The hydrogen education and research landscape

Update of the October 2024 report

October 2025

Disclaimer

The aim of this report is to provide an overview of the training programmes and publicly accessible online educational materials available on the European Hydrogen Observatory, in addition to the trends and patterns in research and innovation activities within the hydrogen sector in Europe as of August 2025, unless stated otherwise. The authors believe that this information comes from reliable sources, but do not guarantee the accuracy or completeness of this information.

The data of the European Hydrogen Observatory will continuously be updated. These updates will take place annually for most datasets, while for some it can also be done on a case-by-case basis. As a result, the information used as of writing of this report might differ from the updated data that is presented on the European Hydrogen Observatory.

The information and views set out in this report are those of the author(s) and do not necessarily reflect the official opinion of the Clean Hydrogen JU. Neither the Clean Hydrogen JU, other European Union institutions and bodies, nor any person acting on their behalf may be held responsible for the use which may be made of the information contained therein.

This report was prepared for the Clean Hydrogen JU as part of the European Hydrogen Observatory. Copies of this document can be downloaded from https://observatory.clean-hydrogen.europa.eu/.

The European Hydrogen Observatory has been prepared for the Clean Hydrogen JU under a public procurement contract.

Co-funded by the European Union

Clean Hydrogen Partnership

TABLE OF CONTENTS

Executive summary

This report aims to summarise the status of the European hydrogen education and research landscape. It is based on the information available at the European Hydrogen Observatory (EHO) platform, the leading source of data and information on hydrogen in Europe (EU27, EFTA and the UK). Specifically for education, this report provides an overview of the European training programmes and educational materials available in the EHO library. For research, this report gives insights in the trends and patterns of research and innovation activity in the hydrogen sector based on data of patent registrations and publications. The data is sourced from Tools for Innovation Monitoring (TIM) supplied by the Joint Research Council in August 2025. TIM tracks publications from Scopus and patents from PATSTAT based on keywords.

As of June 2025, a total of 261 European training programmes have been identified, up from 253 in 2024. Master's programmes and professional training courses continue to represent the largest share, accounting for 50% and 33% of the total, similar to the previous year. These programmes are offered in 12 languages, with English remaining the predominant language, used in 53% of cases (138 out of 261). The majority of programmes, 82%, are conducted in a single language, while 18% are multilingual. The European Hydrogen Observatory has mapped training programmes across 21 countries, with Switzerland and Ireland newly added. France continues to host the largest proportion of programmes at 37%, followed by Spain with 14% and the United Kingdom with 11%. Interestingly, over half of the mapped training programmes focus exclusively on hydrogen and/or fuel cells. Hydrogen end-use applications in transport, hydrogen production and hydrogen storage, transport, and distribution are the predominant subjects featured in approximately 70% of programmes

The EHO online library offers 245 reliable educational materials available in various formats, including slides, e-laboratories, experiments, games, case studies, lab protocols, and videos. These materials were created between 2006 and 2025, with a steep increase in the release of educational materials in 2024, when 57 new materials were added. The library provides resources in 16 different languages, with English being the predominant language, used in 84% of the materials. The primary focus of these educational materials is on hydrogen end-use applications, covered in 36% of the materials. General information on hydrogen follows, included in 29% of the courses. Most materials are intended for audiences at higher education levels, specifically levels 6 and 7, corresponding to Bachelor’s and Master’s degrees.

From 2006 to 2025, patent and publication activity in specific fields of fuel cells, clean hydrogen production, and hydrogen storage was analysed. In Europe, 22,968 publications and

1,166 patent registrations were identified, representing 22% and 8% of the global totals, respectively. Overall, there is an increasing trend in the numbers of publications and patents in the most recent years. Fuel cells dominated the research landscape in the early years, shifting progressively toward hydrogen production more recently.

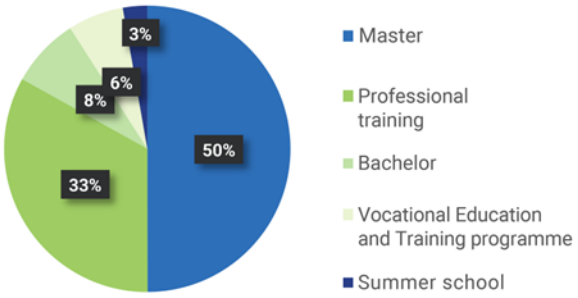
Key insights

Training Programmes & Education Materials

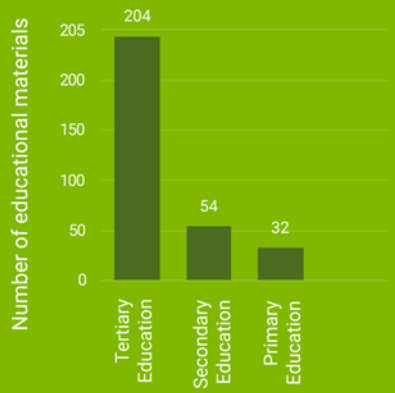
261 training programmes & 245 educational materials available in the EHO online library

Training programmes available in **12 languages** and educational materials in 16, with over 50% offered in **English**.

Training programmes by type



Education materials by level



Primary Education: Primary school and middle school (ISCED 1–2)

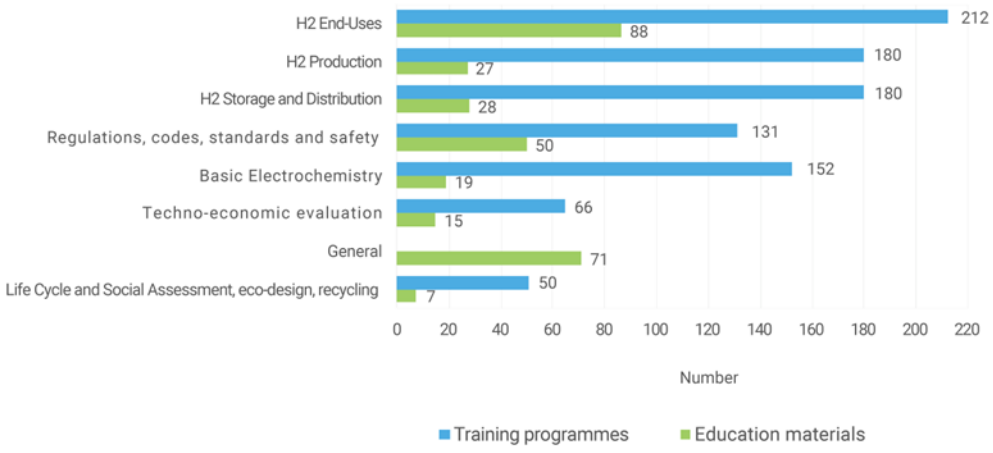
Secondary Education: High school and post-secondary non-tertiary education (ISCED 3–4)

Tertiary Education: Short-cycle programmes, bachelor's, master's, and doctoral degrees (ISCED 5–8)

The majority of the materials are intended for audiences with higher level of understanding, specifically **Bachelor's and Master's levels.**

62% of the training programmes are taking place in **France, Spain and UK.**

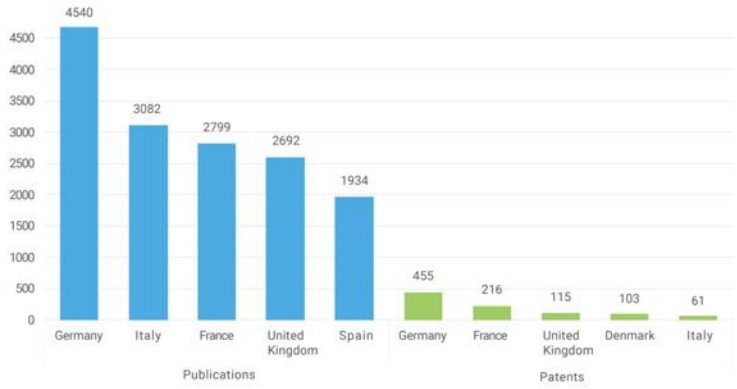
Training programmes and education materials by topic



Publications & Patents

The publication and patent data cover **fuel cell** (PEM, SO and alkaline), **clean hydrogen production** (PEM, SO, alkaline and non-elecrolysis) and **hydrogen storage** (only onboard storage) sectors.

Top 5 European countries in publications and patents



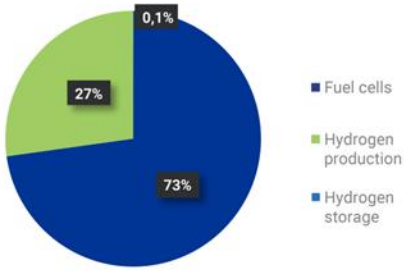
Hydrogen production has gained **increasing importance** in recent years in the **research** landscape **compared to fuel cells.**

A total of **22,968 publications** have been identified in Europe from 2006 to 2025

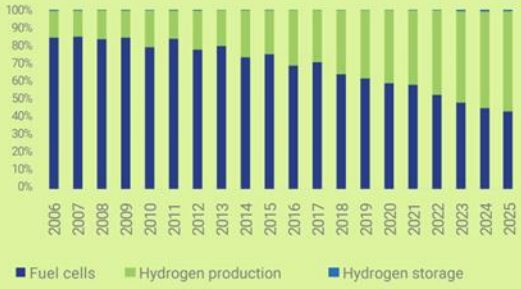
A total of **1,166 patents** have been identified in Europe from 2006 to 2023

Publications in Europe by topic

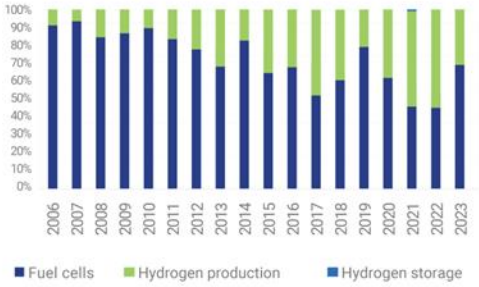
Patents in Europe by topic



Historical data of publications in Europe by topic from 2006 to 2025



Historical data of patents in Europe by topic from 2006 to 2023*



*Patents are only published starting from 18 months after filling, so data from 2023 onwards may not yet be fully complete

Overview

In the rapidly evolving landscape of modern industries, education and research are crucial for fostering innovation, workforce readiness, and economic growth. As the global focus shifts towards sustainability and renewable energy, hydrogen technology demands robust educational frameworks, comprehensive training programmes, and cutting-edge research.

Education provides essential knowledge for advancing hydrogen technologies, with specialized programmes preparing individuals for hydrogen production, distribution, and end-use. Training programmes bridge theory and practice, equipping the workforce with practical skills and facilitating the re-skilling of workers from declining industries, thereby promoting job creation and economic resilience. Research drives continuous innovation in hydrogen technologies, leading to efficiency improvements, cost reductions, and solutions to technical challenges. Patents protect intellectual property and publications disseminate new knowledge, fostering further industry innovation.

The synergy between education and research creates a robust ecosystem supporting the hydrogen sector's development. By investing in these areas, stakeholders can ensure the growth of the hydrogen economy and its contribution to global sustainability goals.

This report includes information on European training programmes, educational materials and the trends and patterns of research and innovation activity in the hydrogen sector with data of patent registrations and publications. It is based on the information available at the European Hydrogen Observatory (EHO) website (https://observatory.cleanhydrogen.europa.eu/), the leading source of hydrogen data in Europe. The data presented in this report is based on research conducted until the end of August 2025.

The training programmes section provides insights into major European training initiatives, categorized by location. It allows filtering by type of training, focus area and language. It covers a wide range of opportunities such as vocational and professional trainings, summer schools, and Bachelor's or Master's programmes.

The education materials chapter summarizes the publicly accessible educational materials available online. Documents can be searched by educational level, by course subject, by language or by the year of release.

The section referring to research and innovation activity analyses trends and patterns in the hydrogen sector, using aggregated datasets of patent registrations and publications by country.

01

Training programmes

Introduction

This chapter provides an overview of the European training programmes that are registered in the EHO database and are relevant to the hydrogen sector. This chapter provides statistics of the training programmes based on location, the type of training, focus of the training and language.

The data on training programmes presented on the European Hydrogen Observatory website are shared by training providers and processed by Hydrogen Europe Research and reflects the situation as of June 2025. The information is provided by organizations and individuals through completion of our questionnaire. For a training programme to be listed, it must include a minimum set of information and web references to facilitate posting.

Interactive data dashboards on training programmes can be accessed on the European Hydrogen Observatory website.

1.1. Overview

Currently, 261 training programmes are listed in the Observatory's online library, reflecting an increase of 8 programmes since 2024 (+3%).

Table 1, gives an overview of the different filters available in the training programmes dashboard, allowing users to refine their search according to specific needs. Users have the ability to filter their search results based on three criteria: type of training (5 options), course focus (11 subjects), and language availability (12 languages).

In addition to the three criteria mentioned above, organizations and individuals are able to provide additional information about their training programmes. Table 2 presents the extra information a training programme may provide in the EHO database, that can be seen by the user when navigating though the library, such as the name of the organization, target audience, training duration and many more.

Table 1. Categories of training programmes available on the EHO website.

Type of training	Course focus	Language
Bachelor Master Professional training Summer school Vocational Education and Training (VET) programmes	Basic electrochemistry H_2 End-uses: buildings H_2 End-uses: energy, power generation H_2 End-uses: industry H_2 End-uses: transport H_2 Production H_2 Storage, Transport and Distribution Life Cycle and Social Assessment, eco-design, recycling Regulations, Codes, Standards Safety Techno-economic evaluation	Danish Dutch English French German Greek Italian Norwegian Portuguese Romanian Spanish Swedish

Table 2. Additional information data providers may provide for training programmes.

Additional information on training programmes	
Question	**Answer**
Name of the organization providing the training	e.g. Université Grenoble Alpes
Location (address):	• For in-person training: address where the training takes place • For online training: location of the training provider
Is the programme entirely focused on hydrogen and/or fuel cells?	• Yes • No
Target audience for the training	E.g., Master students in engineering, electricians, trainers, etc.
How is the training taught?	• In person • Online • Hybrid / both options possible
Requirements from applicants	Minimum degree, prerequisite to attend the training, etc.
Materials / Infrastructures proposed	• Books / e-books • Demonstration platforms • E-Learning tools e.g. MOOCs • Handouts • Infrastructure visits • Labs (physical or virtual) • Serious games • Simulation environment • Slides
Duration of the training	• One day or less • Between a day and a week • Between one week and a month • Between one and six months • Between six months and a year • Between one and two years • More than two years
Recognition of the training	Issuance of a certificate by the organisation, obtention of a recognised degree, ECTS or ECVET granted, microcredentials, other
Is the programme complimentary?	• Yes • No
If the programme is not complementary, how much does it cost?	e.g. cost in €
Capacity of the training	Maximum number of participants
Possibility to combine the training with employment	Description of the relevant scheme applying: apprenticeship, evening classes, study time arranged to combine the training with work etc.

1.2.
Training programmes by category

1.2.1.
Training programme type

Figure 1 shows the various training programme types and their respective shares of the total number of training programmes listed in the EHO database. These categories include bachelor's, master's, VET programmes, professional trainings, and summer schools.

Master's programmes represent the largest segment among the registered training programmes, totalling 130, which accounts for 50% of the total. Professional training programmes follow with 87 entries, comprising 33% of the total, while the remaining categories collectively make up approximately 17% of the programmes. One programme is classified as both a master's and a professional training programme.

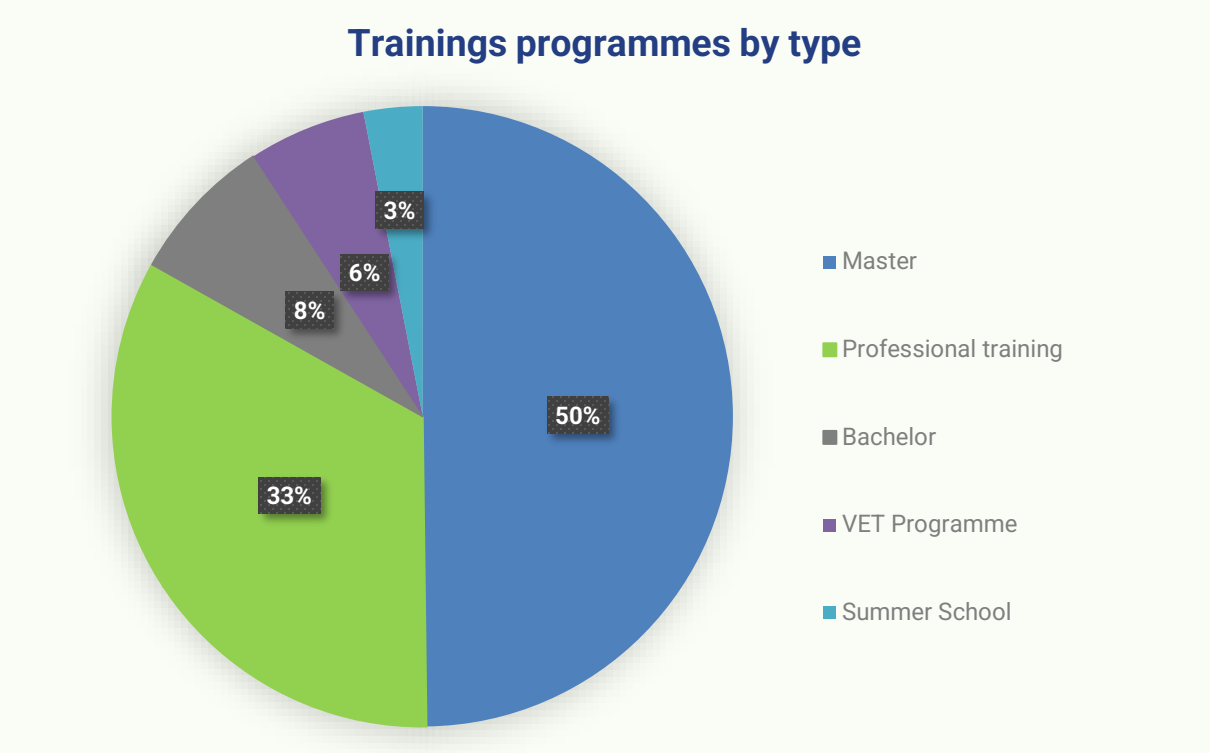


Figure 1. Share of training programmes in Europe by type.

Figure 2 illustrates the evolution of the training programmes registered in the EHO database from 2021 to 2025.

Overall, all categories of programmes showed notable growth during this period. Master's programmes recorded the most significant overall increase, rising by 141% to reach 130 programmes in 2025. VET programmes also experienced substantial growth, increasing by 129% to 16 programmes. Professional training programmes expanded by 83%, reaching a total of 86, while Bachelor's programmes rose by 67% to 20. Summer school programmes saw the most modest increase, growing by 60% to a total of 8 programmes in 2025.

The most substantial growth for most programme types, namely Master's, Bachelor's, Professional training, and VET occurred between 2021 and 2022. During that year, Master's programmes more than doubled, increasing from 54 to 117 (117% increase). Bachelor's programmes grew from 12 to 22 (83% increase), while Professional training rose from 47 to 73 (55% increase), and VET programmes expanded by 57%. In contrast, the Summer school programmes experienced their highest annual increase between 2022 and 2024, with a 40% rise.

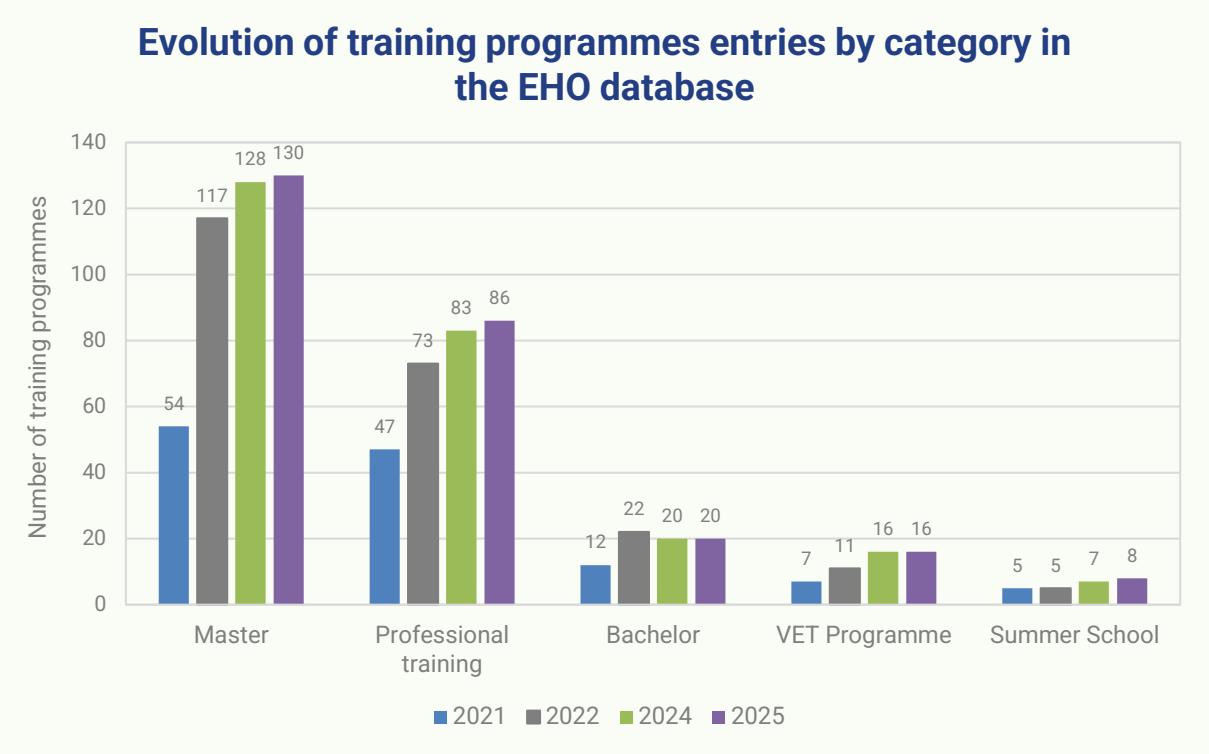


Figure 2. Evolution of training programmes offerings in Europe by category in the EHO database.

1.2.2.

Language

The registered training programmes provide learning opportunities in 12 different languages. Figure 3 presents a summary of the languages in which the programmes are most abundantly available. Note that some programmes are available in multiple languages, so the counts reflect the availability in each language.

English is the predominant language, used in 53% of the programmes (138 out of 261). French follows as the next most common language, utilized in 33% of the programmes. Spanish is available in 12% of the programmes, while German is offered in 9%. Italian and Dutch are each available in 3% of the programmes. Other languages such as Greek, Norwegian, Portuguese, Swedish, Romanian, and Danish continue to be offered less frequently, collectively accounting for less than 5% of total programmes.

It is also worth noting that not all countries with training programmes offer them in the local language. Some programmes are conducted in English, especially those under international schemes like Erasmus Mundus Masters. Additionally, certain programmes are available both in English and in the local language of the country where the training takes place.

As shown in Figure 4, the majority of the programmes mapped in 2025 (82%) are conducted in a single language, comprising 213 programmes, while multilingual programmes account for 18%, totalling 48 programmes. Multilingual programmes usually mean bilingual, typically offered in English and the language of the country where the training takes place.

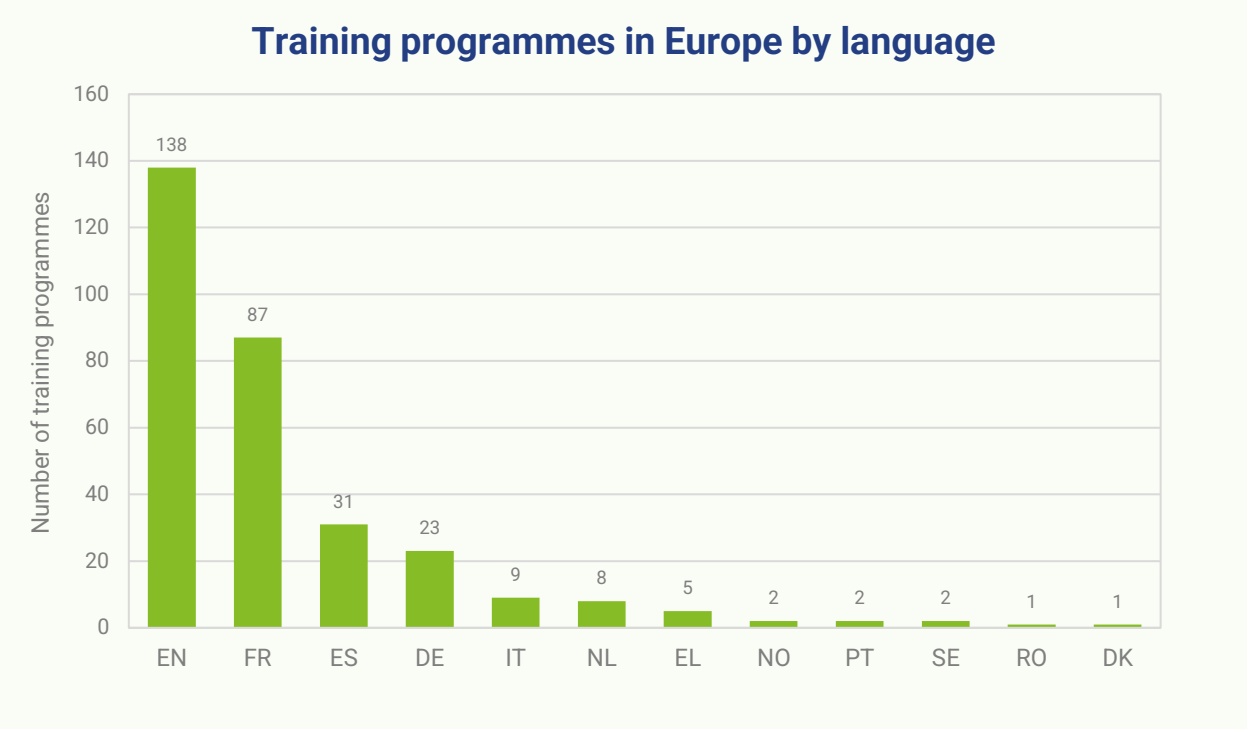


Figure 3. Breakdown of training programmes in Europe available in the EHO library by language [1].

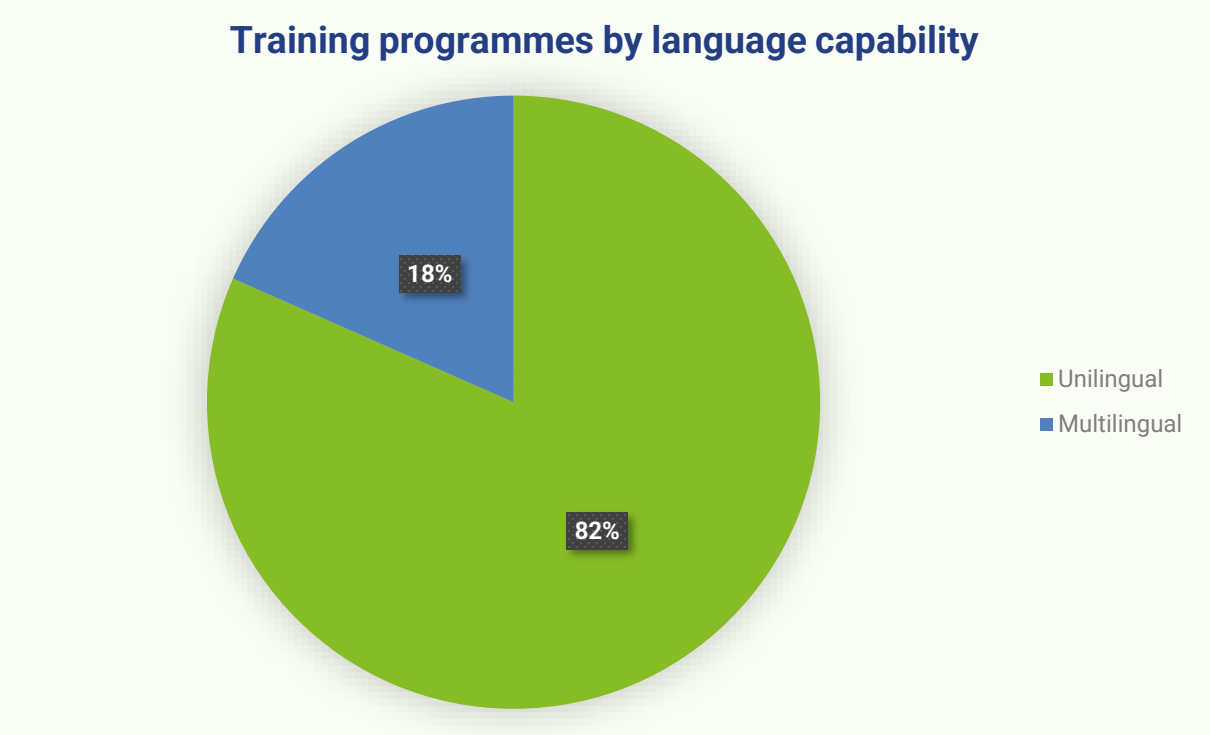


Figure 4. Share of training programmes in Europe by language capability.

[1] The abbreviations used in this figure refer to the country codes used by Eurostat and available here: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes

1.2.3.

Location

The Observatory's mapping of training programmes covers 21 European countries in 2025, up from 19 countries in 2024. The two new additions are Ireland and Switzerland. Figure 5 provides an overview of the geographical distribution of training programmes categorized by ranges of programme numbers, while Figure 6 details the number of programmes per country.

The training programmes are predominantly located in France, where 37% of the trainings are taking place, followed by Spain with 14%, and then the United Kingdom with 11%. Between 5% and 10% of the programmes are found in Germany (7%), Italy (7%), and the Netherlands (5%). Additionally, 5 programmes are available online.

As a general tendency, trainings in the field of hydrogen seems to be more often provided in Western Europe. It is important to note that the EHO database may not capture all available training programmes. Training providers are encouraged to register their programmes by filling out the provided form.

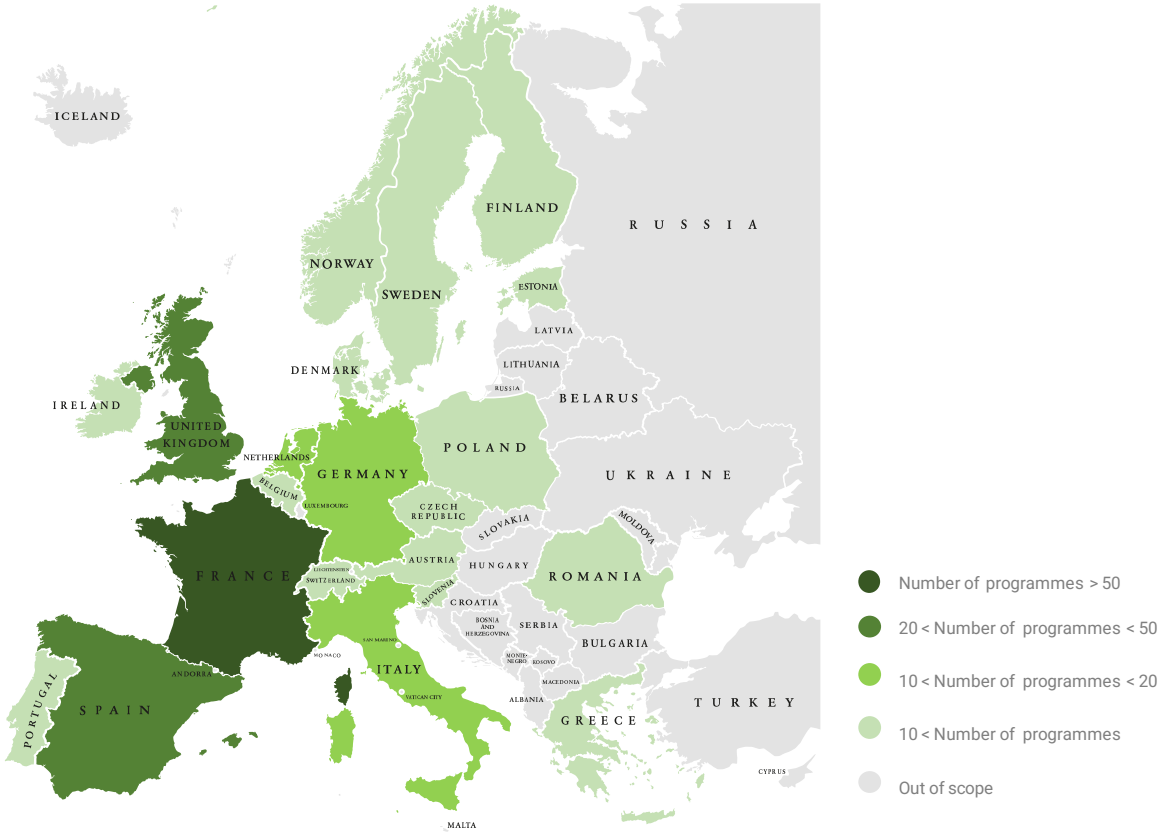


Figure 5. Geographical distribution of training programmes in Europe by ranges.

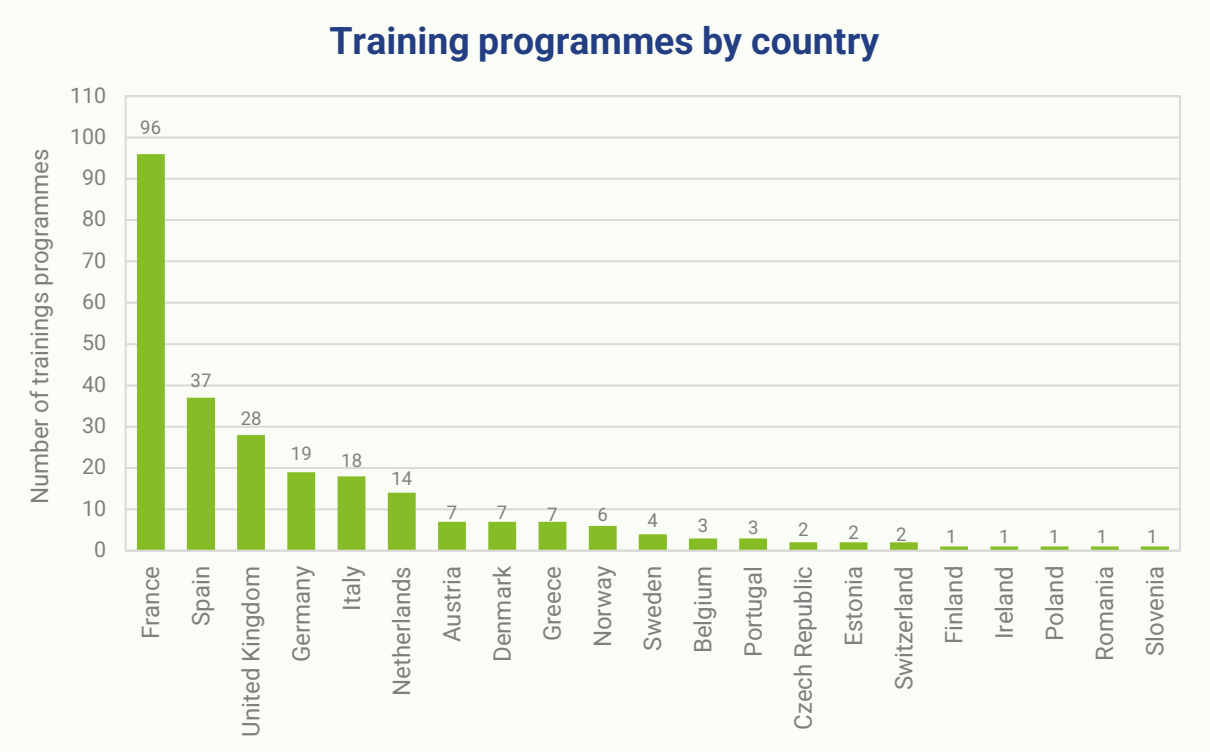


Figure 6. Number of training programmes in Europe by country available in the EHO library.

1.2.4.

Training focus

Most of the mapped training programmes are not entirely focused on hydrogen and/or fuel cells. As shown in Figure 7, just over half of the programmes (132 out of 261, or 51%) now concentrate solely on hydrogen and fuel cells, while the remaining 49% (128 out of 261) cover broader subjects where hydrogen and fuel cells are only part of the overall curriculum.

Table 3 provides an overview of the available subject categories related to the hydrogen topic, including detailed explanations for each item. Figure 8 illustrates the number of training programmes associated with each of these subject categories. It is important to note that most programmes address multiple topics, so the counts represent the extent to which each topic is included in the programmes.

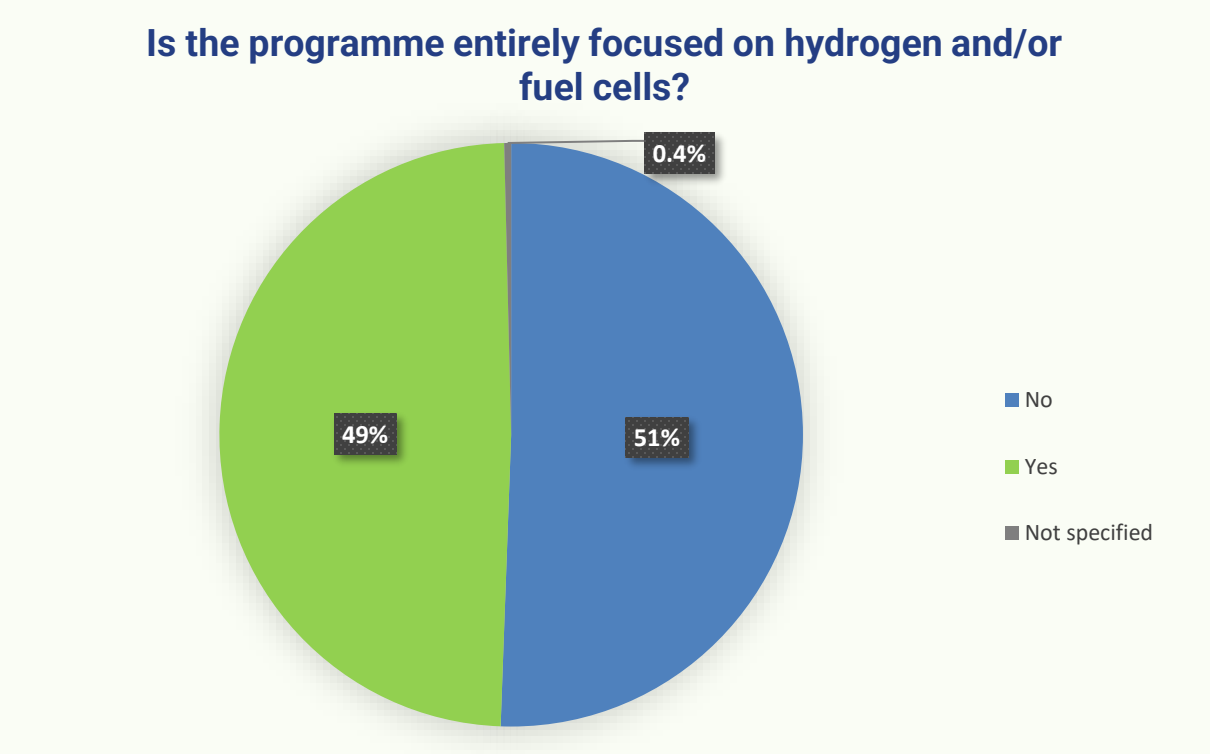


Figure 7. Share of programmes entirely focused on hydrogen and/or fuel cells.

Table 3. Overview of training programmes subject categories.

Training focus	Description
Basic Electrochemistry	Refers to the theory behind the electrochemical reactions that are taking place in electrolysis or fuel cell devices.
H_2 Production	Refers to the different means to produce hydrogen (electrolysis, gasification of biomass, pyrolysis, etc.)
H_2 Storage, Transport and Distribution	Refers to the methods used to store, transport and distribute hydrogen (e.g. storage in salt cavern, transport via pipelines, etc.)
H_2 End-uses: transport	Refers to vehicles using hydrogen or hydrogen derivative synthetic fuels in fuel cells or ICE. All transport sectors are included: road, maritime, aviation, rail and off-road.
H_2 End-uses: industry	Refers to hydrogen used in some industrial processes (e.g. steel manufacturing, chemicals, etc.)
H_2 End-uses: buildings	Refers to electrical, heating and cooling applications including fuel cells, CHP, boilers, etc. using hydrogen or hydrogen derivative synthetic fuels.
H_2 End-uses: energy, power generation	Refers to the production of electricity using hydrogen or hydrogen derivative synthetic fuels in turbines and/or fuel cells.
Regulations, Codes, Standards	Refers to the applicable regulations and the development and use of harmonized performance-based standards for hydrogen appliances and systems.
Safety	Refers to the safe production, handling and use of hydrogen or its derivatives.
Life Cycle and Social Assessment, eco-design, recycling	Refers to environmental and sustainability aspects of hydrogen.
Technical-economic evaluation	Refers to training courses at the crossroad of business and engineering to evaluate the technical possibilities of the technology whilst considering its economic cost.

Hydrogen end-use applications in transport, hydrogen production and hydrogen storage, transport, and distribution are the predominant subjects featured in approximately 69-70% of programmes. Basic electrochemistry and end-use applications in energy and power generation are covered by 58% and 56% of the programmes respectively.

Other subjects are covered less frequently: safety (46%), end-use applications in industry (40%), end-use applications in buildings (33%), regulations, codes and standards (28%), technical-economic evaluation (25%) and life cycle and social assessment, eco-design and recycling (19%).

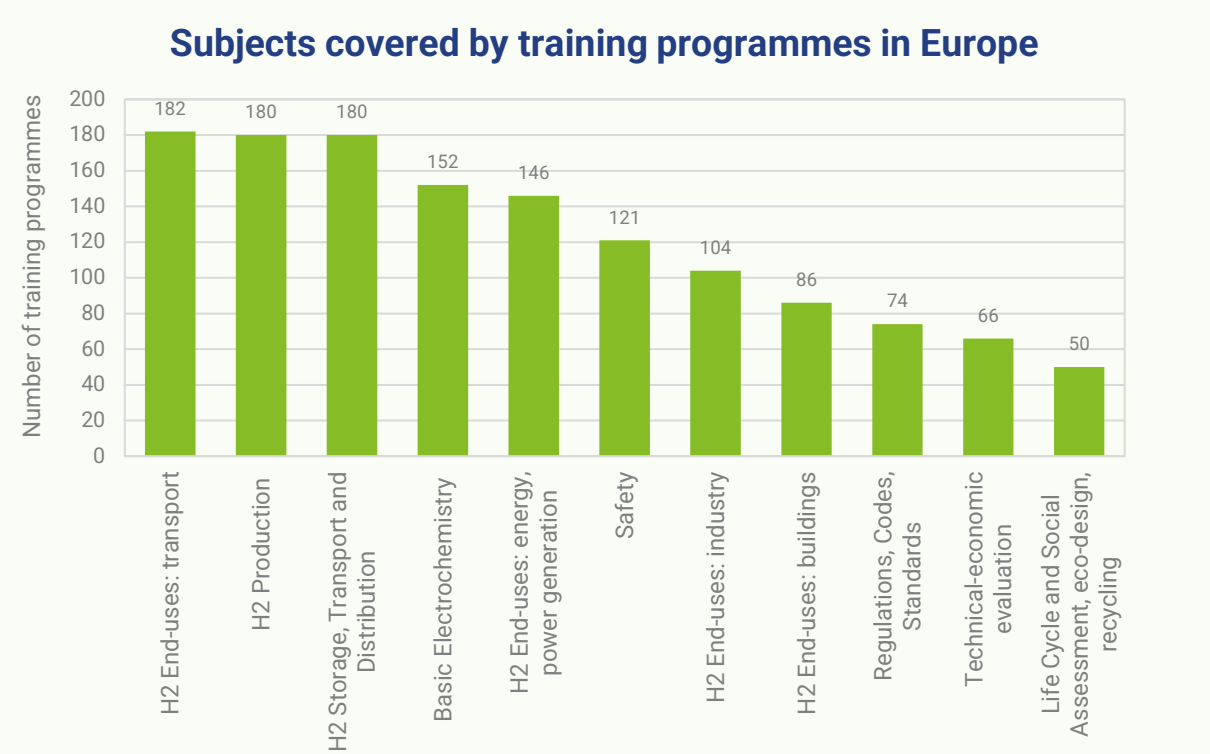


Figure 8. Number of training programmes in Europe by subject.

02

Education materials

Introduction

This chapter provides an overview of the current education materials in the EHO database for learners and students interested in the field of hydrogen.

The EHO database provides an online library relevant for all different levels of education, as described by the International Standard Classification of Education (ISCED) and covers many different course subjects and languages. Only materials intended for public use are shared in the library.

The data on educational materials presented on the European Hydrogen Observatory website are collected by Hydrogen Europe Research from European projects' deliverables (Clean Hydrogen Partnership and other EU programmes) as well as other reliable sources identified through desk research and reflects the situation as of June 2025. Individuals and organizations wishing to contribute to this open-access library are encouraged to contact the EHO team.

Interactive data dashboards on education materials can be accessed on the European Hydrogen Observatory website.

2.1. Overview

245 reliable materials may be retrieved on the online library of the EHO, reflecting an increase of 8 materials since 2024 (+3%). It is the go-to-resource for finding hydrogen related materials developed in the framework of European projects.

Table 4 provides an overview of the filters that are available to refine the search of users according to their needs. The filters include the education level (ranging from 0 to 8 ISCED level), the course focus, and the language.

The International Standard Classification of Education (ISCED) levels, developed by UNESCO, is an internationally recognized system that categorizes education programmes and qualifications by level and field, enabling consistent comparison across different education systems globally. By aligning the materials with each ISCED level, a clear and structured understanding of the various stages of education is provided.

Table 4. Categories on educational materials available on the EHO website.

Level of education	Course focus	Language
ISCED 0: Early childhood education	Basic electrochemistry	Czech
ISCED 1: Primary education (primary school)	General	Danish
ISCED 2: Lower secondary education (middle school)	H_2 Production	Dutch
ISCED 3: Upper secondary education (high school)	H_2 Storage and Distribution	English
ISCED 4: Post-secondary non-tertiary education	H_2 End-uses	French
ISCED 5: Short-cycle tertiary education	Life Cycle and Social Assessment, eco-design, recycling	German
ISCED 6: Bachelor's or equivalent level	Regulations, Codes, Standards & Safety	Greek
ISCED 7: Master's or equivalent level	Techno-economic evaluation	Hungarian
ISCED 8: Doctoral or equivalent level		Italian
		Norwegian
		Polish
		Portuguese
		Romanian
		Serbian
		Spanish
		Turkish

Additionally, users can search for relevant materials based on their release year. The educational materials available were created between 2006 and 2025. Figure 9 illustrates the number of educational materials released within this period. The highest number of materials were released in 2024 (57 materials), 2006 (43 materials), 2012 (38 materials) and 2019 (32 materials). Conversely, the fewest materials were released between 2015 and 2018, with fewer than five materials released each year. In 2025, only one material has been published so far, likely because many current projects are still in progress and have not yet produced final educational outputs.

The increase in the number of materials reported for 2024, rising from 50 in the previous report released in October 2024 to 57 in the current dataset, reflects the inclusion of additional materials published after June 2024, thereby providing a more complete overview of the full year.

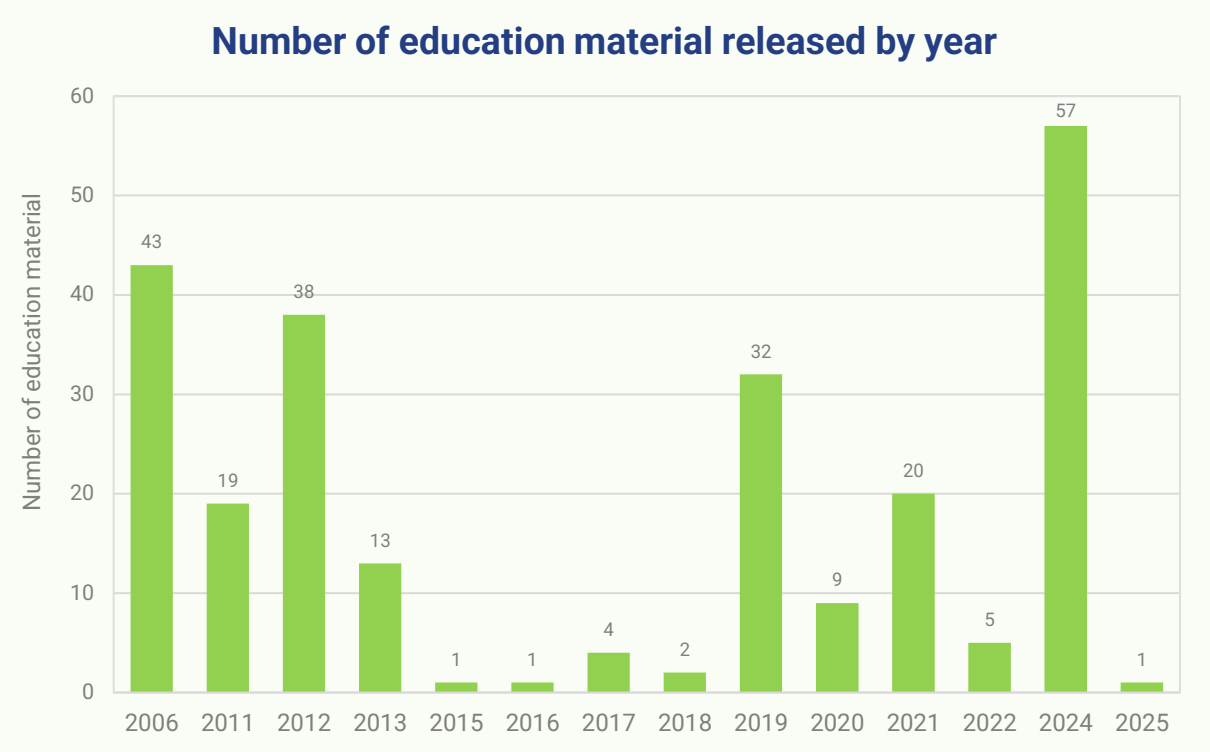


Figure 9. Number of education materials released by year.

The educational materials are available in various formats, mainly slides, but also e-laboratories, experiments or games, case studies, lab protocols, videos and more.

The sources include CertifHy, CLEAN-kWAT, College of the Desert and SunLine Transit Agency, ene.field, FCH Train, FCHGO, GreenSkillsforHydrogen, H_2 Training, HyFacts, HyResponder, HySchools, Jess Summer School 2011 and 2012, JUST GREEN AFRH2ICA, NET-Tools, PACE, SkillSea, Sustainability by Biotechnology, UpHyMob and US Department of Energy.

2.2.
Education materials by category

2.2.1.
Language

Education materials spanning 16 different languages are currently listed in the EHO library. Those languages include Czech, Danish, Dutch, English, French, German, Greek, Hungarian,

Italian, Norwegian, Polish, Portuguese, Romanian, Serbian, Spanish and Turkish.

Figure 10 displays the languages in which educational materials are available in the EHO library. Note that some materials are available in multiple languages, so the counts reflect the availability in each language.

English is the predominant language, available in 84% of the materials (207 out of 245). Italian follows with 20 percent (49 materials), French with 17 percent (41 materials), Spanish and German with 16 percent each (40 and 38 materials, respectively). Less than 10 percent of the materials are available in the remaining languages.

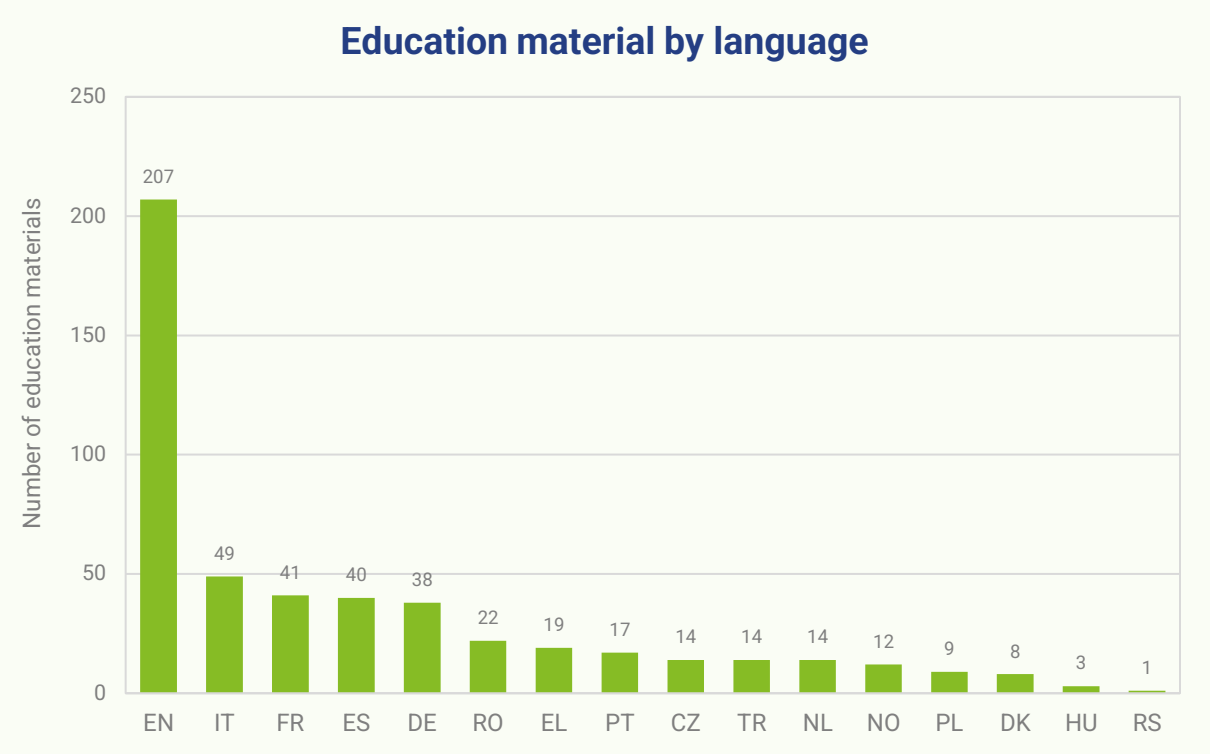


Figure 10. Breakdown of education materials available in the EHO library by language[2].

2.2.2.

Course topic

Like the training programmes, the education materials are categorized according to their course topics. Table 5 provides a comprehensive overview of these topics, including detailed explanations for each.

[2] The abbreviations used in this figure refer to the country codes used by Eurostat and available here: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Country_codes

Figure 11 illustrates the number of courses that each topic is applicable to. It is important to note that most courses address multiple topics, so the counts represent the extent to which each topic is included in the courses.

Table 5. Overview of available education material topics.

Course topic	Description
General	Refers to information remaining at a broad level of understanding, not going into technical details.
Basic Electrochemistry	Refers to the theory behind the electrochemical reactions that are taking place in electrolysis or fuel cell devices.
H_2 Production	Refers to the different means to produce hydrogen (electrolysis, biomass gasification, pyrolysis, etc.)
H_2 Storage and Distribution	Refers to the methods used to store, transport and distribute hydrogen (e.g. storage in salt cavern, transport via pipelines, etc.)
H_2 End-Uses	Refers to hydrogen usages in transport, industry, buildings or to generate power.
Regulations, codes, standards and safety	Refers to the applicable regulations and the harmonized performance based standards for hydrogen appliances and systems, as well as the safe production, handling and use of hydrogen, particularly hydrogen gas fuel and liquid hydrogen.
Life Cycle and Social Assessment, eco-design, recycling	Refers to environmental and sustainability aspects of hydrogen.
Techno-economic evaluation	Refers to training courses at the crossroad of business and engineering to evaluate the technical possibilities of the technology whilst considering its economic cost.

Hydrogen end-use applications is the predominant topic, covered in 36% of courses. General information on hydrogen is included in 29% of courses.

Regulations, codes, standards, and safety are addressed in 20% of courses, while hydrogen storage and distribution is covered in 11% of courses.

Other topics include hydrogen production (11%), basic electrochemistry (8%), techno-economic evaluation (6%) and life cycle and social assessment, eco-design, and recycling (3%).

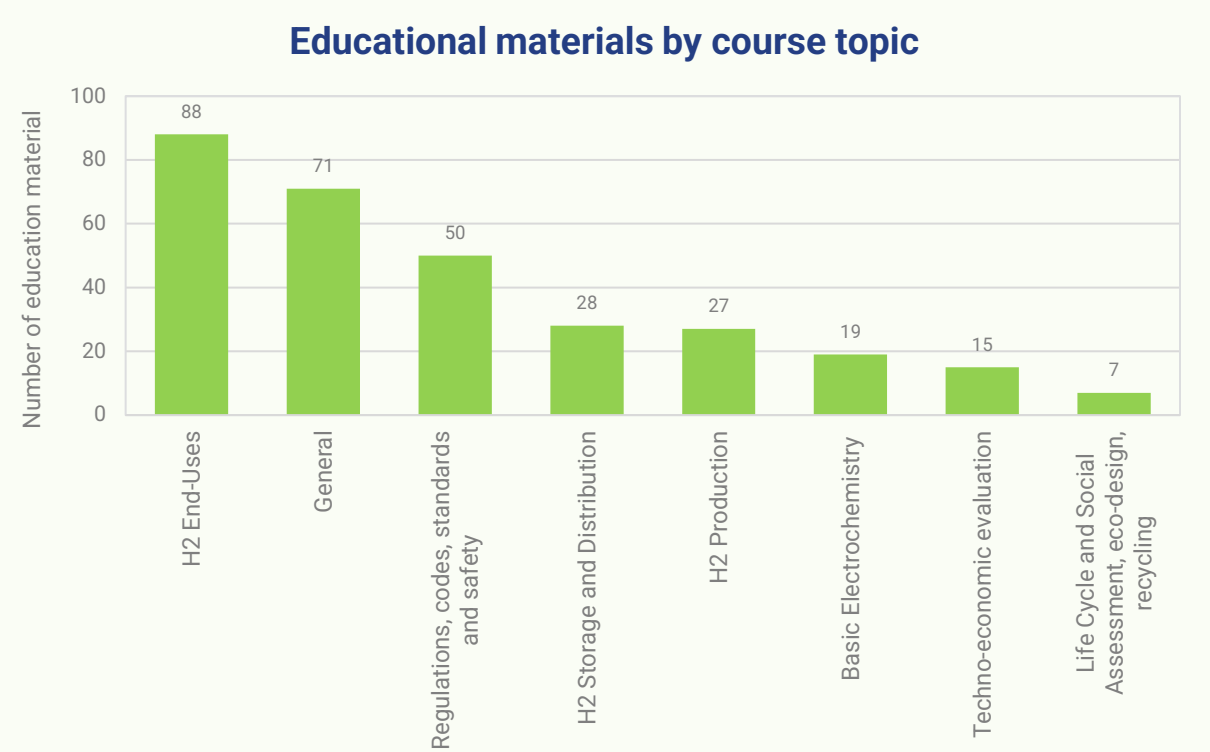


Figure 11. Educational materials available in the EHO library by topic.

2.2.3.

Education level

This section provides a comprehensive overview of educational materials, organized by the ISCED framework.

Figure 12 displays the number of educational materials categorized by ISCED level, ranging from level 1 to 8. The descriptions of each ISCED level are provided in the introduction of this chapter. It is important to note that many materials cover multiple ISCED levels, so the counts reflect the total inclusion across these levels.

As illustrated in Figure 12, most of the materials are intended for audiences with higher levels of understanding. ISCED 6 is the predominant education level, targeted by 66% of the courses This is followed by ISCED 7, associated with 53% of the educational materials. Additionally, ISCED 5 is targeted by 49% of the materials.

It is also worth noting that lower-level education is targeted in several courses. These courses are often translated into different languages to ensure accessibility for various national audiences. However, the educational materials available in the EHO library do not target early childhood education (ISCED 0), as hydrogen-related topics are relatively complex and not yet suited for this age group.

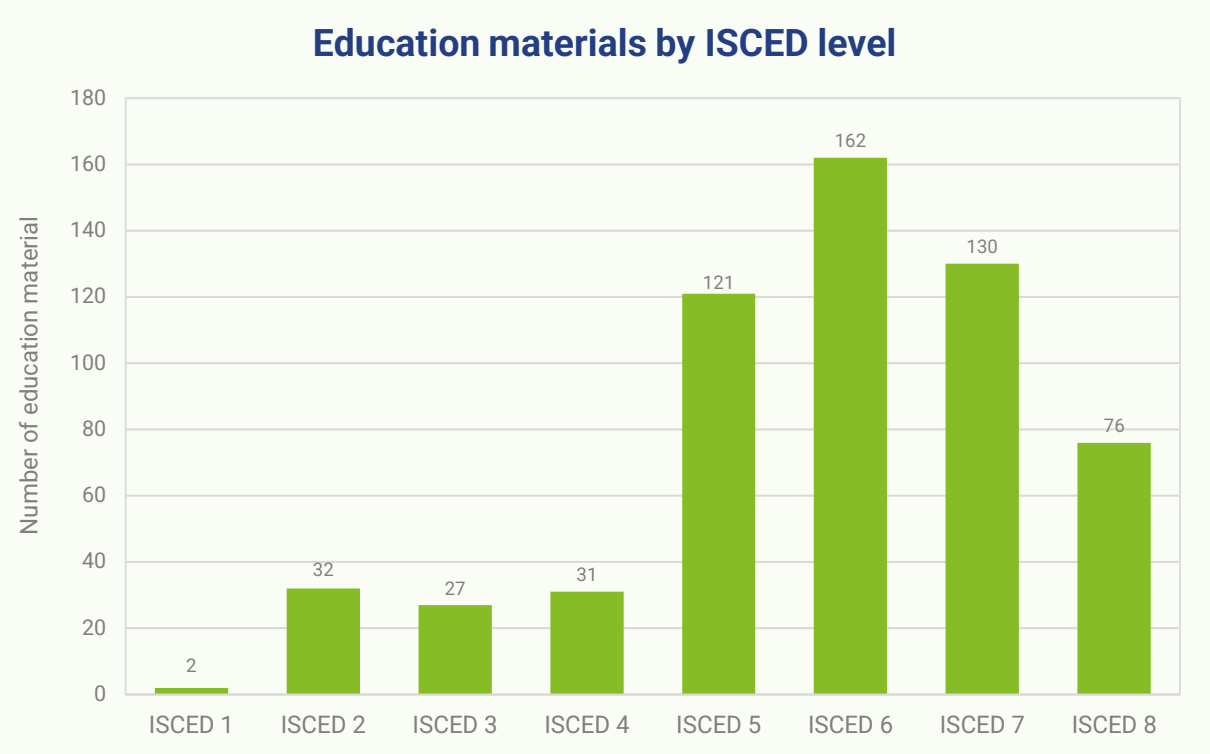


Figure 12. Number of education materials by ISCED level.

03

Research and innovation activity

Introduction

This chapter provides an overview of trends and patterns in research and innovation activity in the hydrogen sector, using aggregated datasets of patent registrations and publications by country.

Data for patents and publications is sourced from Tools for Innovation Monitoring (TIM) supplied by the Joint Research Council in August 2025. TIM tracks publications from Scopus and patents from PATSTAT based on keywords. The data summarized from the TIM datasets encompasses patents and publications as of 2006 and will be updated annually. The data are categorized into three main topics: (1) fuel cells, which include Solid Oxide (SO), Proton Exchange Membrane (PEM), and alkaline technologies; (2) hydrogen production, encompassing SO, PEM, and alkaline electrolysis as well as other clean production methods; and (3) hydrogen storage, focusing specifically on onboard storage solutions. The TIM database covered only these hydrogen technologies, so for this reason no statistics are presented for e.g. other end-use technologies.

It is acknowledged that when conducting searches, duplicates may exist between the different TIM 'spaces' (categories) as for example, one patent or publication might cover both SO and PEM fuel cell technologies. Nevertheless, duplicates cannot exist within the same dataset and therefore we believe that the TIM data is an accurate way to portray trends in patents and publications within the hydrogen topic. Fractional counting is used to determine the number of patents and publications per country for patents filed and publications written by institutions from multiple countries.

For more information on hydrogen patent activity, we recommend the 'Hydrogen patents for a clean energy future' report of the IEA and EPO, which provides the most comprehensive and up-to-date global review of patenting trends in a broad range of technologies.

Interactive data dashboards on patents and publications can be accessed on the European Hydrogen Observatory website.

3.1. Publications

The scientific and technical literature on hydrogen spans a wide range of topics, reflecting the multidisciplinary efforts to harness its potential. Publications in this field highlight significant advancements in technologies such as electrolysis, fuel cells, and hydrogen storage materials. They also address the challenges and opportunities in scaling up hydrogen production,

improving efficiency, and integrating hydrogen into existing energy infrastructures.

This dataset seeks to identify emerging research trends in the hydrogen sector.

A total of 103,426 publications worldwide have been identified from 2006 to 2025 in the fields of fuel cells, clean hydrogen production, and hydrogen storage. This represents a 16.4% increase in just one year compared to the previous report covering publications up to 2024. Figure 13 illustrates the geographical distribution of these publications, focusing on Europe (EU27, EFTA, and UK) and the rest of the world, as well as the distribution of publications by topic.

Publications in Europe account for a smaller share of the global total, comprising 22,968 (22%). Within Europe, the predominant topic is fuel cells, which represent 67% of the publications, totalling 15,345. The remaining publications primarily focus on hydrogen production and in a small extent on storage.

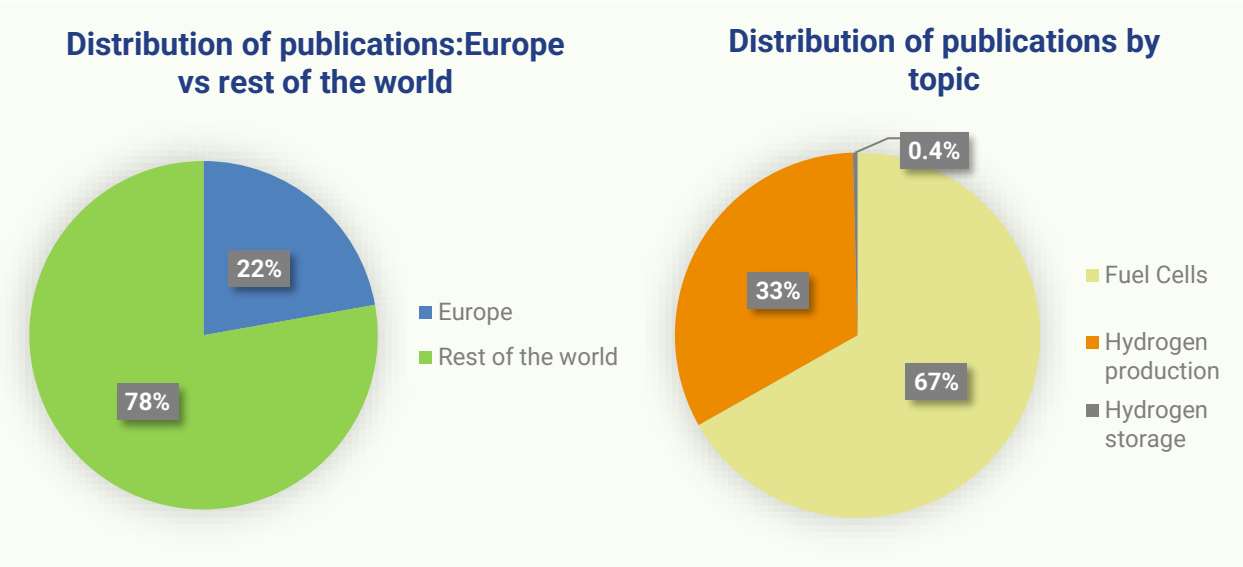


Figure 13. Geographical and topic distribution of publications from 2006 to 2025.

3.1.1.
Publications by topic and technology

Figure 14 presents the distribution of European publications since 2006 by selected topics and technologies. In fuel cells, PEM and SO technologies account for 31% and 30% of total publications, respectively, representing 47% and 45% within the fuel cell category. Alkaline technologies represent 5% of total publications.

For hydrogen production, other clean methods lead with 13% of total publications (41% within the hydrogen production category), while both PEM and alkaline electrolysis account for 8% each. Regarding hydrogen storage, only publications related to onboard storage are

included, accounting for 0.4% of total publications.

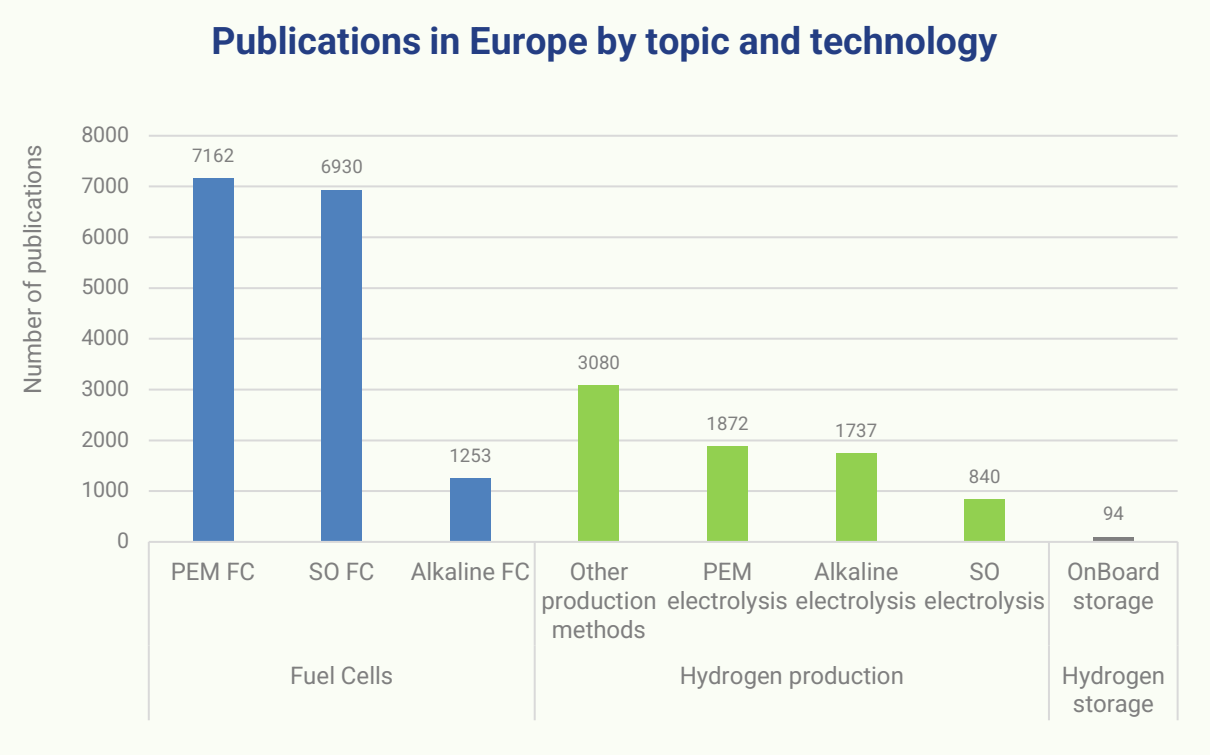


Figure 14. Breakdown of publications in Europe by topic and technology from 2006 to 2025.

Figure 15 presents the historical data on the number of publications for selected topics and technologies in European countries (EU27, EFTA, and the UK) from 2006 to 2024.

The data reveals a fluctuating pattern, with periods of growth followed by declines. However, an overall upward trend in publications can be seen, particularly from 2019 onwards, where significant growth is observed. When looking at the individual technologies, especially a strong increase is observed in publications related to hydrogen production, while for fuel cells it remained more constant.

Fluctuations in hydrogen-related publications can stem from varying research funding cycles, technological advancements, policy changes, market dynamics, international collaboration, and media coverage. These factors collectively influence the level of research activity and publication outputs, shaping the observed trends over time.

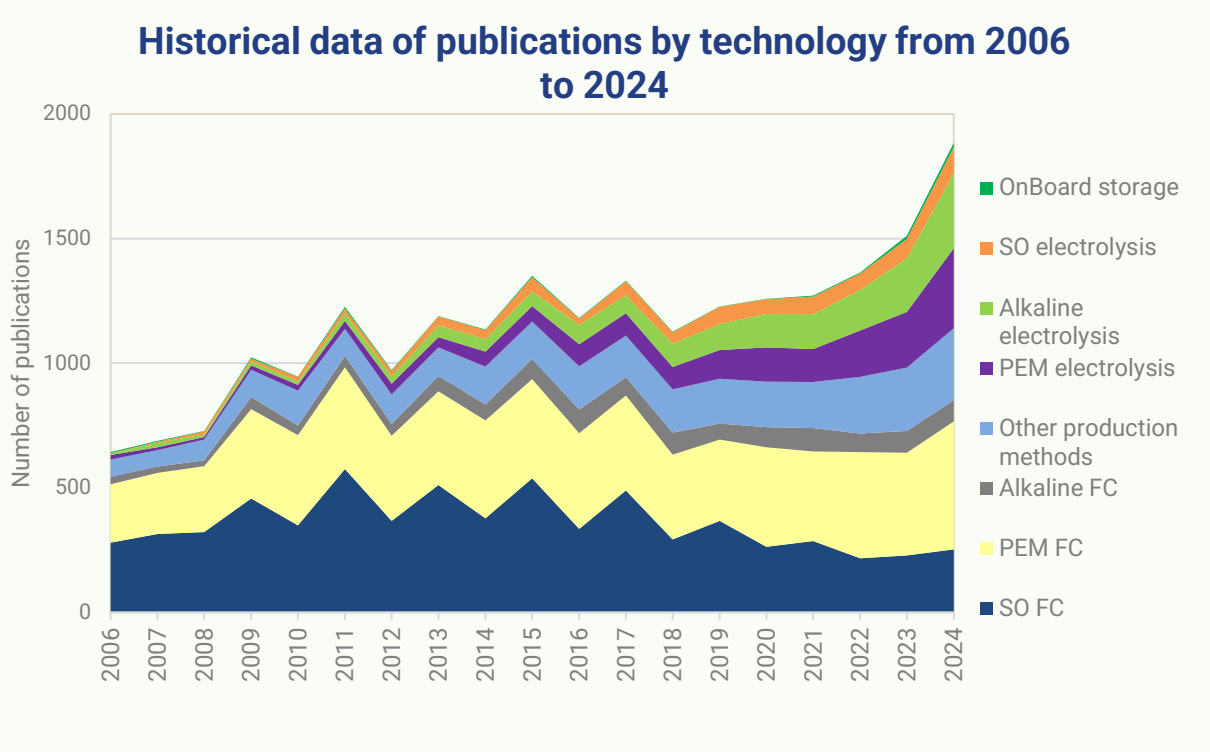


Figure 15. Historical data of publications in Europe by technology from 2006 to 2024.

3.1.2.

Geographical distribution

Figure 16 provides an overview of the geographical distribution of publications in Europe categorized by ranges of publication numbers, while Figure 17 details the number of publications per country and technology, covering the period from 2006 to 2025.

Germany stands out as the leading country with the highest number of publications (4,540), comprising 20% of the total mapped publications. Among the top ten countries with the highest publication numbers are Italy (13%), France (12%), United Kingdom (12%), Spain (8%), Denmark (5%), Poland (4%), Switzerland (3%), Sweden (3%), and the Netherlands (2%).

The remaining countries collectively contribute less than 17% of the total publications. In most countries, Solid Oxide (SO) and Proton Exchange Membrane (PEM) technologies in fuel cells dominate the historic publication landscape.

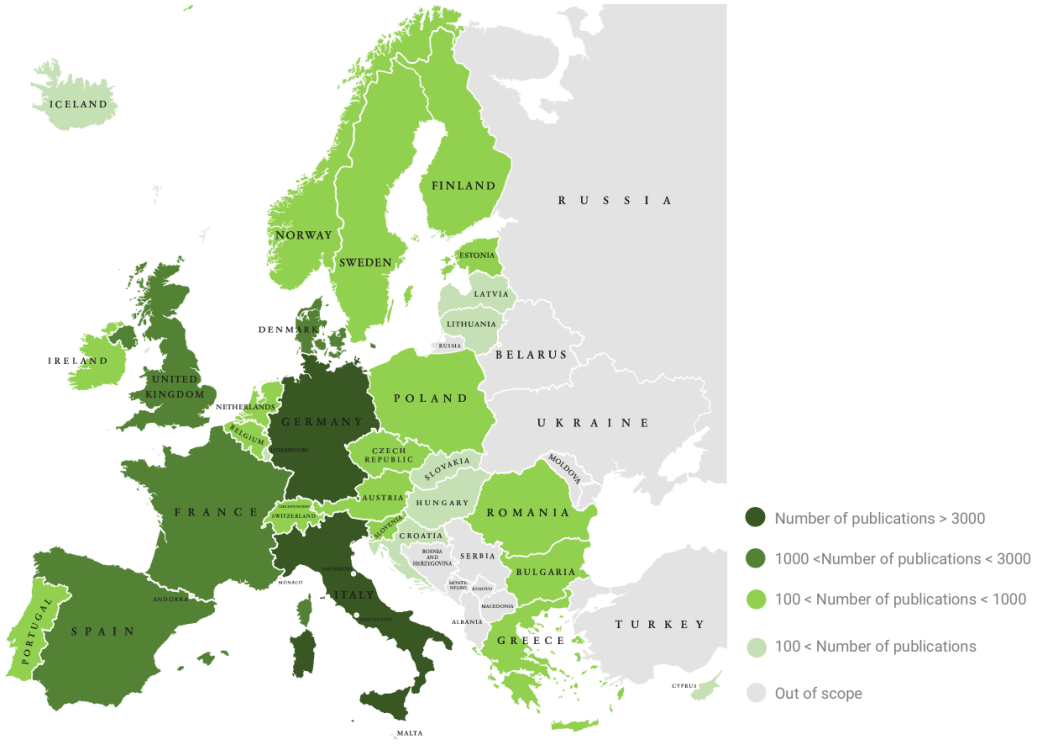


Figure 16. Geographical distribution of publications in Europe by ranges in the period 2006 - 2025.

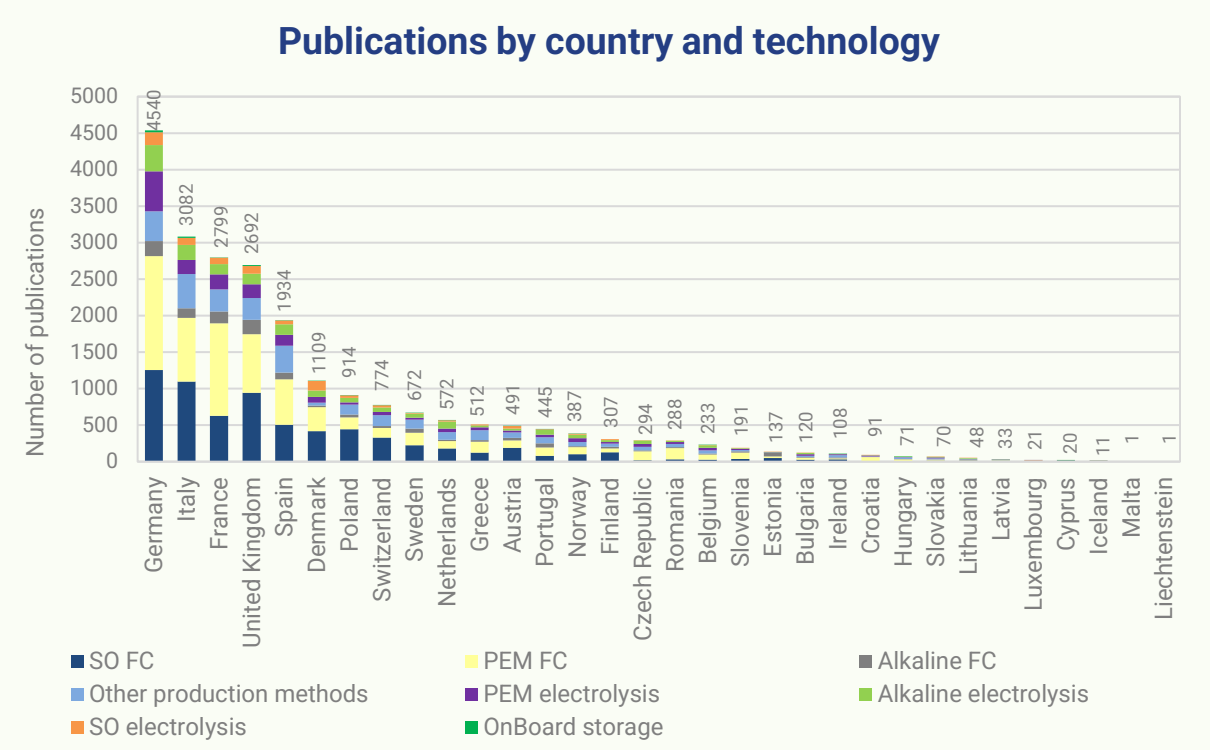


Figure 17. Number of publications by country and technology in Europe in the period 2006 - 2025.

Figure 18 illustrates the publication trends by examining the evolution in the top 10 countries with the highest number of publications over three consecutive five-year periods (2010-2014, 2015-2019, 2020-2024) by topic.

Out of the ten countries analysed, eight demonstrated an overall increase in the number of publications when comparing the periods 2010-2014 to 2020-2024. The Netherlands experienced the most significant rise, with a 79% increase, followed by Poland with a 59% increase. Germany, Italy, Spain, Sweden, the United Kingdom, Denmark, and Switzerland also saw increases in their publication numbers, with overall rises of 55%, 36%, 32%, 29%, 16%, and 10%, respectively. In contrast, Denmark and France showed declines in their publication numbers, with decreases of 9% and 1%, respectively, over the same period.

However, distinct patterns emerged across the three time periods analysed. 6 out of the 10 countries examined, namely Germany, Italy, Poland, Switzerland, Sweden, and Netherlands exhibited a consistent upward trend in publication numbers throughout these periods. Poland and Germany experienced the most substantial increases between the first and second periods, with rises of 37% and 34%, respectively. Meanwhile, Netherlands and Spain saw the most notable growth between the second and third periods, with increases of 50%, and 42%, respectively.

On the other hand, Denmark exhibited a different trend, with publication numbers increasing by 11% from the first to the second period, followed by a subsequent decline of 18% between the second and third period.

Conversely, France, United Kingdom and Spain exhibited an initial decline in publication numbers between the first and second time periods, with decreases of 4%, 3%, and 7% respectively. This was followed by a subsequent increase from the second to the third period, with growth rates of 2% for France, 19% for the United Kingdom, and a notable 42% for Spain.

In the analysis of research trends across various countries, it is evident that publications in the field of fuel cells were predominant, particularly during the first time period. However, there has been a noticeable shift over time, with increasing activity and growing emphasis on publications related to hydrogen production. This trend suggests a broadening of research focus as the importance of hydrogen production gains recognition alongside fuel cell technologies.

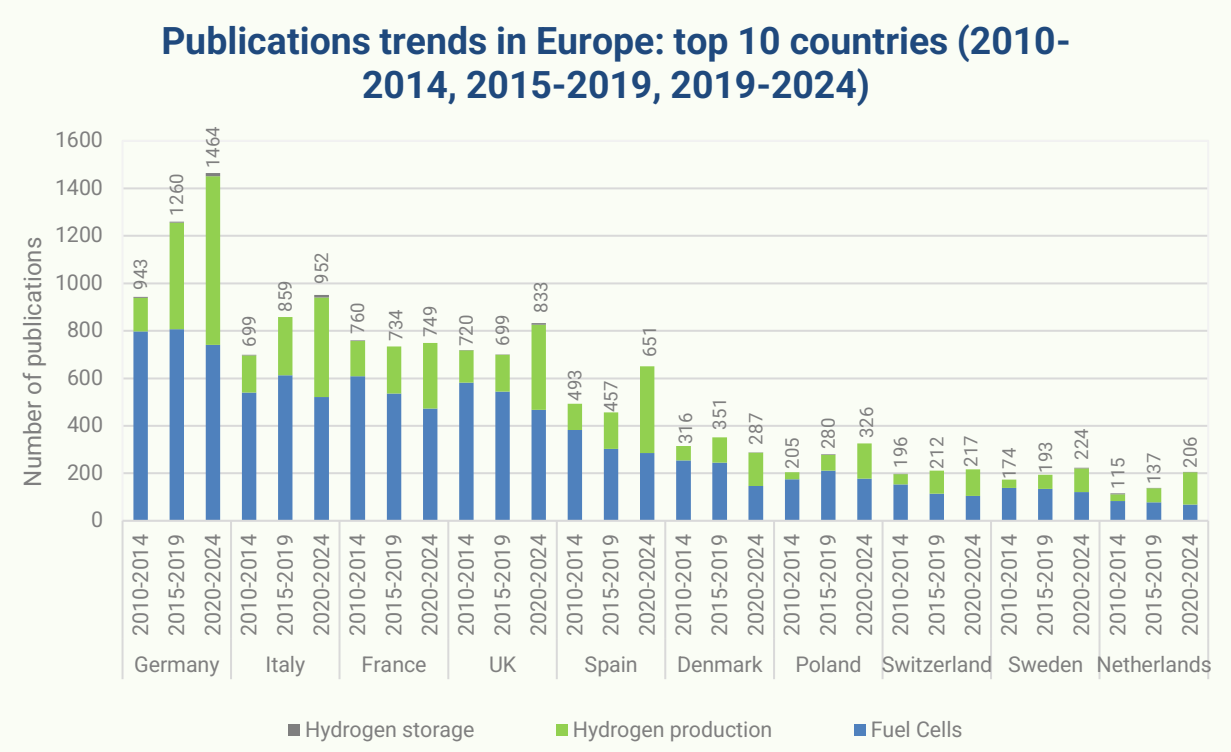


Figure 18. Publications trends in the top 10 countries over three consecutive five-year periods (2010-2024).

3.2.

Patents

3.2.1.

Overview

Patents are monopoly rights granted by Patent Offices in respect of inventions which are new, inventive, and industrially applicable. Patents are territorial and are granted by individual national or regional patent offices in respect of those territories. As such, the geographical extent of filing of a patent application is an indicator of the perceived value an inventor has for the underlying invention.

Almost all countries around the world have adopted a 'first-to-file' system which awards the first inventor to file a patent application at a Patent Office. This means that inventors are encouraged to file patent applications early in the research and development process and, because of this, patent filing statistics are a significant marker of research and development activity. For many inventions patents are the only source of

published technical information relating to the underlying principles upon which an invention is founded.

Patent applications are published approximately eighteen months after filing. In many cases this is the first time the public can see information relating to the invention.

The mapped patent data show the number of inventions in the fuel cell, clean hydrogen production, and hydrogen storage sectors. These numbers are broken down by technology type and year of application, offering a detailed view of innovation trends. By focusing on these specific sectors, the data illustrate the areas where patent registrations are concentrated, revealing the global priorities in developing sustainable energy technologies. This analysis highlights the progress and research efforts in different countries to advance cleaner energy solutions over time.

A total of 15,038 patents worldwide have been identified from 2006 to 2024 in the fields of fuel cells, clean hydrogen production, and hydrogen storage. This represents a 16% increase in just one year compared to the previous report covering patents up to 2023. Figure 19 illustrates the geographical distribution of the patent registrations related to the hydrogen topic, focusing on Europe (EU27, EFTA, and UK) and the rest of the world, as well as the distribution of patents by topic.

Patent registrations in Europe account for a small share, comprising 1,166 registrations (8%) from 2006-2024. Within Europe, the predominant topic is fuel cells, which represent 73% of the patents, totalling 846 registrations. The remaining patents are primarily related to hydrogen production.

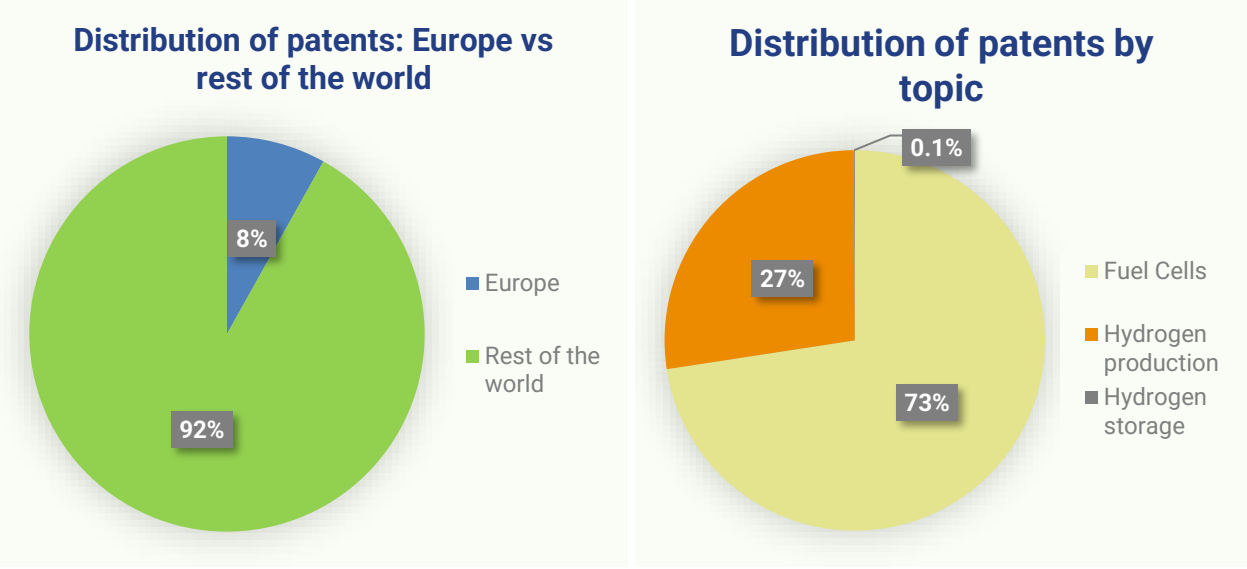


Figure 19. Geographical and topic distribution of patents from 2006 to 2024.

3.2.2.

Patents by topic and technology

Figure 20 presents the distribution of European patents registered since 2006, categorized by selected topics and technologies. In the field of fuel cells, the majority of patents are related to PEM technology, which represents 39% of the total patents and 54% of the patents specifically on fuel cells. The remaining patents in this category are mainly related to SO and in a lower extent to alkaline technologies, totalling 347 and 44 patents, respectively.

In the area of hydrogen production, most patents focus on PEM electrolysis technology, which accounts for 10% of the total patents and 35% of the patents specifically on hydrogen production. The remaining patents in this category are related to alkaline electrolysis, SO electrolysis, and other production methods, totalling 99, 61, and 47 patents, respectively.

Regarding hydrogen storage, only patents related to onboard storage are included, accounting for <0.1% of total patents.

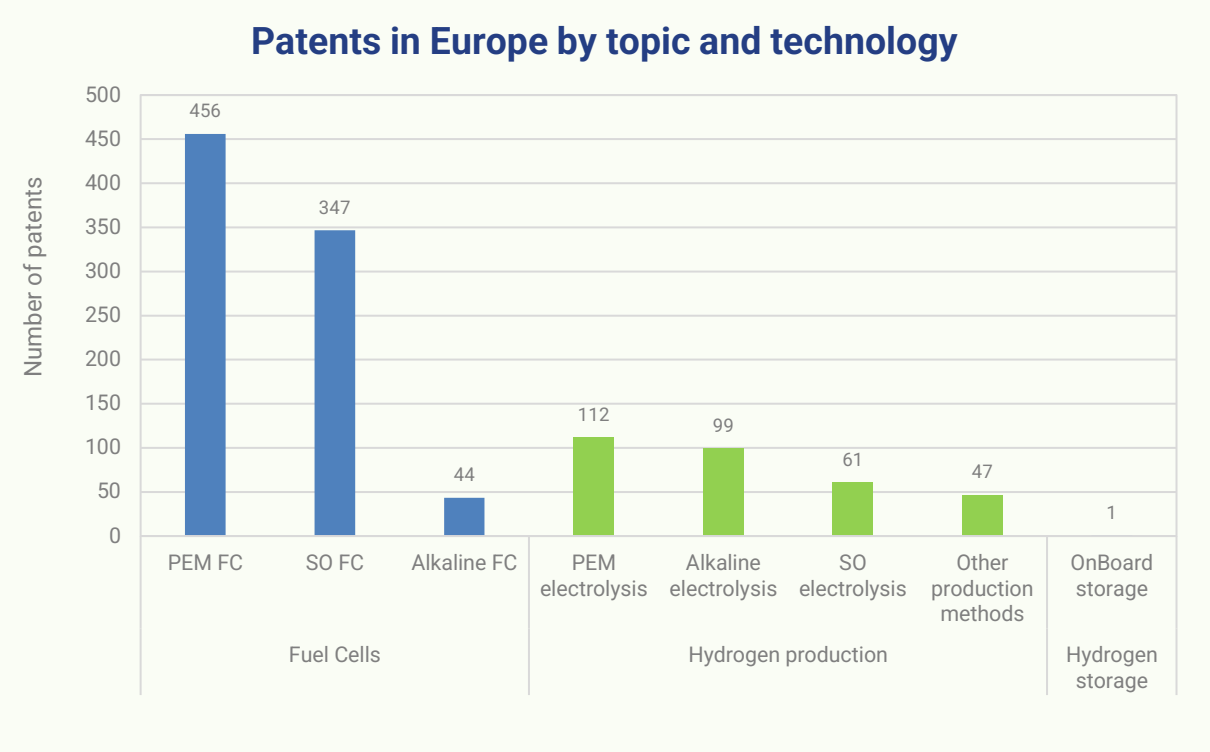


Figure 20. Breakdown of patents by topic and technolog in the period 2006-2023.

Figure 21 presents the historical data on the number of patents for selected topics and technologies in European countries (EU27, EFTA, and the UK) from 2006 to 2023.

Overall, there was a declining trend in patent activity, especially for fuel cell technologies, up to 2018, after which again an increasing trend is observed in the most recent years. Notably, there are four peaks in 2007, 2012, 2017, and 2022, with 93, 93, 58, and 98 patents respectively.

The sharp drop in the number of patents in 2023 can be attributed to the delay in the patent publication process. Patent applications are published at the earliest eighteen months after filing, resulting in a delay in their appearance in the database. Consequently, data for 2023 is not yet complete.

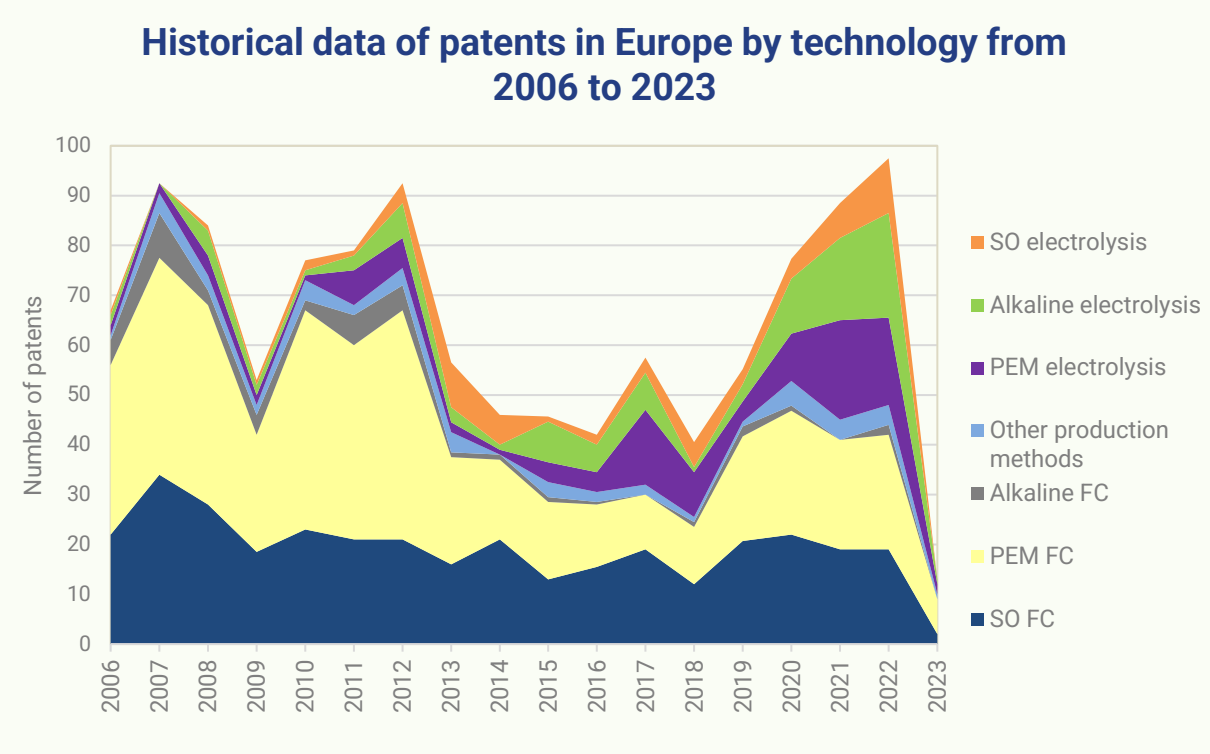


Figure 21. Historical data of patents in Europe by technology from 2006 to 2023.

3.2.3.

Geographical distribution

Figure 22 provides an overview of the geographical distribution of patents categorized by ranges of patents numbers, while Figure 23 details the number of patents per country and technology, covering the period from 2006 to 2023. Germany leads with 455 patents, representing 39% of the total. Among the top ten countries, France holds 19%, the UK 10%, Denmark 9%, Italy 5%, and Spain, Switzerland, the Netherlands, Romania, and Finland each contribute 2%. The remaining countries collectively contribute less than 8% of the total registrations of patents. In most countries, Solid Oxide (SO) and Proton Exchange Membrane (PEM) technologies in fuel cells dominate the patent landscape.

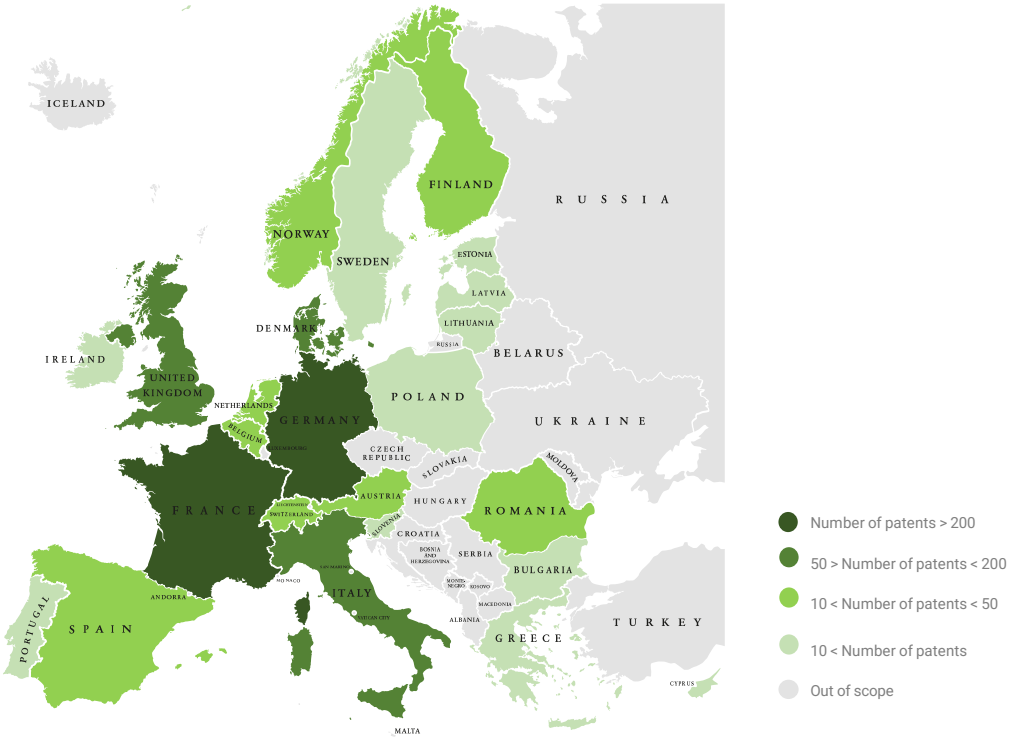


Figure 22. Geographical distribution of patents by ranges.

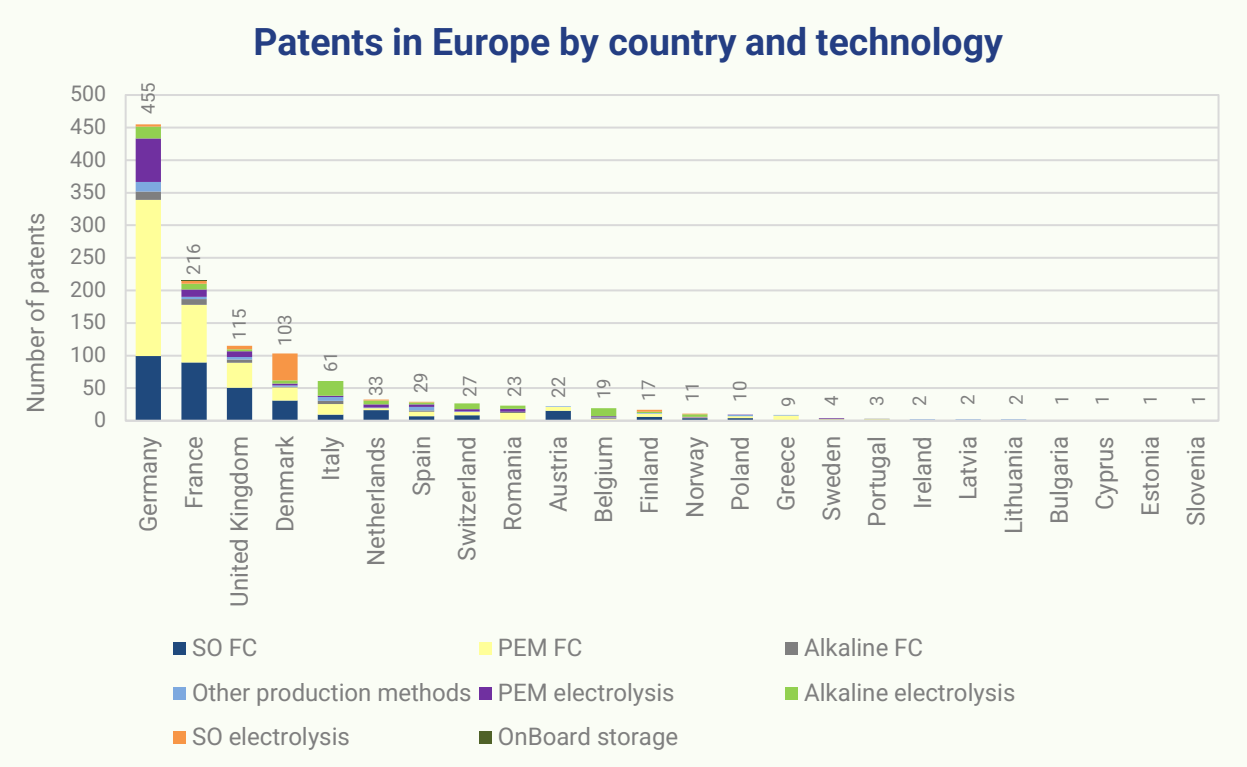


Figure 23. Number of patents by country and technology in Europe.

Figure 24 illustrates the patents trends by examining the evolution of their numbers in the top 10 countries with the highest number of registrations over three consecutive five-year periods (2008-2012, 2013-2017, 2018-2022).

Out of the ten countries analysed, nine demonstrated an overall increase in the number of registrations when comparing the periods 2008-2012 to 2018-2022. The most significant growth was observed in the Netherlands, Austria, and Italy, each recording increases of over 100%. In contrast, Switzerland saw a decline in patent registrations, with a 31% decrease over the same period.

However, distinct patterns emerged across the three time periods analysed.

Most countries under examination experienced a decline in patent registrations between the first and second periods. Spain showed the largest decrease at 92%, followed by Germany (62%), Romania (56%), the United Kingdom (34%), and France (16%). In contrast, Denmark, Italy, and Switzerland reported increases during the same period, with growth rates of 50%, 33%, and 13%, respectively. The Netherlands remained stable across the two periods, with no significant change. Notably, Austria recorded its first patent filings during the second period, having reported no activity in the first.

From the second to the third period, Denmark and Switzerland experienced declines of 39% and 28%, respectively. Conversely, all other countries demonstrated growth during this interval, with Spain showing the most substantial increase. Germany, the United Kingdom, Romania, the Netherlands, and Austria each achieved growth exceeding 100%, while Italy and France recorded increases of 70% and 44%, respectively.

Similar to publications, recent years have also seen growing interest in hydrogen production in patent activities.

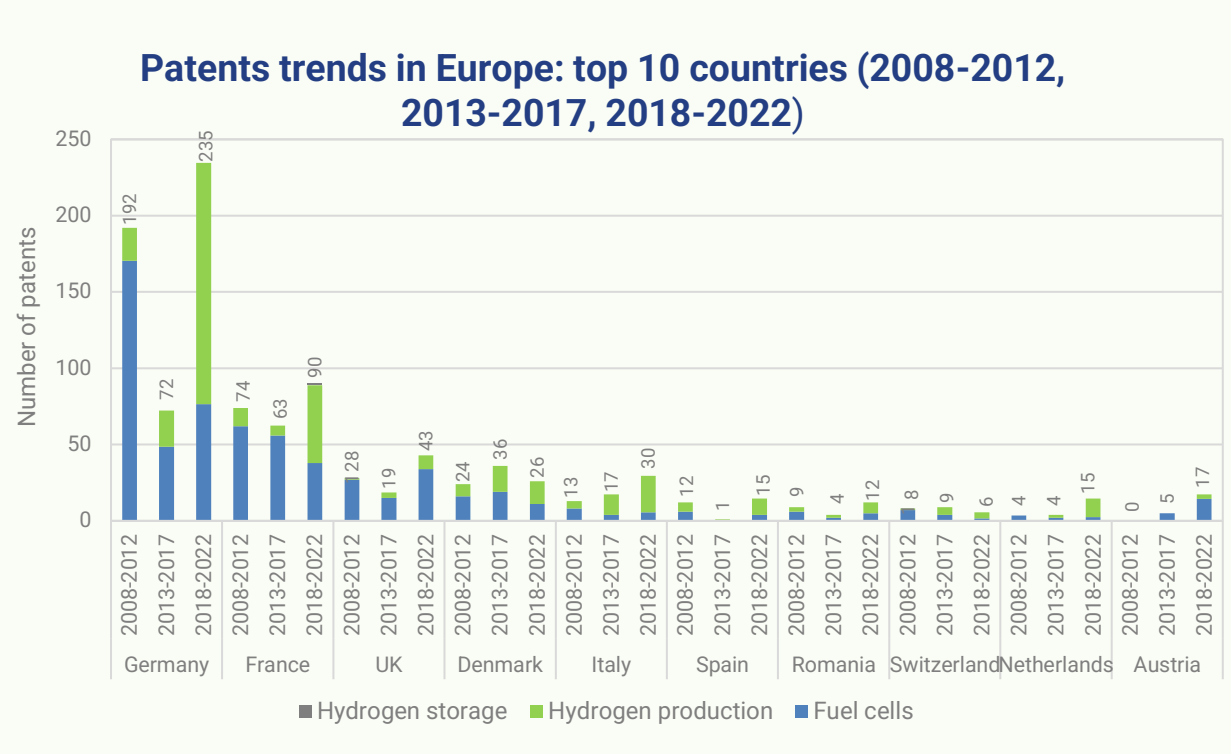


Figure 24. Patents trends in the top 10 countries over three consecutive five-year periods (2008-2022)[3].

[3] Data from 2023 were limited and therefore excluded.

Conclusions

The purpose of this report is to provide a comprehensive overview of the latest statistics covering the hydrogen education and research landscape, encompassing training programmes, educational materials, publications, and patents in the hydrogen sector. This is the second report released following the relaunch of the European Hydrogen Observatory, which introduced a more focused scope by narrowing its attention exclusively to developments within the EU. By focusing on the EU, the Observatory enables a more detailed and targeted analysis of regional progress in hydrogen research and education, thereby supporting more effective policy-making and strategic planning to advance the hydrogen economy across the region.

Training programmes

A total of 261 training programmes are listed in the Observatory's online library, reflecting a 3% increase since 2024. On the programme level, master's and professional training programmes, represent the largest segments among the registered training programmes, accounting for 50% and 33% of the total.

The registered training programmes are offered in 12 different languages, with English being the primary language in most programmes. The European Hydrogen Observatory now maps 21 countries, with the addition of Ireland and Switzerland. France is leading in the number of training programmes offered.

"Hydrogen End-Uses: Transport", "Hydrogen Production" and "Hydrogen Storage, Transport and Distribution" are the predominant subjects among the 11 categories, each being covered in approximately 70% of the training programmes.

Education materials

The EHO online library contains 245 reliable materials. The highest number of materials were released in 2024, totalling 57, while the fewest materials were released between 2015 and 2018, with fewer than five materials released each year. Educational materials in 16 different languages are currently listed in the EHO library. English is the predominant language, available for 84% of the materials.

Hydrogen end-use applications is the predominant topic, covered in 36% of the materials. General information on hydrogen is the second most common topic, included in 29% of the materials. The majority of the materials are intended for audiences with higher levels of understanding, specifically levels 6 and 7, which correspond to bachelor’s and master’s levels.

Research and innovation activity

Publications and patents registrations in Europe (EU27, EFTA and UK) account for 22% and 8% of those identified worldwide respectively, in the fields of fuel cells (PEM, SO and alkaline), clean hydrogen production (PEM, SO, alkaline and other production methods) and hydrogen storage (onboard storage) from 2006 to 2025. Overall,

there is an increasing trend in publications, while patent activity declined until 2018, particularly in fuel cell technologies, and has been increasing again in recent years.

In Europe, fuel cells dominate the research landscape, accounting for 67% of publications and 73% of patents. However, this prominence was more pronounced in earlier years. Recently, there has been a notable shift towards increased activity and a growing emphasis on publications and patents related to hydrogen production. This trend indicates a broadening of the research focus, highlighting the rising recognition of hydrogen production alongside fuel cell technologies.