Foundation

Global Safety Evidence Centre

Who funds engineering safety research?

Safety Science

Research Report

Technical Report

Preface

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To find out more about the Global Safety Evidence Centre, visit *gsec.lrfoundation.org.uk*

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This report is authored by: **Martin Szomszor, Katie Sykes, Charlie Coyte**.

Executive summary

This report presents a comprehensive mapping and analysis of the global landscape of engineering safety research (ESR) and its funders. Commissioned by Lloyd's Register Foundation (the Foundation), it aims to provide detailed insights into ESR topics, geographic distribution, funding sources and sector-specific research to inform strategic decisions in research funding and collaboration. 'Engineering safety' is defined in this report as the theory and practice of applying scientific and engineering principles to assess and control risks within engineered systems and processes, to prevent accidents and reduce harm to people and property. ESR, therefore, is the generation and sharing of knowledge to continuously improve understanding and practice in this field.

Rationale

We envisage that this study will give ESR funders and other stakeholders a clearer picture of their own position within this ecosystem, including greater awareness of their similarities to, and differences from, other organisations within the ESR community; support them to identify potential collaborators with strengths and priorities complementary to their own; and give them a stronger sense of the topics or types of research that are currently receiving a great deal of (or very little) funding in order to guide their decision-making.

Methodology

The study employed bibliometric analysis primarily using the Web of Science database, supplemented by data cleaning and manual review to ensure accurate funder identification. We identified ESR publications using a search string developed with input from the Foundation, focusing on safety-related concepts in engineering contexts relevant to the Foundation's current strategy and excluding unrelated safety areas such as occupational health or food safety. We used topic modelling based on natural language processing techniques to categorise ESR publications into 50 topics grouped into 11 clusters, enabling thematic analysis. The study focused on publications from 2015 to 2025, analysing author affiliations, funder acknowledgements and research topics. We conducted additional desk research on selected funders to gain deeper insights.

ESR landscape analysis

ESR has experienced significant growth over the past decade, with an average annual publication increase of 18%, outpacing the 4% growth in overall engineering publications. ESR publications span various research disciplines, with 62% appearing in engineering journals, and notable contributions from computer science and chemistry. Topic modelling identified emerging topics such as Machine Learning and Data-Driven Methods and Lithium-Ion Battery Safety, which showed the most significant growth. Geographically, China leads in ESR authorship, with its share rising substantially from 24% of research publications in 2015 to 58% in 2025. International collaboration varies, with areas such as Hong Kong and Belgium exhibiting high collaboration rates, while China and South Korea predominantly engage in domestic collaborations.

ESR funder analysis

Approximately 66% of ESR publications disclose their funding sources, with significant variation across countries. China funds by far the most ESR of any country, with the US and South Korea coming a distant second and third. Eight of the world's top ten funders of ESR are Chinese, with the National Natural Science Foundation of China (NSFC) leading the field. The funding landscape shows a strong preference for domestic research, with 96% of Chinese-funded ESR having Chinese first authors. Government bodies are the largest source of ESR funding, accounting for 53.4% of publications.

Sector deep-dives

We selected four sectors for deep-dive analysis of related ESR publications and funding trends: Maritime, Chemical Processing, Electric Power and Industrial Manufacturing. While China is the most prolific funder across all these sectors, our deep dives found that Chinese funders are comparatively less active in the maritime and electric power sectors (where EU funders play a larger role) than in the chemical-processing and industrial-manufacturing sectors.

Acknowledgements

We have been able to conduct this study because of the contributions of colleagues at the Foundation. We would like to thank Nancy Hey for providing steer and support over the course of the study. We are also grateful for the expert contributions of Dr Jan Przydatek, Dr Chris White, Caitlin Vaughan and Dr Dana Vilistere provided through a workshop and written queries. Finally, we would like to thank RAND Europe colleagues Dr Nick Fahy and Giulia Maistrello for their valuable comments and contributions through their review of the final report.

Contents

Abbreviations

ERC	European Research Council
ESR	Engineering Safety Research
EC	European Commission
EU	European Union
INAIL	Istituto Nazionale per l'Assicurazione Contro gli Infortuni sul Lavoro (Italian National Institute for Insurance Against Accidents at Work)
KETEP	Korea Institute of Energy Technology Evaluation and Planning
MOST	Ministry of Science and Technology of the People's Republic of China
NRF	National Research Foundation of Korea
NSFC	National Natural Science Foundation of China
OSH	Occupational Safety and Health
RCN	Research Council of Norway
WS	Workshop

1. Introduction and background

1.1. Engineering safety research

Safety is a critical component of the engineering discipline and profession. It is embedded in the design, maintenance, and decommissioning of engineered structures and systems for humanitarian, legal, and financial reasons (Brauer 2022). Safety is frequently incorporated into regulatory and accreditation systems affecting engineers and engineering (e.g. the UK Health and Safety at Work Act 1974; the Construction Products Regulation [European Union] and the International Fire Code), as well as in engineering courses (Altabbakh et al. 2015). To ensure the knowledge and application of safety in engineered systems are effective and up to date, research is needed to identify emerging risks, evaluate current safety practices and develop innovative methodologies that integrate safety considerations throughout the engineering lifecycle.

We define 'engineering safety' as the theory and practice of applying scientific and engineering principles to assess and control risks within engineered systems and processes to prevent accidents and reduce harm to people and property. 'Engineering safety research' (ESR), therefore, is the generation and sharing of knowledge to continuously improve understanding and practice in this field. We developed and applied this operationalisation in consultation with Lloyd's Register Foundation (the Foundation) to set a scope that reflects the research priorities of the Foundation, distinguishing it from other usages of 'safety research' or similar terms not consistently used in the literature and/or varying in scope from what this study aims to address. ESR shares features with other fields of research, such as safety engineering, occupational safety and health (OSH) and security research. We highlight the conceptual distinctions in Table 1 to clarify the nature of ESR. In practice, however, there can be substantial overlap in the interests and audiences of ESR and these other fields, as reflected in the topics that emerge from our analysis of ESR publications.

1.2. The importance of ESR

Our definition of ESR encompasses both basic research with safety ramifications and applied safety research and development (R&D). Both aspects are vital, helping to expand our theoretical and practical knowledge and understanding of safety in engineered systems. This might include:

- Enhancing understanding of how engineered systems function and the factors that make them more or less safe, e.g. research into human factors in aviation (Salas et al. 2010) or ground deformation during tunnelling operations (Zhang et al. 2024).
- Developing and testing new technologies and/or approaches for building safer systems, e.g. the development of the ACAS-X family of next-generation airborne collision avoidance systems, which drew on advances in probabilistic modelling to improve aircraft safety (De & Sahu 2018).
- Generating knowledge concerning new and emerging risks (e.g. in the context of climate change or rapid uptake of new technologies) to design systems that are resilient to these risks, as in research into AI interpretability methods (Linardatos et al. 2021).

Ultimately, all this work aims to support the creation of safer engineered systems, particularly in high-risk environments, to minimise fatalities, injuries, accidents, disease and economic losses, and to maximise economic productivity and human health, safety and well-being.

1.3. The ESR landscape

ESR covers a relatively broad range of research under our definition. However, it is not always recognised as a discrete field of research compared with more formalised fields such as the professional-focused 'safety engineering' and the regulation-driven field of 'OSH research'. For example, while there are a few research institutes and university departments focused on ESR-related topics (e.g. the

Table 1. ESR-related fields and their differentiating features

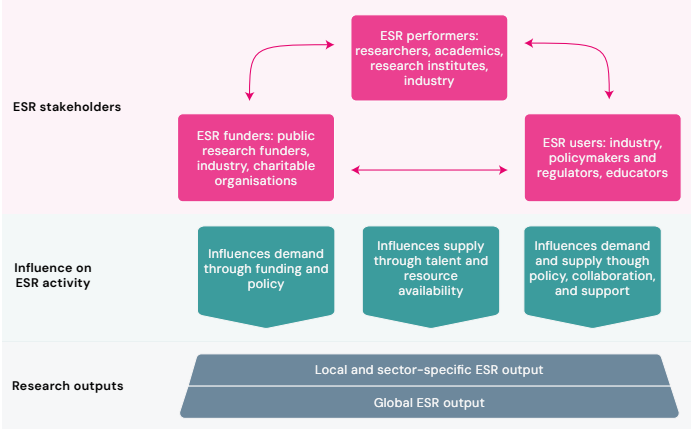
Field	Definition	Differentiation from ESR
Safety engineering	A branch or practice of engineering that aims to 'assure and demonstrate the safety of a system' (Osborne et al. 2024).	The focus is typically on applying specific engineering skills and practices to improve safety. There is a significant overlap with ESR, but ESR also focuses on broader factors that can influence safety outcomes in engineered systems, such as organisational culture and policy.
OSH research	Research on 'the discipline dealing with the prevention of work-related injuries and diseases as well as the protection and promotion of the health of workers' (ILO 1998).	The field's interests include broader health concerns unrelated to accidents or hazards (e.g. illness and long-term injuries). Its focus is also exclusively on workplaces and the workforce, not on wider engineered systems or the people who interact with them.
Safety science / safety research	'Research in the science and technology of human and industrial safety' (Safety Science 2025) and the application of the scientific method for 'evidence in all areas of safety and health, including traffic, workplace, home, and community' (Journal of Safety Research 2025).	Safety science and safety research are generally broader than ESR as they include examination of safety in non-engineering contexts.
Security research	The study and prevention of harm from intentional causes.	Although security research is a broad field of study, the overall focus is on preventing harm from malicious or intentional actors, rather than from (non-malicious) hazards and accidents (Jore 2019).

Institute of Safety Science and Technology at Tsinghua University and the now-closed Lloyd's Register Foundation Centre for Safety and Reliability Engineering at the University of Aberdeen), others such as Ulster University's Fire Safety Engineering and Hydrogen Safety Engineering Centres align with parts of ESR but are focused on a specific topic or application. Several journals publish ESR material (e.g. Journal of Safety Science and Resilience, Reliability Engineering and System Safety, and Structural Safety). However, their focus can range from broader safety science to more specific applications.

Only a small number of funders are dedicated to ESR, including the Foundation. However, many more support specific aspects of the field that overlap with OSH (e.g. the UK's Institution of Occupational Safety and Health and the Health and Safety Executive). National funding organisations provide broad support for safety research as part of grants for engineering and other discipline projects, but do not frequently prioritise ESR topics specifically. Recently, these organisations have recognised the need for safety research to address potential risks posed by emerging technologies. For example, the philanthropic funder Open Philanthropy's 2025 grant call specifically invites Technical AI Safety research proposals (Open Philanthropy 2025).

Due to the lack of formalisation, the landscape of ESR knowledge generation and funding depicted in Figure 1 has not been systematically explored. While there has been some exploration of the use of scientometrics – the quantitative study of scientific communication – to assess safety science (Li et al. 2021), research landscape analyses have typically paid more attention to fields like OSH research (Cao et al. 2021; Streit et al. 2025) and patient safety (Gandhi et al. 2018), or specific areas of ESR like construction safety (Akram et al. 2019). Therefore, this study is the first to investigate the overall ESR landscape.

Figure 1. The ESR funding-and-performance ecosystem



1.4. Study objectives

This study aims to provide an overview of the global ESR landscape, examining the topics ESR research covers, the types of journal that publish it, the countries in which it is conducted and funded, the nature of the organisations that fund it, and changes in its volume, topics and provenance over time. We have also conducted an in-depth analysis of ESR in four specific industries: maritime, chemical engineering, electric power generation, and manufacturing. For each of these industries, we have identified which ESR topics have received the most research over the past decade, where ESR research is being conducted and who is funding it.

We intend that this report shed light on the ESR landscape by establishing a baseline for activity in the ESR ecosystem. We anticipate that this study will a) provide ESR funders and other stakeholders with a clearer understanding of their position within this ecosystem, including greater awareness of their similarities to and differences from other organisations within the ESR community, b) assist them in identifying potential collaborators with complementary strengths and priorities, and c) offer insights into the topics or types of research currently receiving significant or minimal funding, aiding their decision-making.

Our detailed industry analyses aim to provide specific insights into ESR in sectors that could greatly benefit from advancements in knowledge and technology, thus helping to inform industry-specific funding and engagement strategies and identify key stakeholder groups. We hope that this information will help funders and other stakeholders make informed, strategic decisions about their future engagement with ESR research and collaboration within the ESR ecosystem.

1.5. Study approach

1.5.1. Rationale and limitations of our bibliometric approach

Our study of the ESR funding landscape primarily utilised bibliometric methodologies. By examining the content and metadata of ESR publications, we developed a comprehensive overview of where and by whom ESR activities are conducted and funded.

Bibliometric analysis is frequently used to provide detailed insights into the trends and patterns of published research. However, certain limitations must be considered when drawing conclusions about the broader research landscape. Firstly, bibliometric analysis is limited to providing insights into published research. Due to lags between a project's funding and reporting, and between the submission and publication of research articles (Maggio et al. 2020), the latest trends in funded ESR may not emerge from bibliometric analysis. While bibliometrics examines the number of articles funded by an organisation, it cannot generate results on the number or quality of individual funded projects.

Another limitation of bibliometric analysis is the potential underrepresentation of particular research types. Publication bias – the selective publication of research studies with positive findings – may mean that some null results are not published, and are therefore not featured in bibliographic databases (Song et al. 2010). Industry-funded and conducted research might also be underrepresented, as it is not always published in journals due to its commercial sensitivity and (in many cases) applied nature (Kinney et al. 2004). The same is true of grey literature, which, by definition, is not published through traditional, commercial channels.

Finally, while bibliometric databases regularly update and expand the titles they index, questions about the comprehensiveness of coverage of outputs remain, particularly for publications in the Global South and in non-English languages (Simard et al. 2024). Additionally, some features of the bibliometric data we used posed potential accuracy risks to the findings. Therefore, we have taken steps to mitigate these issues, detailed in Chapter 2.

1.5.2. Defining ESR and key industry concepts

As outlined in Section 1.1, the definition of ESR is rarely formally recognised in research systems. As such, there was no pre-existing taxonomy that we could directly apply to identify ESR publications within bibliometric databases. Therefore, our approach to identifying ESR publications required a multi-step process that combined top-down approaches to defining the ESR concept with the development of search strings based on keywords extracted from known ESR sources, and iterated on the method following research team and external expert review. We used a similar, lighter-touch approach for the key industries explored in Chapter 5. Further details on the search approach implemented are presented in Annex A.

1.6. Structure of the report

The three chapters that follow present this study's findings:

- **Chapter 2** outlines the development and application of our study methodology.
- **Chapter 3** provides an overview of the ESR landscape, presenting the number of ESR papers published worldwide over the past decade, the types of journals in which this research has appeared and the topics it has covered. It also sets out our findings on the geographical distribution of ESR, considering the provenance of ESR authors and the degree to which they collaborate across national borders.
- **Chapter 4** discusses ESR funders, identifying the most significant contributors worldwide, exploring changes in this group over time and examining how much ESR each funder supports beyond their home regions. It then establishes which types of organisation (e.g. government bodies, not-for-profits, etc.) are most likely to fund ESR, before investigating the ESR topics favoured by different countries and identifying the key funders of ESR topics that have grown in popularity in recent years.
- **Chapter 5** details the nature of ESR in the maritime, chemical engineering, electric power generation and manufacturing industries. It presents our findings on the number of ESR publications focused on these industries and how this figure has changed over time, considers the topics most often covered in these publications (including key emerging topics), and explores who funds this research and where it is conducted.

2. Methodology

2.1. Concept and search string development

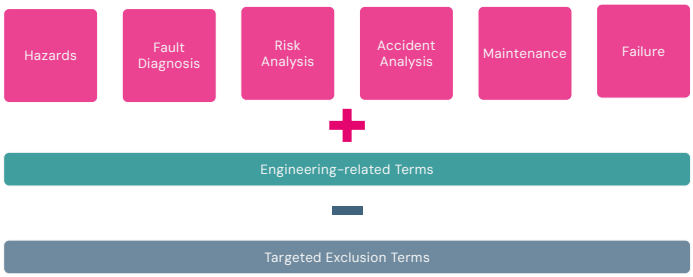
We began the study by developing and refining the ESR concept to ensure agreement across the research team and project stakeholders on our study's scope, and to allow the development of data collection and analysis tools accordingly.

We used a combined bottom-up and top-down approach to identify and fine-tune key components of ESR. We identified journals that publish engineering safety-related topics by searching journal scopes on publishers' websites and by recommendations from experts at the Foundation. We analysed keywords from the last ten years of the journals' outputs to identify the most popular terms and term clusters using topic modelling. In addition, we used OpenAlex – an open-source bibliometric database – and Web of Science to identify the top algorithmically generated topics used by the platforms for those journals' outputs (OpenAlex 2025; Incites 2025). We then used outputs from these activities to generate conceptual frameworks.

At the same time, we engaged with experts from the Foundation to provide feedback on draft conceptual definitions and inclusion/exclusion criteria for the ESR field. Through written feedback and a workshop, we developed the overall conceptual framework and, subsequently, the full search string to identify all ESR publications. We then refined the search string until its output aligned with the agreed details of the conceptual framework.

As depicted in Figure 2, the overall approach to identifying ESR publications involved searching for publications that included at least one term related to six key safety-related concepts in their titles or abstracts: hazards, fault diagnosis, risk analysis, accident analysis, maintenance, and failure. Publications also had to include at least one engineering term, either by specifically referencing 'engineering' or by referencing engineering-related contexts/operations such as manufacturing, construction and energy. To further exclude publications on broader, out-of-scope safety topics, we identified several targeted exclusion terms related to crime, occupational health, patient health and safety, road/traffic/aerospace safety, food and water safety, waste management and consumer and product safety. Additionally, as we developed the search string in English, the majority (98.8%) of the papers were in English. The remaining papers were indexed in Web of Science with English translations of titles and abstracts, and we therefore included them in the reviewed publication set. Annex A provides the finalised search string.

Figure 2. Conceptual framework for ESR publications



To ensure the data we collected related to recent, research-based publications, we limited it to research articles, reviews, and conference proceedings (excluding editorial content) published between 2015 and 2025. Since we extracted the data in July 2025, there is only partial coverage for this year. Hence, plots and tables of counts do not include 2025, whereas relative indicators (e.g. the proportion of publications) do.

2.2. Data collection

From the range of bibliographic databases available, we chose the Web of Science from Clarivate for the majority of our data collection as it provides curated coverage of the scientific literature (where selection requires journals to meet minimum standards with respect to peer-review, coverage and editorial board composition [Clarivate 2025]), full coverage of author-affiliation data, and comprehensive indexing of funder acknowledgements. Several quantitative studies in engineering safety have utilised the Web of Science (Chao et al. 2019; Liu et al. 2019; Zhu et al. 2023). As described earlier in the methodology section, we identified 14 exemplar engineering safety-related journals to inform the development of the search string, all of which are indexed in the Web of Science. While our assessment of the Web of Science indicates that its coverage of ESR material is high, we recognise that there is some variation across other platforms, especially OpenAlex (Simard et al. 2024).

We supplemented information on funders by linking publication-funder data to the Research Organization Registry, a dataset that aims to provide open, persistent identifiers for every research organisation worldwide (Research Organization Registry 2025). However, as research-funder data is sourced from the funding information included in the Funding Acknowledgements section, the accuracy and comprehensiveness of our funding analysis depend on the details provided in the publication itself. As a result, we faced two data challenges: unstructured or inconsistent funder information and missing funder information. We approached each differently. For unstructured funder information, we performed several manual and semi-automated data-cleaning steps to ensure consistency in funders' names and details. More specifically, we performed manual checks to ensure the accuracy of our data on the following groups:

- Funders with ten or more ESR publications.
- Funders listed as a 'facility', as these were often associated with government organisations.
- Funders with 'university' in the title, to appropriately categorise them under 'education' organisations.
- Funders listed as a 'company' in China, as these were often government organisations.
- Funders listed as 'nonprofit', as these were frequently miscategorised.

In the 6% of cases where a funder was named but details such as the country could not be identified, we used the first author's country of affiliation. We made this decision on the basis that funders – especially smaller funders whose details are not in the Research Organisation Registry database – are most likely to support research in the country where they are based. Of these, however, none supported ten or more ESR publications; therefore, the assumption falls short, but this is unlikely to affect the high-level figures or lists of top funders.

For instances of missing funder data, we did not perform any significant mitigating actions. The justification for this lack of action is that we do not have a sound basis on which to make assumptions about whether a funder name is missing because there was no funder or because the authors did not adequately name the funder(s). Additionally, we cannot assume that the missingness of funding information is random. For example, some regions appeared more likely than others to produce ESR that either lacked external funding or did not fully reference its funders (see section 4.1). However, we had insufficient data about these relationships within ESR to apply statistical adjustments. Therefore, although we have not made adjustments, we have detailed the scale of missing funder data by author country and provided associated caveats for interpreting the findings in Chapter 4.

In addition to bibliometric analysis, we conducted desk research on several funders we identified as suitable for 'funder spotlights' based on their ESR publication volume, geographic diversity and the specialisation of the research they funded. To supplement the funder-specific bibliometric ESR data, we reviewed key documentation about funding priorities and allocations to investigate how ESR is featured in or otherwise aligns with their organisational strategies.

2.3. Topic modelling

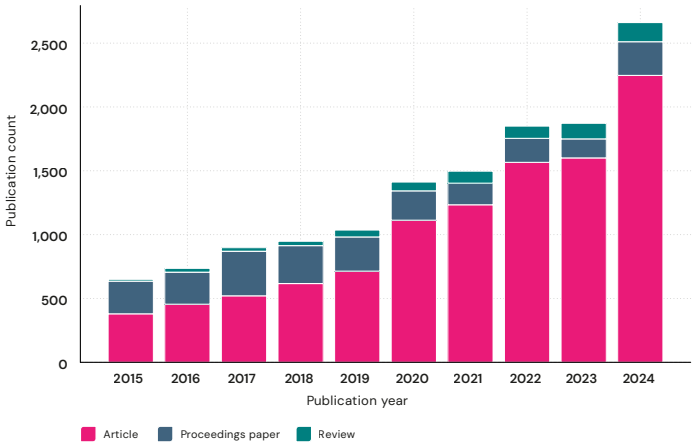
We used topic modelling to identify key themes in the ESR publication content. Topic modelling is a natural-language processing technique that identifies groups of related words (topics) to categorise the underlying data. Because it is data-driven, results are derived from the data itself and thus independent of existing categorical systems (such as journal categories). For ESR, we used publication titles and abstracts to generate a topic model with 50 topics. We generated an indicative label for each topic based on the top ten keywords from ChatGPT, which were subsequently manually curated from a review of assigned sample publications. The topic modelling process assigned up to three topics per publication based on the weight calculated for each topic – those with a weight above a minimum threshold (0.0168 – the 95th percentile of all publication-topic weights) were assigned, with the highest weight assigned as the primary topic.

3. Findings: The current and evolving state of ESR

This chapter presents an analysis of ESR over the last decade, providing an overview of the topics covered in the engineering safety literature, their relationships and their evolution. We also explore the current and changing geographic distribution of engineering safety literature.

A total of 15,705 ESR papers were published between January 2015 and July 2025. ESR is a growing field, with an average annual increase in publications of 18% over the last decade. As demonstrated in Figure 3, the increase in publication volume has been largely driven by growth in research articles, with the number of proceedings papers (often associated with academic conferences and workshops) remaining relatively unchanged. There was a substantial increase in the number of ESR publications in 2024. However, as we discuss below, this increase does not appear to be driven by any one component of ESR publications, nor can it be fully explained by patterns in the broader publication landscape.

Figure 3. Number of engineering safety publications by year and publication type



The growth rate of ESR publications is rapid, even amid the global exponential increase in journal publications (Thelwall & Sud 2022). The average annual increase in volume across all engineering publications during the same decade was 4% (18% over the whole period, see Figure 4)[1]. Although both ESR and engineering publications saw a notable uptick in 2024, the difference from the previous year was more pronounced for ESR (42%) than for all engineering publications (16%). However, because the publication corpus for ESR is much smaller than that for all engineering publications, it may be subject to greater year-to-year fluctuations. Therefore, trend analysis for future years is required to assess the long-term significance of this increase.

1. Engineering includes all publications in journals and other sources categorised as 'Engineering' in the Web of Science platform. Note that not all ESR publications fall under the Engineering Web of Science category. We provide further details on ESR's representation across disciplines in Chapter 3.1.

As demonstrated in Figure 5, the volume and growth of ESR are comparable to several related Web of Science-defined 'micro topics', such as 'Occupational Safety' and 'Damage Detection'. However, none indicate a similar growth in 2024[2].

Figure 4. Number of engineering safety publications versus all publications in the Web of Science 'Engineering' category

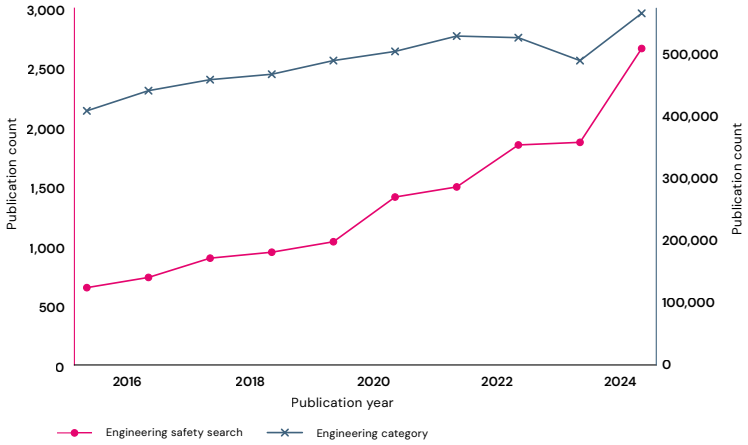
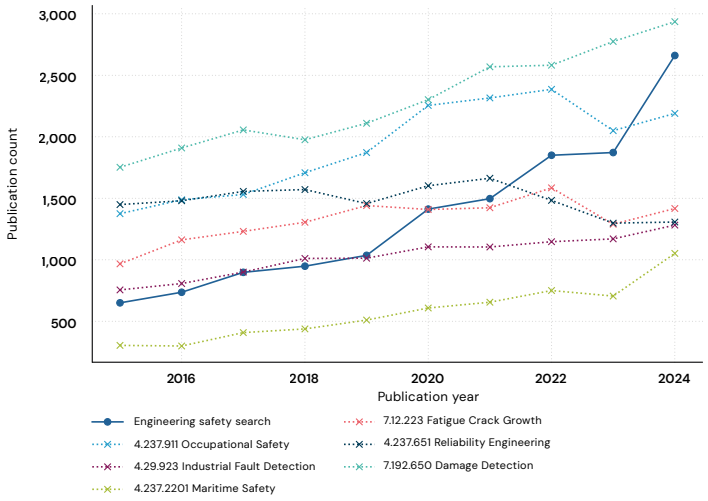


Figure 5. Number of engineering-safety publications (dark-blue line) compared to related micro topics (see legend)

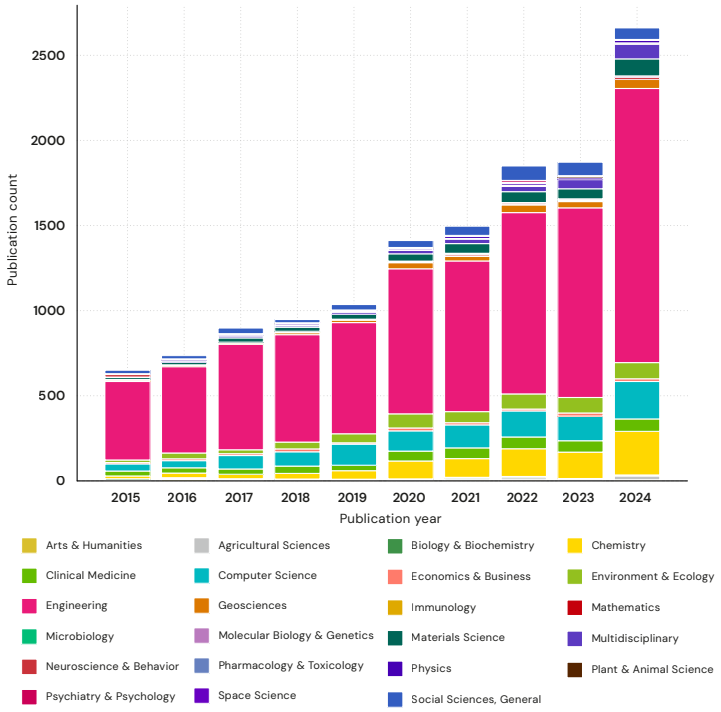


2. Micro-topics are predefined citation-based clusters in the Web of Science that do not necessarily map onto our definition of ESR or the corpus of ESR publications analysed in the majority of our study. They can, however, provide comparable units for comparing ESR trends.

3.1. Disciplines and topics

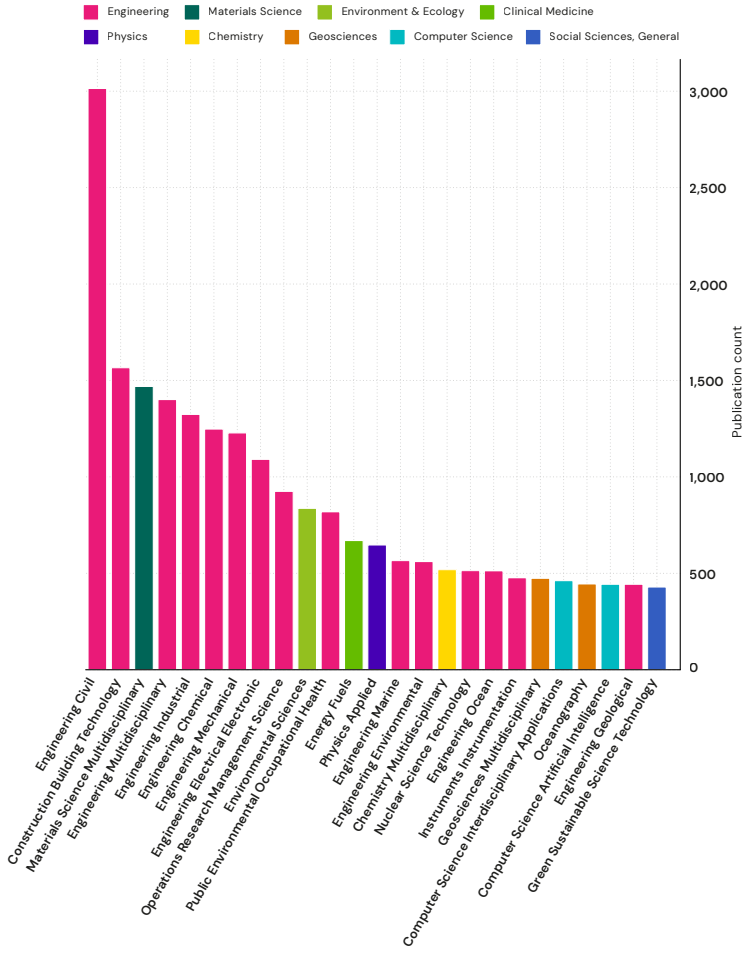
ESR is represented in publications with diverse disciplinary foci. While most ESR publications appear in engineering journals (62%), they also appear frequently in computer science (8%) and chemistry (8%) publications, as demonstrated in Figure 6. The representation of ESR across disciplines has also changed over time. Over the last ten years, the makeup of ESR publications has broadened across disciplines other than engineering, with increases from 2015–2025 in chemistry (2% to 10%), materials science (2% to 4%), and multidisciplinary journals (0% to 3%).

Figure 6. Number of engineering-safety publications categorised by ESI (Essential Science Indicator)



Civil engineering is the most common journal type for ESR papers published over the last decade (19%). Two subject fields in the top ten outside of engineering include multidisciplinary materials science (9%) and environmental sciences (5%) – see Figure 7.

Figure 7. Count of engineering-safety publications by Web of Science category (top 25), coloured by ESI



Using topic modelling, we identified 50 discrete topics for broadly categorising the content of ESR publications. Based on the weights assigned to each topic for all publications, we generated a two-dimensional map of research papers using the machine-learning algorithm UMAP (McInnes et al. 2018), as shown in Figure 8. Based on the distribution of topics in this map, we identified a high-level set of 11 topic clusters (A–K) and assigned labels. The distance between points represents the degree of semantic similarity or difference between the publications. Section 2.3 details the calculations behind the topic model.

The identified topic clusters are typically structured around either the context or the engineering processes and mechanisms involved. For example, Clusters D (Energy and Infrastructure Monitoring), E (Tunnels, Rocks, and Mining Safety), I (Oil, Gas, and Nuclear Power Safety), and J (Industrial and Chemical Process Safety) have clear industry- or engineering-specific foci. Conversely, Clusters A (Geotechnical and Structural Safety), C (Mechanical and Materials Performance), F (Reliability, Failure, and Maintenance), and G (Diagnostics, Detection, and AI) are more closely grouped around overall mechanisms. Multiple clusters involve a combination of context and mechanism relevance, reflecting the fact that some processes are strongly associated with specific contexts, as in the case of Cluster H (Explosion Hazards), which contains topics on coal mining systems as well as broader research on explosion hazards. Compared with the other clusters, Cluster K (Safety and Risk Management) includes the broadest array of topics and has the lowest cohesion, reflecting the unique language used in each.

The cluster includes topics relating to broad safe system factors (42: Human and Causal Risk Factors; 43: Human Error and Human Reliability; 49: Safety Resilience and Organizational Culture), safe system principles and processes (39: Accident Analysis, Investigation, and Prevention; 47: Risk Management and Risk Analysis), as well as specific contexts and applications (40: Construction Safety and Project Risk; 44: Maritime Safety and Collision Risk; 45: Occupational Health, Noise and Exposure Levels), and topics that fall between those categories. The grouping of topics within Cluster K should therefore be interpreted with some caution. However, the proximity between specific topics on the map, such as 44 and 43, suggests that research on Maritime Safety and Collision Risk is more frequently related to Human Error and Human Reliability than to other mapped topics.

Figure 8. Topic map for engineering safety publications, showing each publication as a point coloured by primary topic cluster and sized proportionally to the number of citations

Cluster A: Geotechnical and Structural Safety
1: Dam Safety and Structural Integrity [n=216]
2: Seismic Hazard and Earthquake Engineering [n=492]
3: Slope Stability and Landslide Risk [n=344]

Cluster B: Fire Safety and Thermal Risks
4: Fire Safety and Building Evacuation [n=937]
5: Flame Retardant Materials and Combustion [n=618]
6: Lithium-Ion Battery Safety and Thermal Runaway [n=369]
7: Thermal Hazards and Stability [n=979]

Cluster C: Mechanical and Materials Performance
8: Concrete Structures and Reinforcement [n=464]
9: Corrosion and Material Degradation [n=389]
10: Crack Detection and Fracture Propagation [n=490]
11: Fatigue Analysis and Structural Life [n=531]
12: Steel Structures and Mechanical Performance [n=2,063]

Cluster D: Energy and Infrastructure Monitoring
13: Bridge Engineering and Structure Safety [n=462]
14: Railway and Rail Infrastructure Safety [n=474]
15: Structural Damage Detection [n=763]
16: Structural Health Monitoring and Sensors [n=903]
17: Wind Turbine and Offshore Wind Engineering [n=358]

Cluster E: Tunnels, Rocks, and Mining Safety
18: Coal Mine Safety and Underground Mining [n=852]
19: Mine Water Inrush and Hydrogeological Hazards [n=222]
20: Rock Mechanics and Support in Mining [n=433]
21: Tunnel Construction and Deformation [n=559]

Cluster F: Reliability, Failure, and Maintenance
22: Failure Modes and Probability Analysis [n=1,208]
23: Maintenance Strategies and Predictive Maintenance [n=1,037]
24: Structural Design, Reliability, and Optimization [n=1,612]
25: System Reliability and Safety [n=1,035]

Cluster G: Diagnostics, Detection, and AI
26: Defect and Anomaly Detection [n=1,155]
27: Fault Diagnosis and Industrial Monitoring [n=478]
28: Machine Learning and Data-Driven Methods [n=995]
29: Predictive Modeling and Neural Networks [n=209]

Cluster H: Explosion Hazards
30: Dust, Coal Dust, and Explosion Risk [n=245]
31: Explosion Hazards and Pressure Events [n=500]
32: Hydrogen Energy Safety and Storage [n=264]
33: Spontaneous Combustion in Coal Mining [n=212]

Cluster I: Oil, Gas, and Nuclear Power Safety
34: Gas and Oil Industry Leakage Hazards [n=917]
35: Power Plant Safety [n=624]
36: Pipeline Safety and Failure Risk [n=371]

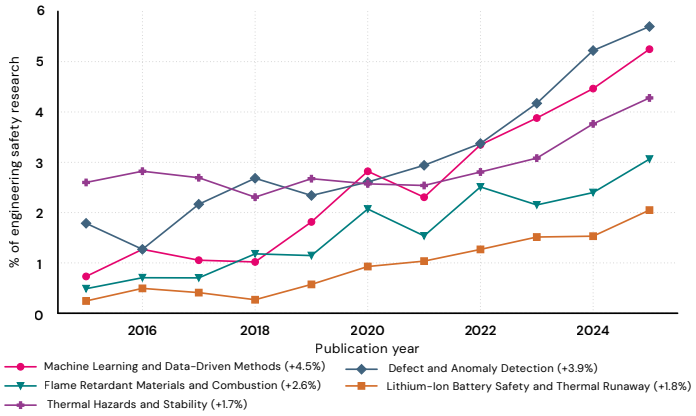
Cluster J: Industrial and Chemical Process Safety
37: Industrial Systems Design and Technology [n=1,474]
38: Process and Chemical Industry Safety [n=929]

Cluster K: Safety and Risk Management
39: Accident Analysis, Investigation, and Prevention [n=773]
40: Construction Safety and Project Risk [n=823]
41: Cybersecurity and Industrial Safety [n=415]
42: Human and Causal Risk Factors [n=1,185]
43: Human Error and Human Reliability [n=688]
44: Maritime Safety and Collision Risk [n=1,035]
45: Occupational Health, Noise, and Exposure Levels [n=1,051]
46: Risk and Safety Assessment Methods [n=1,243]
47: Risk Management and Risk Analysis [n=81]
48: Safety and Risk Management Systems [n=1,469]
49: Safety Resilience and Organizational Culture [n=286]
50: Worker Behavior, Risk Perception, and Safety Training [n=778]

Note: Topic numbers are shown on the map and correspond to those listed in the legend (right).

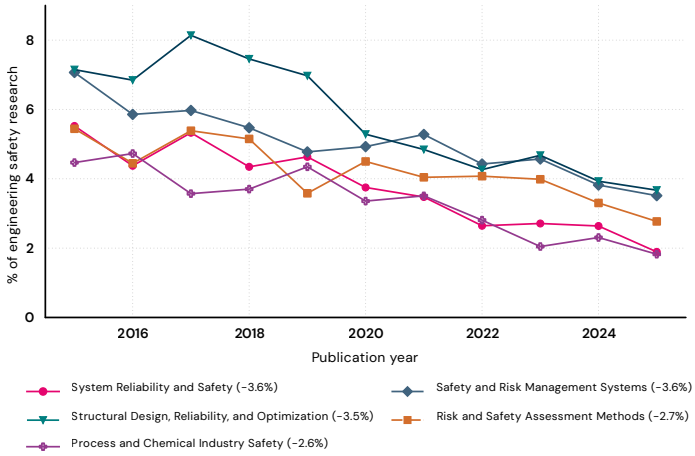
The topics showing the most significant growth over the past decade, especially in the last five years, are those related to the use of technology in engineering-safety processes (Cluster G: Diagnostics, Detection and AI). As depicted in Figure 9, the relative volume of publications on Machine Learning and Data-Driven Methods within ESR publications increased the most, by 4.5 percentage points between 2015 and 2016, followed by Defect and Anomaly Detection, at 3.9 percentage points. The three topics with the next highest level of growth are those related to Fire Safety and Thermal Risks (Cluster B), including research on safety related to lithium-ion batteries and the associated thermal runaway process, likely driven by increased use of lithium-ion batteries for electric vehicles and exploration of battery chemistries across this period (IEA 2023).

Figure 9. Relative proportion of publications for the top five engineering safety topics, 2015–2025



Conversely, topics that have seen a decline in the relative volume of ESR publications are those related to more general safety-system factors and processes, such as System Reliability and Safety and Safety and Risk Management Systems (a decrease of 3.6 percentage points each) – see Figure 10. This pattern may indicate a shift toward authors publishing more specialist research as the field expands and matures.

Figure 10. Relative proportion of publications for the bottom five engineering-safety topics, 2015–2025

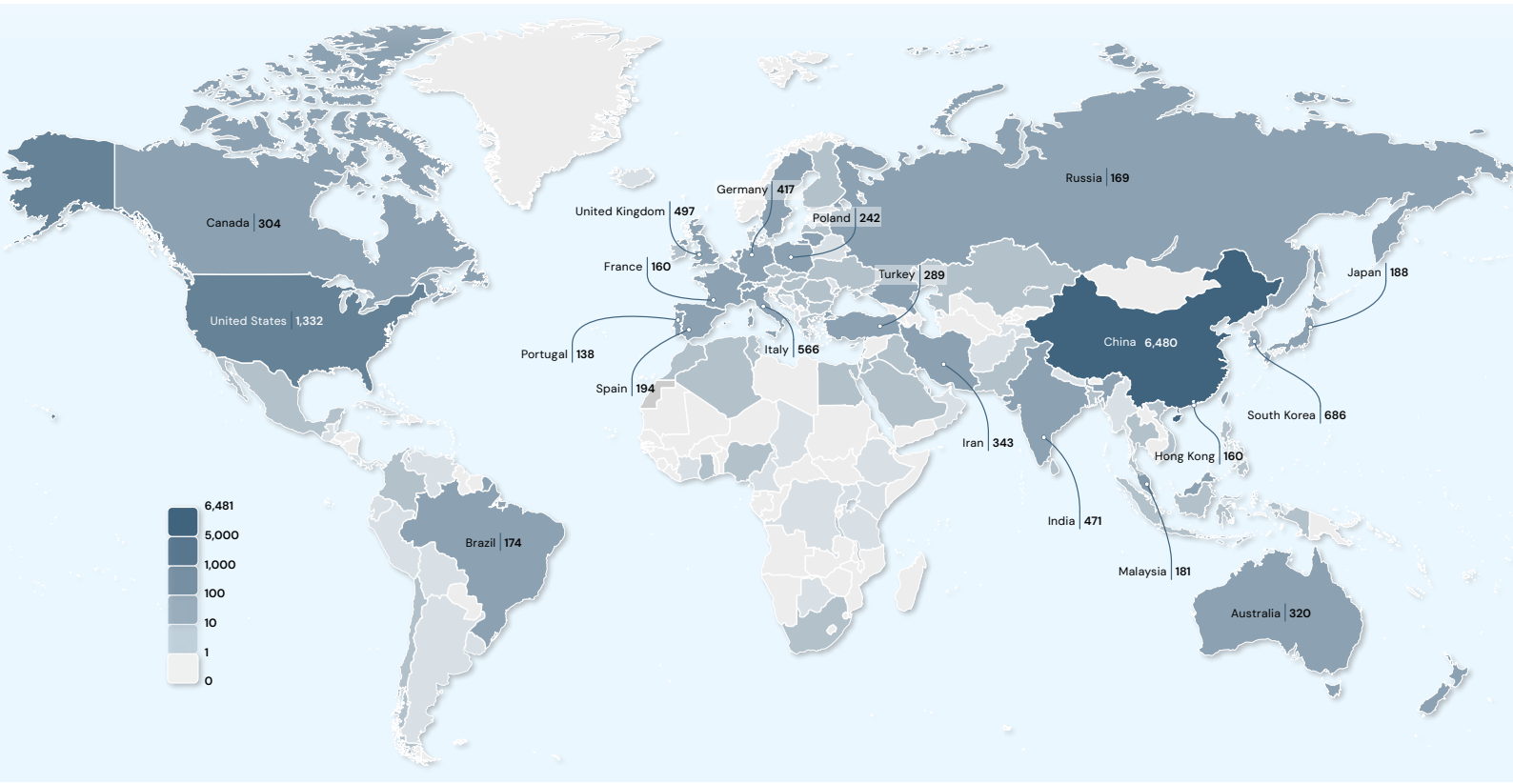


3.2. Geographic distribution of ESR performance

This section explores where ESR is conducted worldwide. Given its application across so many industries and to society more broadly, ESR is a highly global discipline, with first authors from 109 countries publishing ESR articles between 2014 and 2025 (Figure 11). This figure increases to 130 countries when all authors of ESR publications are included (Figure 12). By publication volume, China far outperforms all other countries, with leading authors on 6,480 publications compared with the second-most prolific country, the United States (1,332). Five other countries, including two from Asia – South Korea (686) and India (471) – and three from Europe – Italy (566), the UK (497) and Germany (417) – have published more than 400 ESR publications during this period.

Many areas are associated with significantly higher volumes of ESR publications when contributions from all authors, including non-first authors, are considered. For example, ESR publication counts from Hong Kong [1] and France double. Conversely, China's publication numbers increase by only 4.5%, indicating a lower rate of international collaboration that we explore further in the following chapter.

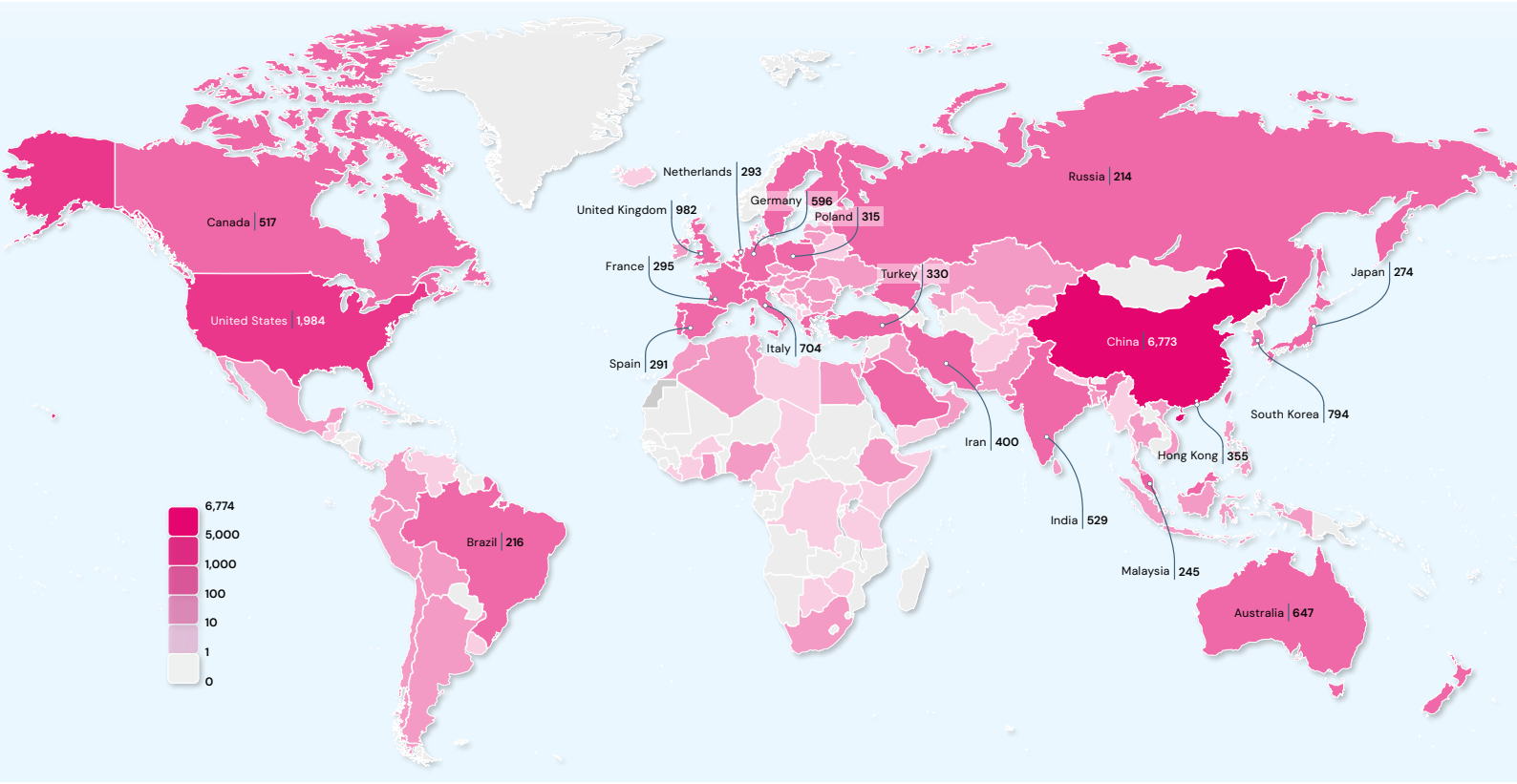
Figure 11. World map showing the number of publications by the first author's affiliation



Note: The six shades represent the output volumes (see legend), with the top 20 countries/regions (by volume) labelled.

1. In this report, 'Hong Kong' references Hong Kong as a Special Administrative Region (SAR) of the People's Republic of China, and 'China' references the People's Republic of China. This terminology reflects common practice in the academic publications reviewed in this report, and does not imply any statement about the legal status of those or other territories.

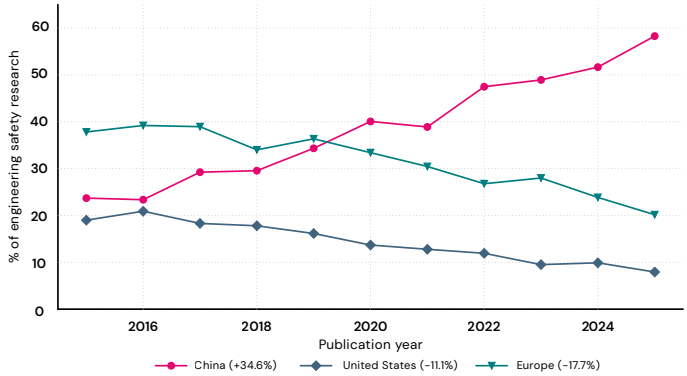
Figure 12. World map showing the number of publications by all author affiliations



Note: The six shades represent the output volumes (see legend right), with the top 20 countries/regions (by volume) labelled.

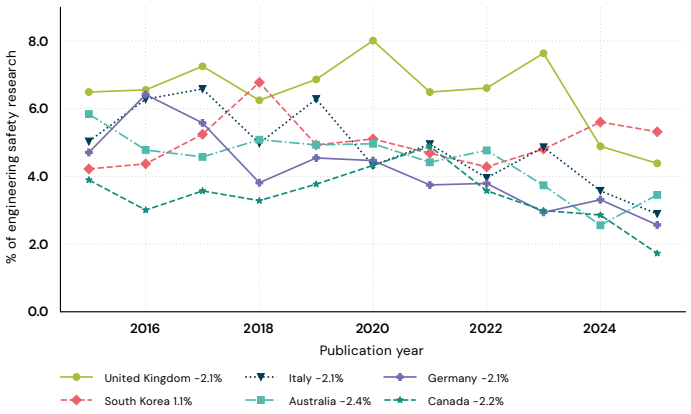
China's prominence in ESR has resulted from a rapid and sustained increase over the past decade. In 2015, European authors accounted for 38% of all ESR publications, with Chinese authors at 24% and US authors at 19% (Figure 13). In contrast, Chinese authors have appeared in 58% of ESR publications so far this year (2025) – an increase of 34 percentage points. By comparison, the proportion of Chinese authorship on all research publications and all engineering research publications has increased by 11 percentage points (18% to 29%) and 19 percentage points (26 to 45%), respectively, indicating that China's volume and growth in ESR stands out as particularly high, even given its current strong overall research performance.

Figure 13. Percentage of engineering-safety publications with an author from China, the US or Europe (excluding the UK)



The next most prolific countries by overall ESR authorship have seen some fluctuation between 2015 and 2025, as depicted in Figure 14. Due to the small publication numbers, however, it is more challenging to conclude whether these figures represent systemic, long-term change.

Figure 14. Percentage of ESR with an author from each of the countries ranked 3–8 by volume



Note: The colours represent the relative change between 2015 and 2025, as described in the legend.

3.3. International collaboration in ESR

This section explores international collaboration (IC) in ESR and its variation across countries. In eight areas, led by Hong Kong (80%), Belgium (79%) and the Netherlands (66%), IC accounts for the vast majority of ESR publications. In contrast, over three-quarters of ESR publications involve only domestic authors in countries such as China, South Korea, Turkey and Russia (Table 2).

These nations' ESR IC patterns broadly follow national IC trends across the research landscape (National Science Board NSF 2023). To emphasise this pattern, Figure 15, Figure 16 and Figure 17 show how IC trends for China (low IC), the US (medium IC) and the UK (high IC) compare with those for engineering publications and all research publications over time.

Table 2. Top 25 countries/ regions (ranked by volume) grouped by IC percentage: low, medium and high

Low IC (0–30%)	Medium IC (30–50%)	High IC (50–100%)
China (20%)	Iran (32%)	Malaysia (50%)
South Korea (23%)	Brazil (32%)	Sweden (52%)
Turkey (24%)	Italy (35%)	France (57%)
Russia (24%)	Poland (37%)	Australia (63%)
India (28%)	United States (37%)	United Kingdom (65%)
Japan (29%)	Germany (38%)	Netherlands (66%)
	Taiwan (38%)	Belgium (79%)
	Spain (41%)	Hong Kong (80%)
	Norway (49%)	
	Canada (50%)	
	Portugal (50%)	

Figure 15. Percentage of Chinese engineering safety publications featuring IC compared to a) all Chinese publications classified in the Web of Science 'Engineering' category, and b) for all publications with a Chinese author, 2015–2025

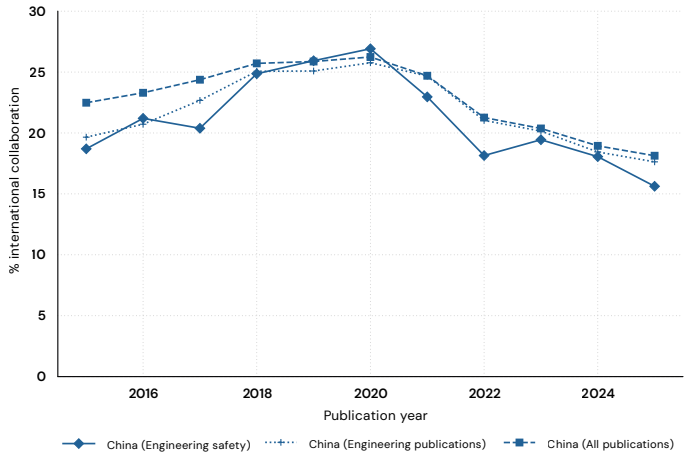


Figure 16. Percentage of US engineering safety publications featuring IC compared to a) all US publications classified in the Web of Science 'Engineering' category and b) all publications with a US author, 2015–2025

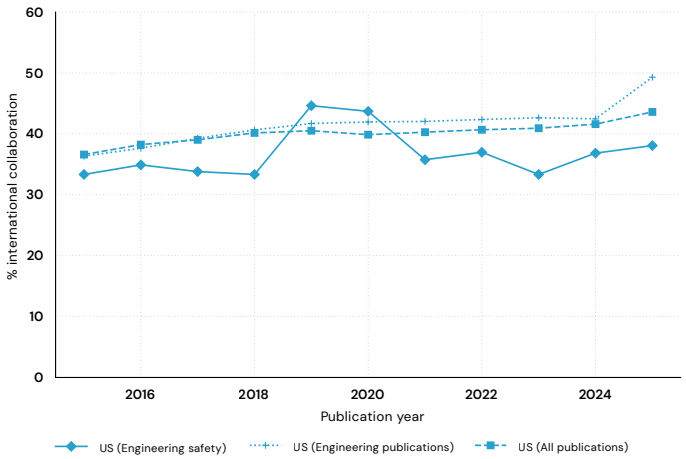
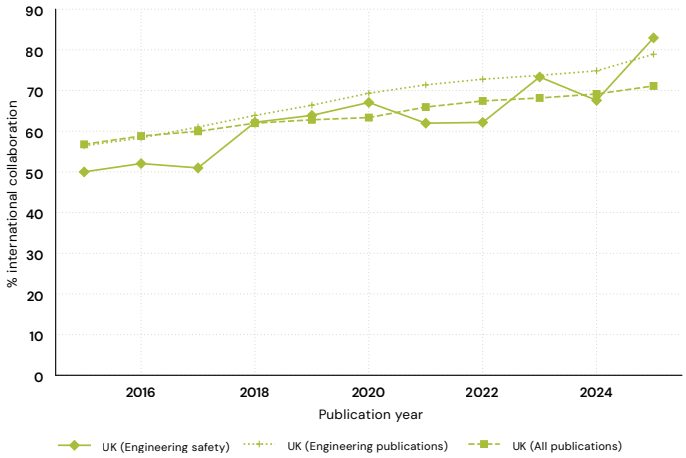


Figure 17. Percentage of UK engineering safety publications featuring IC compared to a) all publications classified in the Web of Science 'Engineering' category, and b) for all publications with a UK author, 2015–2025



4. Findings: ESR funding and funders

This chapter uses funding acknowledgements in ESR publications to identify the main funders of ESR and the topics they are most likely to fund. We begin by identifying the countries and specific organisations that fund the most ESR. We then explore these countries' and organisations' ESR portfolios in more depth, identifying the specific topics they tend to prioritise.

4.1. Funder acknowledgements

Overall, 66% of publications in our sample included funder acknowledgements, but this figure masks considerable variation across countries, as Table 3 demonstrates. For instance, 86% of publications with a first author in China included acknowledgements, compared with only 22% with a first author in Turkey.

The fact that not all ESR articles in our sample acknowledge a funder has ramifications for the statistics presented in this and the next chapter. Since there will likely be systematic differences between articles that acknowledge funders and those that do not, the makeup of our sample of ESR articles with funder acknowledgements will not perfectly mirror that of all ESR articles published in the same timeframe. In practice, this means that countries like China, where acknowledging a funder is common, may be overrepresented in our sample. In contrast, countries like Turkey, where funders are rarely acknowledged, are likely to be underrepresented. Therefore, strictly speaking, the conclusions we reach in this chapter hold only for our sample of ESR articles that include funder acknowledgements. See Chapter 2 for more information on this limitation.

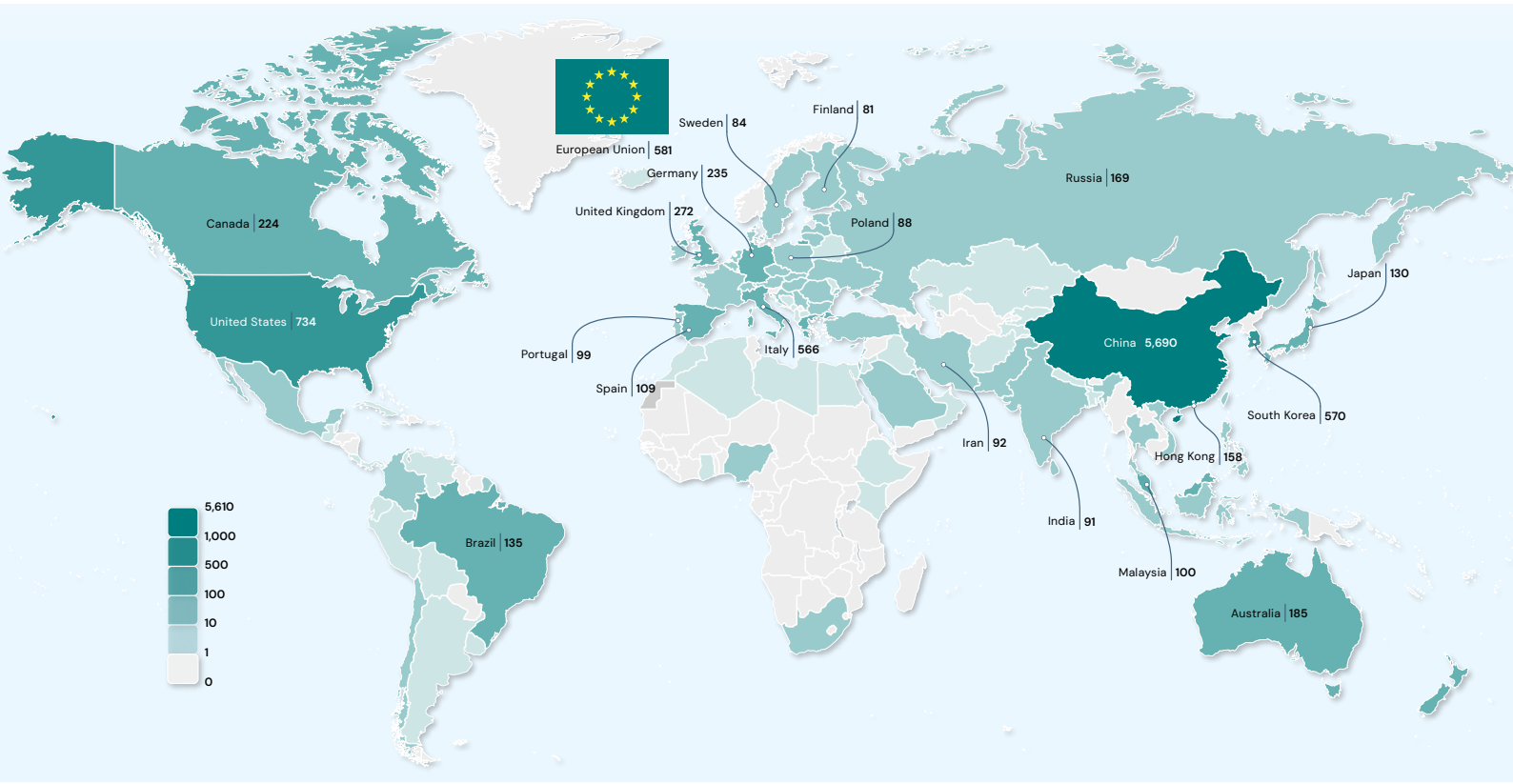
Table 3. Proportion of publications with funding acknowledgements for each of the top 30 countries by first-author affiliation

Country/region	Count	% funding acknowledgement	Country/region	Count	% funding acknowledgement
China	6,480	86	Australia	320	54
South Korea	686	83	Japan	188	51
Hong Kong	160	79	Taiwan	135	50
Portugal	138	75	United States	1,332	50
Finland	91	75	Netherlands	131	48
Singapore	75	75	Poland	242	45
Brazil	174	63	France	160	44
Canada	304	62	Italy	566	43
Sweden	119	61	Greece	80	43
Malaysia	181	61	Indonesia	77	42
Norway	164	60	Iran	343	30
United Kingdom	497	57	India	471	28
Germany	417	57	Russia	169	24
Spain	194	56	Romania	61	23
Switzerland	73	55	Turkey	289	22

4.2. Funder regions

The number of funding acknowledgements received per country in our sample of ESR publications suggests that Chinese organisations are the most active ESR funders by far, with the US a distant second (see Figure 18). A total of 5,609 publications acknowledged a China-based funder, while 734 publications acknowledged a US funder. Interestingly, the country that funded the most ESR after the US and China was South Korea, whose funders were acknowledged in 570 publications – slightly more than the European Union's 561 and more than double the UK's 272. Germany stands out as a particularly strong ESR funder within the EU, with 235 publications attributed to German funders.

Figure 18. World map showing the number of publications acknowledging a funder in each country/region



Note: The six shades represent the output volumes, with the top 20 countries/regions (by volume) labelled.

4.3. Key ESR funders

Given China's predominance in the ESR landscape, it is unsurprising that, of the ten funders that received the most acknowledgements in our sample of publications, eight were from China (see Table 4). These included national-level funders, such as the National Natural Science Foundation of China (NSFC), the Ministry of Education and the Ministry of Science and Technology (MOST), as well as province-level funders, including local governments and provincial departments of science and technology. The top funder, the NSFC, was acknowledged in 3,733 ESR publications – almost a quarter of our sample and more than seven times the number that acknowledged the European Commission (EC), which ranked third.

Between 2015 and 2025, the number of ESR publications acknowledging Chinese funders increased significantly, as shown in Table 4 and Figure 19. For example, the average annual growth rate for publications acknowledging the NSFC was 35% between 2015 and 2024. Comparing Figure 19 to Figure 20 shows that corresponding increases for funders outside of China have been much more moderate. For example, the average annual growth rate for publications acknowledging the EC or the UK Engineering and Physical Sciences Research Council was just 18% and 14%, respectively, as shown in Table 4.

Table 4. Number of publications that acknowledge each of the top 40 funders (ranked by volume)

Funder name	Country/region	Publications funded	% global safety engineering	% country/ region funding	AAGR 2015-24
NSFC	China	3,733	23.8	66.6	35
MOST	China	1,166	7.4	20.8	39
EC	European Union	505	3.2	90.0*	18
Government of Jiangsu Province	China	347	2.2	6.2	34
Ministry of Education of the People's Republic of China	China	306	1.9	5.5	20
National Research Foundation of Korea (NRF)	South Korea	236	1.5	41.4	33
Department of Science and Technology of Shandong Province	China	235	1.5	4.2	51
China Scholarship Council	China	209	1.3	3.7	35
Department of Science and Technology of Guangdong Province	China	177	1.1	3.2	35
Education Department of Shaanxi Province	China	173	1.1	3.1	72
US National Science Foundation	United States	152	1.0	20.7	18
Science and Technology Department of Sichuan Province	China	148	0.9	2.6	93
Natural Sciences and Engineering Research Council	Canada	146	0.9	65.2	40
Science and Technology Department of Hubei Province	China	132	0.8	2.4	46
Education Department of Hunan Province	China	129	0.8	2.3	56
Henan Science and Technology Department	China	100	0.6	1.8	49
Science and Technology Department of Zhejiang Province	China	100	0.6	1.8	76
Engineering and Physical Sciences Research Council	United Kingdom	99	0.6	36.4	14
Department of Science and Technology of Anhui Province	China	98	0.6	1.7	93
Fundação para a Ciência e Tecnologia	Portugal	91	0.6	91.9	29
Australian Research Council	Australia	87	0.6	47.0	12
Zhejiang Provincial Natural Science Foundation	China	80	0.5	1.4	61
Hebei Provincial Department of Science and Technology	China	77	0.5	1.4	65
Chinese Academy of Sciences	China	74	0.5	1.3	62
Beijing Municipal Government	China	73	0.5	1.3	45
Shanxi Science and Technology Department	China	66	0.4	1.2	64
The Research Council of Norway (RCN)	Norway	66	0.4	65.3	50
China University of Mining and Technology	China	65	0.4	1.2	35
US Department of Energy	United States	63	0.4	8.6	10
National Council for Scientific and Technological Development	Brazil	62	0.4	45.9	9
European Research Council (ERC)	European Union	56	0.4	10.0	56
Coordenação de Aperfeicoamento de Pessoal de Nível Superior	Brazil	55	0.4	40.7	36
Shenzhen Science and Technology Innovation Commission	China	53	0.3	0.9	9
State Council of the People's Republic of China	China	52	0.3	0.9	51
Japan Society for the Promotion of Science	Japan	48	0.3	36.9	53
Chongqing Municipal Government	China	47	0.3	0.8	84
Federal Ministry for Economic Affairs and Climate Action	Germany	47	0.3	20.0	52
Deutsche Forschungsgemeinschaft	Germany	46	0.3	19.6	20
Guangxi Science and Technology Department	China	44	0.3	0.8	82
Ministry of Trade, Industry and Energy	South Korea	43	0.3	7.5	30

Note: The table also lists the percentage of all safety engineering outputs (% global safety engineering), the proportion of all publications from the funder country they represent (% country/region funding), and the growth in publications between 2015 and 2024.
**For funders in the EU, the denominator is all funders in the EU, and not all funding from European countries.*

Figure 19. Time series plot for the number of publications acknowledging the top six funders from China, as ranked by volume

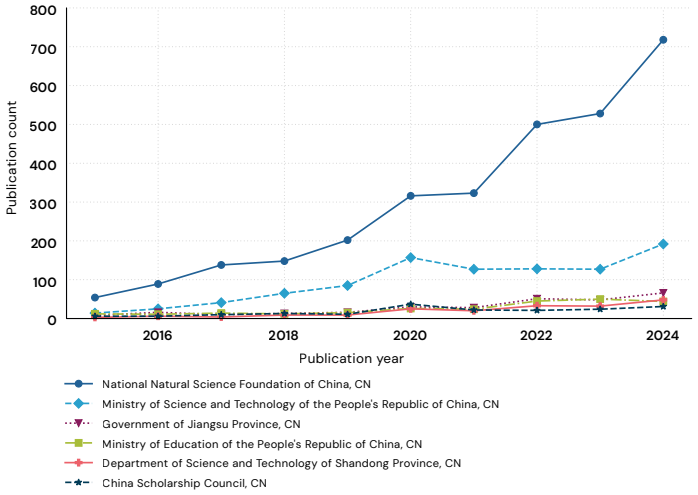
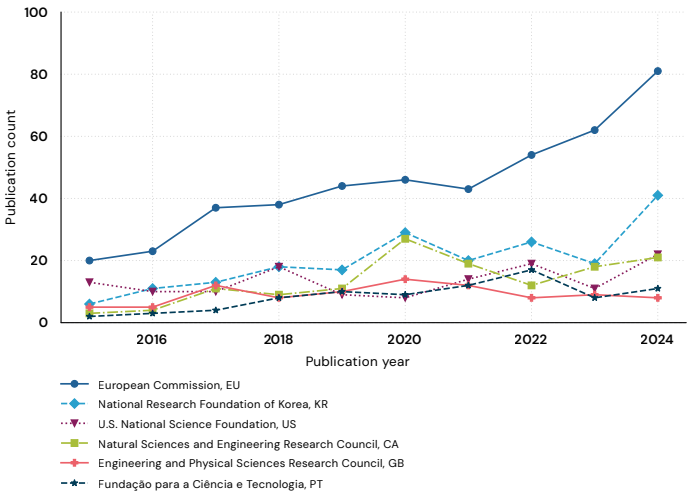


Figure 20. Time series plot for the number of publications acknowledging the top six funders outside China, as ranked by volume



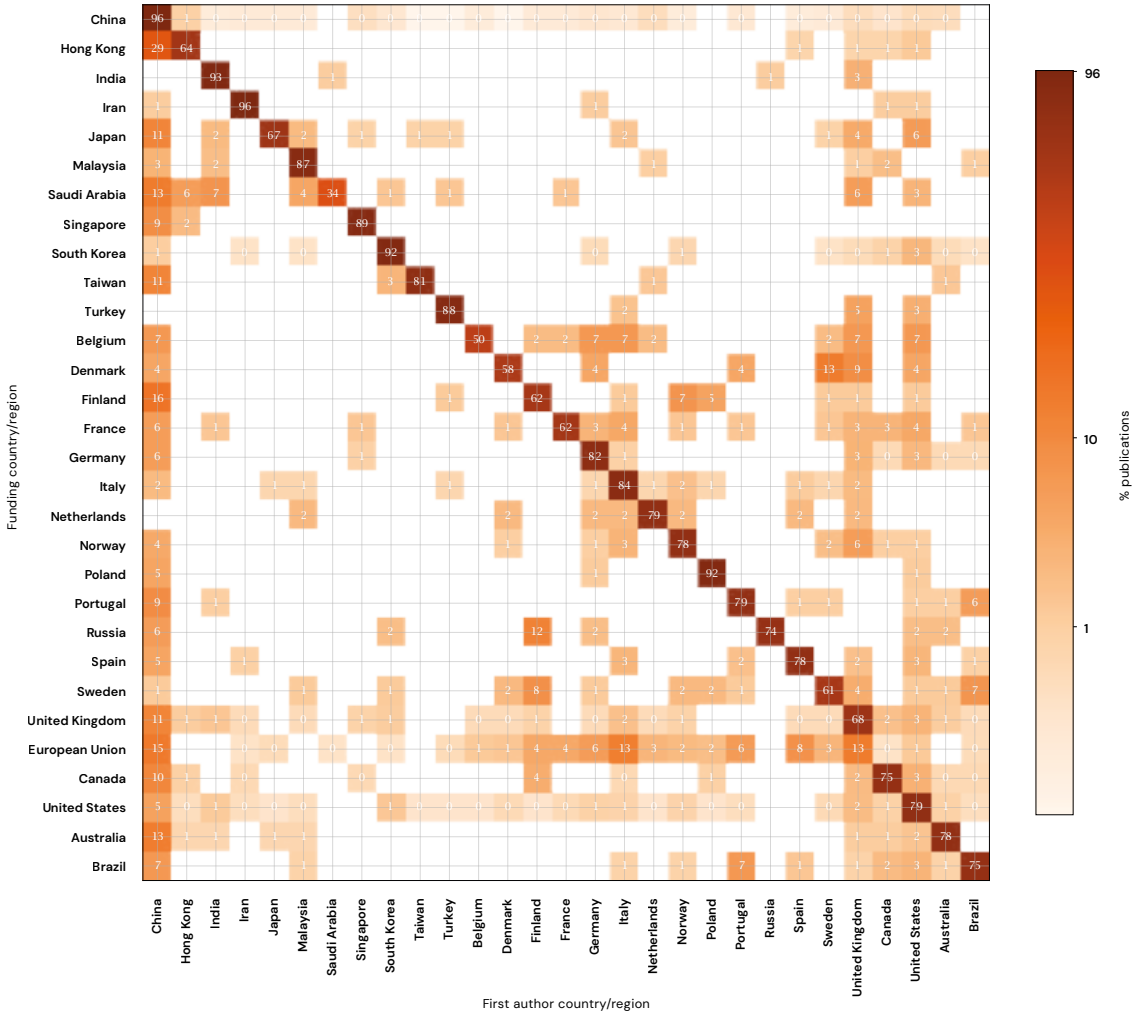
4.4. Cross-border funding

Figure 21 demonstrates that, in almost all cases, funders are much more likely to fund ESR conducted by researchers in their home country than ESR by researchers from other countries. This phenomenon is particularly pronounced in China: 96% of ESR funded by Chinese organisations had a first author from China. However, many funders from other countries have a similarly strong preference for funding ESR research by first authors from their home country. For example, 92% of the ESR funded by South Korean funders had a first author from South Korea, while the figures for India and Iran were 93% and 96%, respectively.

Figure 21. Heatmap showing the percentage of publications with a first author in each country (x-axis) and the country to which the funder acknowledgement is assigned (y-axis)

The US and the UK are slightly less likely than the countries above to fund local ESR researchers, but still more likely than not. In our sample, 79% of US ESR funding went to first authors from the US, while 68% of UK funding went to first authors from the UK. Among the top 20 funders outside China, the funder most likely to fund researchers from outside its home region was the ERC: only 50% of first authors who acknowledged the ERC in their ESR publication were from Europe (excluding the UK; see Table 6).

It is also worth noting that, while China appears to fund very little research outside its borders, Chinese ESR researchers receive significant funding from other countries (see Figure 21). Chinese researchers are first authors in at least 10% of funded publications across nine countries or regions, including the UK (where 11% of funded ESR publications have a Chinese first author). For perspective, UK researchers are first authors in at least 10% of publications in only one area outside the UK (the EU).



Note: The percentage value is listed in non-zero cells. Countries/regions are ordered left-to-right by geographic continent (Asia, Europe, North America, Oceania and South America).

Table 5. Proportion of publications acknowledging the top 20 funders from China (as ranked by volume) with a first author from China

Funder	Country/region	Count	% local funding
NSFC	China	3,733	97.5
MOST	China	1,166	98.2
Government of Jiangsu Province	China	347	99.4
Ministry of Education of the People's Republic of China	China	306	97.4
Department of Science and Technology of Shandong Province	China	235	99.1
China Scholarship Council	China	209	72.7
Department of Science and Technology of Guangdong Province	China	177	97.2
Education Department of Shaanxi Province	China	173	100.0
Science and Technology Department of Sichuan Province	China	148	98.6
Science and Technology Department of Hubei Province	China	132	93.9
Education Department of Hunan Province	China	129	99.2
Henan Science and Technology Department	China	100	99.0
Science and Technology Department of Zhejiang Province	China	100	99.0
Department of Science and Technology of Anhui Province	China	98	95.9
Zhejiang Provincial Natural Science Foundation	China	80	100.0
Hebei Provincial Department of Science and Technology	China	77	100.0
Chinese Academy of Sciences	China	74	95.9
Beijing Municipal Government	China	73	100.0
Shanxi Science and Technology Department	China	66	98.5
China University of Mining and Technology	China	65	96.9

Table 6. Proportion of publications acknowledging the top 20 funders from outside China (as ranked by volume) with a first author from the funder's country

Funder	Country/region	Count	% local funding
Ministry of Trade, Industry and Energy	South Korea	43	98
National Institute for Occupational Safety and Health	United States	42	93
RCN	Norway	66	92
NRF	South Korea	236	92
Federal Ministry for Economic Affairs and Climate Action	Germany	47	91
United States Department of Energy	United States	63	87
Coordenação de Aperfeicoamento de Pessoal de Nível Superior	Brazil	55	87
EC	European Union	505	84
Fundação para a Ciência e Tecnologia	Portugal	91	81
US National Science Foundation	United States	152	81
National Council for Scientific and Technological Development	Brazil	62	81
Deutsche Forschungsgemeinschaft	Germany	46	80
Natural Sciences and Engineering Research Council	Canada	146	79
Engineering and Physical Sciences Research Council	United Kingdom	99	76
Australian Research Council	Australia	87	75
University Grants Committee	Hong Kong	43	74
Ministry of Education, Culture, Sports, Science and Technology	Japan	43	72
Japan Society for the Promotion of Science	Japan	48	71
Hong Kong Polytechnic University	Hong Kong	40	70
ERC	European Union	56	50

Note: For European Union funders, local funding is counted for any author in Europe (excluding the UK).

4.5. Funder types

As Table 7 shows, more than half (53.4%) of the ESR publications in our sample were funded by government bodies, making governments the largest source of ESR funding by far. Educational institutions funded 12.2% of the publications, while not-for-profit organisations funded 2.6%. In 18% of cases, the funder type was unknown.

There is considerable variation between countries in the proportions of ESR funded by governments, educational institutions, not-for-profits, and companies, as Table 8 and Figure 22 demonstrate. Judging by the funder acknowledgements in our sample, a much greater percentage of ESR research is funded by the government in China than in most other countries (see Figure 22). To a more limited extent, the same is true of South Korea and Canada. It is also notable that, compared to researchers from the other seven countries that fund the most ESR, ESR researchers based in Germany are particularly likely to be funded by not-for-profit organisations. In Australia, a greater proportion of ESR than average for our sample of ESR publications as a whole is funded by educational institutions.

Table 7. Number of publications acknowledging each funder type and the relative percentage of all safety-engineering outputs

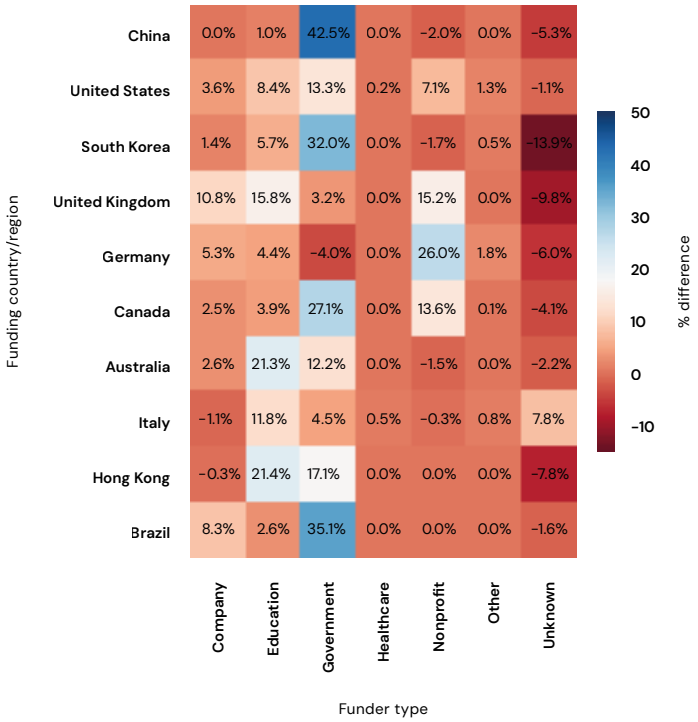
Type	Count	% engineering safety
Company	441	2.8
Education	1,914	12.2
Government	8,392	53.4
Healthcare	11	0.1
Nonprofit	407	2.6
Other[1]	52	0.3
Unknown	2,821	18.0

1. ESR funding organisations whose organisation type was classified as 'other' by ROR include research institutes, professional bodies, societies, consortia and entities that otherwise do not fit in the other five named categories.

Table 8. Number of publications attributed to funders in the top ten countries (as ranked by volume) according to organisation type

Country/ region	Company	Education	Government	Healthcare	Nonprofit	Other	Unknown
China	158	741	5,396	6	3	0	706
United States	47	151	492	2	67	12	123
United Kingdom	37	76	155	0	47	1	22
South Korea	24	102	489	0	2	5	23
Germany	19	39	117	0	66	5	28
Canada	12	36	181	0	35	1	31
Australia	10	62	122	0	1	0	29
Italy	3	42	102	1	3	2	45
Hong Kong	4	53	112	0	0	0	16
Brazil	15	20	120	0	0	0	22

Figure 22. Heatmap showing the percentage differences in outputs based on acknowledged funder type (x-axis) for the top ten countries ranked by volume (y-axis), compared to all safety engineering publications



4.6. Topic focus by country

Figure 23, Figure 24 and Figure 25 show the percentage of each of the four key funder countries' ESR portfolios devoted to each of the topics identified by the topic model, as described in Chapter 2.

Figure 26 provides similar information for the top 30 funder countries, but using absolute publication numbers. Finally, Table 9 shows the ESR topic most commonly funded by each of the top ten funder countries, presenting both absolute publication numbers and percentages.

One particularly striking finding from this part of the analysis is China's ESR portfolio's clear focus on safety in the mining, oil and gas industries (see Figure 24). For instance, publications on Coal Mine Safety and Underground Mining form more than 9% of the ESR portfolio in China; the corresponding figure for the US is just over 4%, while the figures for the EU and UK are under 2%. Similarly, work on Tunnel Construction and Deformation (a major concern in mining) accounts for around 7% of all ESR publications funded by China, compared to less than 1.5% for the US, the EU and the UK. Therefore, not only is China funding more work on these topics in absolute terms (which is unsurprising given the high volume of work it funds overall), but these topics also account for a larger share of its ESR portfolio. This finding likely reflects China's continued investment in the mining, oil and gas industries.

The results also show that Maritime Safety and Collision Risk is a particular priority for the EU, accounting for more than 25% of its overall ESR portfolio, compared to around 8% for the UK, 5% for China and 2% for the US (see Figure 25 and Table 9). The EU also has a strong focus on Risk and Safety Assessment Methods, which accounts for around 12% of its portfolio; the corresponding figures for China, the US and the UK are around 7%, 5% and 4%, respectively.

The UK funds proportionally more research into safety in Industrial Systems Design and Technology than either the EU, China or the US. This topic accounts for around 22% of its ESR portfolio, compared to 20% of the EU's portfolio, just under 15% of the US's portfolio and only around 2% of China's (see Figure 25). Indeed, Industrial Systems Design and Technology is the single ESR topic most often funded by UK funders (see Figure 25 and Table 9). Other topics that account for relatively large proportions of the UK's ESR portfolio include Structural Design, Reliability and Optimisation (around 13% – a greater proportion than in the EU, the US or China), Steel Structures and Mechanical Performance (around 12%), Failure Modes and Probability Analysis (around 12% – again, a greater proportion than in the EU, the US or China), and Maintenance Strategies and Predictive Maintenance (around 9%).

The US has funded a proportionally large volume of ESR in the Occupational Health, Noise and Exposure Levels category: more than 15% of its portfolio is research on this topic, compared to less than 5% for China, the EU and the UK (see Figure 25 and Table 9). Other topics the US appears to prioritise include Industrial Systems Design and Technology (which accounts for more than 14% of its portfolio) and Steel Structures and Mechanical Performance (around 11%).

Figure 23. Proportions of engineering safety publications that acknowledge funders in China, the US, the EU and the UK for topic clusters A–D

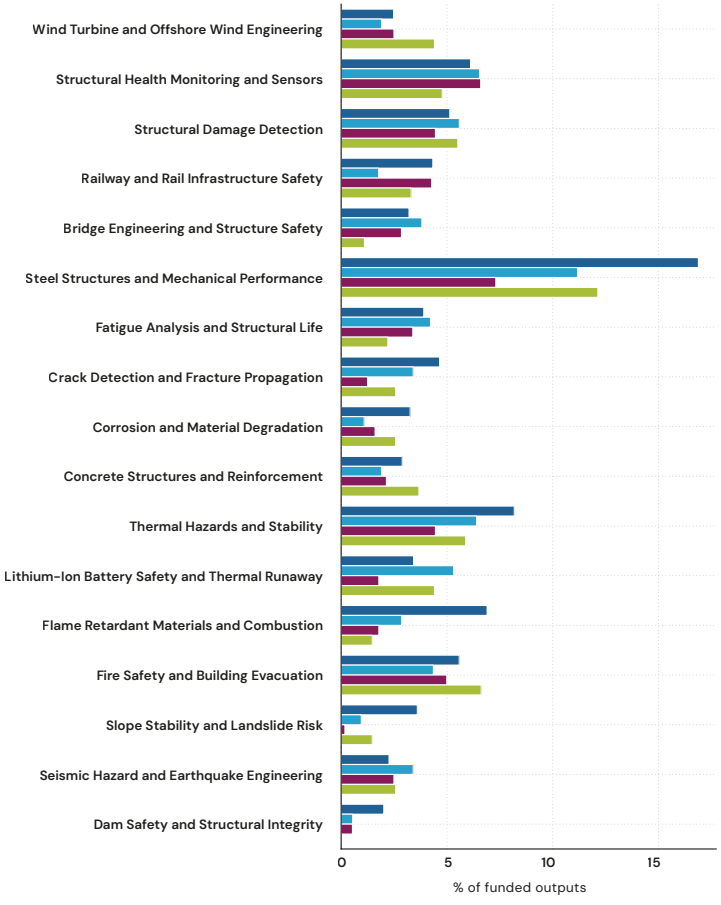


Figure 24. Proportions of engineering safety publications acknowledging funders in China, the US, the EU and the UK for topic clusters E–H

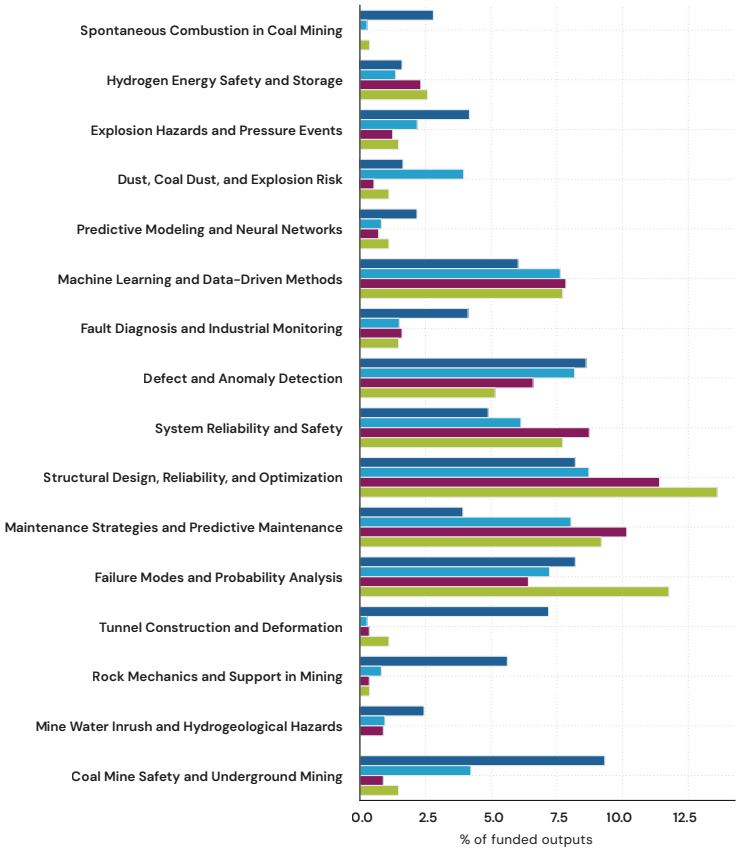


Figure 25. Proportions of engineering safety publications acknowledging funders in China, the US, the EU and the UK for topic clusters I–K

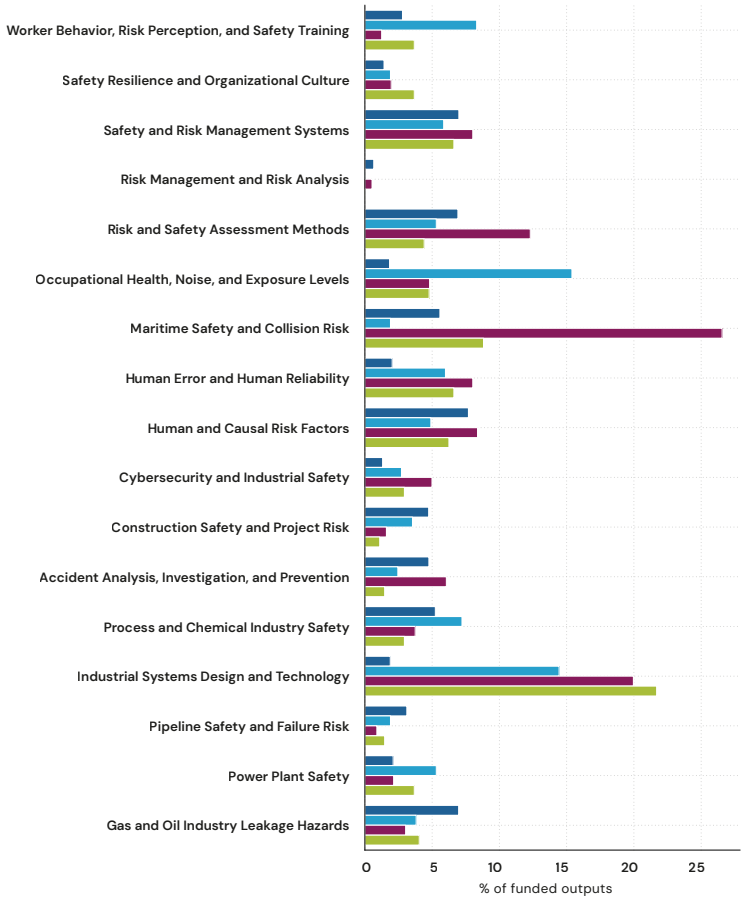


Table 9. Top ESR topics funded for the ten most active ESR funder regions

Country	Total ESR publications funded	Top topic	Top topic count	% top topic
China	5,609	Steel Structures and Mechanical Performance	947	16.9
US	734	Occupational Health, Noise, and Exposure Levels	113	15.4
South Korea	570	Steel Structures and Mechanical Performance	75	13.2
EU	561	Maritime Safety and Collision Risk	149	26.6
UK	272	Industrial Systems Design and Technology	59	21.7
Germany	235	Steel Structures and Mechanical Performance	58	24.7
Canada	224	Safety and Risk Management Systems	37	16.5
Australia	185	Structural Design, Reliability and Optimisation	30	16.2
Italy	175	Maintenance Strategies and Predictive Maintenance	29	16.6
Hong Kong	158	Fire Safety and Building Evacuation	35	22.2

Figure 26. Heatmap showing the number of publications by funders in the top 30 countries/regions (ranked by volume, x-axis) by topic (y-axis)

Note: The colour intensity is proportional to the number of funded publications (see legend). Countries/regions are ordered left to right by geographic continent (Asia, Europe, North America, Oceania and South America).

4.7. Key funders of emerging ESR topics

Table 10 presents data on the top funders of the five most rapidly growing ESR topics: Machine Learning and Data-Driven Methods, Spontaneous Combustion in Coal Mining, Flame-Retardant Materials and Combustion, Lithium-Ion Battery Safety and Thermal Runaway, and Thermal Hazards and Stability.

There is considerable overlap between the top ESR funders overall and those for these emerging topics. The top ten funders are largely identical, except that, in the ranking for emerging topics, the EC cedes third place to the Government of Jiangsu Province, the National Research Foundation of Korea slips to seventh place behind the sixth-ranked Department of Science and Technology of Shandong Province, and the China Scholarship Council drops out of the top ten altogether, moving to eighteenth place. Interestingly, these five emerging topics comprise at least 20% of the ESR portfolios of each Chinese funder featuring in the top 15 global funders of ESR on emerging topics, but only 15% of the portfolio of the fourth-ranked EC, 19% of the portfolio of the seventh-ranked NRF and 20% of the portfolio of the twelfth-ranked US National Science Foundation. This finding could be interpreted in two main ways: either Chinese funders are particularly eager to support work on 'hot topics' in ESR, or they are setting the emerging ESR agenda for the rest of the world.

Table 10. Top 30 funders (by volume) and publication counts for the five most rapidly growing topics

Funder	Country/ region	Machine Learning and Data-Driven Methods	Spontaneous Combustion in Coal Mining	Flame Retardant Materials and Combustion	Lithium-Ion Battery Safety and Thermal Runaway	Thermal Hazards and Stability	Count top	Count all	% top
NFSC	China	212	125	275	139	321	866	3,733	23
MOST	China	69	28	89	63	121	289	1,166	25
Government of Jiangsu Province	China	16	10	36	17	47	98	347	28
EC	European Union	42	0	10	9	21	77	505	15
Ministry of Education of the People's Republic of China	China	20	7	25	5	19	62	306	20
Department of Science and Technology of Shandong Province	China	9	12	18	7	22	54	235	23
NRF	South Korea	23	0	5	8	14	44	236	19
Department of Science and Technology of Anhui Province	China	6	2	21	3	18	41	98	42
Department of Science and Technology of Guangdong Province	China	13	0	11	11	18	41	177	23
Education Department of Shaanxi Province	China	3	13	14	3	17	35	173	20
Science and Technology Department of Hubei Province	China	10	0	14	4	12	32	135	24
US National Science Foundation	US	17	0	4	4	9	31	152	20
Education Department of Hunan Province	China	11	7	14	3	4	30	129	23
Science and Technology Department of Sichuan Province	China	8	1	7	8	10	29	148	20
Science and Technology Department of Zhejiang Province	China	9	3	11	7	7	29	100	29
Zhejiang Provincial Natural Science Foundation	China	7	4	10	4	9	28	80	35
Australian Research Council	Australia	4	4	15	4	9	28	87	32
China Scholarship Council	China	15	2	5	3	6	28	209	13
Natural Sciences and Engineering Research Council	Canada	15	0	5	1	5	26	146	18
Chinese Academy of Sciences	China	3	0	6	9	16	25	74	34
China University of Mining and Technology	China	2	12	8	0	5	23	65	35
State Key Laboratory of Fire Science	China	0	1	14	7	15	22	24	92
Shanxi Science and Technology Department	China	1	8	6	3	12	21	66	32
University Grants Committee	Hong Kong	10	0	5	4	6	21	61	34
Beijing Municipal Government	China	2	3	5	11	6	21	73	29
Engineering and Physical Sciences Research Council	United Kingdom	7	0	2	6	8	20	99	20
Hebei Provincial Department of Science and Technology	China	3	8	4	5	6	20	77	26
Henan Science and Technology Department	China	4	7	3	4	4	19	100	19
United States Department of Energy	United States	1	0	1	7	11	15	63	24
Government of Hong Kong	Hong Kong	2	0	7	6	9	14	38	37

Note: The table also shows the total in these five topics (Count top), total for the funder in all topics (Count all), and percentage of all funded works in the top five (% top).

4.8. ESR funder spotlights

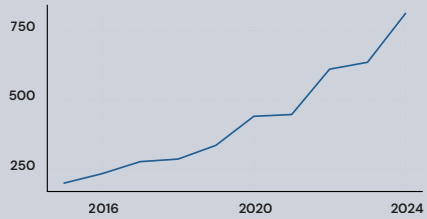
We selected three leading ESR funding organisations to spotlight (see Boxes 1, 2 and 3): the NSFC (which is the world's biggest ESR funder), the EC and the NRF (the world's second-and third-largest non-Chinese ESR funders). We explored these funders' ESR profiles through bibliometric analysis and insights from their strategic and funding performance data.

Box 1. Funder spotlight: The National Natural Science Foundation of China

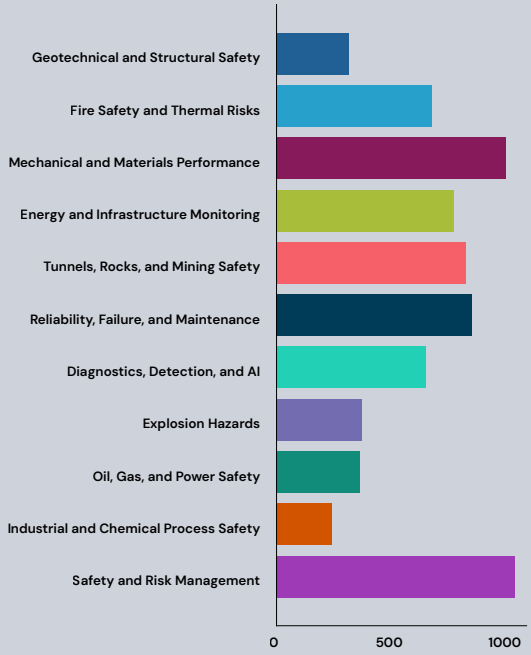
The National Natural Science Foundation of China

The NSFC has funded 23.8% of all ESR publications over the last decade.

ESR publications funded



ESR publications funded since 2015 by topic cluster



Established in 1986, the NSFC is managed by China's Ministry of Science and Technology (MOST). With an annual project budget of approximately CY¥34bn (approximately £3.5bn), it is a major Chinese funder of basic research (i.e. research undertaken to expand fundamental scientific knowledge). It provides funding through a wide range of goal-oriented and free exploration programmes that support research projects, young talent and international exchanges (NSFC 2023).

The NSFC was the top ESR funder between 2015 and 2024, funding almost one-quarter of all ESR publications during that period (23.8%), followed by MOST (its sponsoring government department). NSFC's growth in ESR mirrors that of its home country, China (Figure 13). The topics it funds cover all eleven topic clusters. Outside of the more generic Safety and Risk Management cluster, it has primarily funded Mechanical and Materials Performance, Reliability, Failure and Maintenance, and Tunnels, Rocks and Mining Safety.

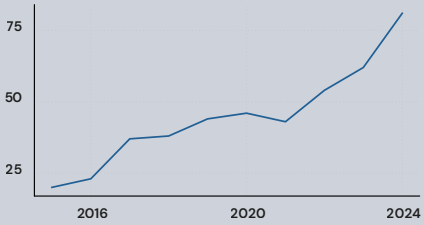
As of 2023, 17% of the NSFC's General Program (which constitutes around one-third of the funder's research budget) was committed to projects in engineering and material sciences – the second-largest departmental allocation after health sciences (NSFC 2023). While the NSFC does not manage any safety-specific divisions or programmes, the top three divisions (or fields) receiving engineering General Program project funding in 2023 all highlight safety practices and/or outcomes as components of interest for the research they fund. These divisions are Mechanics, Design and Manufacturing, Architecture and Civil Engineering, and Mining and Metallurgical Engineering (NSFC 2024). The NSFC's strategic focus is on supporting basic research projects and capabilities, as reflected in its Major Research Plan themes. However, some topics have potential engineering safety applications, including electromagnetic energy equipment in extreme conditions and unconventional battery systems.

Box 2. Funder spotlight: The European Commission

The European Commission

The EC has funded 3.2% of all ESR publications over the last decade.

ESR publications funded



ESR publications funded since 2015 by topic cluster

The EC manages several EU-funded multi-annual work programmes that support research and innovation projects in priority areas for the EU (EC 2025a). These programmes aim to enhance cooperation within the EU and support the EU's innovation capacity. The largest programme is Horizon Europe, the EU's key funding programme for research and innovation, which has a 2021–2027 budget of €93.5bn (EC 2025b). All programmes are open to applicants from the EU and associated countries (including the UK, for Horizon Europe). The EC also supports research through a variety of mechanisms, including co-funding and issuing service contracts.

Despite ranking third in publication volume among ESR funders between 2015 and 2024, the EC funded only 3.2% of publications during that period, underscoring the prominence of the top two Chinese funders in this field. The volume of ESR publications funded by the EC has tripled over the last decade. These publications fall primarily under the most general topic cluster, Safety and Risk Management (see Section 3.1 for a breakdown of topics within this cluster). The EC has also funded a large number of publications in the Reliability, Failure and Maintenance and the Industrial and Chemical Process Safety topic clusters.

ESR could fall under a number of the EC's work programmes, including major programmes such as Horizon Europe and the Social Prerogatives and Specific Competencies Lines programme, as well as smaller, more specific programmes like the Euratom Research and Training Programme and the Research Fund for Coal and Steel.

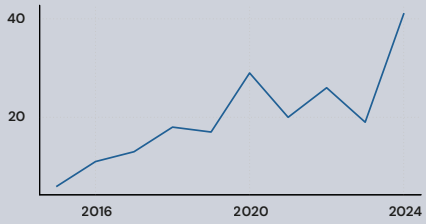
ESR is relevant to several of the EU's current strategic priorities, including sustainable prosperity and competitiveness. Research into safer, more sustainable and resilient engineering systems could help support these priorities (EU 2025) and is highly relevant to the EU's primary industrial strategy, the EU Clean Industrial Deal, which aims to turn decarbonisation into a growth driver for the European economy.

Box 3. Funder spotlight: The The National Research Foundation of Korea

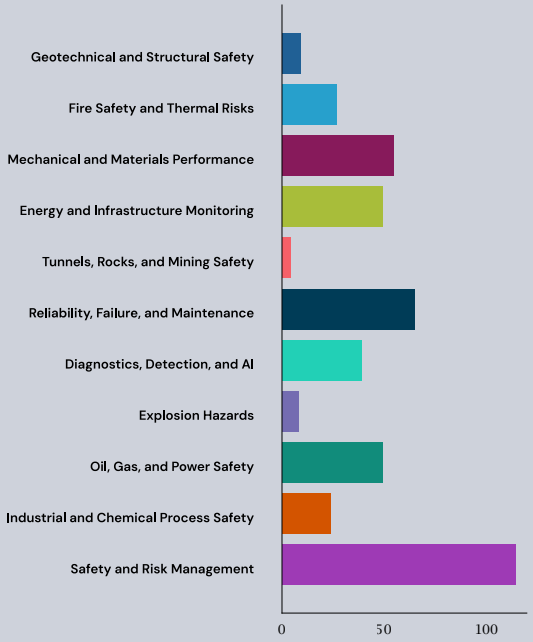
The National Research Foundation of Korea

The NRF has funded 1.5% of all ESR publications over the last decade.

ESR publications funded



ESR publications funded since 2015 by topic cluster



Founded in 2009, the NRF is a governmental organisation that aims to enhance South Korea's research capacity and promote innovation (NRF 2025). In 2019, the last year for which official budget data in English are available, its total budget was over US$5bn (NRF 2019). Its three main funding programmes are Basic Research in Science and Engineering, Academic Research and University Funding, and National Strategic R&D Programmes, all of which support individual researchers, research groups and infrastructure development. The NRF also provides financing for cooperative initiatives involving collaboration between universities and industry.

The NRF is the sixth-largest funder by volume of ESR publications between 2015 and 2024. It has funded 1.5% of publications in the field, rising from almost zero at the start of that period to a spike of over 40 in 2024. Outside of the more general Safety and Risk Management topic clusters, its ESR research focuses on Reliability, Failure, and Maintenance; Mechanical and Materials Performance; and Oil, Gas, and Nuclear Power Safety.

Around a third of the NRF's total budget goes to foundational research in science and engineering (NRF 2019). However, sustainability is another of its strategic priorities, which may explain its support for ESR, which is relevant to both.

5. ESR funding and funders: Sector deep-dives

This chapter explores the ESR publication landscape across key sectors that are likely to be users, beneficiaries, and potential funders of ESR-generated knowledge. The chapter aims to identify leading funders and performers as well as gaps in sector-related ESR to highlight potential opportunities for further investment and collaboration.

We selected four sectors for deep dives in consultation with the Foundation, based on the following four factors:

- Relevance to the Foundation's strategic priorities
- Opportunity to benefit from ESR
- Limited ESR funding available
- Sufficient relevant ESR publications over the last decade on which to conduct bibliometric analysis.

Using these criteria and insights from the Foundation's experts, along with a review of the overall ESR publication data, we selected the four sectors described in Table 11.

Table 11. Sectors explored in the ESR deep dive

Sector	Definition used
Maritime	Includes all activities related to the sea, including shipping, fishing, and maritime trade, as well as the construction and maintenance of ships and other vessels[1].
Chemical processing	Includes the transformation of raw materials into chemical products through processes such as mixing, heating and refining, as well as the production of pharmaceuticals, plastics and fertilisers.
Electric power	Includes the generation, transmission and distribution of electricity to consumers, utilising various energy sources, with a particular focus on low-carbon approaches such as nuclear power and renewable energy.
Industrial manufacturing	Includes the production of goods, encompassing a wide range of industries that create products from raw or pre-processed materials, including automotive, electronics and consumer goods.

The search string we used to identify relevant ESR publications for each sector is available in Annex A.

Figure 27 and Figure 28 contain statistics for all four deep-dive sectors, as discussed in the following four sub-sections.

1. We did not specifically include offshore energy platforms in this deep dive. However, we considered offshore wind platforms in the Electric Power deep dive.

Figure 27. Publication volumes by sector, 2015–2024

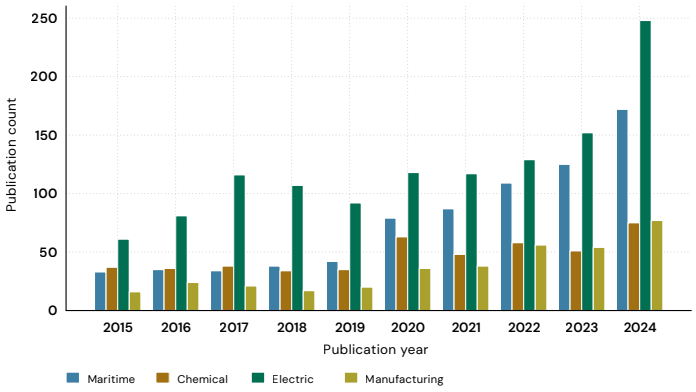
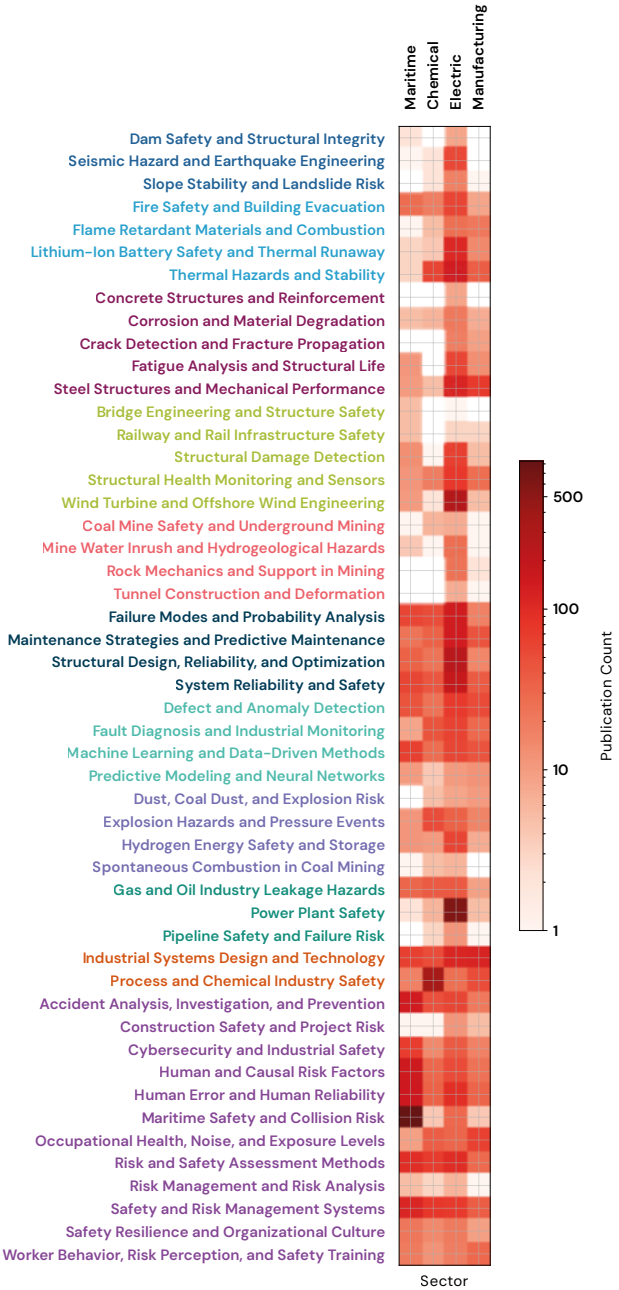


Figure 28. Heatmap showing publication counts by topic (y-axis) and sector (x-axis)



Note: A higher intensity of red indicates a larger number (see legend).

5.1. Maritime sector

5.1.1. Volume and topics

The volume of ESR publications relating to the maritime sector has grown significantly over the past decade. As Figure 27 shows, our sample of ESR publications included roughly 30 articles published in 2015 compared to around 170 published in 2024.

Unsurprisingly, the most common topic for maritime-related ESR publications in our sample was Maritime Safety and Collision Risk (see Figure 28), followed by Human and Causal Risk Factors, Human Error and Reliability, and Accident Analysis, Investigation and Prevention.

Alongside the heatmap showing the topics most covered in maritime-related ESR over the past decade (Figure 30), we also present 2022, 2023 and 2024 publication counts for the ten most common topics researched in maritime-related ESR articles (Table 12) to show which topics have recently attracted the most researcher interest. Table 12 also shows the average annual growth rate for each topic between 2022 and 2024.

Notably, the figures in Table 12 suggest that the Machine Learning and Data-Driven Methods topic has grown in popularity within maritime-related ESR between 2022 and 2024, with an average annual increase in publications of 76%. However, since the counts underlying this average annual growth rate were small in absolute terms (ten in 2022, six in 2023 and thirteen in 2024), we must interpret this cautiously.

Table 12. Publication counts and growth rates (% average annual growth rate [AAGR]) for the top-ranked maritime-related topics, 2022–2024

Topic	Count 2022–2024	2022	2023	2024	% AAGR 2022–2024
Maritime Safety and Collision Risk	382	100	120	162	24
Human and Causal Risk Factors	71	19	14	38	50
Human Error and Human Reliability	67	19	24	24	13
Accident Analysis, Investigation, and Prevention	62	17	19	26	21
Safety and Risk Management Systems	44	11	15	18	19
Risk and Safety Assessment Methods	39	13	12	14	24
Cybersecurity and Industrial Safety	33	8	10	15	30
Machine Learning and Data-Driven Methods	29	10	6	13	76
Defect and Anomaly Detection	26	4	9	13	156
Industrial Systems Design and Technology	24	5	6	13	96

5.1.2. Funder and researcher affiliations

Figure 29 shows that China, Turkey, South Korea, Finland, Norway and the UK authored the most maritime-related ESR publications between 2015 and 2024. Publication counts for all of these countries were low (<10) between 2015 and 2018 but began increasing from 2019 onwards, rising particularly rapidly for China. By 2024, Chinese authors were the most prolific publishers of maritime-related ESR with more than 65 publications, compared to fewer than 25 for researchers from each of the other top five countries.

Table 13 lists the countries or regions that funded (as opposed to authored) the most maritime-related ESR in our sample. Once again, China, South Korea, Finland, Norway and the UK are among the top six, joined by the EU (which we counted as a funder, but not as a home region for authors). Turkey, however, dropped to ninth place. However, it is worth noting that only 22% of ESR papers with Turkish first authors acknowledged a funder, as discussed in section 4.1, suggesting that our sample might underrepresent Turkish funders.

Figure 29. Maritime-related publication counts by author nationality for the top six countries/regions (ranked by volume), 2015–2024

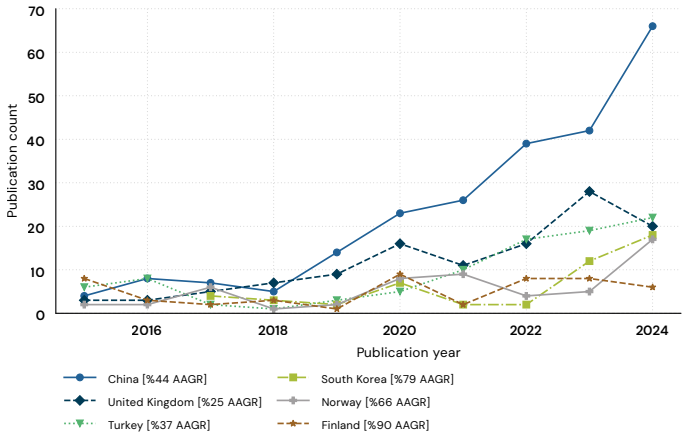


Table 13. Maritime-related publication counts, proportions and change in proportions (% diff) for the top ten countries/regions (ranked by maritime publication volume) for the 2015–2017 and 2022–2024 periods

China	251	12	120	12	30	18
EU	124	20	60	20	15	-5
South Korea	41	3	22	3	5	2
Finland	29	9	7	9	2	-7
Norway	29	6	12	6	3	-3
UK	24	2	10	2	2	1
Poland	18	0	9	0	2	2
Canada	16	0	5	0	1	1
Turkey	14	2	8	2	2	0
US	11	2	4	2	1	-1

5.1.3. Key funders

The biggest funders of maritime-related ESR over the past decade were the NFSC (180 maritime-related publications in total in our sample), the EC (107 publications), and the MOST (69 publications) – see Table 14. While five of the top ten funders of maritime-related ESR are Chinese, the top ten funders also include the ERC (22 publications), the RCN (21 publications), the South Korean Ministry of Oceans and Fisheries (18 publications), and Portugal's Foundation for Science and Technology (Fundação para a Ciência e a Tecnologia, 11 publications).

Table 14. Top 25 funders ranked by the volume of maritime publications, including their country, total number of ESR publications (Count ESR) and the percentage of their ESR publications that are maritime (% Maritime)

Funder	Country	Count ESR	Count Maritime	% Maritime
NSFC	China	3,733	180	5
EC	EU	505	107	21
MOST	China	1,166	69	6
China Scholarship Council	China	209	30	14
Science and Technology Department of Hubei Province	China	132	26	20
ERC	EU	56	22	39
RCN	Norway	66	21	32
Ministry of Education of the People's Republic of China	China	306	19	6
Ministry of Oceans and Fisheries	South Korea	23	18	78
Fundação para a Ciência e Tecnologia	Portugal	91	11	12
State Council of the People's Republic of China	China	52	10	19
Gdynia Maritime University	Poland	9	9	100
Natural Sciences and Engineering Research Council	Canada	146	8	5
Istanbul Technical University	Turkey	10	8	80
Research Council of Finland	Finland	34	7	21
Scientific and Technological Research Council of Turkey	Turkey	19	7	37
Department of Science and Technology of Shandong Province	China	235	7	3
Shenzhen Science and Technology Innovation Commission	China	53	6	11
Dalian Maritime University	China	15	6	40
Canada First Research Excellence Fund	Canada	9	6	67
Business Finland	Finland	9	6	67
Ministry of Industry and Information Technology	China	23	6	26
Guangxi Science and Technology Department	China	44	5	11
Australian Research Council	Australia	87	5	6
Department of Science and Technology of Guangdong Province	China	177	5	3

Some of these funders make the top ten simply because they are prolific ESR funders overall. For instance, this is the case for the NSFC, for which maritime-related ESR constitutes only 5% of its overall ESR portfolio. Other top ten funders have portfolios with a particularly strong maritime focus. For example, 78% of the South Korean Ministry of Oceans and Fisheries' ESR portfolio is maritime-related. The top ten European funders of maritime ESR also tend to have portfolios with a considerable maritime focus. For example, maritime-related ESR makes up 21% of the EC's ESR portfolio, 39% of the ERC's and 32% of the RCN's (but only 12% of the Portuguese Foundation for Science and Technology's).

A similar picture emerges when we consider the top 25 funders of maritime-related ESR. Some are Chinese institutions that fund a great deal of general ESR, such as China's provincial departments of science and technology. Others, however, fund very little general ESR but have portfolios with a particularly strong maritime focus. For example, Gdynia Maritime University in Poland funded nine publications in our sample, all of which were maritime-related, while Istanbul Technical University funded ten, of which eight were maritime-related.

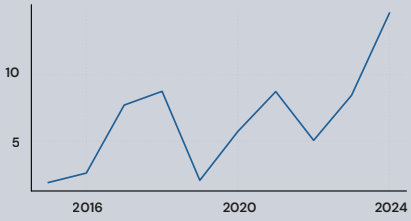
5.1.4. ESR funder spotlight: The maritime sector

Box 4. Maritime-sector funder spotlight: The Research Council of Norway

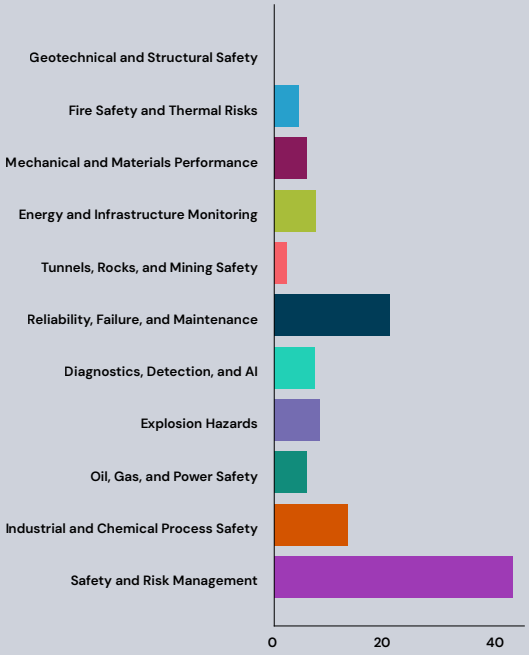
The Research Council of Norway

The RCN has funded 4% of maritime sector ESR publications over the last decade.

ESR publications funded



ESR publications funded since 2015 by topic cluster



The RCN is a Norwegian government agency and national strategic body for research, development and innovation. It receives 22% of R&D grants from the Norwegian state budget, of which it distributed NOK11.5bn (approximately £860m) through R&D projects and basic grants in 2023 (RCN 2025d).

RCN ranks seventh in maritime sector ESR publications funded by volume, exceeded only by Chinese and Europe-wide funders, reflecting Norway's prominence as a funder of research in this field (Figure 29). ESR publications related to the maritime sector make up almost one-third of RCN's overall funded ESR publications (32%).

Research on ocean-related industries and ecosystems is frequently identified as a strategic priority by the RCN, reflecting the importance of maritime, fishing and related sectors to Norway's economy (RCN 2025b, RCN 2020a). The organisation sporadically highlights safety in the maritime sector as one of its specific priority areas. At present, RCN is establishing a NOK75–100m Maritime Artificial Intelligence Centre whose research will focus on autonomy and digitalisation, green shipping and safety at sea (RCN 2025a). Through its research grants, RCN has funded several substantial projects with the safety of maritime operations at their core (RCN 2025c), including funding the Arctic University of Norway's Maritime Safety Science (MARSCI) Research Group (UiT 2025). In recent years, RCN has invested substantial effort in supporting several programmes that examine the interaction between the maritime industry and the environment, including participating in the Maritime Low Emission Network (MarLEN 2025) and developing actions for the United Nations Decade of Ocean Science (RCN 2020b). While these programmes do not explicitly target safety priorities, ambitions to support the transition to more environmentally friendly energy options for shipping are likely to require the generation of new knowledge on safety and efficacy.

5.2. Chemical processing

5.2.1. Volume and topics

The number of ESR publications relevant to the chemical processing sector has grown moderately year on year over the past decade, rising from around 25 in 2015 to around 70 in 2024 (Figure 29). This is a smaller increase than that observed for maritime-related ESR.

Unsurprisingly, the most common topic investigated in chemical processing-related ESR by a large margin was Process and Chemical Industry Safety (see Figure 30), followed by Risk and Safety Assessment Methods, Thermal Hazards and Stability, Fault Diagnosis and Industrial Monitoring, and Safety and Risk Management. As Table 15 shows, the publication counts for chemical processing-related ESR are too low to allow meaningful conclusions about specific topics that have attracted substantial increases in ESR in the past three years.

Table 15. Total publication counts, annual publication counts and average annual growth rates (AAGR) for top-ranked topics (by volume) in the chemical processing sector, 2022–2024

Topic	Count 2022–2024	2022	2023	2024	% AAGR 2022–2024
Process and Chemical Industry Safety	120	38	30	52	28
Risk and Safety Assessment Methods	24	5	7	12	28
Thermal Hazards and Stability	22	7	7	8	30
Fault Diagnosis and Industrial Monitoring	22	8	2	12	162
Safety and Risk Management Systems	21	6	6	9	33
Gas and Oil Industry Leakage Hazards	20	7	7	6	79
Accident Analysis, Investigation, and Prevention	19	5	6	8	68
System Reliability and Safety	16	6	6	4	156
Explosion Hazards and Pressure Events	16	3	5	8	23
Human and Causal Risk Factors	13	4	4	5	8

5.2.2. Funder and researcher affiliations

Over the past decade, China has funded significantly more chemical-processing-related ESR than any other country (see

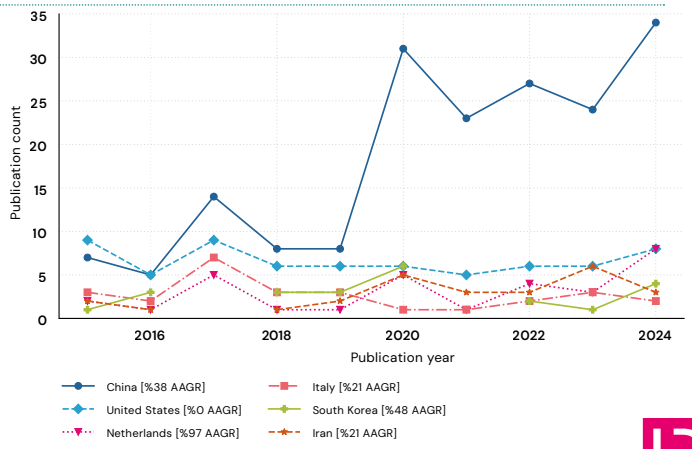
Table 16). It funded 189 chemical processing-related publications in our sample, distantly followed by the US, which funded only 25. Publication counts for the other top-ten countries are relatively low, making it difficult to determine whether they reflect genuine country trends or simply noise. Interestingly, Canada, Iran, Malaysia, Brazil, India and Japan all feature, ranking fifth to tenth (after China, the US, South Korea and the EU).

Table 16. Chemical-related publication counts, relative proportions and change in proportions (% diff) for the top ten countries/regions, as ranked by volume of chemical publications, for the 2015–2017 and 2022–2024 periods

Funder country/ region	Maritime count	2015–2017	2022–2024	% 2015–2017	% 2022–2024	% diff
China	189	22	82	20	45	25
US	25	3	9	3	5	2
South Korea	16	2	4	2	2	0
EU	13	3	1	3	1	-2
Canada	9	1	2	1	1	0
Iran	9	2	2	2	1	-1
Malaysia	7	1	4	1	2	1
Brazil	6	0	4	0	2	2
India	6	1	5	1	3	2
Japan	6	1	1	1	1	0

Similar patterns hold for the number of chemical processing-related ESR publications authored (as opposed to funded) by the countries in our sample. Chinese authors produce far more ESR on chemical processing than authors from other countries (see Figure 30). Another noteworthy finding shown in Figure 30 is that the Netherlands and Italy appear to be strong producers of chemical processing-related ESR within the EU (although, once again, their absolute publication counts are low).

Figure 30. Chemical processing publication counts for the top six countries (ranked by volume), 2015–2024



5.2.3. Key funders

Eight of the top ten funders of ESR relevant to chemical processing were Chinese (see Table 17). As in our overall ESR sample, the NSFC was by far the most prolific funder. The two non-Chinese institutions in the top ten were the EC, which ranked fifth, and the Natural Sciences and Engineering Research Council of Canada, which ranked tenth. It is noteworthy that eight of the top ten funders of chemical-processing ESR were also among the top ten overall ESR funders.

No major funder had chemical processing research as a large part of their ESR portfolio, with chemical processing accounting for only single-digit percentages of the top ten funders' portfolios. Some smaller funders had a stronger focus on chemical processing. For example, Texas A&M University funded 24 ESR publications in our sample, of which seven concerned chemical processing, and American Express funded three publications, all relevant to chemical processing.

Table 17. Top 25 funders (ranked by volume of chemical publications), along with their total number of ESR publications (Count ESR) and the percentage of their ESR publications that are chemical (% Chemical)

Funder	Country	Count ESR	Count Maritime	% Chemical
NSFC	China	3733	101	3
MOST	China	1166	49	4
Government of Jiangsu Province	China	347	20	6
Ministry of Education of the People's Republic of China	China	306	13	4
EC	EU	505	13	3
Department of Science and Technology of Shandong Province	China	235	13	6
China Scholarship Council	China	209	11	5
Department of Science and Technology of Guangdong Province	China	177	10	6
Science and Technology Department of Zhejiang Province	China	100	9	9
Natural Sciences and Engineering Research Council	Canada	146	9	6
US National Science Foundation	US	152	7	5
NRF	South Korea	236	7	3
Texas A&M University	US	24	7	29
Zhejiang Provincial Natural Science Foundation	China	80	6	8
Science and Technology Department of Sichuan Province	China	148	4	3
Slovak Research and Development Agency	Slovakia	19	4	21
RCN	Norway	66	4	6
Qingdao Municipal Science and Technology Bureau	China	28	3	11
Engineering and Physical Sciences Research Council	UK	99	3	3
American Express (US)	US	3	3	100
US Department of Energy	US	63	3	5
Science and Technology Commission of Shanghai Municipality	China	39	3	8
Department of Science and Technology of Anhui Province	China	98	3	3
National Council for Scientific and Technological Development	Brazil	62	3	5
Canada Research Chairs	Canada	34	3	9

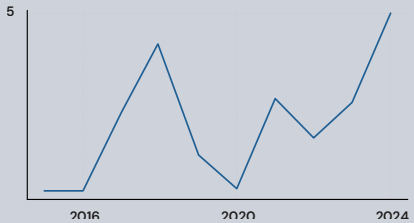
5.2.4. ESR funder spotlight: chemical processing sector

Box 5. Chemical processing sector funder spotlight: Texas A&M University

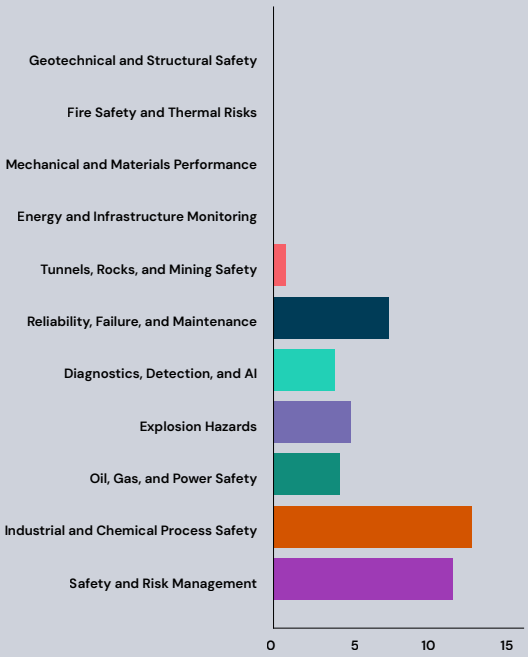
Texas A&M University

Texas A&M University has funded 2% of all chemical-processing-sector ESR publications over the last decade.

ESR publications funded



ESR publications funded since 2015 by topic cluster



Texas A&M University is a large public research university in the US with an annual research expenditure of US$1.278bn (approximately £940m) (Texas A&M University 2025b).

As a university, an organisation that primarily receives research grants rather than distributing them, Texas A&M University makes an unexpected appearance as the #13 funder of chemical-processing-sector ESR research (#5 when excluding funders in China). This finding indicates that the university is investing at least some of its own funds and/or resources in research in this field.

'Process safety' is one of the seven research areas of the institution's Department of Chemical Engineering (Texas A&M University 2025a). Additionally, the University hosts the Mary Kay O'Connor Process Safety Center (MKOPSC), an education, research, consultancy and engagement forum for industry, government and others (Texas A&M University 2025c). Its research areas draw on process safety, traditional chemical engineering, and the multidisciplinary aspects of safe systems and analysis (Texas A&M University 2025d).

5.3. Electric power

5.3.1. Volume and topics

As is the case for most ESR subjects, the volume of ESR publications relating to electric power has grown year-on-year over the past decade, from roughly 15 publications in 2015 to around 75 in 2024 (see Figure 29).

As Figure 30 demonstrates, the most common topic featured in electric-power-related ESR publications over the past decade was Power Plant Safety, followed by System Reliability and Safety and Lithium-Ion Battery Safety and Thermal Runaway. Again, relatively low publication counts make it difficult to pinpoint key emerging topics with certainty. However, the Lithium-Ion Battery Safety and Thermal Runaway topic appears to have generated increasing research interest over the past few years, with ten electric power-related ESR publications researching it in 2022, 13 in 2023 and 30 in 2024 (see Table 18). Electric power-related publication counts for Wind Turbine and Offshore Wind Engineering, Maintenance Strategies and Predictive Maintenance, and Thermal Hazards and Stability have also seen sizeable year-on-year increases since 2022.

Table 18. Top-ranked topics (by volume), annual publication counts and overall growth rates (% AAGR) for publications relating to the electrical-power-generation sector, 2022–2024

Topic	Count 2022–2024	2022	2023	2024	% AAGR 2022–2024
Power Plant Safety	193	49	53	91	24
Wind Turbine and Offshore Wind Engineering	113	25	41	47	42
Structural Design, Reliability, and Optimisation	70	17	26	27	15
System Reliability and Safety	59	20	19	20	18
Lithium-Ion Battery Safety and Thermal Runaway	53	10	13	30	104
Thermal Hazards and Stability	53	10	14	29	53
Failure Modes and Probability Analysis	49	17	19	13	4
Maintenance Strategies and Predictive Maintenance	48	10	11	27	56
Steel Structures and Mechanical Performance	41	10	14	17	13
Industrial Systems Design and Technology	33	6	9	18	42

5.3.2. Funder and researcher affiliations

China has authored and funded more electric-power-related ESR than any other country over the past decade (see Figure 31 and Table 19). However, it is perhaps less dominant in this ESR subfield than in others. It funded 412 electric-power-related ESR publications over the past decade, compared to South Korea's 111 and the US's 89. The UK and Germany are also relatively active creators and funders of electric-power-related ESR, featuring in the top six countries for both authorship and funding. India too is a top-six producer of electric-power-related ESR, but only the eighth-largest funder.

Figure 31. Publication counts for the electricity-generation sector in the top six countries (ranked by volume), 2015–2024

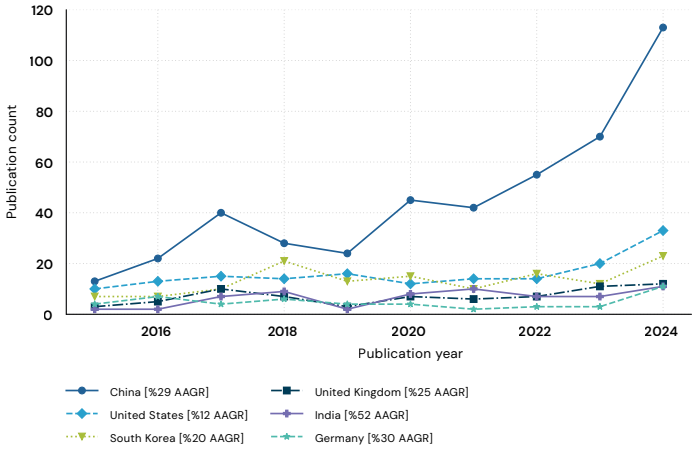


Table 19. Chemical publication counts, relative proportions and change in proportions (% diff) for the top ten countries/regions (as ranked by volume of chemical publications), for the 2015–2017 and 2022–2024 periods

Funder country/ region	Electric count	2015–2017	2022–2024	% 2015–2017	% 2022–2024	% diff
China	412	41	191	16	36	20
South Korea	111	14	40	5	8	2
US	89	12	39	5	7	3
EU	37	6	14	2	3	0
UK	32	6	10	2	2	0
Germany	23	4	9	2	2	0
Japan	14	1	2	0	0	0
India	13	2	4	1	1	0
Spain	12	3	3	1	1	-1
Canada	12	2	4	1	1	0

5.3.3. Key funders

Table 20 shows that, of the top ten funders of electric-power-related ESR, only five are Chinese, making this sector less dominated by Chinese research organisations than most other sectors. The top ten also features two US funders (the US Department of Energy and the Nuclear Energy University Program), two South Korean funders (the NRF and the Korea Institute of Energy Technology Evaluation and Planning [KETEP]), and the EC.

The first- and second-ranked funders (the Chinese NSFC and MOST) do not have a particular focus on electric power-related ESR, which accounts for only 7% of their overall ESR portfolios. Interestingly, however, several of the top ten funders clearly do prioritise ESR related to electric power. For example, electric-power-related ESR accounts for 23% of the NRF's ESR portfolio, 41% of the US Department of Energy's, 67% of the US Nuclear Energy University Program's and 49% of KETEP's. South Korea has a particularly strong presence in electric-power-related ESR, with six institutions featuring in the top 25 funders (including some relatively small institutions with a strong focus on this subject, such as the Korea Foundation of Nuclear Safety).

Table 20. Top 25 funders ranked by volume of electric publications, showing total ESR publication counts (Count ESR) and the proportion of ESR publications that are electric (% Electric)

Funder	Country	Count ESR	Count Maritime	% Chemical
NSFC	China	3,733	256	7
MOST	China	1,166	84	7
NRF	South Korea	236	54	23
EC	EU	505	35	7
Department of Science and Technology of Guangdong Province	China	177	29	16
United States Department of Energy	US	63	26	41
Government of Jiangsu Province	China	347	24	7
KETEP	South Korea	37	18	49
Engineering and Physical Sciences Research Council	UK	99	17	17
Chinese Academy of Sciences	China	74	16	22
China Scholarship Council	China	209	14	7
Nuclear Energy University Program	US	21	14	67
Department of Science and Technology of Shandong Province	China	235	13	6
Shenzhen Science and Technology Innovation Commission	China	53	12	23
State Grid Corporation of China (China)	China	29	11	38
Ministry of Education of the People's Republic of China	China	306	11	4
Government of the Republic of Korea	South Korea	22	10	45
Ministry of Science and ICT	South Korea	24	10	42
Korea Foundation Of Nuclear Safety	South Korea	13	9	69
Education Department of Hunan Province	China	129	9	7
Federal Ministry for Economic Affairs and Climate Action	Germany	47	9	19
Ministry of Trade, Industry and Energy	South Korea	43	8	19
Beijing Municipal Government	China	73	8	11
RCN	Norway	66	8	12
Science and Technology Department of Sichuan Province	China	148	8	5

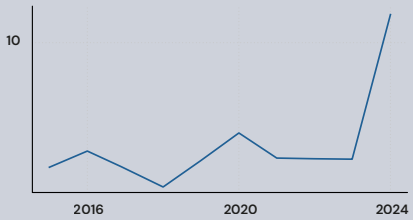
5.3.4. ESR funder spotlight: The electric-power sector

Box 6. Electric-power-sector funder spotlight: Korean Energy Technology Evaluation and Planning

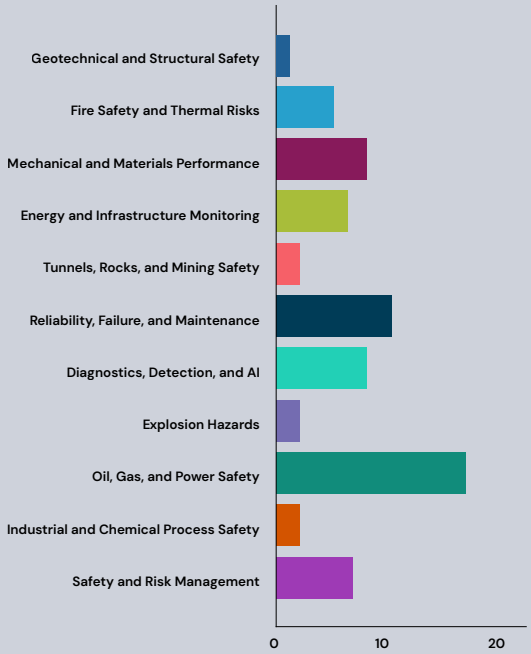
Korean Energy Technology Evaluation and Planning

KETEP has funded 2% of all electric-power-sector ESR publications over the last decade.

ESR publications funded



ESR publications funded since 2015 by topic cluster



KETEP is a funding agency for energy R&D (KETEP 2025). Founded in 2009 and sitting under the Korean Ministry of Trade, Industry and Energy, KETEP plans, manages and evaluates national energy R&D projects. Its mission is to contribute to a stable national energy supply and national economic development by efficiently supporting energy technology development and industry growth. While its focus is national, it frequently enters into international partnerships with research institutions from outside South Korea. It also has a Tech-to-Market programme that supports energy innovation ventures and startups.

KETEP is the ninth-ranked funder for electric-power research, despite not ranking in the top 40 for ESR overall. It funded 37 ESR publications during the study period, of which about half were relevant to the electric power industry, and many were published in 2024.

KETEP appears to have a strong focus on renewable and low-carbon energy: it currently has six ongoing R&D programmes covering nuclear power, hydrogen, renewable energy, electric power, energy efficiency, natural resources and carbon capture, utilisation and storage (CCUS).

5.4. Industrial manufacturing

5.4.1. Volume and topics

As with the other sectors considered in this chapter, the volume of ESR related to industrial manufacturing has increased over the past decade, from around 15 publications in 2015 to around 75 in 2024 (see Figure 29).

The two most common manufacturing-related ESR topics were Industrial Systems Design and Technology and Steel Structures and Mechanical Performance (see Figure 30). Publication counts were generally too low to enable reliable conclusions about manufacturing-related ESR topics that are growing in popularity. However, Machine Learning and Data-Driven Methods certainly seem to have attracted increasing research interest over the past three years, with publication counts of 7 in 2022, 9 in 2023 and 11 in 2024 (see Table 21).

Table 21. Top-ranked topics (ranked by volume) along with publication counts and overall growth rates (% AAGR) for publications relating to the manufacturing sector, 2022–2024

Topic	Count 2022–2024	2022	2023	2024	% AAGR 2022–2024
Industrial Systems Design and Technology	47	10	18	19	29
Steel Structures and Mechanical Performance	29	11	8	10	58
Machine Learning and Data-Driven Methods	27	7	9	11	100
Defect and Anomaly Detection	26	4	9	13	56
Process and Chemical Industry Safety	21	7	3	11	95
Occupational Health, Noise, and Exposure Levels	20	8	5	7	6
Thermal Hazards and Stability	19	6	4	9	64
Fault Diagnosis and Industrial Monitoring	17	6	4	7	81
Safety and Risk Management Systems	17	4	4	9	75
Human Error and Human Reliability	14		6	8	78

5.4.2. Funder and researcher affiliations

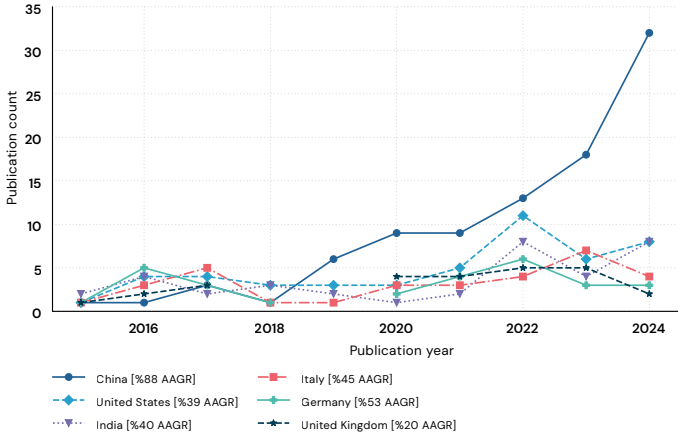
Not unexpectedly, the three regions that funded the most manufacturing-related ESR over the past decade were China, the US and the EU (see Table 22), with South Korea, Germany, Italy and the UK ranking fourth to seventh.

Table 22. Manufacturing-related publication counts, relative proportions and change in proportions (% diff) for the top ten countries/regions, as ranked by volume of manufacturing publications, for the 2015–2017 and 2022–2024 periods

Funder country/ region	Electric count	2015–2017	2022–2024	% 2015–2017	% 2022–2024	% diff
China	98	2	45	3	24	21
US	21	3	11	5	6	1
EU	16	2	9	3	5	2
South Korea	15	1	8	2	4	3
Germany	13	4	5	7	3	-4
Italy	9	0	3	0	2	2
UK	6	0	3	0	2	2
Spain	6	0	4	0	2	2
Malaysia	6	0	1	0	1	1
India	5	0	5	0	3	3

Patterns for authorship are similar. As with other ESR subfields, the number of publications generated by Chinese researchers began rising rapidly in 2019 (see Figure 32), making China the largest creator of manufacturing-related ESR by 2024 by a large margin. The other top-six countries for authorship of manufacturing-related ESR were the US, Germany, Italy and the UK; India also featured in the top six, while South Korea did not.

Figure 32. Publication counts relating to the manufacturing sector for the top six countries (ranked by volume), 2015–2024



5.4.3. Key funders

As Table 23 shows, seven of the top ten funders of manufacturing-related ESR were Chinese. These funders include many of China's big players, such as the NSFC and MOST, again ranking first and second. The three non-Chinese top-ten funders of manufacturing-related ESR were also major funders of general ESR: the EC, the NRF and the US National Science Foundation.

Looking beyond the top ten funders, several relatively small ESR funders appear to play an outsize role in funding manufacturing-related ESR specifically (see Table 23). For instance, Italy's National Institute for Insurance Against Accidents at Work (Istituto Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro [INAIL]) is a top-20 funder of manufacturing-related ESR, despite not featuring in the top 40 general funders of ESR (Table 4). The same is true for the Italian Ministry of Public Education (Ministero dell'Istruzione e del Merito) and the German Rectors' Conference. However, it is worth noting that the publication counts for funders outside of the top three are low: for instance, the Italian National Institute for Insurance Against Accidents at Work funded just 15 ESR publications over the past decade, of which three were manufacturing-related.

Table 23. Top 25 funders (ranked by volume of manufacturing publications), along with their total ESR publication counts (Count ESR) and proportion of ESR publications that are manufacturing-related (% Manufacturing)

Funder	Country	Count ESR	Count Maritime	% Chemical
NSFC	China	3,733	67	2
MOST	China	1,166	26	2
EC	EU	505	16	3
Government of Jiangsu Province	China	347	9	3
NRF	South Korea	236	8	3
Department of Science and Technology of Guangdong Province	China	177	6	3
US National Science Foundation	US	152	5	3
Shanxi Science and Technology Department	China	66	4	6
Science and Technology Department of Zhejiang Province	China	100	4	4
Istituto Nazionale per l'Assicurazione Contro gli Infortuni sul Lavoro (INAIL)	Italy	15	4	27
Federal Ministry for Economic Affairs and Climate Action	Germany	47	3	6
Ministero dell'Istruzione e del Merito	Italy	36	3	8
Korea Occupational Safety and Health Agency	South Korea	3	3	100
Ministry of Education of the People's Republic of China	China	306	3	1
Education Department of Shaanxi Province	China	173	3	2
German Rectors' Conference	Germany	18	3	17
Australian Research Council	Australia	87	3	3
Natural Sciences and Engineering Research Council	Canada	146	3	2
Ministry of Education, Culture, Sports, Science and Technology	Japan	43	2	5
Chinese Academy of Sciences	China	74	2	3
Shahid Beheshti University of Medical Sciences	Iran	6	2	33
Japan Society for the Promotion of Science	Japan	48	2	4
Education Department of Hunan Province	China	129	2	2
Hebei Provincial Department of Science and Technology	China	77	2	3
Kashan University of Medical Sciences	Iran	3	2	67

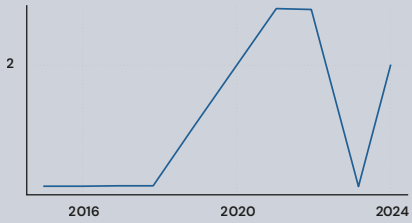
5.4.4. ESR funder spotlight: The industrial manufacturing sector

Box 7. Industrial-manufacturing sector funder spotlight: The National Institute for Insurance against Accidents at Work

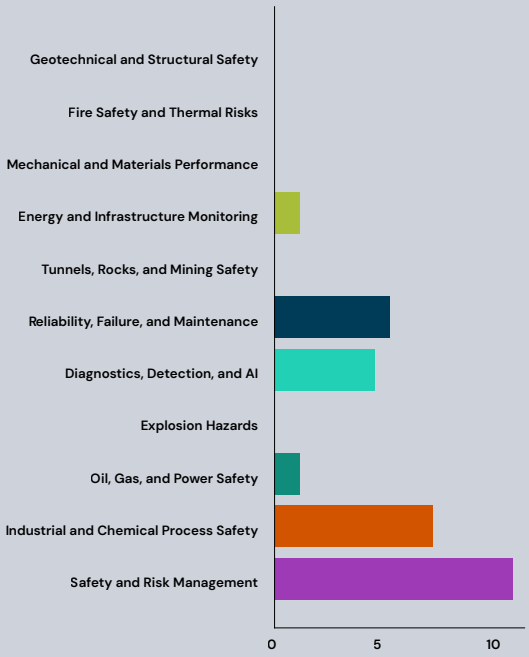
The National Institute for Insurance against Accidents at Work

INAIL has funded 1.6% of all industrial manufacturing-sector ESR publications over the last decade.

ESR publications funded



ESR publications funded since 2015 by topic cluster



INAIL is an Italian statutory not-for-profit corporation overseen by the Ministry of Labour and Social Policies (INAIL 2025) that aims to safeguard workers against physical injuries and occupational diseases. To this end, it provides mandatory insurance for workplace injuries and occupational diseases, conducts prevention initiatives, provides rehabilitation services for workers and funds research.

INAIL is the tenth-largest funder of manufacturing-related ESR. However, the actual volume of manufacturing-related ESR publications it produced is minimal: it released only 4 publications over the study period and 15 publications overall.

INAIL began conducting research in 2010 following a merger with the Istituto Superiore per la Prevenzione e la Sicurezza del Lavoro (Higher Institute for Prevention and Safety at Work). Its research primarily focuses on injury prevention, workplace safety, health protection, safety training and promotion of a safety culture.

6. Conclusion

This study has provided an overview of the global ESR landscape, examining where it has been conducted, who has conducted it, the volume of research produced, and the topics that have been funded over the past decade. In this section, we will highlight some of the key findings from the study.

Firstly, ESR is a rapidly growing field: the number of ESR publications worldwide has risen by an average of 18% every year since 2015. There was a notable uptick in ESR in 2024, with the number of ESR publications increasing by 42% compared to 2023. Further analysis will be required to determine whether this accelerated growth is sustained.

Perhaps the most striking finding of this study is China's preeminence in the global ESR ecosystem. China is by far the most active creator and funder of ESR. Researchers from China were first authors on 6,480 of the 15,705 ESR publications in our sample. Moreover, we found that eight of the top ten global funders of ESR (by the number of ESR publications funded) are Chinese. We also established that China has significantly strengthened its position in the ESR landscape over the past decade: Chinese researchers authored 24% of ESR publications in 2015, compared to 58% so far in 2025.

Outside of China, countries that are particularly active creators of ESR include the US, South Korea, India, Italy, Germany and the UK. However, it is worth emphasising that China significantly outperforms all of these countries: researchers from the US (the second-ranked country for authorship of ESR) were first authors on just 1,332 papers, less than a quarter of the number of papers authored by Chinese researchers, while researchers from Italy, Germany and the UK produced less than a tenth of the number of papers produced by Chinese researchers.

There is significant variation in the extent to which ESR is produced and funded across national borders. ESR researchers from some countries, such as China, Russia and South Korea, collaborate very little with researchers in other countries; in other areas, such as Hong Kong and some smaller European countries, international collaboration is widespread. Funders in general prefer funding domestic ESR research, but some are more open to funding researchers from outside their home region than others: 96% of Chinese ESR funding went to Chinese first authors, for instance, while just 68% of UK ESR funding went to UK first authors.

There are also significant differences in emphasis within different regions' ESR portfolios. For instance, China produces proportionally more ESR related to the mining, oil and gas industry than other countries, the EU's ESR portfolio focuses particularly on the maritime sector and risk assessment, and the US appears to prioritise ESR work concerning OSH. Our deep dives turned up similar variations in countries' areas of focus. China was the largest funder of ESR in all four deep-dive sectors. However, it is more prominent in some of these sectors than others: for example, only five of the top ten funders of maritime- and electric power-related ESR were Chinese, compared to seven for manufacturing-related ESR and eight for ESR related to chemical processing. EU funders were comparatively more active in ESR related to the maritime and electric power sectors.

This study has investigated trends in the ESR landscape between 2015 and mid-2025. As future work to establish whether these trends persist into the late 2020s and beyond could be valuable, we have included our full search strings in Annex A to enable our searches and analysis to be replicated in years to come. Our approach could be adapted to address some of the limitations of our methodology, such as by comparing the field across different publication databases, such as OpenAlex, whose coverage of some journals is higher than that of Web of Science, especially in East Asia and the Global South (Simard et al. 2024).

Additionally, our study highlights areas for further investigation into the ESR ecosystem beyond the limits of bibliometric analysis. For example, while our findings indicate that China influences the field's shape through the sheer volume of its ESR outputs, the extent to which its priorities will affect the direction and capabilities of global ESR stakeholders is unclear. The drivers of ESR funders also require further investigation to determine who will shape the future of ESR and how. Our study indicates that national funders account for a large share of ESR. However, the field is rarely explicitly identified as a research priority, unless linked to goals such as addressing climate change. A question for future studies is whether public funders perceive ESR as falling within the remit of their wider research strategies, or whether they see it primarily as the private sector's role to deliver.

A key limitation of our study is that the bibliometric data used do not account for all potential research outputs, including commercial R&D, where publication in journals is less common than in academia. Therefore, our research may have underestimated the scale of ESR conducted by industry, and therefore the nature of the potential knowledge generated. Additionally, industry stakeholders assume multiple roles in the ESR ecosystem as funders, performers, and users of the resulting knowledge. Their influence on the field warrants further exploration, especially if there are opportunities to enhance knowledge sharing where research currently remains locked behind closed doors due to concerns about commercial sensitivity.

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Annex A. Detailed methodology: Full search string

A.1. ESR publications search string

```
TS=(
  (
    ("occupational safety") OR ("safety management") OR
    ("safety climate") OR ("safety performance") OR
    ("safety culture") OR ("process safety") OR
    ("safety training") OR ("safety assessment*") OR
    (construction NEAR/2 safety) OR ("safety measure*") OR
    (safety NEAR/2 risk) OR ("safety analysis") OR
    ("safety analyses") OR ("safety science") OR
    ("workplace safety") OR ("system safety") OR
    ("fire safety") OR ("safety compliance") OR
    ("safety research") OR ("safety professional*") OR
    ("safety reliability") OR ("safety leadership") OR
    ("safety outcome*") OR ("safety practic*") OR
    ("safety evaluation") OR (safety NEAR/2 critical) OR
    ("safety system*") OR ("safety intervention") OR
    ("workers safety") OR ("maritime safety") OR
    ("reliability safety") OR ("safety factor*") OR
    ("safety standard*") OR ("safety hazard") OR
    ("structural safety") OR ("operational safety") OR
    ("work* safety") OR ("safety regulations") OR
    (safety NEAR/2 design) OR ("transportation safety") OR
    ("safety control") OR ("safety incident*") OR
    ("enhanc* safety") OR ("improv* safety") OR
    ("assess safety") OR ("safety engineering") OR
    ("industr* safety") OR "Demolition safety" OR
    (mining NEAR/2 safety) OR (mine* NEAR/2 safety) OR
    ("safety monitoring") OR
    ("safety policy" OR "safety policies") OR
    ("safety concern") OR ("safety quality") OR
    ("occupational hazard*")
  )
  AND
  (
    (
      (
        "thermal hazard*" OR "fire hazard*" OR
        "thermal runaway" OR "thermal stability" OR
        "seismic hazard" OR (hazard* NEAR/2 chemical*) OR
        "hazardous material*" OR "explosion hazard*" OR
        "wind hazard*" OR "height hazard" OR
        "tsunami hazard" OR "electrical hazard*" OR
        "mechanical hazard*" OR "flood hazard" OR
        "exposure hazard*" OR "radiation hazard*" OR
```

```
    "noise exposure" OR "vibration exposure" OR
    "Dust exposure" OR "Airborne Dust" OR
    "coal dust" OR "gas exposure" OR
    "methane exposure" OR "carbon dioxide exposure"
    "gas explosion*" OR "fire* explosion*" OR
    "dust explosion*" OR "explosion accident*" OR
    "explosion suppression" OR "methane explosion" OR
    "underwater explosion" OR "hydrogen explosion" OR
    "spontaneous combustion"
) OR
(
    "fault diagnosis" OR "fault detection" OR
    "bearing fault" OR "fault propagation" OR
    "machinery fault" OR "fault tolerance" OR
    "fault monitoring" OR
    "anomaly detection" OR "damage detection" OR
    "leak* detection" OR "fire detection" OR
    "defect detection" OR "failure detection"

) OR
(
    "risk analysis" OR "risk management" OR
    "risk factor*" OR "quantitative risk" OR
    "probabilistic risk" OR "risk perception" OR
    "risk level*" OR "risk assessment*" OR
    "risk reduction" OR "risk control" OR
    "risk evaluation" OR "operational risk*" OR
    "risk factor*" OR "risk indicator*"     OR
    "risk index" OR "risk model"
) OR
(
    "accident analysis" OR "accident prevention" OR
    "accident scenario*" OR "accident report*" OR
    "accident causation" OR "accident investigation" OR
    "explosion accident*" OR "maritime accident*" OR
    "marine accident*" OR "industrial accident*"
) OR
(
    "human reliability" OR "human factor*" OR
    "human error*" OR "human performance" OR "human failure"
) OR
(
    "preventive maintenance" OR "maintenance polic*" OR
    "condition-based maintenance" OR "maintenance cost*" OR
    "predictive maintenance" OR "maintenance strateg*" OR
    "inspection maintenance" OR (repairable NEAR/2 system) OR
    "reliability analysis" OR "system reliability" OR
    "reliability assessment" OR "structural reliability" OR
    "network reliability" OR
    "maintenance repair" OR "repair replacement" OR
    "failure repair" OR "repairable component*" OR
    "repair cost*" OR "machine repair" OR
    "remaining useful life" OR "decommissioning" OR
    "resilience assessment" OR "resilience engineering" OR
    "system resilience" OR "seismic resilience" OR
    "network resilience" OR "resilience evaluation" OR
    "degradation process*" OR "degradation model*" OR
    "performance degradation" OR "photocatalytic degradation" OR
    "degradation mechanism" OR "system degradation"

) OR
(
    (deformation NEAR/2 (
        plastic OR failure OR fracture OR elastic OR
        bending OR shear OR stress OR rock OR tunnel OR
        tensile OR thermal OR detection
    )) OR
    (fatigue NEAR/2 (
        crack* OR failure* OR damage OR strength OR fracture* OR
        corrosion OR load* OR analysis OR limit OR cycle OR
        bending OR risk OR vibration OR Embrittlement OR
        contact OR fretting OR detection OR thermal
    )) OR
    ("Paris' law")
    (stress NEAR/2 (
        concentration OR residual OR corrosion OR distribution OR
        tensile OR shear OR thermal OR contact OR oxidative OR
        compress* OR amplitude OR yield OR detection OR thermal
    )) OR
    (wear NEAR/2 (
        resistance OR abrasive OR mechanism* OR failure* OR
        damage OR friction OR erosion OR tool OR fatigue OR
        surface OR wheel* OR sliding OR rail OR oxidative
    )) OR
    (crack* NEAR/2 (
        surface OR propagate* OR longitudinal OR shear OR
        micro OR secondary OR intergranular OR corrosion OR
        formation OR transverse OR tensile OR subsurface  OR
        detection
    )) OR
    (friction NEAR/2 (
        coefficient OR stir OR wear OR internal OR block OR
        heat OR surface OR sliding OR resistance OR contact
        OR dry OR wear OR force
    )) OR
    (embrittlement) OR
    (corrosion NEAR/2 (
        rate OR pitting OR failure OR defects OR damage OR
        localized OR intergranular OR galvanic OR hot OR
        steel OR pipeline OR erosion OR co2 OR atmospheric OR
        detection
    ))
)
) AND
```

```
    (
      construction OR
      (mining NEAR/1 (
        coal OR industry OR operation* OR area* OR underground OR
        technique* OR process OR safety OR compan* OR method* OR \
        sector OR accident* OR deep OR seam OR surface
      )) OR
      (mine NEAR/1 (
        coal OR industry OR operation* OR area* OR underground OR
        technique* OR process OR safety OR compan* OR method* OR \
        sector OR accident* OR deep OR seam OR surface
      )) OR
      manufactur* OR industrial OR maritime OR
      building* OR structural OR steel OR
      concrete OR
      (tunnel* NEAR/1 (
        shield OR construction OR utility OR face OR lining OR
        excavation OR structure OR wind OR boring OR metro OR
        road OR highway OR collapse OR fire
      )) OR
      "deep excavation" OR
      "nuclear power plant" OR "thermal power plant" OR
      "fossil fuel power plant" OR "energy sector" OR
      "wind turbine" OR "offshore wind" OR
      "energy industry" OR "heavy machine*" OR
      "production line" OR "assembly line" OR
      (process NEAR/2 chemical) OR "chemical industry" OR
      "chemical plant*" OR "petrochemical plant" OR
      "petrochemical industry" OR "chemical production" OR
      "chemical engineering" OR "chemical plant" OR
      "oil gas industry" OR "oil gas pipeline*" OR
      "offshore oil gas" OR "oil industry" OR
      "oil pipeline*" OR "oil refinery" OR
      "gas industry" OR "gas pipeline*" OR
      "gas turbine*" OR
      "combustion engine" OR
      "high-speed railway" OR "rail transit" OR
      "urban rail" OR "rail corrugation" OR
      "railway track" OR "railway system"
      "railway network" OR
      (engineering NEAR/2 structur*) OR
      (engineering NEAR/2 failure*) OR
      (engineering NEAR/2 critical*) OR
      (engineering NEAR/2 civil) OR
      (engineering NEAR/2 science) OR
      (engineering NEAR/2 maintenance) OR
      (engineering NEAR/2 risk*)
    )
  )
)
AND
DT=(Article OR Proceedings Paper OR Review)
AND
PY=(2015-2025)
NOT TS=(
  "occupational health" OR "health care worker*" OR
  "community hospital*" OR "patient safety" OR
  "drug safety" OR "healthcare setting*" OR
  "hospital staff" OR "public hospital*" OR
  "hospital setting" OR "healthcare practitioner*" OR
  "medical practitioner*" OR "musculoskeletal disorders" OR
  "Public safety" OR "Community safety" OR
  "Child welfare" OR "psychosocial risk factors" OR
  "Crime prevention" OR "Crime reduction" OR
  "Crime control" OR "Public protection" OR
  "Public health and safety" OR "Public order" OR
  "Civil protection" OR "public health" OR
  "Population health" OR "Community health" OR
  "Health protection" OR "Epidemiology" OR
  "Road safety" OR "Traffic safety" OR
  "Traffic accident" OR "Road accident" OR
  "Vehicle accident" OR "Traffic collision" OR
  "bus crash" OR "car crash" OR "vehicle crash" OR
  "Road collision" OR "Traffic injury" OR
  "Road injury" OR "Pedestrian safety" OR
  "Cyclist safety" OR "bicycle safety" OR
  "Motor vehicle safety" OR "Driver behavior" OR
  "Driving behavior" OR "Distracted driving" OR
  "Impaired driving" OR "Drunk driving" OR
  "Drugged driving" OR "Traffic calming" OR
  "Traffic enforcement" OR "Highway safety" OR
  "Aerospace safety" OR "aviation safety" OR
  "Aircraft safety" OR "Air traffic safety" OR
  "Flight safety" OR "Air traffic management" OR
  (Accident AND (airplane OR aircraft OR aviation)) OR
  "Aerospace health and safety" OR "Space safety" OR
  "Avionics safety" OR "Food safety" OR
  "Food hygiene" OR "Foodborne illness" OR
  "Foodborne disease" OR "Food poisoning" OR
  "Food contamination" OR "Critical Control Point" OR
  "food quality" OR "pesticide residue" OR
  "Water safety" OR "Water quality" OR
  "Water contamination" OR "Waterborne disease" OR
  "Water treatment" OR  "Waste safety" OR
  "Waste management" OR "Hazardous waste" OR
  "Biomedical waste" OR "medical waste" OR
  "Radioactive waste" OR "Nuclear waste" OR
  "Chemical waste" OR "Electronic waste" OR
  "Waste handling" OR "Waste collection" OR
  "Waste disposal" OR "Waste transport" OR
  "Product safety" OR "Product recall" OR
  "Product warning" OR "Product defect" OR
  "Product hazard" OR "Consumer safety" OR
  "Consumer protection" OR "Electrical appliance safety" OR
  "Toy safety" OR "Cosmetic safety"
)
```

A.2. Sector deep-dive publications search string

A.2.1. Maritime sector

\b(?:maritime|

(cruise|container|autonomous|linear|passenger|global|arctic|cargo|smart|sustainable|surface|merchant) ships?(ping)?|

ships?(ping)? (industry|collisions?|network|lines?|accidents?|fires?|company|companies|freight|finance|market|regulation)|

port (authorities|state control|operations|development|authority|industry|efficiency|congestion|governance|infrastructure)|

(container|green|smart|regional|dry|) port|

ocean transport|sea transport|merchant marine|

marine logistics|naval architecture|

international trade (?:&|and) shipping|

autonomous vessels?|green shipping|

IMO regulations?|ballast water|marine pollution|

seafarer training|ocean governance)\b

A.2.2. Chemical processing sector

\b(?:chemical process|chemical processing|chemical process industry|chemical manufacturing|

manufacturing plants?|chemical industry|chemical plants?|

petrochemical plants?|petrochemical industry|chemical production|

chemical engineering|reaction engineering|membrane separation|

catalytic processes?|electrochemical processes?|HAZOP|

chemical engineers?)\b

A.2.3. Electric power sector

\b(?:electric power|electric fields?|electrical energy|electrical power|

Electricity market|Electricity pricing|Electricity regulation|

Energy transition|Electricity demand|Electrification|Grid stability|Energy security|

electricity consumption|electricity production|

hydroelectric power|thermoelectric generator|

power transmission|power distribution|grid infrastructure|Energy systems|

Smart grid|Microgrid|Power plants?|Renewable energy|Hydropower|

Wind power|wind turbines?|offshore wind|wind farms?|

Solar power|solar energy|solar cells?|solar photovoltaic|

Nuclear power|nuclear reactor|nuclear industry|nuclear accident|nuclear safety|

nuclear fuel|nuclear energy|

Battery storage|Energy storage|Decarbonising electricity)\b

A.2.4. Manufacturing sector

\b(?:manufacturing sector|manufacturing industry|manufacturing processes?|manufacturing systems|

production systems?|industrial production|industrial sector|factory operations?|manufacturing plants?|

additive manufacturing|3D printing|advanced manufacturing|smart manufacturing|

lean manufacturing|just-?in-?time(?: production)?|JIT production|

precision manufacturing|materials processing|industrial engineering|

metal fabrication|machining|assembly processes?|manufacturing supply chain|

production planning|logistics (?:and)?manufacturing|industrial logistics|

smart factories?|manufacturing policy|sustainable manufacturing|

green manufacturing|circular manufacturing|low-?carbon manufacturing|

)\b