



Abstract

Gas hydrate is a broad and diverse field with enormous potential, encompassing a wide range of topics from energy and environmental impacts to heat storage and transport, utilization themes, etc. Recent bibliometric and scientometric analyses on the topic of gas hydrates have been limited to single-topic assessments to gauge the historical development of all related fields of research and delineate the level of cross-institutional and cross-national collaborations. This work represents outcomes of novel techniques to explore the latest developments in gas hydrate research in various sub-themes, with a view to where and how research is heading and being translated from theory and experiments to industrial and field practice.

Keywords: Gas Hydrate; Methane Clathrate/ Hydrate; Hydrate Formation; Hydrate Formation/Decomposition; Energy Resource/Storage/Transport; Permafrost; Runaway Greenhouse Effect; Global Warming; Climate Change.

Introduction

Estimations suggest the existence of 2×10^{15} to 2×10^{16} m³ of methane in the Earth's crust in the form of solid hydrate (methane clathrate, Figure 1). The recovery of this methane, however, presents various challenges to engineers:

Recovery Challenges

The extraction of methane from gas hydrates presents substantial engineering challenges, raising questions about the feasibility and suggesting the need for more sustainable technologies with lower capital requirements and risks associated with hydrate energy development.

Environmental Impact & Domino Effect

The runaway greenhouse effect (RGE), could increase permafrost hydrate decomposition rate, releasing more greenhouse gas at a faster rate, thus cumulatively fueling global warming.

Interdisciplinary nature

In addition to understanding such complex phenomena, it is essential to have a vision of the whole process that links the hydrate decomposition processes, methane release rate, release methane reactions, etc. to better quantify the impact and seriousness of the RGE.

Bibliometric and Scientometric Analyses

Such research topics on energy and environment, coupled with other research involving hydrates in the field of energy and heat storage and transport among other scientific and utilization themes, illustrate the breadth and diversity of gas hydrate research.

Bibliometric and scientometric analyses of the scientific literature are valuable tools for better understanding how these topics are advancing relative to each other, guiding effort and investment in the most promising fields and informing policy and regulatory development.

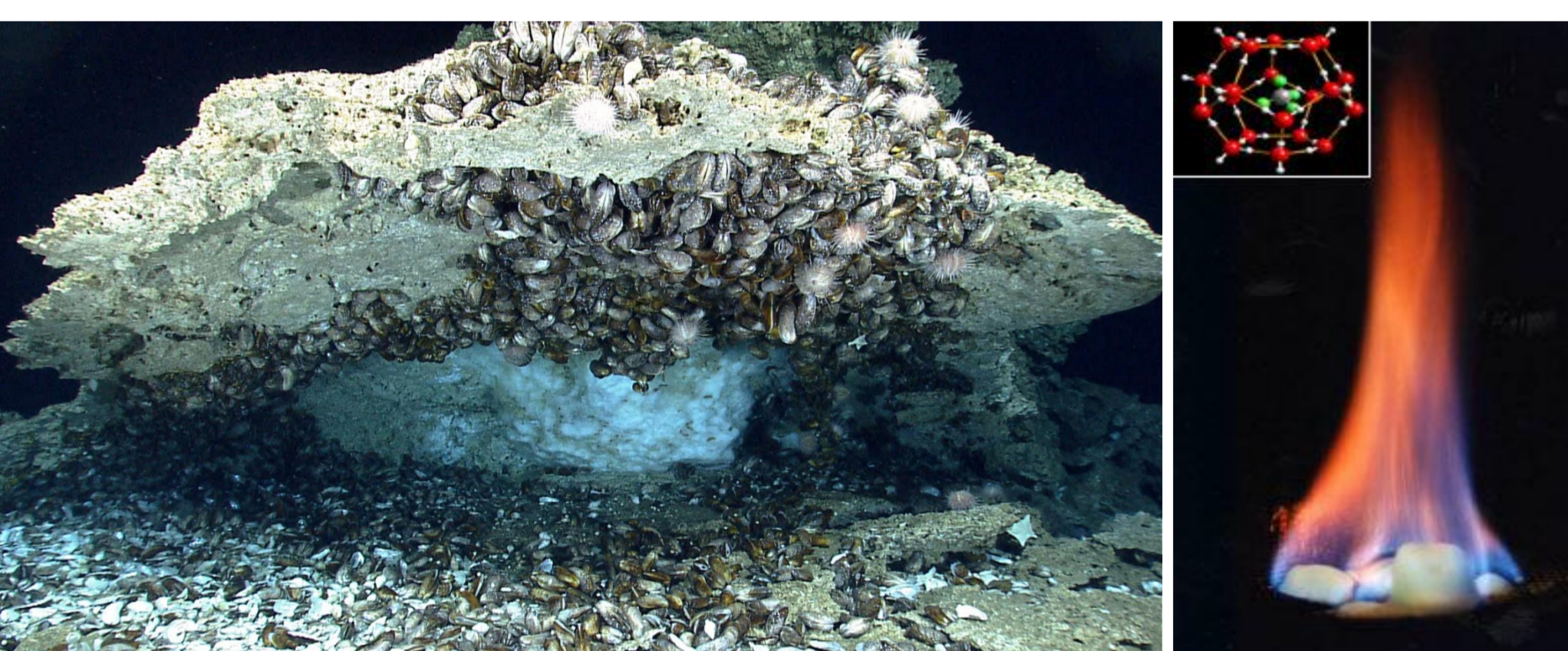


Figure 1. Left: Gas hydrate (methane clathrate) beneath carbonate rock covered by deep-sea mussels on the 966 m deep seafloor of the northern Mexico Gulf [1]. Right: A piece of burning methane hydrate [2]

Methodology

Recent bibliometric and scientometric analyses on the topic of gas hydrates have been limited to single-topic assessments to gauge the historical development of all related fields of research and delineate the level of cross-institutional and cross-national collaborations [3]. The limitation of these types of analyses is that they exclusively utilize inclusive search strings (e.g., {"Gas Hydrate*" OR "Clathrate Hydrate*" OR "Methane Hydrate*"}), which aims at capturing as much of the relevant literature as possible but does not allow the analysis to differentiate among the various aims and motivations for the research involving the topic. The presented work utilizes a technique for comparative analysis that relies on:

- Identifying suitable keywords that represent each unique research direction of the main topic.
- Using a variety of logical operators to produce independent records of literature on each research sub-theme.
- Utilizing "publication ratio" and data normalization techniques to directly compare developments in each sub-theme irrespective of size.

To access & use keywords & queries

Among the major databases, PubMed is more focused on medical journals, and Scopus covers more non-journal sources and newer journals that are not yet indexed in the stricter Web of Science™ (WOS)/Journal Citation Reports™ (JCR). Therefore, and due to the lack of access to Scopus, this study explores the desired keywords in published and indexed studies in WOS in the recent five years.

Results and Discussion

Based on the number of publications¹, China was by far the biggest role player in gas hydrate studies in recent years. USA, Russia, India, and Iran are the next contributors to this list.

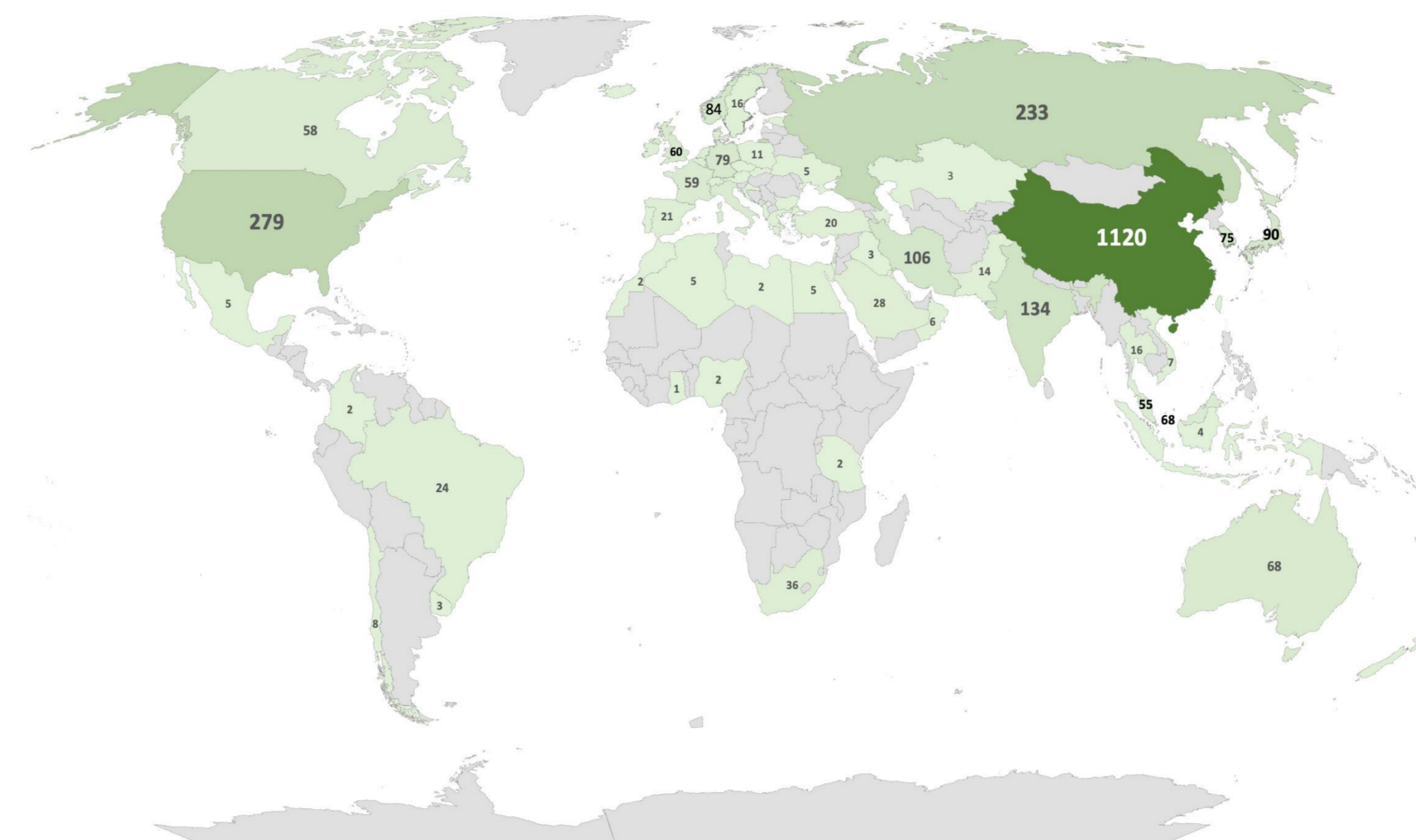


Figure 2. Global contribution to gas hydrate studies based on the number of publications.

¹The year 2023 data is as of June 16, 2023.

Analysis of the funding agencies (Figure 3) and affiliation of researchers (Figure 4) also supports this and suggests a significant investment in gas hydrate studies from China: Over 806 fundings make NSFC the top in this list, while the majority of the top three and top ten educational institutes in this list also are from China.



Figure 3. Top ten funding agencies that funded research with a significant focus on gas hydrate based on the affiliation of authors

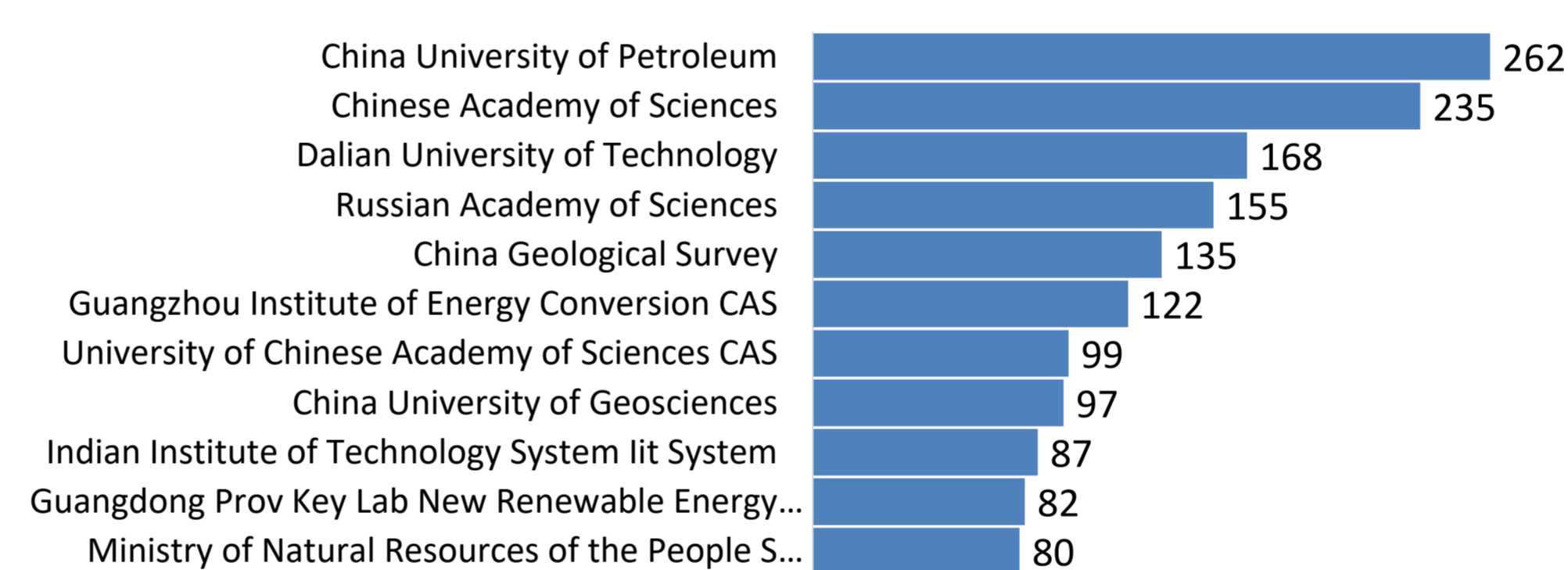


Figure 4. Top ten research institutes with a significant focus on gas hydrate based on the affiliation of authors

Analysis of the author's number of publications (Figure 5) also suggests a considerable focus on this area: The top author has over 100 publications and the top three and top ten authors have over 70 and 42 publications in the gas hydrate field, respectively.



Figure 5. The top authors in the gas hydrate field and desired keywords based on the number of publications

Analysis of the most focused gas hydrate fields of the top ten countries based on the number of authors suggests a major focus on the chemistry of gas hydrates (Figure 6). The environment is the second topic for China, USA, Russia, Norway, Germany and South Korea, while energy is the second rank for Japan and Australia, and Iran and India's second focus is on multidisciplinary studies on gas hydrates.

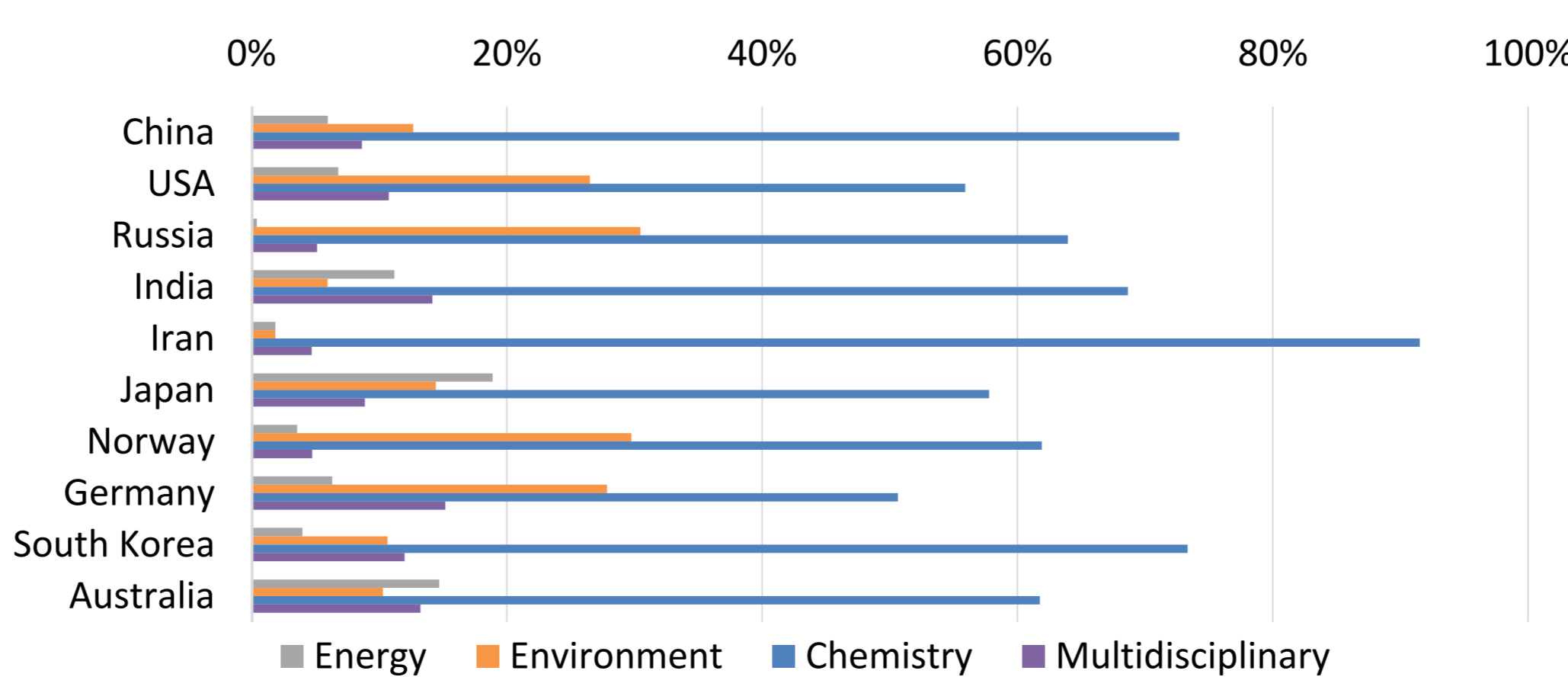


Figure 6. The number of gas hydrate publications in each WOS category

Analysis of the publication ratio and developments in each classified sub-theme (Figure 7) suggests a significant focus on the chemistry (71.16%), then environmental (15.12%) aspects of gas hydrates for the studied query keywords.

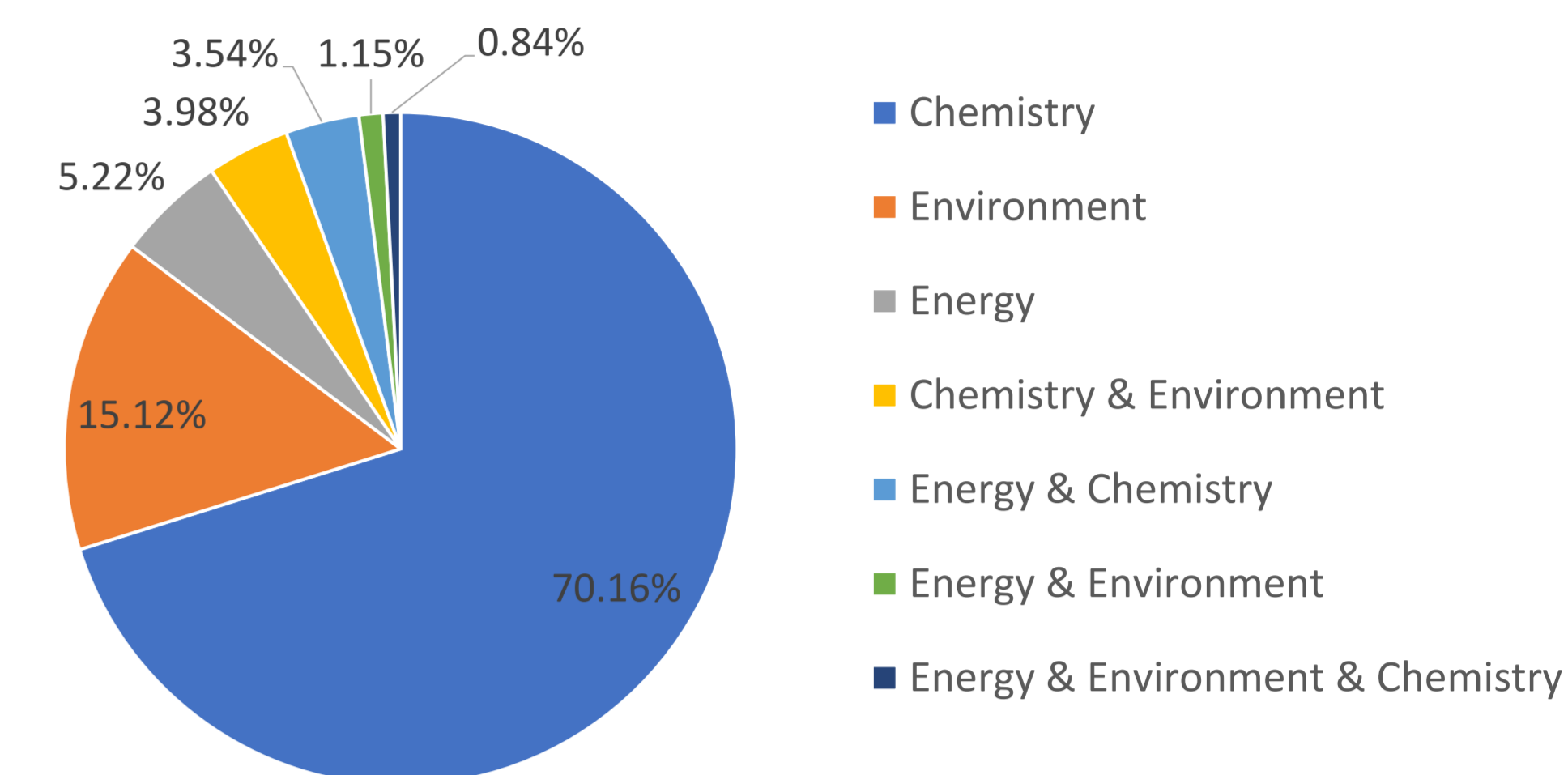


Figure 7. The publication ratio in each sub-theme for the studied queries.

Analysis of the publication trends in the recent five years (Figure 8) also suggests chemistry of gas hydrates is the favorite sub-theme. These trends also suggest that the slight decline in environmental and energy publications that reached its minimum in 2021 is reversed in the next years.

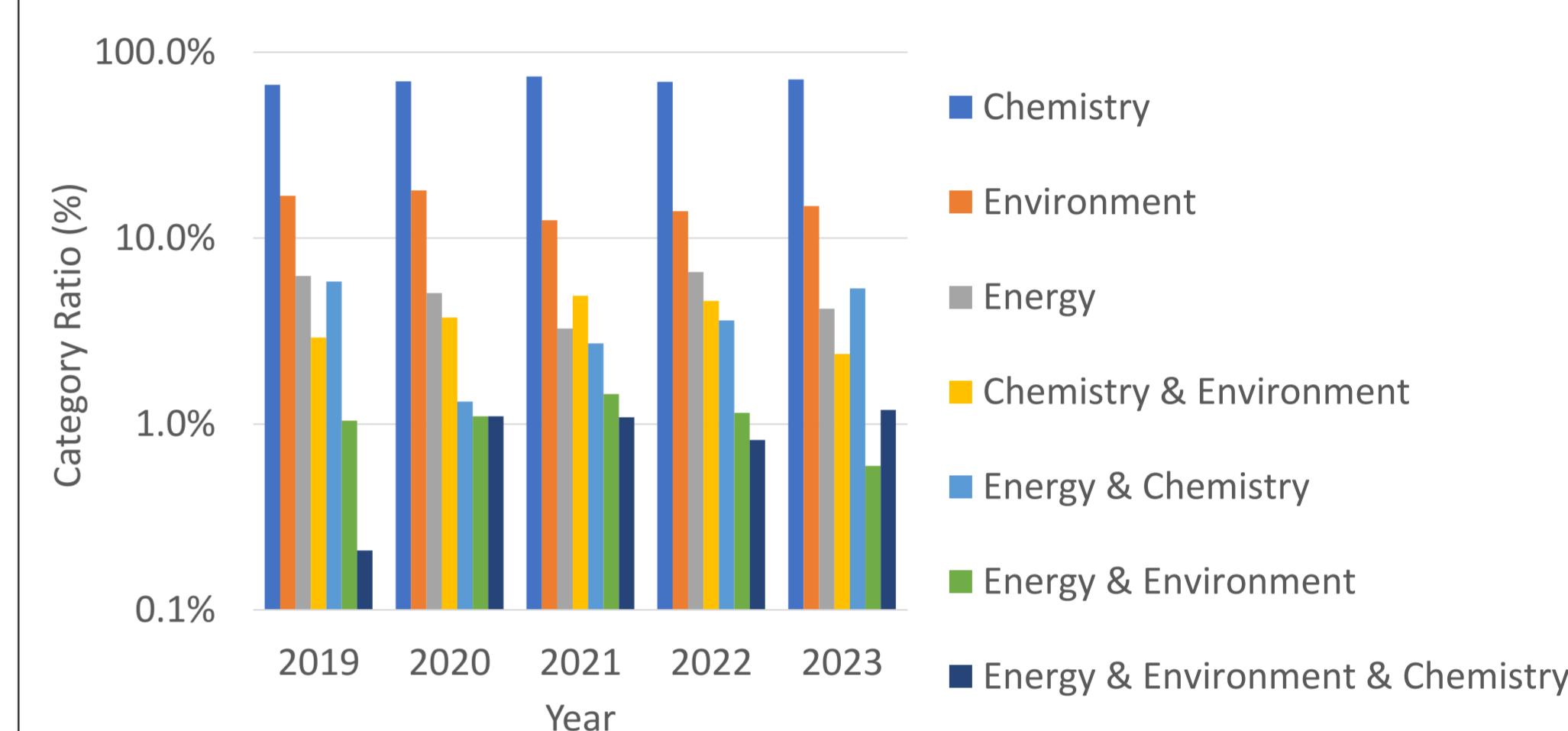


Figure 8. Gas hydrates sub-theme publication ratios for each of the studied queries.

Conclusion

The presented work explored the recent studies on gas hydrates focusing on how research is heading and being translated from theory and experiments to industrial and field practice. For the studied keywords, analysis of results suggests that:

- Based on the number of publications, as well as authors, China is by far the biggest contributor in the field of gas hydrates.
- The number of fundings suggests a significant investment in gas hydrate studies from China.
- The chemistry of gas hydrates is by far the most focused topic, and environmental studies follow as the second category.
- Trends suggest a slight increase in the portion of environmental and energy sub-themes since 2021.

References

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