The Emerging Trends of Risk Management in Renewable Energy Projects

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Abstract. The development of renewable energy (RE), due to the ever-growing increase in energy demand and the negative impact of fossil fuels on the environment, has become an increasingly important development area at present, with broad prospects. Compared with traditional energy projects, RE projects often involve long life cycles, complex uncertainties, and they exert for-reaching impacts on risk management. The Citespace software was used to systematically summarize the research hotspots development, and frontiers of researches on the risk management in renewable energy projects in China from 1997 to 2018. Results show that the overall evolutionary trend of risk management in renewable energy field is from RM practice to technology driven integration system. Based on the trend, knowledge gaps and future research directions were found out and discussed.

1. Introduction
The development of renewable energy (RE), due to the ever-growing increase in energy demand and the negative impact of fossil fuels on the environment, has become an increasingly important development area at present, with broad prospects [1-3]. Compared with traditional energy projects, RE projects often involve long life cycles, complex uncertainties, and they exert for-reaching impacts on risk management [4]. Risk management in renewable energy (RM-RE) projects is one of the basic tools for preventing unwanted events as well as efficient and effective support tool in the process of project management. The emerging trends of RM-RE is highly multi-disciplinary which includes the risk management, technology development, system integration, and modelling technology from several areas [5]. The aim of this study is to systematize the discussion on the concept of RM-RE, its evolution, gaps opportunities and trends. To this end, we applied a systematic literature review with scientometric analysis, covering the period 1997-2018. The theoretical potential of RM-RE projects study is significant. This paper provides valuable guidance and in-depth understanding for researchers, practitioner and policy makers to promote RM-RE sustainability.

2. Materials and Methods
To review the intellectual structure and evolution of RM-RE projects, we first identified a list of academic journals that publishes RM-RE projects researches. To provide a comprehensive search, the list of publications was obtained from Web of Science (WoS). The WoS core database is considered to be the most authoritative database for studying literature in many fields [6], since it covers the most prestigious and important journals all over the world. Publication data was extracted from the WoS...
core collection database (SCI-EXPANDED, SSCI) in June 2019. The main conclusions of each paper should be determined by its research objectives, methodologies, and major contributions. In order to conduct a comprehensive analysis, this study follows a number of steps, as shown in Figure 1.

The first stage identifies the related key terms of RM-RE publications by going over a number of highly-cited papers on the topic of RM-RE. After reviewing these papers, the most frequently appeared search terms concerning RM-RE were identified. The second stage conducts a preliminary search to include papers in peer-reviewed journals. The keywords used in this study is risk management and renewable energy. Based on preliminary search, 749 papers are extracted. The third stage double checks the selected papers to exclude book reviews, editorials, and conference proceedings. Based on preliminary search, 749 papers are extracted. The third stage double checks the selected papers to exclude book reviews, editorials, and conference proceedings by using an identical analytical construct in terms of research aims and methods [7]. Finally, the timespan
of the publication is limited to 1997-2018. After all the three stages, 448 papers are identified for further analysis.

Figure 2 shows the number of publications of 448 RM-RE studies from 1997 to 2018. A significant surge in the number of publications was shown from 2011 to 2018. This is because many countries and regions introduced financial support to encourage the development of RE. For example, Apak et al. (2011) examined the evolving financial RM instruments to meet the needs of the RE sector in both the UK and Turkey. The widely spread concepts of RM and RE, together with the financial, policy and regulation support have significantly promoted the RM-RE research, with 110 paper published in 2018.

![Figure 2. Number of studies from 1997 to 2018](image)

### 3. Results

3.1 The Major Published Journals

The 448 journals we extracted were published in the most influential journals in the field. Table 1 shows the performance of top 16 productive journals that have published at least five articles on RM-RE projects from 1997 to 2018. The top 16 journals account for 41% of the 448 articles indicating that theses journals have a high concentration of articles on RM-RE projects. Moreover, the top 3 journals account for 16.2% of the total articles which may imply that these 3 journals are the most renowned and influential publications on RM-RE projects. Energy Policy published the highest quantity of articles with 25 (5.6%), slightly higher than the second and third journals, and both Applied Energy and Energies published 24 papers (5.4%). The journal with highest impact factor is Applied Energy with 8.426, followed by IEEE Transactions on Sustainable Energy with 7.65.

| No. | Journal Name       | No. of Articles | Impact Factor |
|-----|--------------------|----------------|---------------|
| 1   | Energy Policy      | 25             | 4.88          |
| 2   | Applied Energy     | 24             | 8.426         |
| 3   | Energy             | 24             | 5.537         |
| 4   | Energies           | 18             | 2.707         |
| 5   | Renewable Energy   | 14             | 5.439         |
3.2 Brust detection

We explore the evolution of RM-RE projects by burst detection and time-zone view of keyword. The objective of burst detection is to find the sharp increase of appearance of an entity when compared with its peers. Burst detection can also detect the frequency and significant fluctuations of specific keywords in a short period of time. If the frequency of a keyword increases dramatically in a short period of time, it often shows that this keyword denotes an active research area. Accordingly, a keyword burst is employed as an indicator of a highly active sub-field that represents changes in importance among keywords from a historical perspective [8]. It should be pointed out that the identified keywords by burst detection may not be the words with high frequency. CiteSpace provides a keyword burst function to identify emerging trends in a knowledge domain as well as significant alternations over time [9].

Figure 3 shows a visualization of the keyword burst detection in the risk management field from 1997 to 2018 in chronological order, the top 13 bursting keyword are also shown, as sorted based on their beginning year of burst. The frequency of the term “climate change” experience a significant surge from 2000 to 2012, and have a burst time of 12 years, which imply that climate change is the major concern for renewable energy project and gained worldwide attention. The keywords “security” and “energy efficiency” have continued bursting from 2003-2012, which is consistent with the findings of the timeline view in Figure 3. This case is unsurprising based on the results of keyword burst detection. After 2008, a diverse group of tropics were presented by researchers and each topic lasted 4 to 5 years. The typical keywords in this period are “greenhouse gas”, “China”, “management”, “energy system”, and “decision making”. In this period, these studies focus on energy management and decision-making practice in different economics. Due to industrial policy support and the implementation of mega projects, the term “China” experienced a significant surge.
Keywords burst detection enables us to comprehend chronological changes in the knowledge domain since 2000, but detailed information on research hot topics in the past six years remains unclear. In order to further visualize the hot research topics and trends in the last six years, we constructed a time zone view to present the keywords co-occurrence from 1997-2018, as shown in Figure 4. The connecting lines between nodes are co-occurrence links between keywords. The line colours show the time when a connection has been firstly made. With the combination of burst detection and time zone view, the evolutionary trend of the RM-RE projects studies can be better illustrated. The timeline view may show an emphasis away from risk management to modelling technology, to system operation and to demand response. Many scholars engaged in “sustainability” (2001), “strategy” (2015), including simulation of potential impact of policies and RM approaches, system design, and integration management. Increasing interests have been emerging on “system”, “smart grid”, “energy storage” and “integration”, since 2013.

Many burst keywords from 1997 to 2018 (Figure 4), also appeared in keywords timeline view (Figure 3), such as climate change (2000), security (2003), China (2008), and decision making (2008). According to Figure 3 and Figure 4, earlier keywords tend to focus on risk management in the renewable energy to ensure security and energy efficiency, corresponding to climate change and sustainable development. Given the importance of new technology development, global participant, and multi renewable energy projects implement, “bioenergy”, “biofuel” and “wind power” were used.

| Keywords     | Year | Strength | Begin | End   |
|--------------|------|----------|-------|-------|
| climate change | 1997 | 4.5793   | 2000  | 2012  |
| security     | 1997 | 4.8294   | 2003  | 2012  |
| energy efficiency | 1997 | 3.8826   | 2003  | 2012  |
| greenhouse gas | 1997 | 3.9702   | 2008  | 2012  |
| china        | 1997 | 3.9708   | 2008  | 2010  |
| management   | 1997 | 3.6327   | 2008  | 2013  |
| energy system | 1997 | 4.5428   | 2008  | 2012  |
| decision making | 1997 | 3.8997   | 2008  | 2012  |
| energy       | 1997 | 3.7159   | 2008  | 2012  |
| technology   | 1997 | 4.1489   | 2013  | 2015  |
| sustainability | 1997 | 4.1489   | 2013  | 2015  |
| biofuel      | 1997 | 3.9352   | 2014  | 2015  |
| electricity  | 1997 | 3.4117   | 2014  | 2015  |

**Figure 3.** Top 13 keywords with the strongest citation bursts from 1997 – 2018
3. Knowledge gaps and future research directions

Based on scientometric analysis, this paper has further proposed a comprehensive framework for RM-RE, including knowledge evolution, knowledge domains, knowledge gaps, and potential research directions. According to the review of RM-RE research from 1997 to 2018, this paper aims to determine gaps and some potential ideas that need further investigation. The gaps and future research direction are listed as follows.

The first knowledge gap is to seek Integration of new technologies and methods in the life cycle of RM-RE project. New technologies, including big data analysis, artificial intelligence, IOT technology, have been used widely and are regarded as the best management tools for RM, particular in risk identification process. While the existing research has largely investigated the modelling technology from optimization, scheduling, and programming, more research is needed to explore how to promote risk assessment.

The second knowledge gap is to explore the integrated management system. Since burst in 2013, the concept of “system” refers to smart grid, energy storage, and power system that can support risk assessment, analysis, and control. Since the term “integration” burst in 2018, how to construct and operate an integrated system is a significant issue that require further exploration.

4. References

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