

Bibliometric assessment of global shale gas research 2009 – 2018:

Project summary and methodology

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1. Summary

This document outlines the background to, and the execution of the joint Royal Society and Royal Academy of Engineering bibliometric analysis of the research carried out into shale gas exploration and exploitation from 2009 to 2018. The document outlines the methodology behind, the steps taken to ensure accuracy and main observations that arise from the bibliometric analysis.

2. Introduction

Against a background of international interest in shale gas exploitation, the Joint Academies commissioned a bibliometric analysis to assess the worldwide research effort in this field as an aid to academics, industrialists and governments interested in this field. The *Bibliometric Assessment of Global Shale Gas Research 2009 – 2018* has produced a quantitative analysis of published studies that highlights trends in shale gas research on different topics and in different global regions. This analysis was conducted by Elsevier Analytical Services.

This work is limited in nature compared to the 2012 Joint Academies report on Shale Gas exploitation; it is not an update of that report and as stated previously is a review of research publications in this area.

The project scope was initially restricted to published, peer reviewed research. However, it was later extended to record relevant grey literature. For the purpose of this report, we define grey literature as research that is not formally published by journal publishers or research with limited distribution namely those not listed in online bibliographic database systems. The grey literature does not form part of the bibliometric analysis due to the nature of that assessment. It should also be noted that the inclusion of records or papers in either the bibliometric corpus or the grey literature list does not indicate the endorsement or otherwise for that paper by either the Royal Society or the Royal Academy of Engineering.

3. The Steering Group

A Steering Group was established to guide the work:

Professor Mike Bradshaw, University of Warwick.

Professor Mike Bickle FRS, University of Cambridge.

Professor Joe Cartwright, University of Oxford.

Professor Richard Davies, Newcastle University.

Professor Zoe Shipton, University of Strathclyde.

Professor Mike Stephenson, British Geological Survey.

Professor Hywel Thomas CBE FREng FRS (Chair), Cardiff University.

The Group were supported in their work by Dr Richard Sandford, Cardiff University; Frances Bird, Paul Davies and Elizabeth Surkovic of the Royal Society and Keyne Walker of the Royal Academy of Engineering.

4. Methodology

The Steering Group decided on the scope of the bibliometric analysis, identifying the following main topics and sub-groups.

Topic A: Resource estimation

- A1: Shale geology
- A2: Mechanical and flow properties of shales
- A3: Geophysics

Topic B: Fracturing fluid, composition, treatment, storage and disposal

- B1: Composition of the fracturing fluid and the wastewater
- B2: Treatment, storage, transportation and disposal of wastewater
- B3: Technologies to reduce or eliminate water usage

Topic C: Methane leakage and groundwater contamination

- C1: Well integrity
- C2: Methane and contaminant leakage through the overburden

Topic D: Monitoring seismicity

Topic E: Public perception and governance

- E1: Public perception of shale gas extraction
- E2: Governance and regulation of shale gas activities

The Steering Group decided to focus their interest on the time period 2009 – 2018 so that a trend analysis of two time periods (2009 – 2013 and 2014 – 2018) could be determined.

An expert workshop took place at the Royal Society on 26 October 2018, details of which are given in Annex 1. Elsevier Analytical Services presented their findings to that date and the invited audience provided comments on the results presented together with suggestions for further work.

5. A three-stage approach

The results presented in the Elsevier Analytical Services report were obtained by adopting the following three-stage process. The first step was the selection of keywords relevant to the particular category (or sub-category) listed above. The second step was the interrogation of the Scopus database, to extract the corpus possessing the chosen keywords within their titles, abstracts or author-selected keywords. The third stage was manual curation, in which the title and abstract of each paper was scrutinised to ensure its relevance to that particular category or sub-category (see Manual curation).

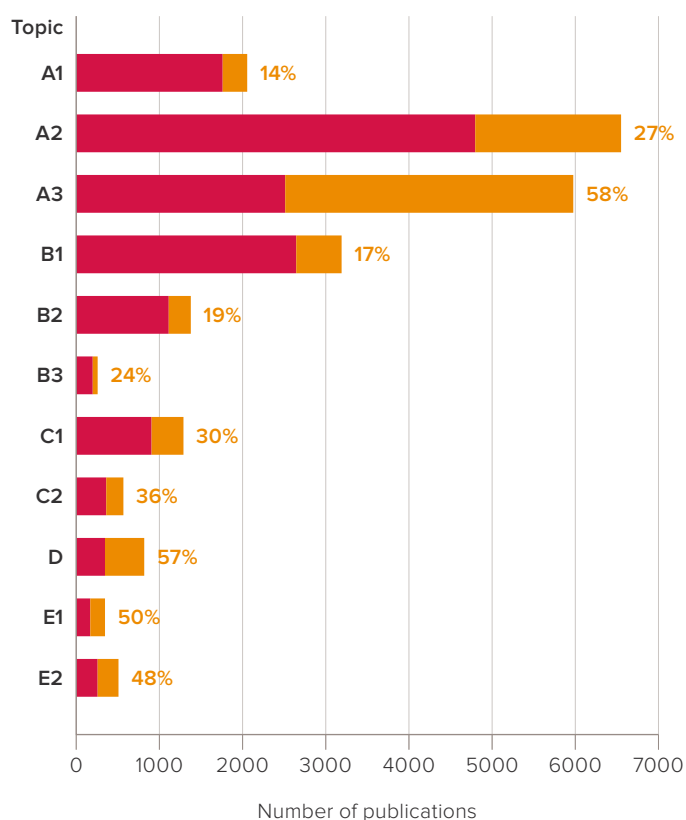
The search queries used in this study are as listed in Appendix A of the Elsevier report. The format of each search query is such that documents were sought that possessed at least one of the range of keywords specific to each category (or sub-category) in combination with at least one generic keyword of relevance to the broader scientific area (examples of such generic keywords include: 'shale gas', 'hydraulic fracturing', 'unconventional gas'). The search queries were developed by the members of the Steering Group and the results obtained from the various Scopus databases queries were scrutinised by members of the Steering Group to ensure that documents known to belong to the relevant research topic were present in the results. If a document known to belong to the relevant research topic was found to be missing from the results, the search queries were modified, and checks were repeated on the updated set of results. While the obtained final results are deemed to be representative of the corpus pertinent to each category (or sub-category), it is acknowledged that some documents may not have been captured.

6. Manual curation

Manual curation was deemed essential to the integrity of the work to ensure that the main scientific focus of each document admitted to the corpus was appropriate to the category or sub-category under consideration. The criterion for exclusion of a document was based purely on perceived relevance to the category, without any judgement on the perceived quality of that document. Judgement on relevance was made based exclusively upon reading the title and abstract of a document. The curation process ensured that documents with abstracts bearing a passing reference to a particular keyword or combination of keywords, but with a clear scientific focus in an area beyond the scope of the category or sub-category, were omitted. The curation process also ensured that documents with a very broad scope, such as entire conference proceedings, were omitted so as to not unduly bias the results. The subjective nature of the manual curation process is acknowledged, particularly in the adjudication of the scientific focus of a document based on the title and abstract. In the case of doubt, the principle of inclusivity was applied. All documents types were admitted to the corpus, including original research papers published either in journals, book chapters or for conferences, as well as review papers.

FIGURE 1

Manual curation of the Scopus dataset featuring the % of the total publications that were removed from the final dataset (2009 – 2018)

**KEY**

■ Included publications ■ Removed publications

Figure 1 details the proportion of the original corpus of each category or sub-category that was excluded following manual curation. For most of the categories and sub-categories, the exclusion percentage is low – less than 40%. However, some topics such as Topic A3 had a higher exclusion percentage (58%) as the keywords used had to be kept general to ensure the majority of the published corpus was captured in the relevant fields. The experts decided to confine the corpus to research on shale rather than, for example, fracking operations in coal bed methane and recognised the duplication of papers appearing in Topic D: Seismic Monitoring. Papers from geothermal, coal bed methane, gas hydrates and conventional fractured reservoirs were excluded except where the theoretical content was applicable to shale operations.

Whilst every effort has been made to ensure that this curated bibliometric analysis is a fair representation of the field, the Steering Group recognise there may be a small number of papers that may have been omitted or may continue to be erroneously listed. It should be noted that efforts have been made to ensure that the correct data has been collated, the nature and limitations of such database searches does not preclude the inclusion of a small number of extraneous records.

7. Grey literature

It was recognised that not all relevant research would have been recorded in academic journals and the Steering Group agreed that the project would seek to build a list of ‘grey literature’. This would primarily include published data that sought to expand scientific or technical knowledge of shale gas extraction. The grey literature list (2012 – 2018) was compiled from suggestions from the Steering Group and inputs from attendees at the workshop. It should be noted that the list is not exhaustive and undoubtedly many useful papers are not included. The inclusion of records or papers in the grey literature list does not indicate the endorsement or otherwise for that paper by either the Royal Society or the Royal Academy of Engineering. Whilst many of the documents in the grey literature list may have been subject to scrutiny, there is no guarantee that they have undergone the same level of external scrutiny as papers in the Scopus database. They have therefore not been included in the analysis, but the list can be found in Annex 2.

8. Comments on the study

8.1. General research trends

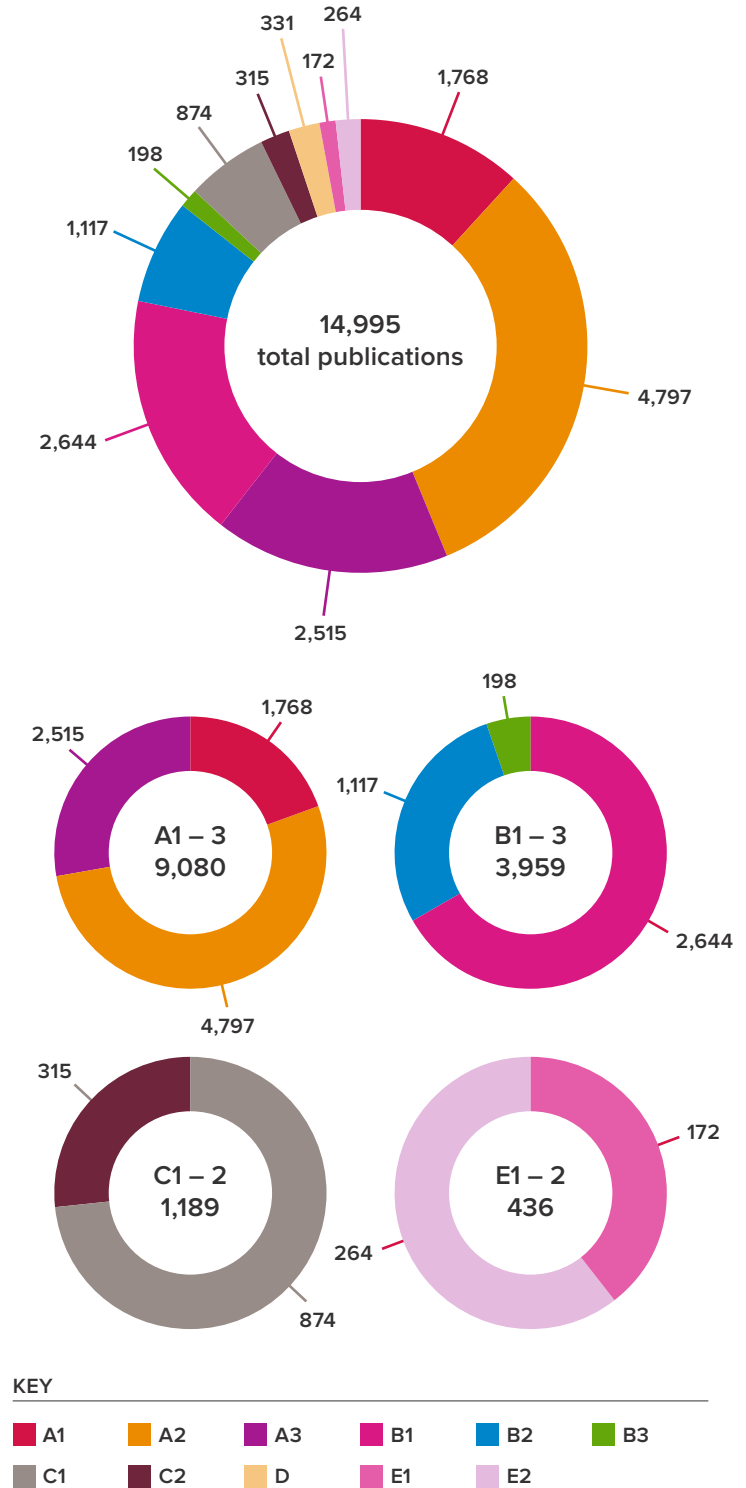
The bibliometric analysis has revealed that hydraulic fracturing in shale, as a research field, has in recent years undergone rapid growth. The research in this field is, in aggregate, of high scientific influence, as measured by the field-weighted citation impact, which is above average across all research fields. A subset of the research published in this field can be classed as highly impactful, as adjudicated by the inclusion of a portion of the research in this field attracting a sufficiently high number of citations so as to be placed within the cohort of publications receiving the top 1% of citations across all research fields.

The bibliometric analysis does, however, point towards some slowing of the rate of growth of the field in recent years and also some reduction in the impact of that research. Specifically, a comparison of the research published from 2009 to 2013 with that published from 2014 to 2018 reveals that the field-weighted citation impact, while remaining above the average for all fields, has reduced. The overall trend that emerges is that hydraulic fracturing in shale has developed rapidly into an impactful research field, although there is now some dilution of that impact and some reduction in the growth rate, indicating that the field is beginning to mature. The research publication rate of a particular country with respect to its contribution to the field tends to correlate principally with the maturity of the shale gas industry within that country. The study identifies that the United States and China are the two countries that dominate the field, with the growth rate in China increasingly significantly across the study period.

The bibliometric analysis has revealed that the overwhelming majority of the publications across the study period are within the category of 'Topic A: Resource Estimation' (Figure 2). This category has been sub-divided into the three further sub-categories with the search query for the first sub-category, 'Topic A1: Shale Geology', devised to extract those publications concerned with studies on the geological properties and behaviour of shale that govern the propensity for methane extraction. The significance of the work in this sub-category is evidenced by the presence of some publications that have individually attracted more than 1000 citations. These publications concern fundamental studies on particular properties of shales (for example, those concerned with determining pore size distributions), which provide fundamental data, relevant across the majority of scientific disciplines within the field. The dominance of the United States and China is particularly prominent within this sub-category.

FIGURE 2

Total number of publications in the study across all topics between 2009 – 2018



Many of the countries that lead in fossil energy production are observed among the top publishers in shale gas research, particularly in the second period. Corporate entities such as Schlumberger, Halliburton, SINOPEC and PetroChina also have a strong publication output across many of the shale gas topics.

8.2. Overlap of papers

It should be noted that it is quite common for research papers to cover several aspects of shale gas research and this has resulted in the inclusion of a number of relevant papers in the results for more than one sub-category (Figure 3).

9. Concluding remarks

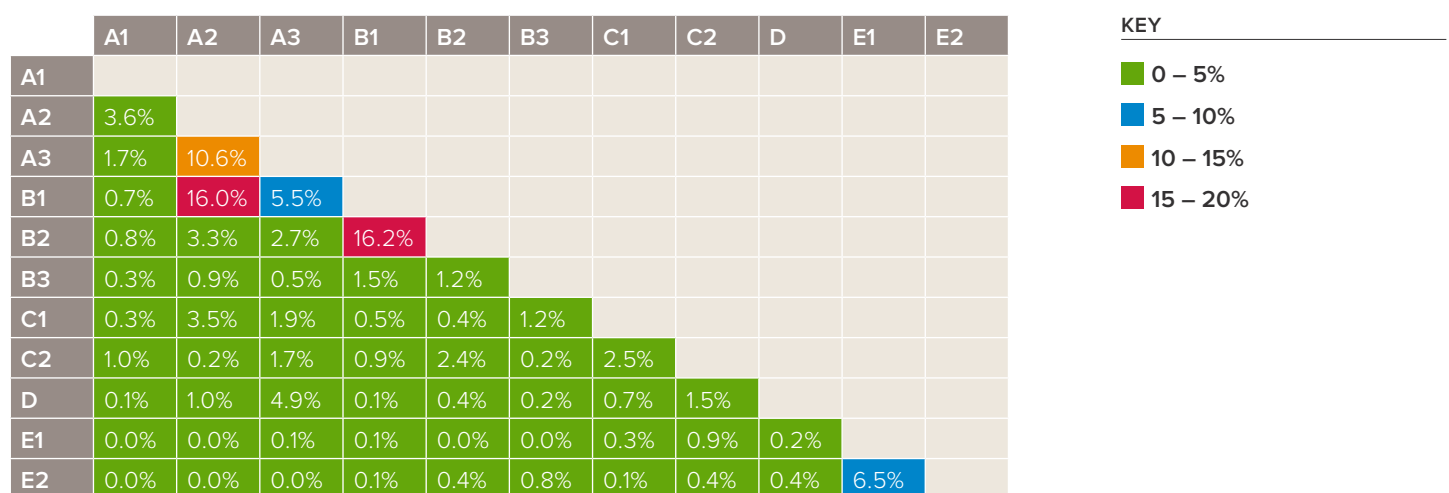
The data and analysis presented both here and in the Elsevier report, is intended to provide an overview of the diversity and change in growth of shale gas research around the world. The Royal Academy of Engineering and the Royal Society publish it with the expectation that researchers, governments and others will find this information of value in determining the future direction of shale gas research.

10. Funding for this project

Funding for the project was provided by the Royal Society's own reserves.

FIGURE 3

Percentage paper overlap between and within topics (2014 – 2018)



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Annex 1. Workshop held on 26 October 2018: research into shale gas exploration and extraction

Workshop background

The Royal Society and the Royal Academy of Engineering hosted a workshop on the 26 October 2018 at the Royal Society to discuss research into shale gas exploration and extraction.

Prior to the workshop, a systematic bibliographic search of the primary literature relevant to this research question was conducted. To support this evidence, the workshop aimed to gather further valuable evidence not commonly found on online databases, otherwise known as grey literature.

Workshop agenda

Welcome and introduction

Purpose and aims of the workshop

- Hywel Thomas FREng FRS,
Chair of the Shale Gas research review project
- Professor Lord Robert Mair FREng FRS,
Chair of the 2012 Royal Society/Royal Academy
of Engineering review

Session 1: Primary literature review

A presentation of an analysis of the academic research collected to date

- Elsevier

Open discussion and questions

- Panel: Steering Group members

Attendees are invited to comment on the data

- Panel: Steering Group members

An outline of the breakout sessions and what the project team hope to get out of it

- Hywel Thomas FREng FRS

Session 2: Evaluating the study to date

Breakout sessions – everyone has been allocated to two half hour sessions at one of the following stations:

- Resource Estimation
- Fracturing fluid: Composition, treatment, storage and disposal
- Methane leakage and groundwater contamination
- Induced seismicity
- Public perception and understanding, governance and regulation

- Attendees discuss research within pre-allocated groups led by Steering Group members

Summary of the breakout discussions from the group leaders

- Attendees discuss research within pre-allocated groups led by Steering Group members

Workshop agenda and output

The attendees discussed the scope and aims of the project and were invited to comment on the initial Elsevier bibliometric data. In addition, they were invited to suggest documents to be added to the grey literature list.

The scope of the project as set out in the five main topic heading was generally accepted by those attending and minor adjustments were suggested for grey literature collection. The comments and suggestions received at the workshop were subsequently considered by the Steering Group.

Individuals from the following organisations attended the workshop

- British Geological Survey
- Cardiff University
- Cuadrilla
- Department for Business, Energy & Industrial Strategy
- Earth Institute, Columbia University
- Economic and Social Research Council
- Elsevier
- Encompass
- Environment Agency
- FracMaven Ltd
- Geological Survey of Northern Ireland
- Green Alliance
- Health and Safety Executive
- IGas
- Imperial College
- INEOS Shale
- National Trust
- Natural Environment Research Council
- Newcastle University
- Northumbria University
- Oil and Gas Authority
- Public Health England
- Royal Academy of Engineering
- Shell
- The Chartered Institution of Water and Environmental Management
- The Weir Group
- Third Energy
- United Kingdom Onshore Oil and Gas
- University of Bristol
- University of Cambridge
- University of Cardiff
- University of Edinburgh
- University of Exeter
- University of Leeds
- University of Oxford
- University of Strathclyde
- University of Sussex
- University of Warwick
- Zetland Group