicating a growing trend in academic contributions to water-related technology innovations in these regions.

As illustrated in Figure 12, potable water harvesting holds the highest share of IPFs from universities and PROs at 13%. This share has risen sharply, exceeding 21% in the most recent five-year period from 2017 to 2021. The prevention and mitigation of surface water contamination, along with wastewater and sludge treatment, are two additional fields where university and PRO shares have been consistently high, each remaining over 10% throughout the entire period from 1992 to 2021. These figures climbed to 17% and 16% respectively when focusing solely on the period from 2017 to 2021.

Conversely, protection against water-related hazards and efficient water utilisation have seen the lowest contributions from universities and PROs over the past 30 years, with shares of 6% and 3%, respectively. However,

Figure 12

Trends in shares of IPFs contributed by universities and PROs by technology field, 1992–2021



Source: EPO

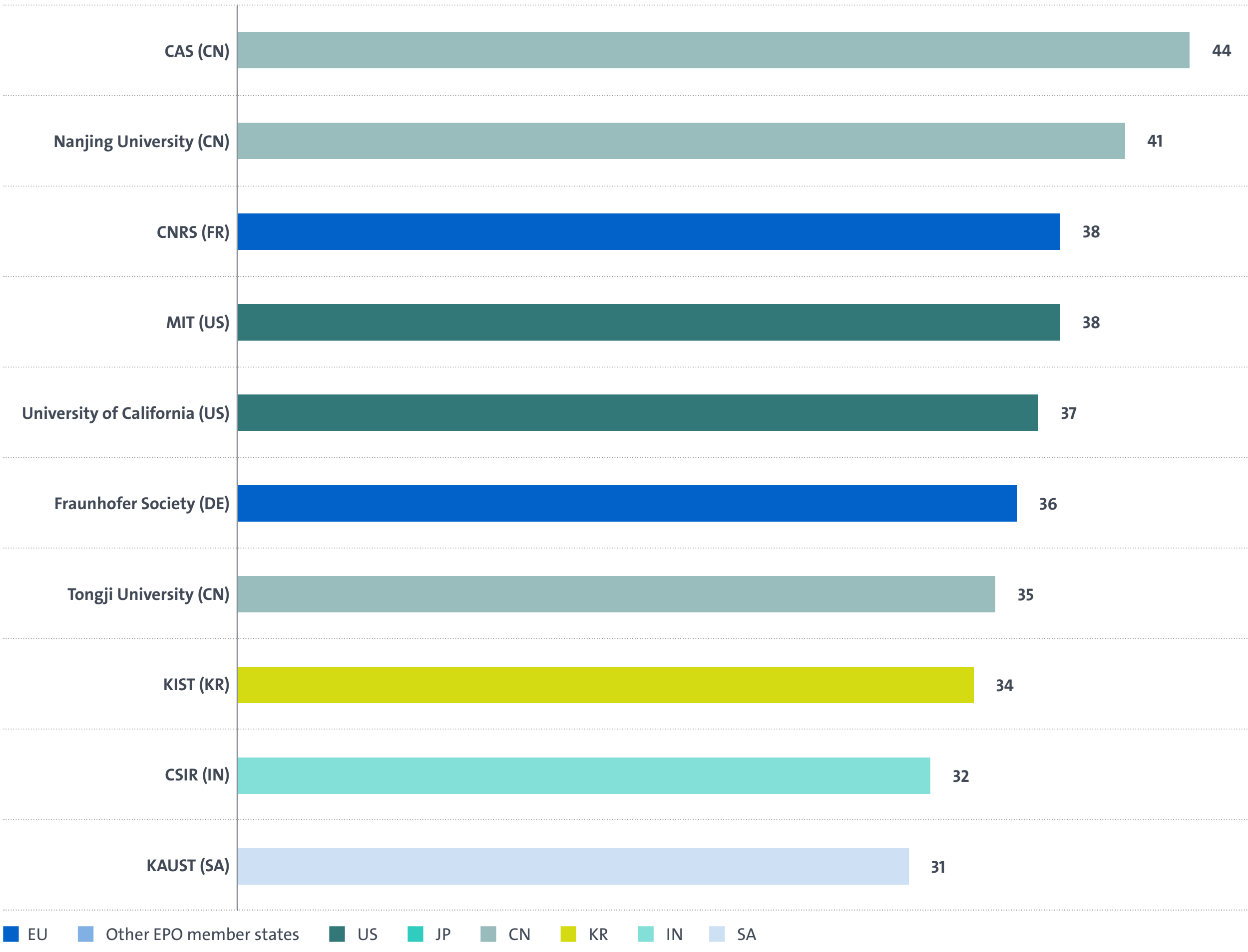
the technology field protection against water hazards has shown an increase, with its share rising to almost 10% in the most recent five-year period. These trends underscore a growing recognition of the value that academic R&D bring to addressing complex challenges in water management and technology innovation in this field.

Between 1992 and 2021, the Chinese Academy of Sciences and Nanjing University in P.R. China led the field of water-related technologies among academic research institutions, filing 44 and 41 IPFs, respectively, primarily in wastewater and sludge treatment, but also in protection against water-related hazards (Figures 13 and 14). These institutions were closely followed by France's CNRS and MIT (tied for third), both focusing on wastewater and sludge treatment, with CNRS also innovating in protection against water-related hazards. The University of California was fifth. The two US institutions not only contributed significantly to wastewater and sludge treatment, but also made notable advances in potable water harvesting.

In Germany and R. Korea, the Fraunhofer Society and KIST emerged as the non-corporate leaders respectively. Additionally, the Indian Council of Scientific and Industrial Research (CSIR) and King Abdullah University of Science and Technology (KAUST) in Saudi Arabia rounded out the top ten. Notably, KAUST has been particularly influential in potable water harvesting, marking its strong presence in this crucial area of water-related research.

Figure 13

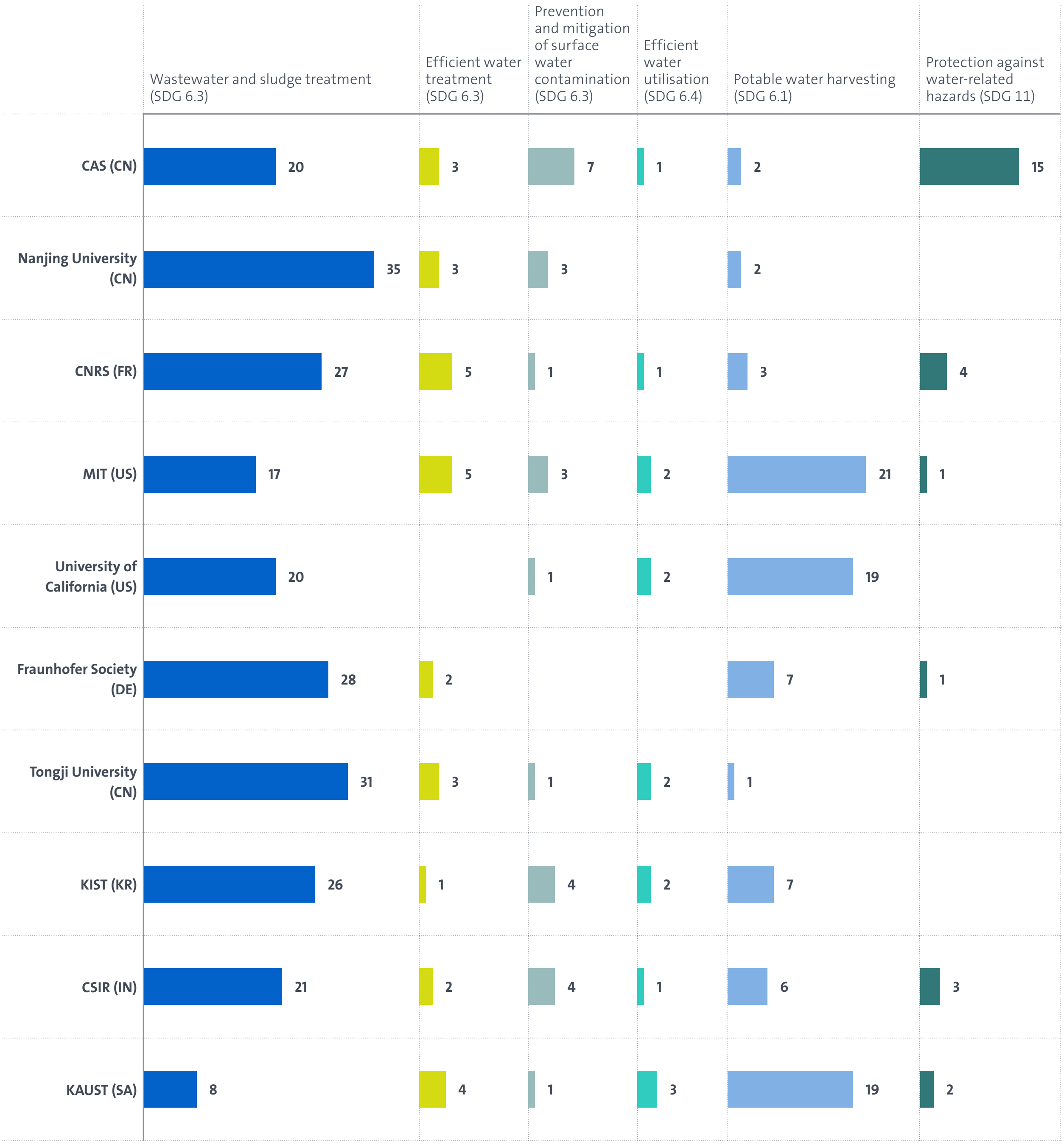
Top UNI/PRO applicants in water-related technologies, 1992–2021



Source: EPO

Figure 14

Technology profiles of top UNI/PRO applicants in water-related technologies, 1992–2021



Source: EPO

CASE STUDY: Voltea

Company	Voltea
Headquarters	Formerly Sassenheim, the Netherlands, now Texas, US
Founded	2006
Products	CapDI: water deionisation technology that removes dissolved salts from water using electrochemistry
Technology field	Potable water harvesting (SDG 6.1)

For almost twenty years, Voltea has developed solutions for softening and deionising water. The company's membrane capacitive deionisation (CapDI) system is its core technology and is used in a range of applications requiring soft water. These include automotive paint lines, agriculture, breweries, cooling towers, municipal water treatment facilities and commercial laundries. The system features capacitive carbon electrodes and ion exchange membranes that eliminate ions from water. This enables high water recovery rates, low energy consumption and improved temperature stability. The system also helps to extend the lifespan of industrial equipment, making it a sustainable solution that offers lower operational costs.

From project to product

Patent applications for the electrochemical deionisation of water were first filed in the 1960s, new materials, such as carbon nanotubes, boosted the field in the 1990s. In 2004, Bert van der Waal and Hank Reinhoudt were part of a Unilever project working on an ion softener for washing machines and other consumer appliances. Unilever recognised that the project had potential, and in 2006, the inventors founded Voltea. While Unilever no longer played a role in research and development (R&D), it provided venture capital and assigned six patent applications to the new spin-off.

Initially, Voltea focused on CapDi and enhancing the membrane patented by the original developer, Biosource Inc. Utilising patented inventions from both companies later provided Voltea with a strategic advantage, making them the sole company in the market with patents on ion-exchange membranes in CDI devices. While the founders faced some difficulty in securing early investors, strategic patenting and intensive R&D paid dividends. In 2008, with backing from Pentair and Rabobank, Voltea acquired Biosource Inc. along with its patented membrane technology.

Turning point

The company initially used its IP portfolio to safeguard its products in key markets. By carefully monitoring the field, Voltea was also able to identify and negotiate licensing agreements. However, the water deionisation field began to grow rapidly, and van der Waal and Reinhoudt realised that the company needed to think beyond washing machines.

Voltea shifted its IP strategy from one based on defence and enforcement to one geared for growth, with patents helping to secure funding. As it began to explore new markets and niches, the company found that CapDI technology could be applied to a broad range of industries. Their IP enabled them to collaborate with a series of new commercial partners and develop new applications for industries ranging from automotive to agriculture.

Expansion across industries and markets eventually limited Voltea's in-house R&D capacity. Voltea then turned to large multinationals to provide R&D support, business networks and distribution channels. In turn, these large enterprises would benefit from Voltea's proprietary technology protected by a solid IP portfolio. Crucially, these co-operation agreements gave Voltea access to IP rights, giving the company freedom to operate for its products.

Adaptability has been a constant feature for Voltea. With each new business challenge or opportunity, the company has shifted the way it manages and uses IP. Looking ahead, the company may prepare for the future with long-term IP investment planning, driven by company goals rather than external factors.

You can read the full EPO innovation case study about Voltea at: https://www.epo.org/en/learning/learning-resources-profile/business-and-ip-managers/innovation-case-studies/sme-case-studies

5. Trends across different water-related technologies

This section delves deeper into the specific trends within various water-related technology fields. It examines technologies that enhance the provision of potable water, those aimed at purifying polluted water, innovations that improve water efficiency in industrial and everyday use, and technologies designed to protect against water-related hazards. Each segment is explored to understand its development and impact over time, taking into account that many of the developments were often incentivised by the introduction or changes to regulation. It has been well noted in the literature that changes to legislation, if properly designed, can stimulate technological innovation in environmental technologies (Clausen, L.P.W., et al., 2023). In the US, for example, amendments to the Clean Water Act, regulations on national drinking water standards, all had a positive impact on inventive activity related to drinking water quality, wastewater treatment and water quantity (Li and Horatiu, 2019).

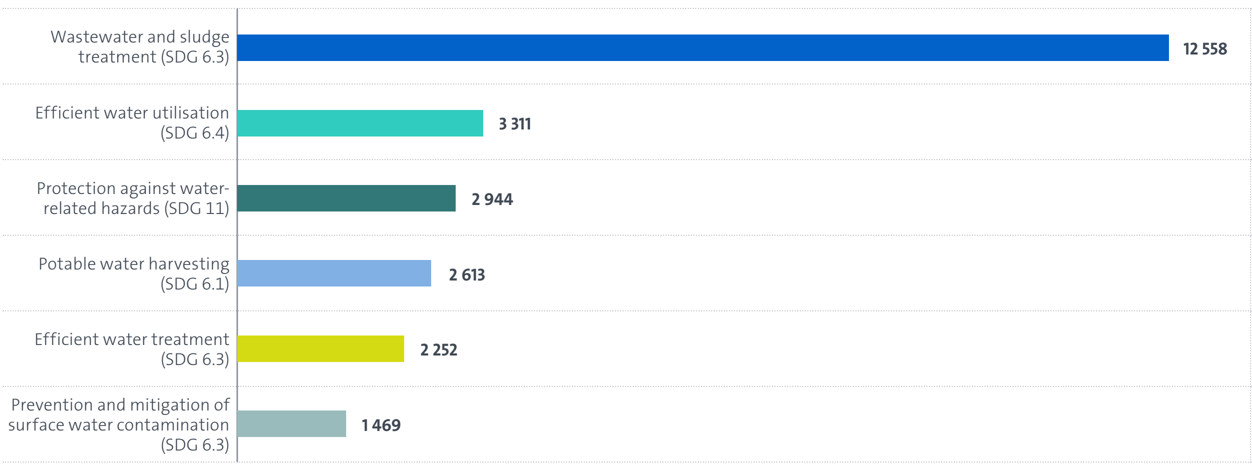
5.1 From wastewater treatment technologies to protection against water

The majority of water-related IPFs fall within the realm of water treatment, comprising 14 914 IPFs published between 1992 and 2021, or 66.7% of the total. Over 12 500 of these IPFs are in the field of water and sludge treatment – the largest of the six water-related technology fields (Figure 15). Additionally, technologies aimed at enhancing water treatment efficiency accounted for over 2 250 IPFs, while 1 469 IPFs were dedicated to the prevention and mitigation of surface water contamination, making these the two smallest technology fields in focus.[21]

The field water and sludge treatment saw consistent growth over the three decades in question, with its most rapid expansion occurring between 2006 and 2011 (Figures 16 and 17). Although growth slowed until 2016, it subsequently experienced a resurgence. Similarly, technologies for the prevention and mitigation of surface water contamination and for enhancing water treatment efficiency also showed growth from the 1990s into the early 2020s, with the most substantial increases seen in the early 2010s.

Figure 15

IPFs in water-related technologies by technology field, 1992–2021

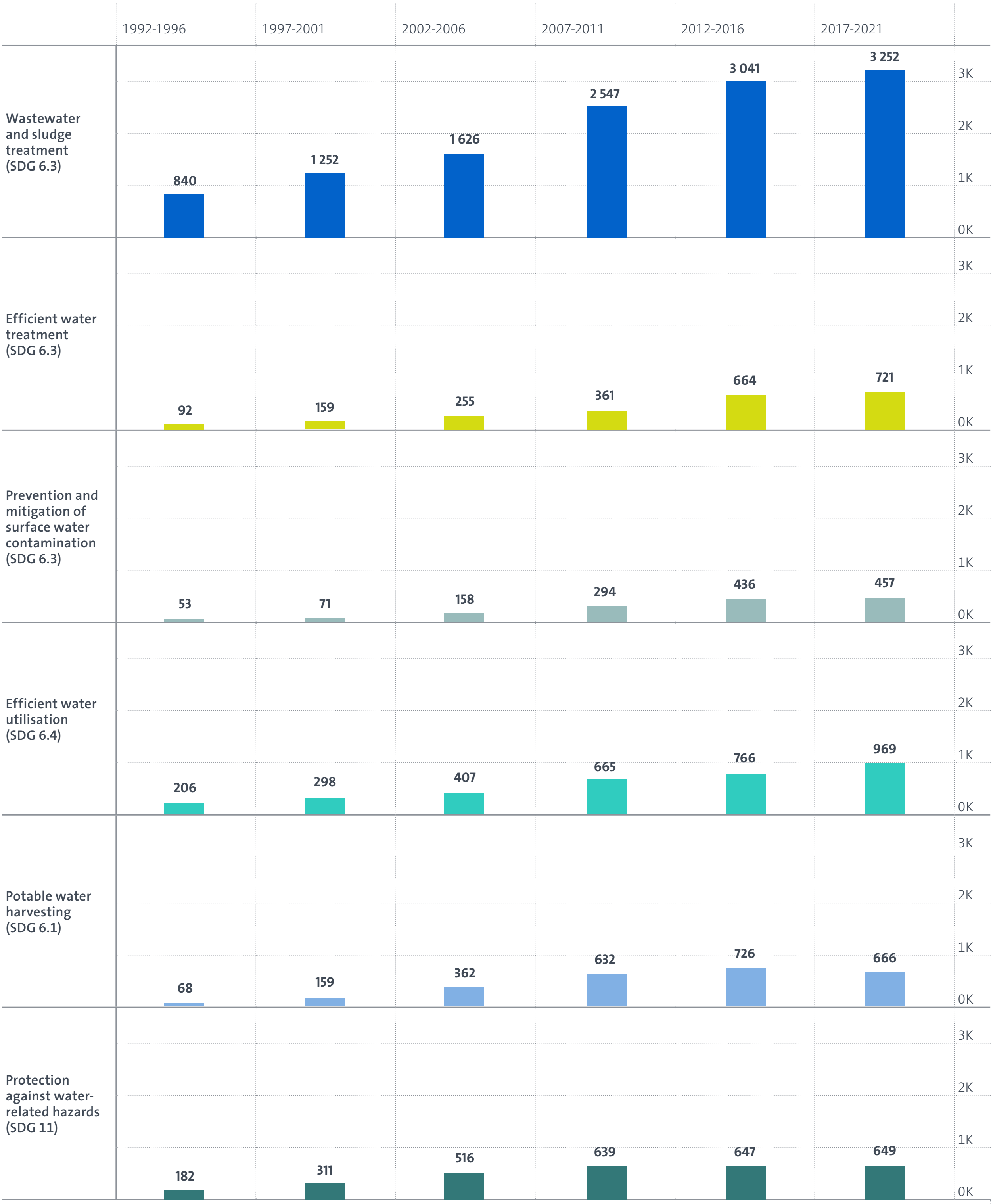


Source: EPO

21 An invention can be relevant for several water technology fields.

Figure 16

Trends in IPFs in water-related technology fields, 1992–2021



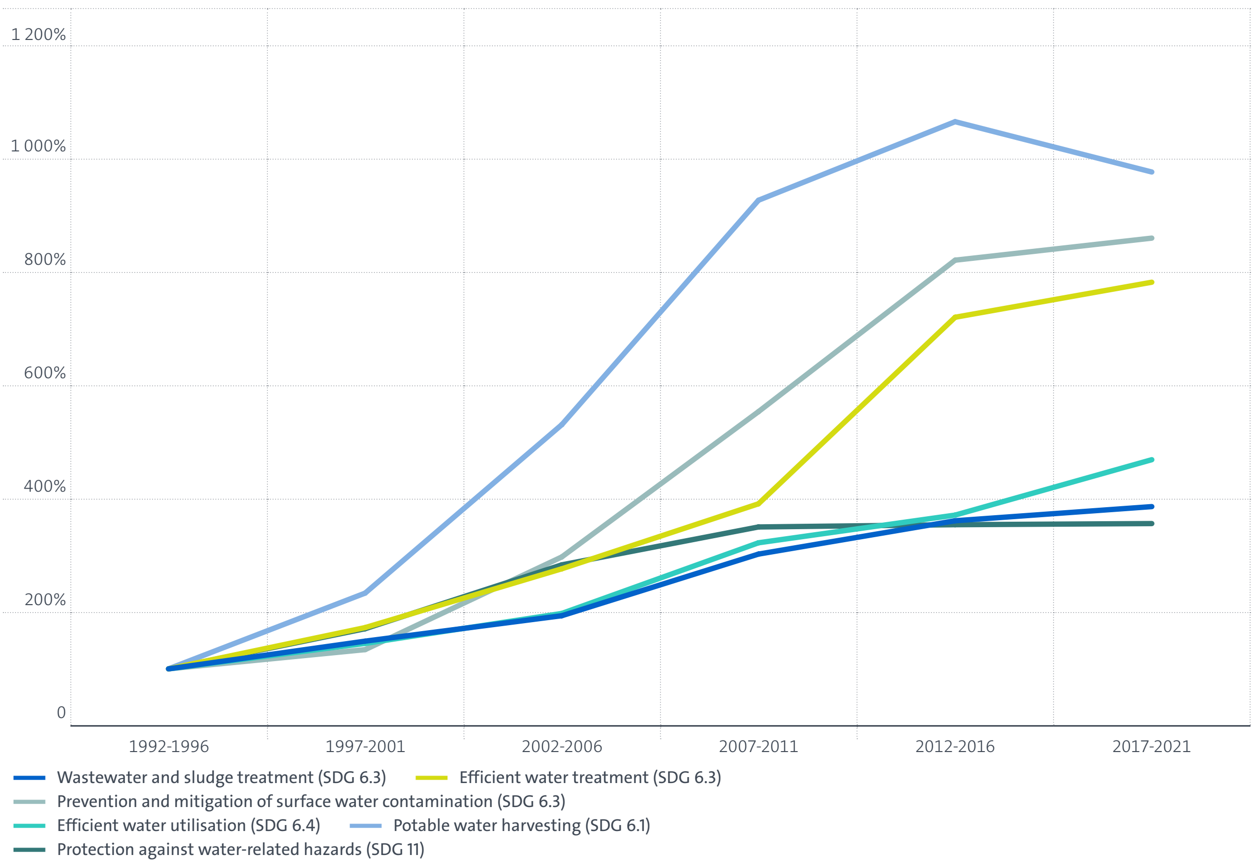
Source: EPO

Efficient water utilisation emerged as the second largest water-related technology field, with 3 311 IPFs recorded between 1992 and 2021. This was followed by protection against water, with almost 3 000 IPFs, and potable water harvesting, which accounted for 2 613 IPFs. All three areas experienced rapid growth from the mid-1990s until around 2010; particularly in potable water harvesting, which saw the highest growth rates. While the number of IPFs related to water protection remained relatively stable afterwards, those in potable water harvesting began to decline. By contrast, efficient water utilisation continued to grow throughout the 2010s.

European applicants consistently led in contributions across all six water-related technology fields from 1992 to 2021 (Figure 18). Europe's contributions are particularly dominant in technologies designed to protect against water hazards, where they account for nearly 50% of all IPFs and an RTA of 1.7 (Figure 19), despite a decline in absolute contributions during the periods 2012–2016 and 2017–2021 (Figure 20). Efficient water utilisation follows closely, with European applicants accounting for 45% of all IPFs and an RTA of 1.5 in this field, which has seen continuous growth in contributions from European applicants over the past three decades. However, Europe's smallest shares, though still substantial and with an RTA above 1, are in the fields of protection and mitigation of surface water contamination (34%) and potable water harvesting (32%). The former field has experienced robust growth in IPFs from European applicants over the decades, but recent years have seen a decrease, with US applicants now leading for the period 2017–2021.

Figure 17

Growth in IPFs in water-related technology fields between 1992–2021 (IPFs in 1992-1997 = 100%)



Source: EPO

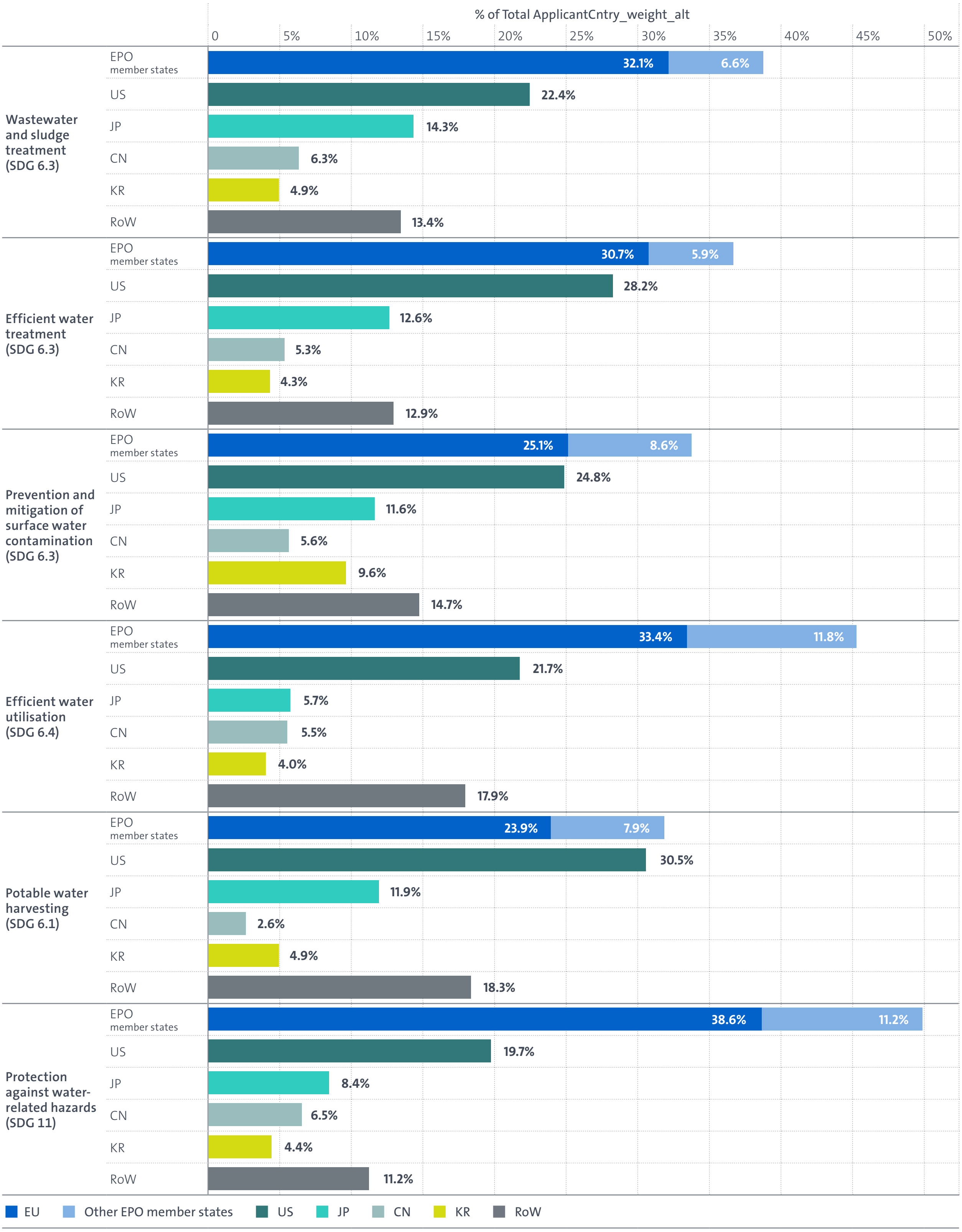
For the entire 30-year period, US applicants closely trail European contributions in potable water harvesting, accounting for over 30% of all IPFs. In efficient water treatment, where it holds 28% of IPFs, the US shows its second-strongest performance and an RTA of above 1. US absolute contributions here surged in the mid-2010s and have stabilised since. In all other fields the US has an RTA of below 1. The lowest US share is in protection against water hazards, at just under 20% and an RTA at around 0.8. Japan shows no specialisation in any of the six technology fields. Its highest share is in IPFs in wastewater and sludge treatment, which contribute nearly 15%, while its lowest is in efficient water utilisation. Notably, Japanese contributions have decreased across all technology fields in the period 2017–2021.

By contrast, contributions from Chinese applicants increased in every water-related technology field during the most recent five-year period, particularly in water treatment and protection against water hazards. This trend aligns with China's broader environmental policy agenda and its efforts to address water pollution and scarcity challenges.[22] However, its RTA indices over the full period 1992–2021 still remain below 1 in all water-related technology fields. Meanwhile, countries in the rest of the world show their highest shares in potable water harvesting and efficient water utilisation, each at about 18%, but their contributions are lowest in protection against water hazards at 11%.

22 See for example: "China announces action plan to tackle water pollution", english.gov.cn, https://english.www.gov.cn/policies/latest_releases/2015/04/16/content_281475090170164.htm.

Figure 18

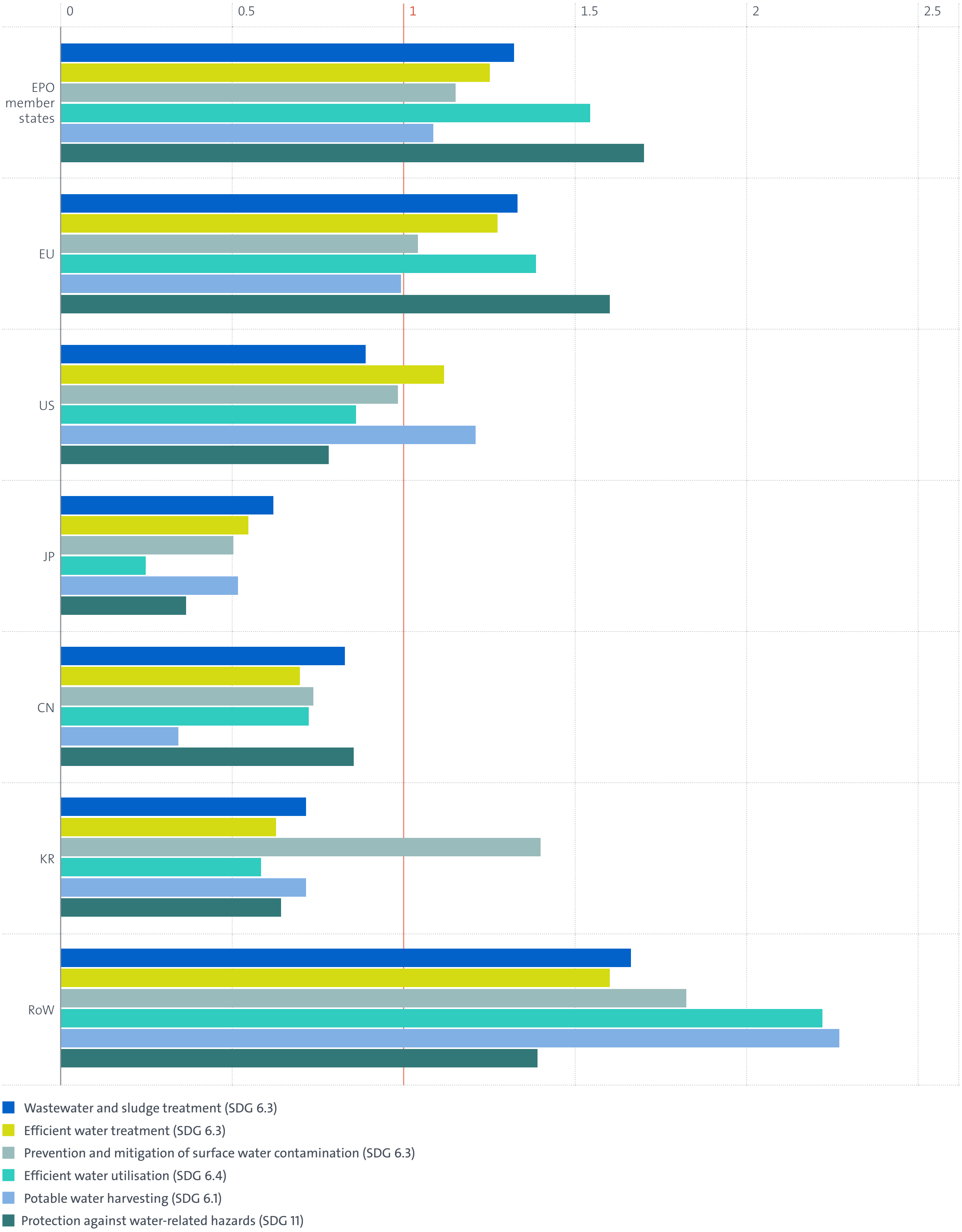
Share of IPFs in different water-related technology fields by region, 1992–2021



Source: EPO

Figure 19

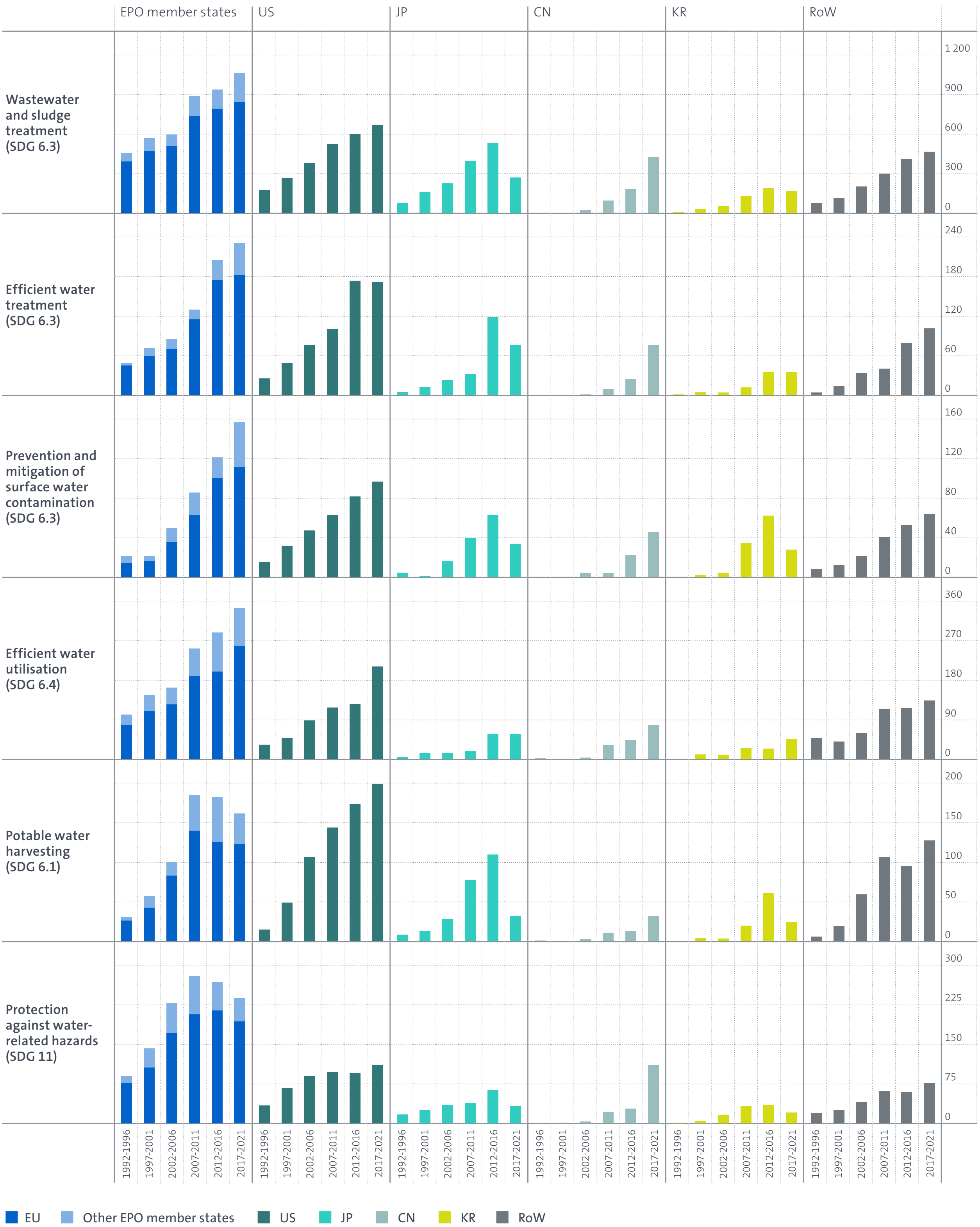
RTA in different water-related technology fields by region, 1992–2021



Source: EPO

Figure 20

Trends in IPFs in different water-related technology fields by region, 1992–2021



Source: EPO

5.2 Developments in selected water technologies

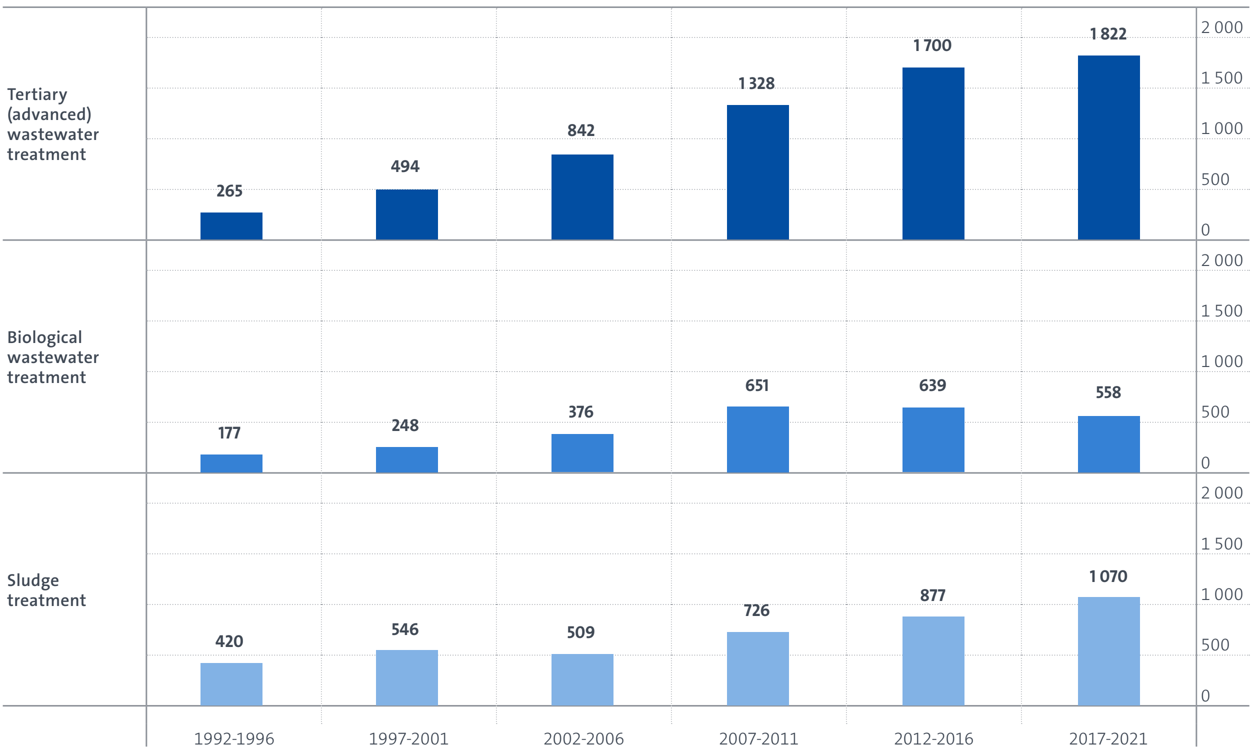
This section reports on the trends and patterns in technologies in the six water-related technology fields and the geographic distribution of the applicants in the latest ten-year period 2012–2021.

Wastewater and sludge treatment (SDG 6.3)

Within the wastewater and sludge technology field, the largest of the six water-related technology fields, tertiary wastewater treatment, stands out as the predominant subfield. As illustrated in Figure 21, this area has seen a continuous increase in IPFs, with over 1 800 IPFs filed between 2017 and 2021, propelled by advances in disinfection technologies and technologies related to the removal of micropollutants such as pharmaceuticals and PFAS. By contrast, the biological wastewater treatment subfield, experienced a post-2011 decline in IPFs due to reduced inventive activity in technologies like membrane bioreactors, and biogas production and valorisation. However, recent years have witnessed a rise in patents for compact devices designed for decentralised wastewater treatment. Additionally, the number of IPFs related to sludge treatment was significant before 2007, but subsequently increased further, driven by innovations in dewatering and drying technologies and the valorisation of sludge, transforming it into valuable resources or products. Technological developments in this area were largely triggered by regulatory requirements related to the usage of sewage sludge as a fertilizer in the agricultural sector. In Europe this is regulated in the Council Directive 86/278/EEC, which was introduced in 1986, with the aim of ensuring the safe and beneficial use of sewage sludge in agriculture while safeguarding environmental and public health.[23] Europe is the leading region in all three subfields of wastewater and sludge technologies, with the highest shares in sludge treatment and lowest in tertiary wastewater treatment (Figure 22).

Figure 21

Trends in IPFs in wastewater and sludge technologies, 1992–2021

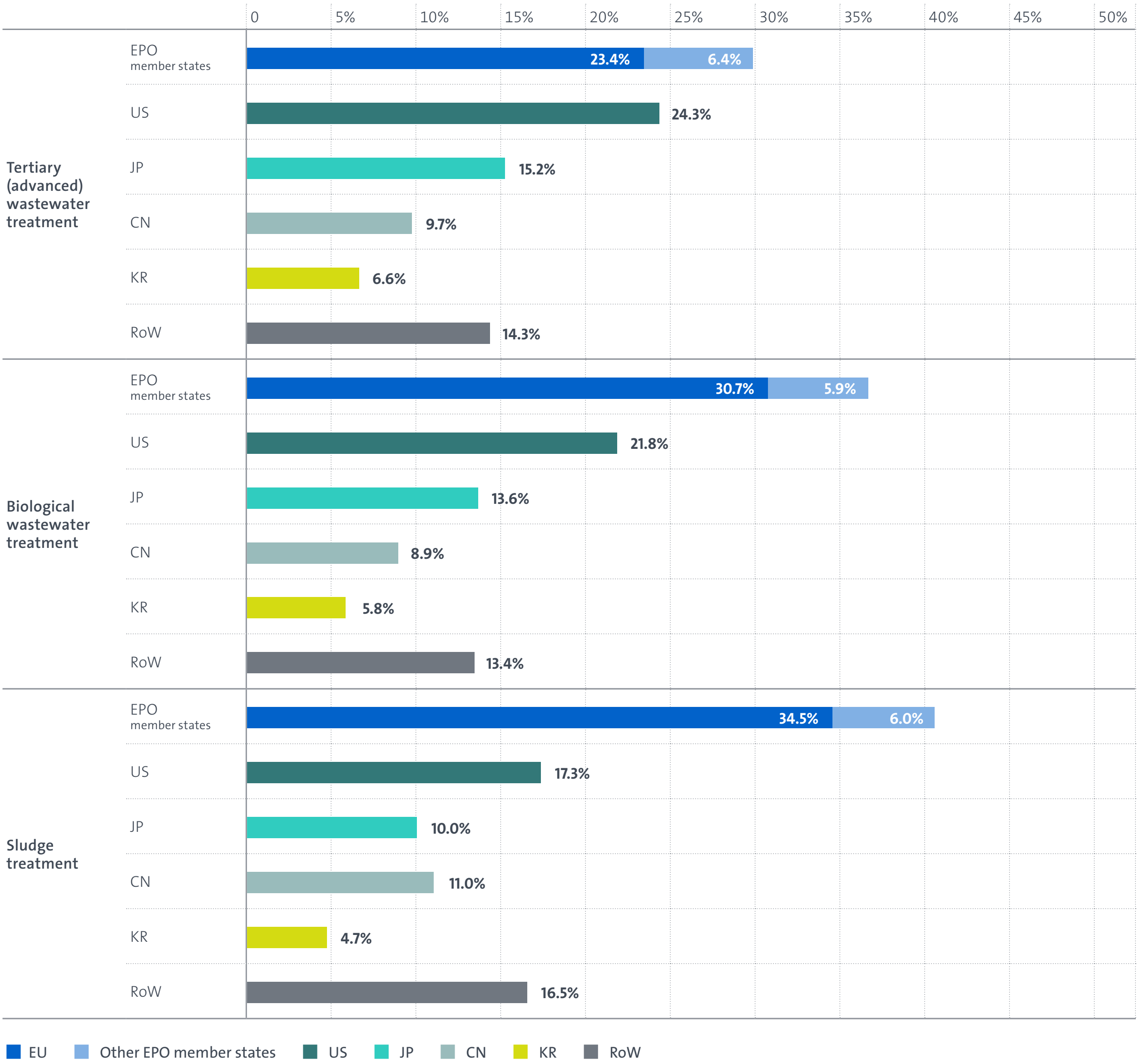


Source: EPO

23 For more information see https://environment.ec.europa.eu/topics/waste-and-recycling/sewage-sludge_en.

Figure 22

Share of IPFs in wastewater and sludge technologies, 1992–2021



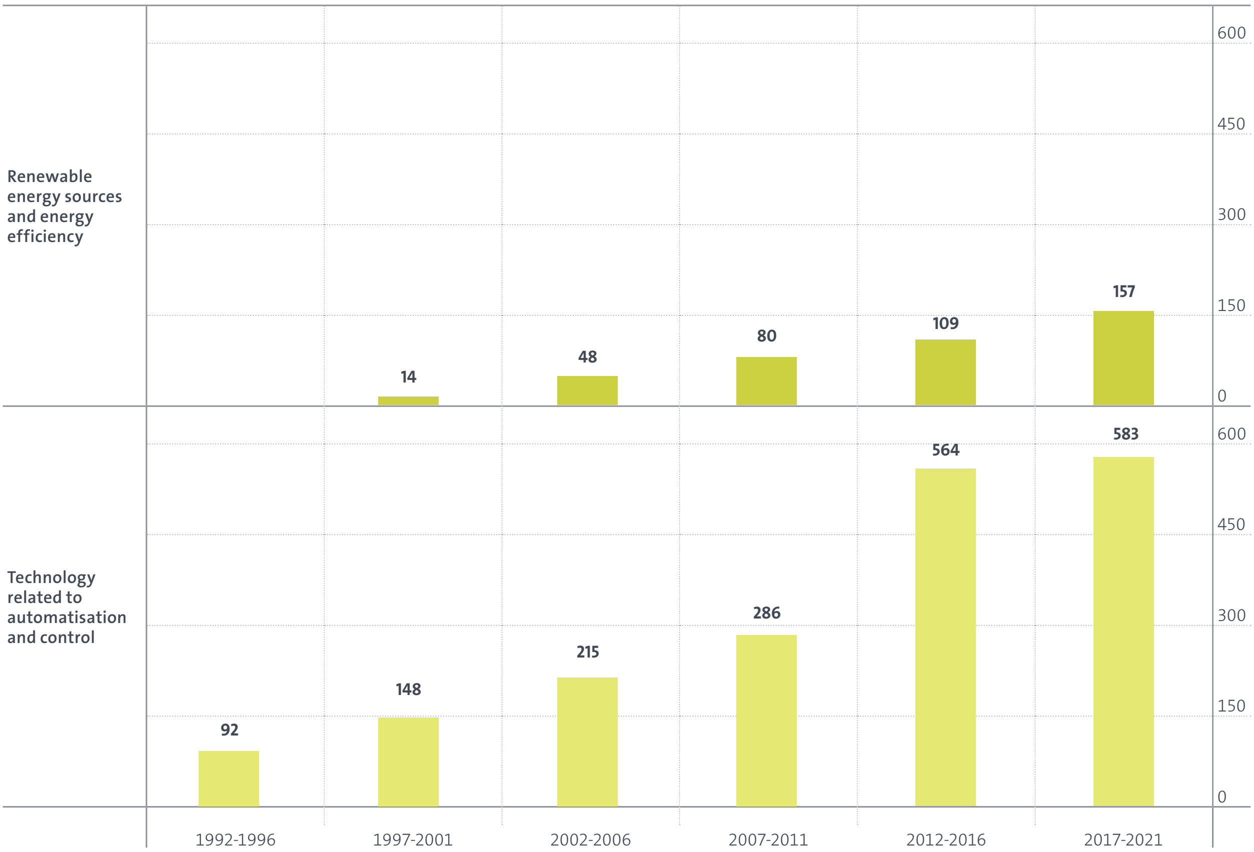
Source: EPO

Efficient water treatment (SDG 6.3)

Efficient water treatment is divided into two subfields: the integration of renewable energy sources with energy-efficient processes and advanced control strategies to optimise water treatment operations. As indicated in Figure 23, while both subfields have shown growth, the integration of renewable energy sources – particularly solar and wind – is distinctly smaller but expanding fast. The subfield of automation and control technologies, encompassing nearly 600 IPFs between 2017–2021, remains the larger segment and reflects the increased importance of integrating information and communication technologies into water treatment processes over the last decade. Although it is primarily driven by traditional control and automation technologies, the integration of artificial intelligence and the Internet of Things has seen a rapid increase, particularly in recent years. Notably, European companies lead in technologies associated with the automation and control of wastewater treatment operations, whereas US applicants are more prominent in the integration of renewable energy sources (Figure 24).

Figure 23

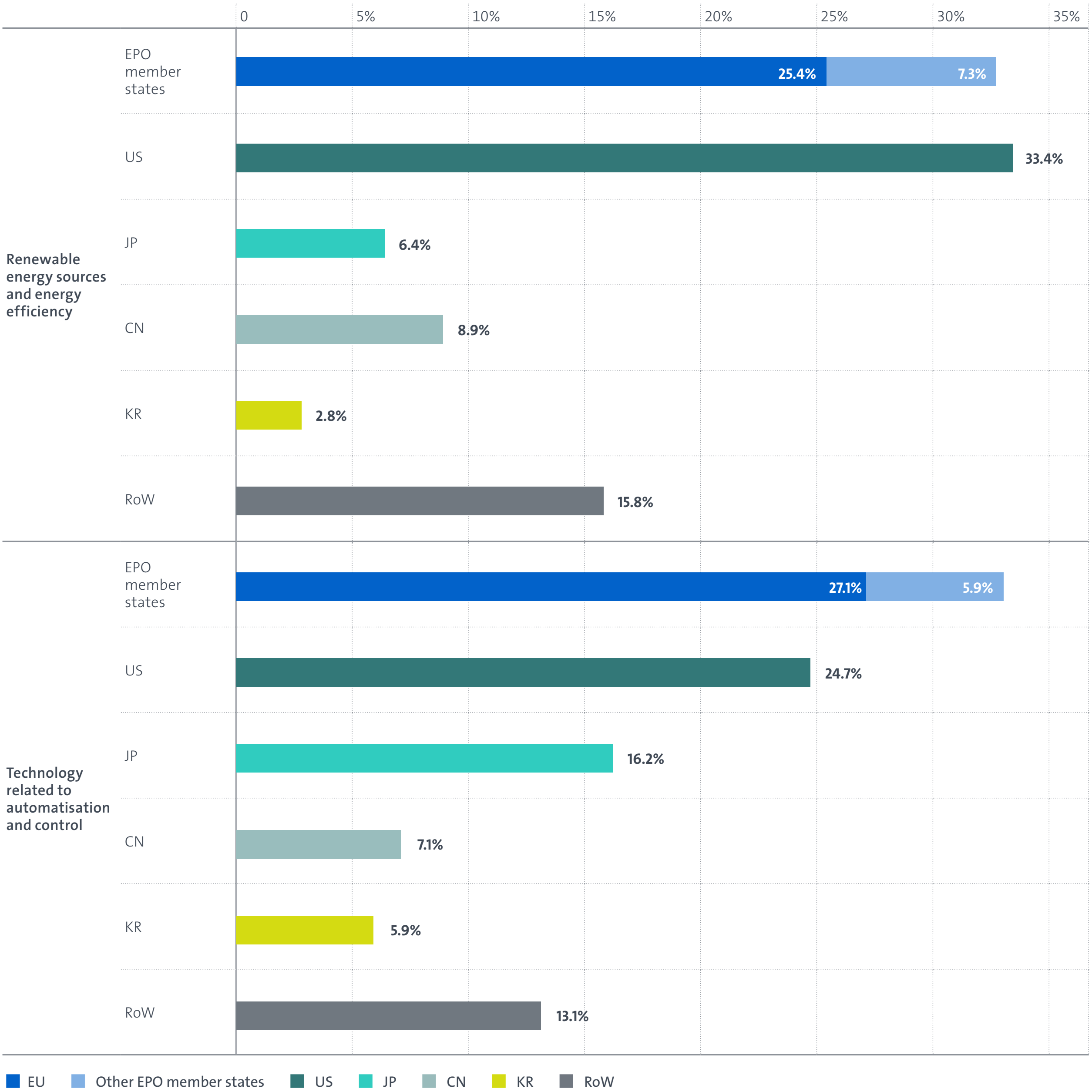
Trends in IPFs in efficient water treatment technologies, 1992–2021



Source: EPO

Figure 24

Share of IPFs in efficient water treatment technologies, 1992–2021



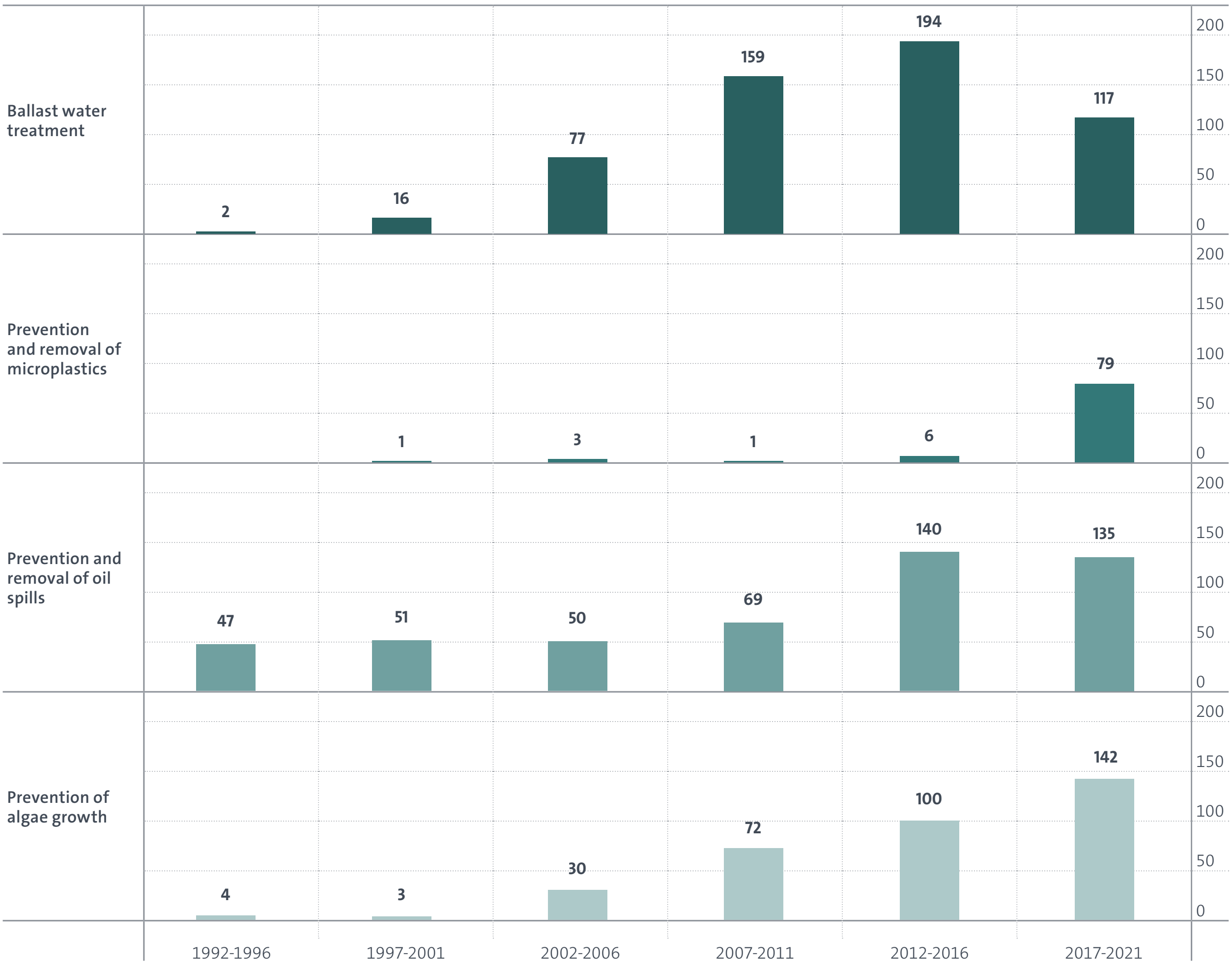
Source: EPO

Prevention and mitigation of surface water contamination (SDG 6.3)

This field is segmented into four subfields, with ballast water treatment being the largest. However, the number of IPFs declined significantly during the most recent five-year period. This can be explained by the introduction of the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) in 2004 with the aim of preventing the spread of harmful aquatic organisms and pathogens through the discharge of ballast water and sediments from ships, which entered into force in 2017. This adoption period triggered significant innovation and patenting activity to enable the industry to comply with the new requirements. Conversely, technologies aimed at the prevention and removal of microplastics and algae growth witnessed substantial increases in IPFs in 2017–2021. Following the Deepwater Horizon oil spill in 2010, IPFs related to oil spill removal doubled between 2007–2011 and 2012–2016 to 140 IPFs and have stabilised since. Europe leads in the prevention and removal of microplastics, accounting for over 50% of all IPFs in this area; although it ranks third, after the US and China, in preventing algae growth. Europe also dominates in ballast water treatment technologies and the prevention and removal of oil spills, with the US also maintaining a significant share in the latter.

Figure 25

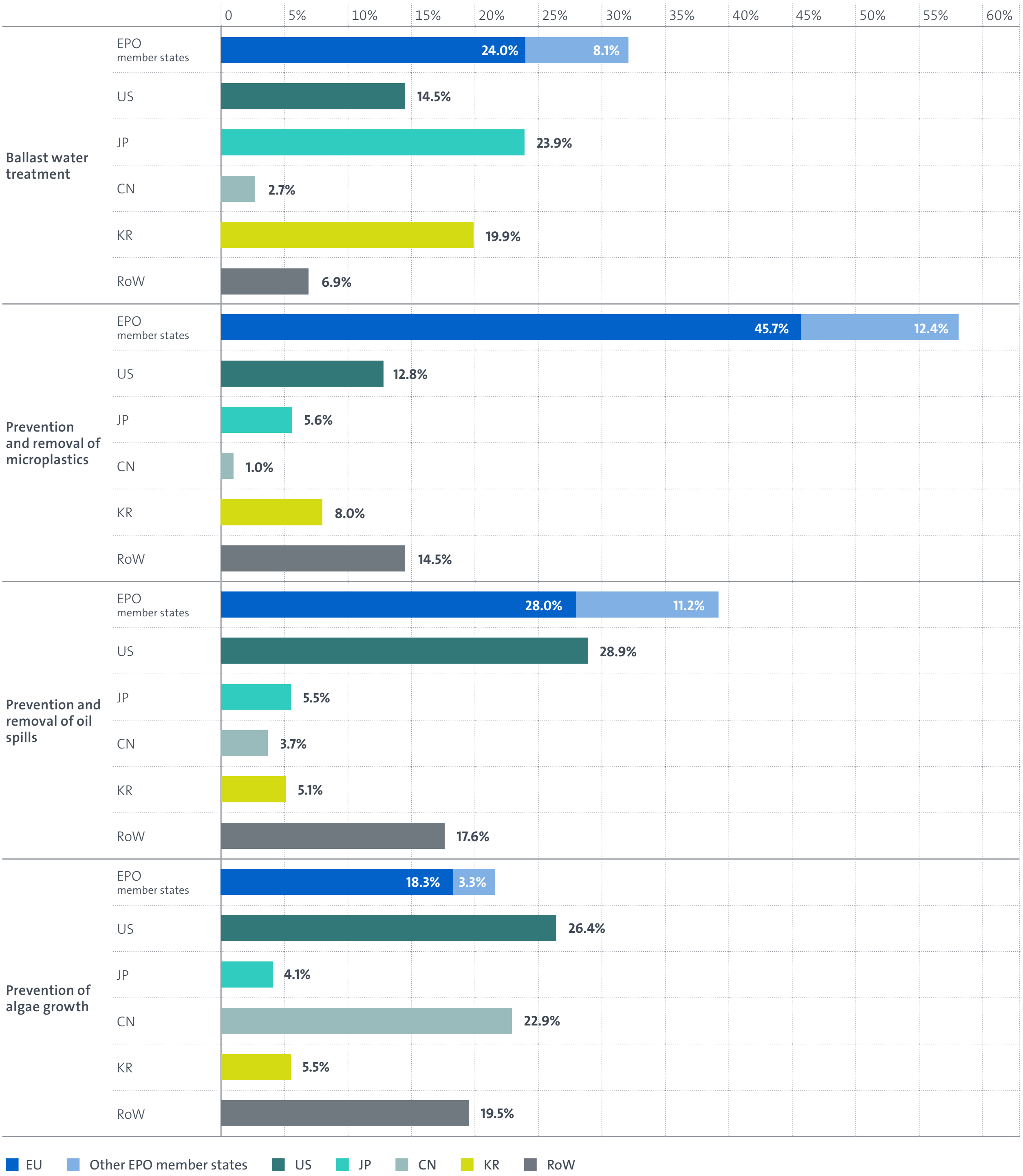
Trends in IPFs in prevention and mitigation of surface water contamination technologies, 1992–2021



Source: EPO

Figure 26

Share of IPFs in prevention and mitigation of surface water contamination technologies, 1992–2021



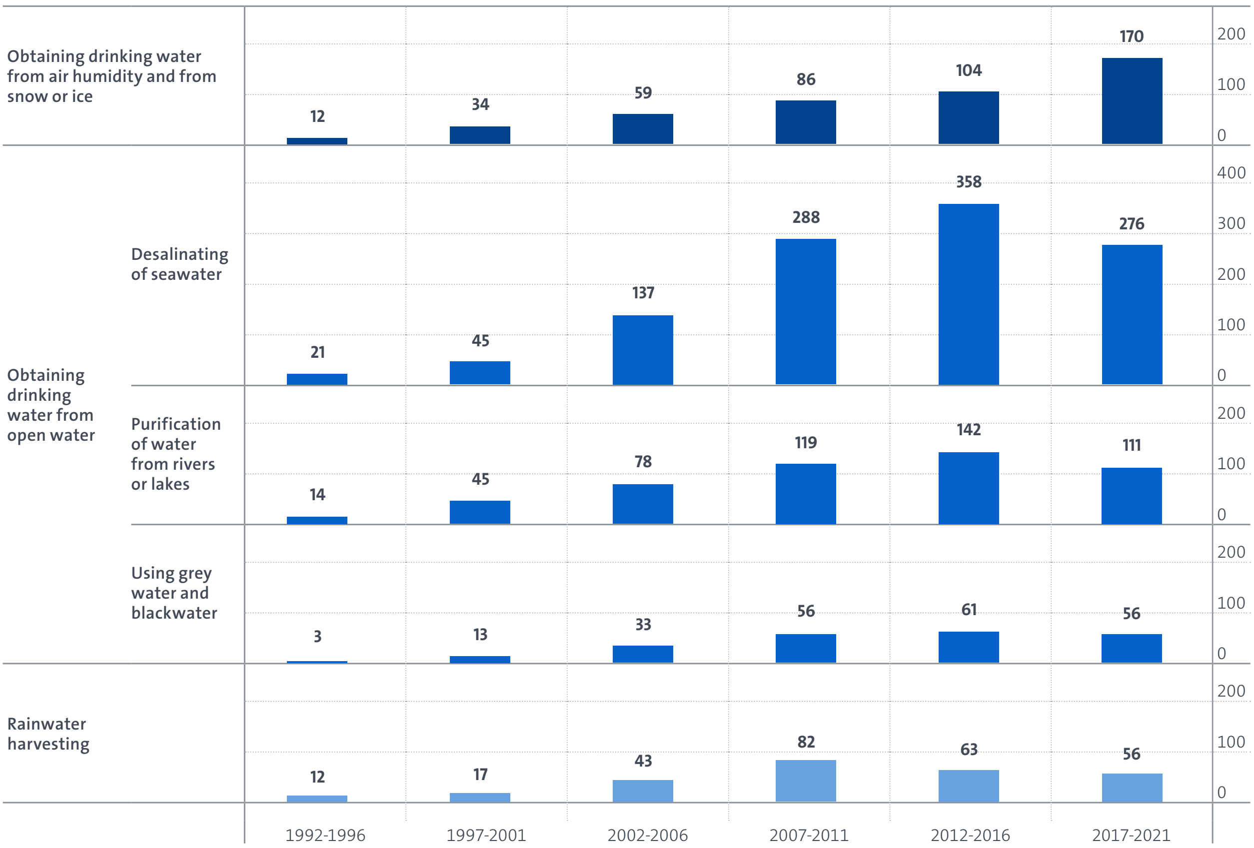
Source: EPO

Potable water harvesting (SDG 6.1)

Obtaining drinking water from open water sources represents the largest subfield within potable water harvesting technologies (Figure 27). The majority of IPFs in this area are associated with the desalination of seawater, followed by the purification of water from rivers and lakes and the treatment of grey and blackwater to produce drinking water. However, the fastest-growing subfield involves extracting drinking water from air humidity, snow, or ice, which saw IPF numbers increase from 104 to 170 between the 2012-2016 and 2017-2021 periods. These technologies can help with growing water scarcity in dry areas, where traditional water sources are insufficient to meet rising demand. In contrast, rainwater harvesting technologies have a comparatively smaller number of IPFs, peaking during the 2007–2011 period and subsequently declining. Interestingly, while Europe holds the largest share in rainwater harvesting, US applicants dominate in the other subfields (Figure 28). The contributions of applicants from the rest of the world are also not to be underestimated, as they account for nearly 20%, or even in excess of this figure in some cases.

Figure 27

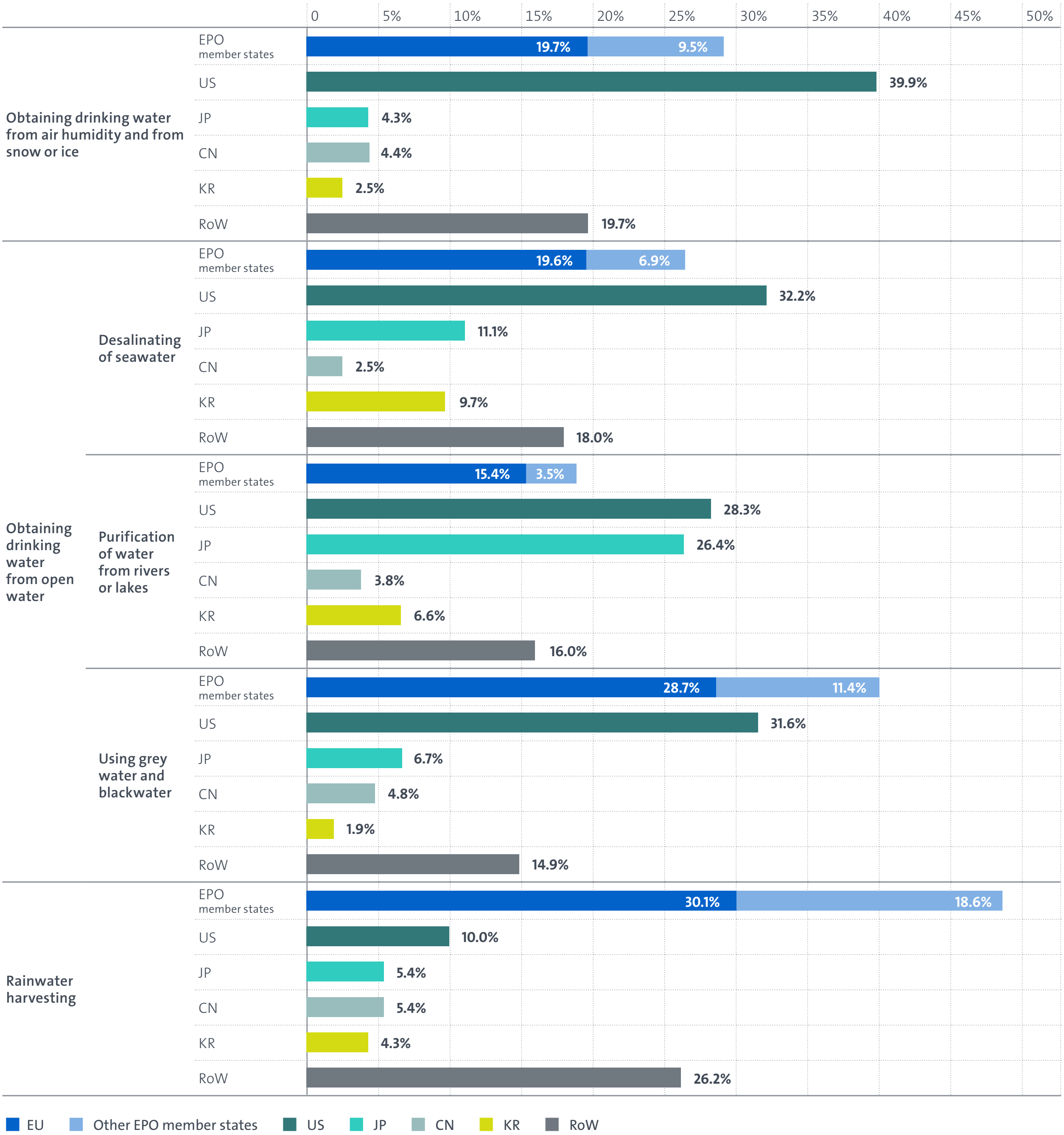
Trends in IPFs in potable water harvesting technologies, 1992–2021



Source: EPO

Figure 28

Share of IPFs in potable water harvesting technologies, 1992–2021



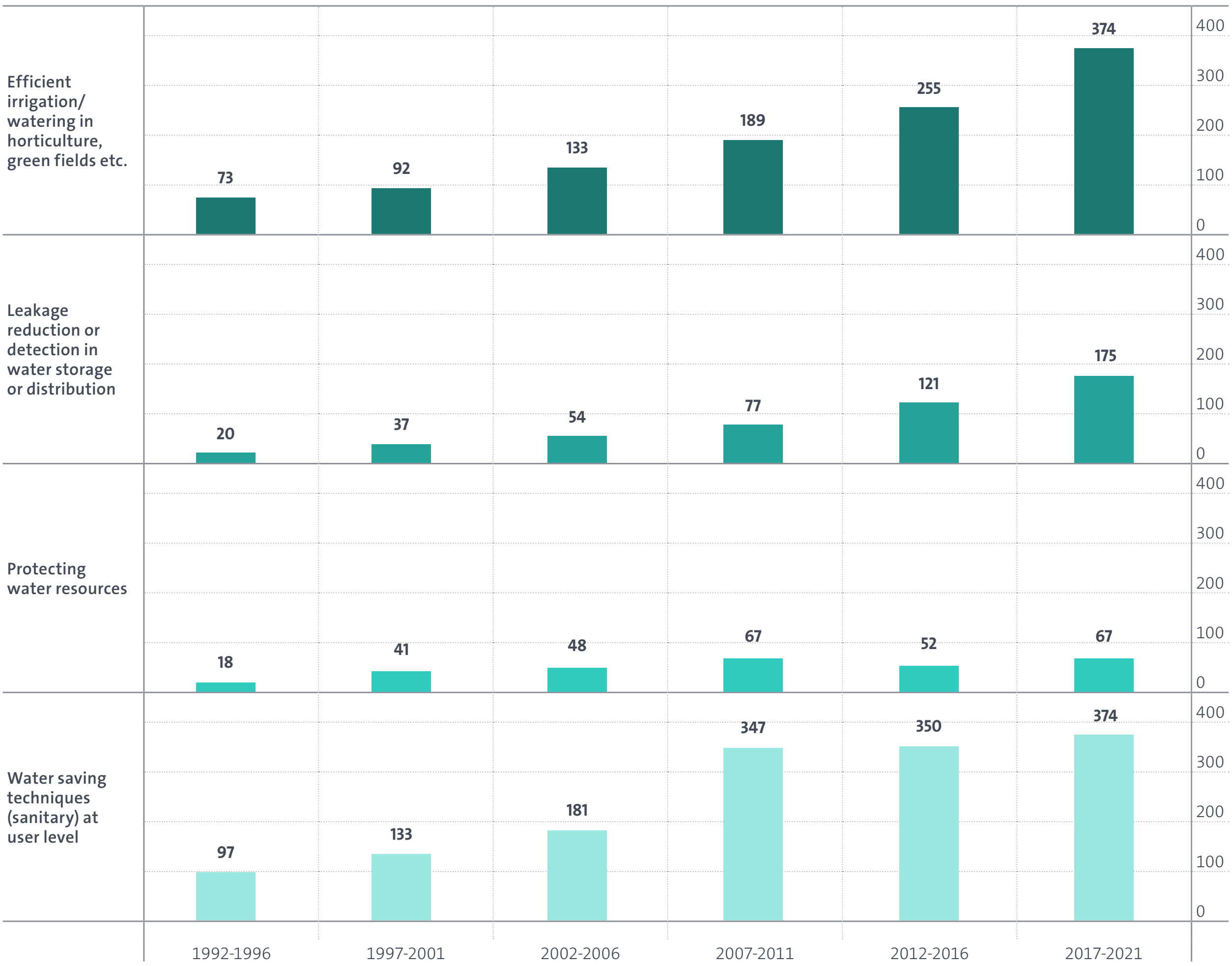
Source: EPO

Efficient water utilisation (SDG 6.4)

This technology field encompasses four distinct subfields: water-saving techniques at the user level, which is the largest, followed by efficient irrigation techniques, leakage reduction or detection in water storage and the protection of water resources, which is the smallest. As depicted in Figure 29, efficient water irrigation has recently experienced the fastest growth, spurred by advancements in the control of watering systems in open-field irrigation. This subfield saw over 370 IPFs in 2017-2021, nearly matching the scale of IPFs in user-level water-saving techniques. European applicants dominate the latter with almost 60% of IPFs, whereas the US and countries like Israel are leading contributors to efficient irrigation technologies (Figure 30).

Figure 29

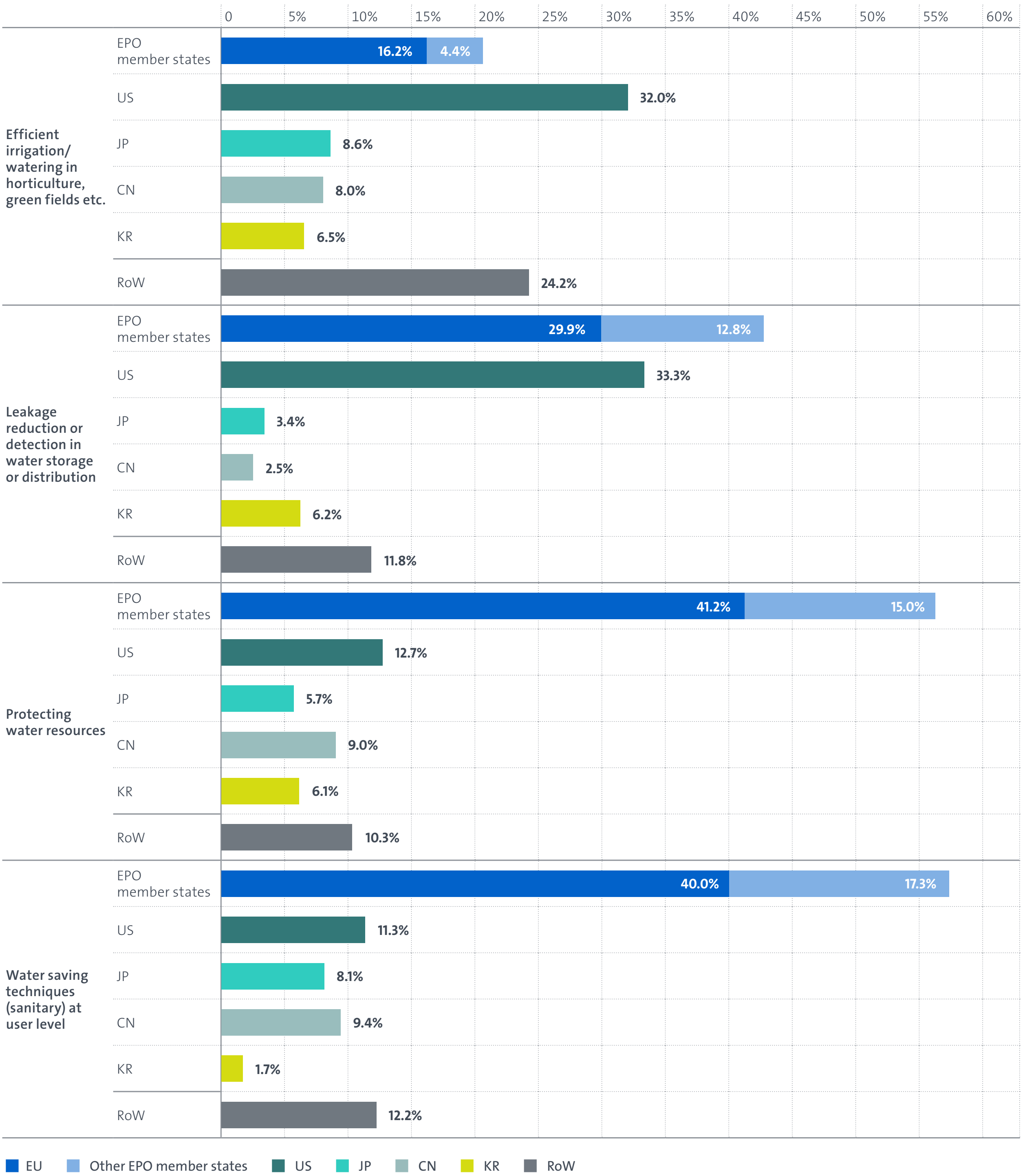
Trends in IPFs in efficient water utilisation technologies, 1992–2021



Source: EPO

Figure 30

Share of IPFs in efficient water utilisation technologies, 1992–2021



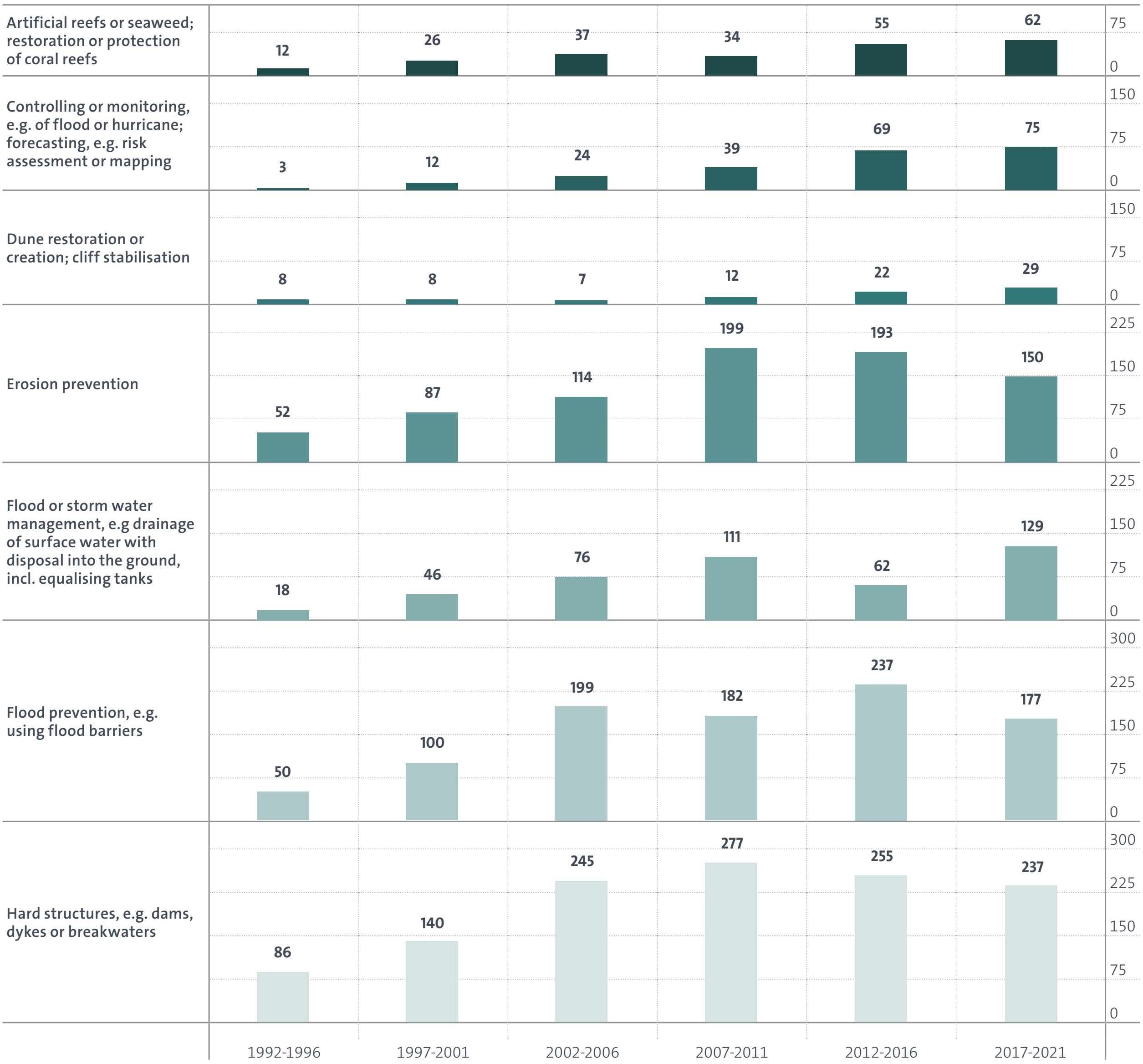
Source: EPO

Protection against water-related hazards (SDG 11)

The majority of IPFs in this field are associated with hard structures such as dams or dykes, alongside flood and erosion prevention technologies. However, these subfields have shown stagnation or even a decline in the number of IPFs recently, as illustrated in Figure 31. By contrast, smaller subfields such as dune restoration, creation of artificial reefs and coral reef protection have seen modest increases. Additionally, like other areas in water technology, there is a growing trend in IPFs related to the application of information and communication technologies (ICT) for controlling, monitoring and forecasting water hazards like floods and hurricanes. Notably, this subfield exhibits the most equitable geographic distribution, whereas other areas are predominantly dominated by European applicants, as shown in Figure 32.

Figure 31

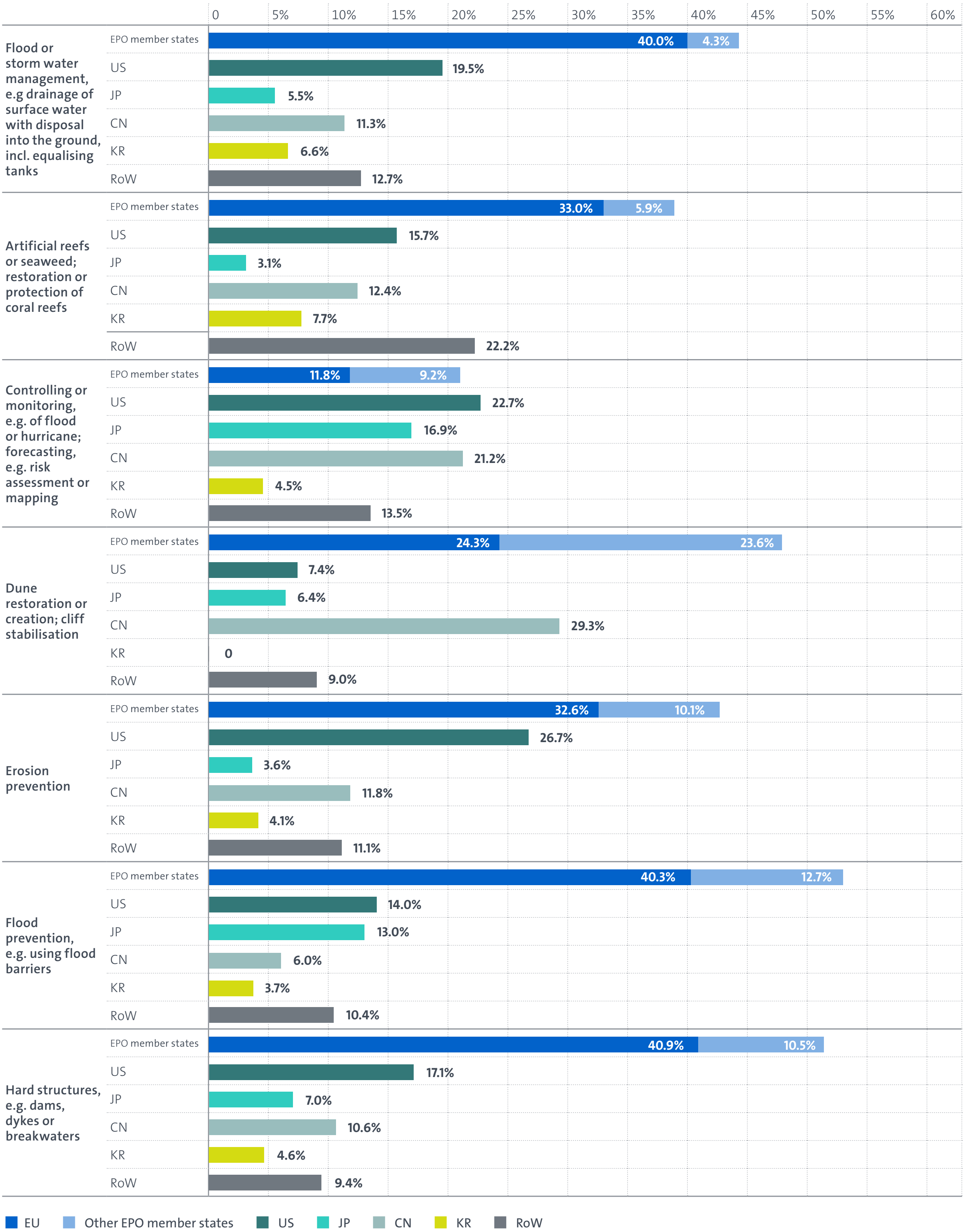
Trends in IPFs in technologies for protection water-related hazards, 1992–2021



Source: EPO

Figure 32

Share of IPFs in technologies for protection against water-related hazards, 1992–2021



Source: EPO

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