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Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Natural gas from shale formation: A research profile

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ARTICLE INFO

Article history:

Received 28 May 2015

Received in revised form

24 October 2015

Accepted 17 December 2015

Keywords:

Natural gas from shale formation

Shale gas

Bibliometric analysis

Social network

Water resources

ABSTRACT

With the unfolding shale gas revolution, the literature related to shale gas has grown dramatically, particularly in the past decades. This study aims at providing updated and systemic research information for scientists, researchers, engineers, policymakers, and other stakeholders of shale gas to stimulate wide discussion about the future studies of shale gas through the investigation of shale gas literature cited on the Science Citation Index Expanded Web of Science database between 1990 and 2014. Using bibliometric techniques and the social network method, we attempt to explore three areas of the research profile: (1) country productivity distribution, (2) country collaboration patterns, and (3) research topics analysis. First, the results show that the USA was the largest contributor of the literature on the subject, followed by China and Canada. Moreover, examining overall trends show that the research on shale gas saw a significant growth along with greater participation in the number of countries. Second, the USA was the most frequent partner among all the international collaborative studies. The number of studies in most European countries was not as high as that in Asian countries. However, their collaboration was considerably active in country-to-country collaboration of shale gas. Third, the trend for all research topics is an increasing one, with the exception of *Geochemistry Geophysics*. Particularly, the areas of *engineering*, *energy fuels*, and *geology* have grown sharply over the past two decades. However, *water resources* have become an extremely hot topic since 2012. The research topic analysis results indicate that the current shale gas development is closely related to the three hot topics (*engineering*, *energy fuels*, and *geology*), whereas its future hinges on *water resources*. In conclusion, future studies of shale gas are suggested to stimulate more discussion for the wide community of those interested in shale gas.

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1. Introduction

Natural gas from shale formation is one of the most important energy revolutions of our time and is transforming the global energy market place [1–7]. It has been widely recognized that shale gas will play a large role in meeting future worldwide energy

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demands and become a significant part of the energy policy mix of many countries [1,3–5,7,8]. With the unfolding shale gas revolution, the literature related to shale gas has grown dramatically, particularly over the past decades.

Existing bibliometric analysis on shale gas has been conducted around patent data. Patent data are widely used to analyze the shale gas field, with patents for shale gas exploitation analyzed using data mining and patent maps. The findings show that shale gas exploitation involves complex technologies and that technological accumulation is a long-term process. For example, the former study is focused on identifying the trends in shale-gas related technologies registered in the U.S. Patent and Trademark Office (USPTO) and to the State Intellectual Property Office of the People's Republic of China (SIPO), respectively, to cluster shale-gas-related technologies [9].

In comparison, few bibliometric analyses on shale gas have focused on literature cited in the Science Citation Index Expanded (SCIE) on the Web of Science database. As we know, it takes roughly one and half-year from application to authorization for a patent. In comparison, much less time is required from submission to publication of literature cited on the SCIE. Furthermore, a patent is a set of exclusive rights granted by a sovereign state to an inventor or assignee for a limited period of time in exchange for detailed public disclosure of the invention. An invention is a solution to a specific technological problem and is a product or a process [10,11], whereas research-based literature is published once accepted by a journal. Thus, literature can provide more updated information for scientists and researchers than patents.

This study is aimed at providing updated and systemic research information for scientists, researchers, engineers, policymakers, and other stakeholders of shale gas through bibliometric techniques that investigate the shale gas literature cited on the SCIE database between 1990 and 2014. To this end, this research has three main goals: (1) to explore the growth of shale gas literature published and identify the productivity distribution by country on this subject; (2) to identify the scientific collaboration and characteristics of the shale gas literature by country level; and (3) to reveal the hottest topics and anticipate future developmental trajectories, and discover the emphasis of research concentration by leading countries.

2. Methodology and data

2.1. Data sources

For the present work, the database of the SCIE, a product of the Thomson Scientific, is utilized to retrieve data from 1965 to 2005 and from 1990 to 2014. SCIE is adopted because it is recognized as the leading English-language supplier of indexing services, providing access to the published information in multidiscipline fields of science and technology [12–14]. In this study, shale gas was selected as key search words as part of the research profile. Our data are collected from the SCI-Expanded citation database in the Web of Science. We use the subject of shale gas as the research term. In total, 3407 papers from 1990 to 2014 are collected.

2.2. Methods

Bibliometrics is a set of methods to quantitatively analyze scientific and technological literature [14–16]. Most historians generally recognize that bibliometrics owes its systematic development largely to Price and Garfield as founders [16,17]. A more unambiguous definition given by White and McCain [17,18] is that bibliometrics is the quantitative study of literature as reflected in

bibliographies; its task is to provide evolutionary models of science, technology, and scholarship.

A social network refers to a group of people, each of which has connections of some kind to some or all of the other members of the network [19–21]. In this research, the main method adopted is social network analysis (SNA), including the network structure, for example, drawing the collaboration maps to analyze country collaborative situations.

Collaboration network analysis is a kind of social network analysis. A social network is a network of social relations, reflecting a relationship between actors. In this method, actors in the network are positioned as nodes and the relationships between them are seen as the links between the nodes [22–24].

3. Analyses and results

As an emerging technology, shale gas appears to make good strategic sense, which means there is now a need to better understand the technology development of countries and explore the collaboration among them in this area. However, shale gas research began a long time ago, and it is just recently increasing sharply over the past two decades. In fact, Thomas published the earliest research paper on shale gas in 1951. Before 1990, the number of papers increased slowly, from only one in 1951 to 19 in 1990. The years between 1990 and 2014 saw a period of significant publication on shale gas according to the number of papers cited in the SCIE. Due to national energy strategies, policies and advantages of shale gas, it is obvious that extensive studies on shale gas have been conducted worldwide since 1990. Moreover, the papers on shale gas have increased sharply, reaching 674 in 2014.

3.1. Country productivity distribution

From 1990 to 2014, countries have devoted research to the field of shale gas. The contribution of the different countries is included on the basis of the country affiliation of at least one author of the published paper. The top 30 countries with more than 20 papers are ranked by their number of published articles, as shown in Table 1, which means that there are 30 countries contributing more than 20 papers on shale gas all over the world. Table 1 shows

Table 1

Country productivity distribution of shale gas literature from 1990 to 2014.

Rank	Country	Paper (%)	Rank	Country	Paper (%)
1	USA (US)	1295 (38.01)	16	India (IN)	39 (1.14)
2	China (CN)	454 (13.33)	17	Switzerland (CH)	36 (1.06)
3	Canada (CA)	270 (7.92)	18	Italy (IT)	33 (0.97)
4	England (UK)	246 (7.22)	19	Jordan (JO)	32 (0.94)
5	Germany (DE)	240 (7.04)	20	Egypt (EG)	32 (0.94)
6	Australia (AU)	146 (4.29)	21	Saudi Arabia (SA)	29 (0.85)
7	France (FR)	140 (4.11)	22	Brazil (BR)	29 (0.85)
8	Estonia (EE)	113 (3.32)	23	Iran (IR)	28 (0.82)
9	Turkey (TR)	100 (2.94)	24	Nigeria (NG)	26 (0.76)
10	Russia (RU)	73 (2.14)	25	South Korea (KR)	25 (0.73)
11	Netherlands (NL)	72 (2.11)	26	Denmark (DK)	23 (0.68)
12	Norway (NO)	70 (2.05)	27	South Africa (ZA)	21 (0.62)
13	Poland (PL)	65 (1.91)	28	Morocco (MA)	21 (0.62)
14	Spain (ES)	48 (1.41)	29	Austria (AT)	21 (0.62)
15	Japan (JP)	45 (1.32)	30	Israel (IL)	20 (0.59)

The sum of papers published by the top 30 countries is 3972. A paper may be co-authored by many authors from different countries; therefore, the sum of papers published by each country is larger than the total number of papers. Moreover, the same applies to the country collaboration patterns analysis and research topics analysis. In addition, the papers published by England and Scotland are all merged into England (UK).

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