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# RENEWABLE ENERGY ONLINE LEARNING: A SYSTEMATIC LITERATURE NETWORK ANALYSIS

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**Abstract**

This study aims to reveal state-of-the-art, trending topics and future work in Renewable Energy Online Learning (REOL). The research used the Systematic Literature Network Analysis (SLNA) method. SLNA in this study is a combination of Systematic Literature Review (SLR) using the PRISMA protocol followed by a Bibliometric Analysis with the help of VOSviewer software. The results of the study show The REOL publications are increasing yearly. The results of the VOSviewer analysis shown by network visualization show several emerging keywords (research topics) related to REOL, including electric power systems and reinforcement learning in the first cluster, engineering education and students in the second cluster, laboratories/virtual lab and solar cells/solar energy in the third cluster, and power and wind are in the fourth cluster. The visualization of overlay output results shows several trending research topics, including machine learning, reinforcement learning, deep learning, and virtual power plants. The results of a search on one of the emerging research topics (energy storage) show future work can be done, including measuring student feedback, learning outcomes, the relationship between satisfaction with software simulations, and hardware scenarios required for Smart Grid analysis. The results of this study can guide researchers in the REOL field to select and determine REOL research topics in the future.

Keywords: E-Learning, Online learning, PRISMA-P, Renewable energy, SLNA.

# 1. Introduction

The COVID-19 outbreak has caused a global economic downturn and significantly impacted the higher education system [1]. The sudden closure of campuses as a social distancing measure to prevent the transmission of the epidemic between communities has shifted face-to-face classes to online learning systems [2]. This incident forced all education stakeholders to switch to the use of e-Learning tools and platforms. In post-pandemic situations, e-Learning and virtual learning become integral to the higher education system. Universities need to plan post-pandemic education and research strategies to ensure optimal achievement of student learning outcomes and improvement of educational quality standards [3]. The readiness of universities to prepare online learning infrastructure will make the lecture system more adaptive and flexible. The renewable energy (RE) course is one of the courses affected by the COVID-19 outbreak. This course is designed to provide students with a learning experience in understanding various renewable energy concepts, conducting practical work in the laboratory, field studies, and developing prototype tools that require face-to-face hands-on activities. Covid-19 has changed courses from face-to-face to online mode as Renewable Energy Online Learning (REOL) [4]. Thus, research on developing the REOL mode of recovery must continue to be developed. This study aims to uncover REOL research trends to find future opportunities for developing REOL lectures.

# 2.Literature Review

Renewable energy sources in the world (see Fig. 1) have the potential to provide more than 3000 times the current global energy needs [5]. Education plays an essential role in increasing public literacy related to renewable energy. Since 2005, the implementation of REOL is shown in the performance of e-Learning and virtual laboratories in RE lectures supported by the increasingly massive use of the internet [6]. Modern internet-based learning methods and instruments are in great demand by students and instructors because of their practicality and transparency [7]. E-Learning provides dynamic and creative learning, while virtual laboratories have become a center of creativity that fulfils every thought, even for phenomena that are not accessible [8]. In practice, apart from e-Learning, RE learning can also be packaged through video sharing on the YouTubeTM platform [9] and project-based online learning (e-PBL). Content analysis of the effect of e-PBL on synchronous and asynchronous modes shows students are more comfortable using social interaction sites provided through e-PBL to more freely do collaborative group work outside of campus hours [10]. The online-based format allows for more flexible study times and locations. A possible lack of learning motivation can be addressed by the features of online learning platforms [11].

# 3.Methods

This study used the Systematic Literature Network Analysis (SLNA), which combines Systematic Literature Review (SLR) and Bibliometric Analysis (BA). The SLNA procedure in this study was adapted from previous research [12, 13]. The SLR process in this study adapted the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Protocol [14]. The Bibliometric analysis used VOSviewer software. The PRISMA-P procedure is shown in Fig. 2. The literature search was taken from the Scopus database. The search keywords were "online learning" OR "E-learning" AND "renewable energy". Search articles based on title, abstract, and keywords. The search was conducted in August 2022. The search time is 2004-2022. 2004 was the first article detected by Scopus, and 2022 was the last article at the time of the search.

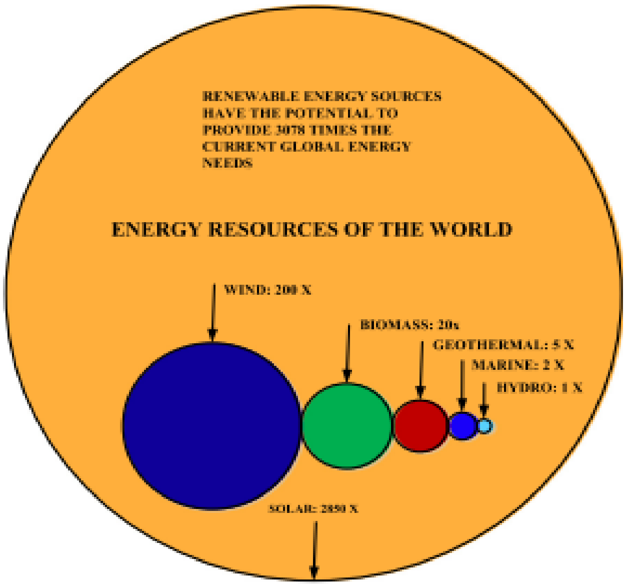


**Fig. 1. Energy resources of the world (adapted from reference [5]).**

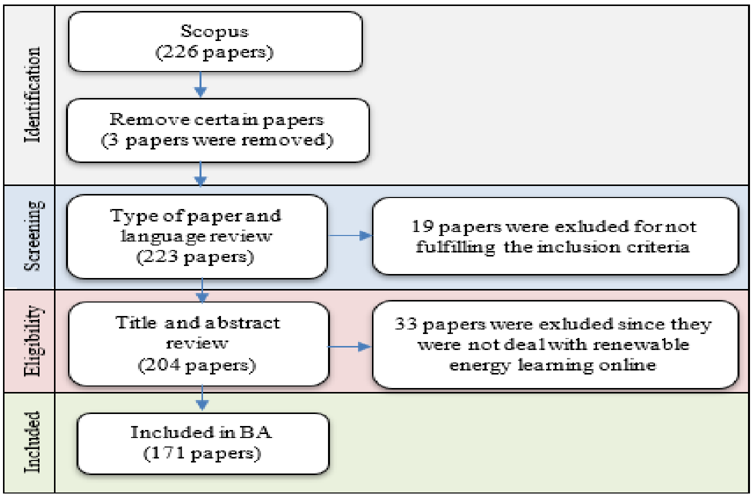


**Fig. 2. PRISMA-P flow diagram.**

## 4. Results and Discussion

226 papers were detected. The first phase of selection is shown in published reports. 3 documents are still in the process of publication (article in press). Thus, they must

be issued for further processing. The next phase is the selection of pepper based on the type. The papers were classified into two types: journals and proceedings. 19 papers were not chosen because they were sourced from conference reviews, book chapters, books, and reviews. The paper processed in the next phase is 204 papers. After going through a detailed review process based on the abstract, only 171 documents would be analyzed through BA.

## 4.1. The state of art map of REOL

The state-of-the-art on the topic of REOL begins with mapping the number of articles (journals, proceedings) indexed by Scopus (2004-2022). The number of articles collected and analyzed was 171 (see Fig. 3). REOL research tends to increase every year. The decline in 2022 is possible because the data access time still leaves four months, and there may be an increase in the number of articles at the end of the year. This fact shows that REOL research still deserves to be carried out. The state-of-the-art of REOL is shown through co-occurrence analysis using VOSviewer to map the relationship between concepts and the strength of the relationship.

Table 1 shows the mapping of clusters and keywords along with the number of repetitions. With a minimum number of keywords, occurrences are 5, from 1,707 keywords, 72 meet the threshold. from 72 keywords divided into 4 clusters (red: 32 items, green:19 items, blue: 13 items, and yellow: 8 items). The colour of each cluster is shown in Fig. 4.

Table 1 shows each cluster has a relatively diverse number of keywords. The strength of the concept or research topic depends on the size of the node (round). Cluster 1 is about electric power systems (27, learning (33), reinforcement learning (28), and renewable energy resources (82). Cluster 2 is about e-Learning (152), engineering education (40), renewable energy (115), and students (39). Cluster 3 is about laboratories (18), solar cells (30), solar energy (29), and a virtual lab (17). Cluster 4 is about electrical engineering (15), power (39), virtual reality (16), and wind (30). Concepts with many repetitions indicate research topics are widely discussed, while the close distance between the two concepts suggests the size of the relationship between the two concepts. For example, virtual power plants have a close relationship with energy storage because of their proximity.

The close relationship between concepts occurs in one cluster, such as machine learning and online systems in the red cluster, renewable energy and engineering education in the green cluster, electrical engineering and education tools in the yellow cluster, and solar cells and electric batteries in the blue cluster. Concept proximity also occurs between clusters such as solar energy (blue) adjacent to e-Learning (green) and renewable energy (red).

## 4.2. The Emerging and Trending Research Topic in REOL

VOSviewer features a visualization of overlays to show research topics, which are old (begin to be abandoned in 2014) and trending (in the 2020s) (see Fig. 5). Examples of trending research topics include machine learning, reinforcement learning, deep learning, and virtual power plants. The old topics include virtual labs, distance education, the internet, and virtual reality.

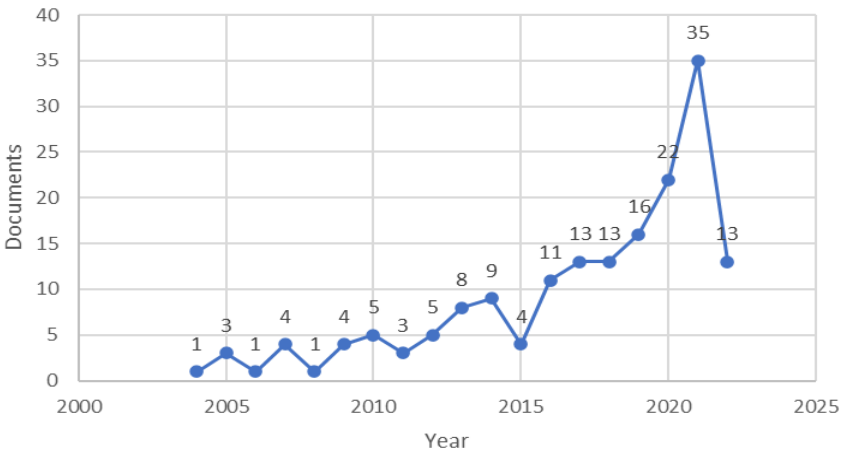


**Fig. 3. Number of Scopus documents on REOL (2004-2022).**

**Table 1. Keywords representing each cluster.**

| No. | Cluster | Keywords |
|---|---|---|
| **1** | **Cluster 1 (32 items)** | alternative energy (7), costs (7), decision making (7), deep learning(19), digital storage (8), distributed computer systems (5), electric power system (27), energy efficiency (10), energy harvesting (9), energy management (16), energy storage (8), forecasting (22), knowledge acquisition (6), learning (33), learning algorithms (16), machine learning (23), Markov processes (6), microgrid (17), model predictive control (5), neural networks (11), online learning (38), online systems (12), optimization (8), reinforcement learning (28), renewable energy resources (82), scheduling (5), smart grid (23), solar radiation (6), stochastic system (11), support vector machine (5), uncertainty (6), virtual power plant (16). |
| **2** | **Cluster 2 (19 items)** | artificial intelligence (7), curricula (20), digital twin (5), e-Learning (152), education (33), education computing (12), energy policy (5), engineering education (40), natural resources (10), personnel training (6), professional aspects (5), project management (5), renewable energy (115), renewable energy technologies (6), students (39), surveys (7), sustainable development (16), teaching (31), websites (5). |
| **3** | **Cluster 3 (13 items)** | distance education (15), educational laboratory (5), electric batteries (10), energy conservations (5), energy conversion (7), fuel cells (6), internet (6), laboratories (18), multimedia (8) systems, remote laboratories (16), solar cells (30), solar energy (29), virtual lab (17). |
| **4** | **Cluster 4 (8 items)** | computer aided instruction (11), educational tool (7), electrical engineering (15), energy utilization (10), Matlab (5), power (39), virtual reality (16), and wind (30). |

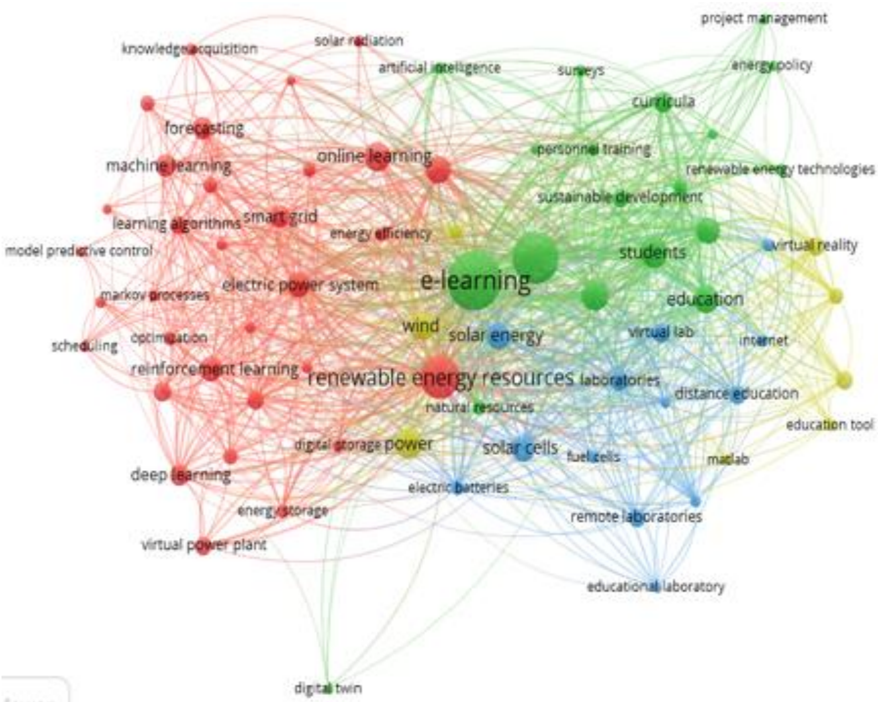


**Fig. 4. Network visualization related to REOL.**

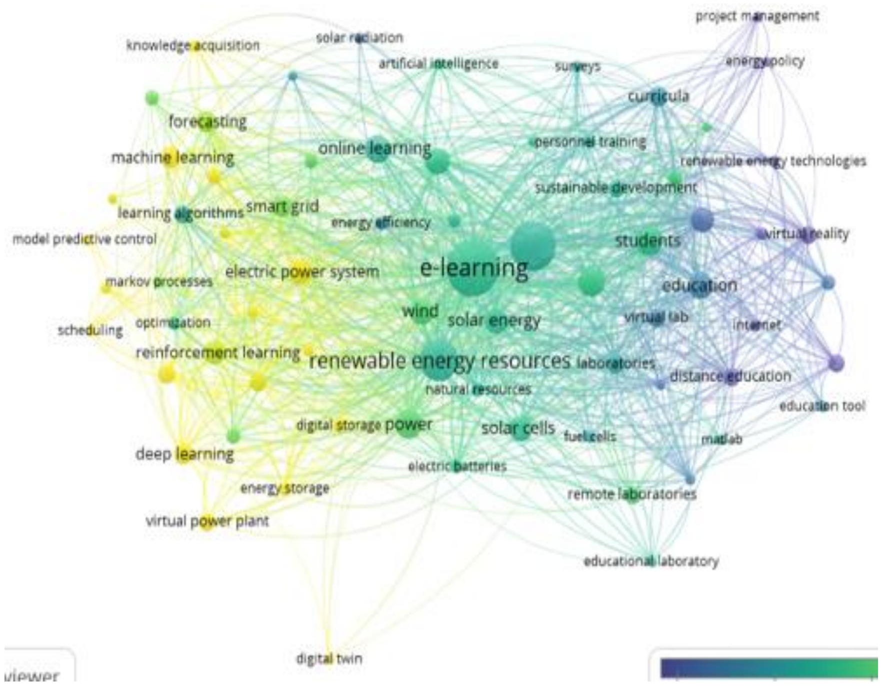


**Fig. 5. Visualization of overlays related to REOL.**

## 4.3. The future work in REOL

Figure 5 shows the direction of future research. Research topics coloured yellow can be enlarged and illustrate the relationship between concepts and the surrounding issues, as shown in Fig. 6. Through the help of Openrefine software, researchers will be easily directed to articles with selected topics. For example, if researchers are looking at future work on energy storage, researchers can type the word energy storage in the keyword search. One article that uses the keyword energy storage is “A multipurpose problem-based learning platform for education and research under the smart grid umbrella” by Haidar et al. published in 2020. Future work on energy storage of the article is found in the conclusions section and future work. The first direction of future studies would be to obtain student feedback and measure the educational outcomes of teaching the subjects under the smart grid umbrella. The second direction of future studies will look at the relationship between satisfaction with software simulations and hardware scenarios required for smart grid analysis to integrate its technologies [15]. This result confirms the effectiveness of bibliometric analysis [16-23] to explore and visualize the current literature that can be used for deciding whether further research be done.

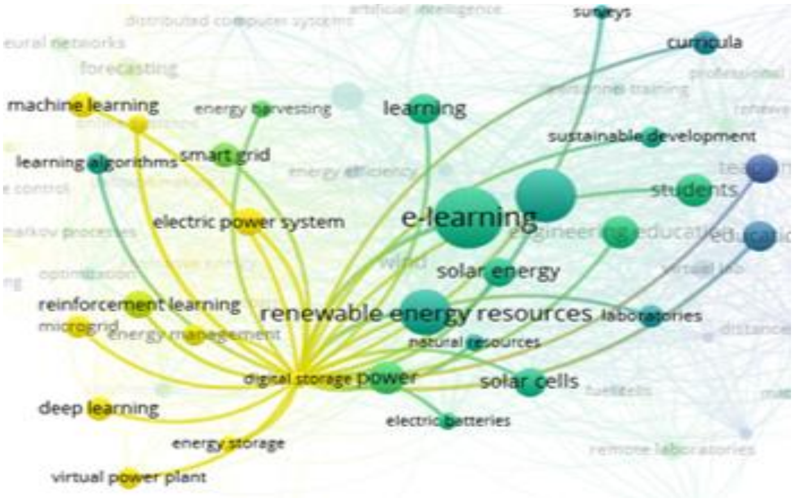


**Fig. 6. The future work about energy storage.**

## 5. Conclusion

This research has succeeded in showing three aspects: (i) research related to REOL shows a positive trend from year to year. Co-occurrence analysis on the VOSviewer feature showed the relationship between the concepts and the strength of the relationship; (ii) the visualization of overlays image shows what research topics are old, starting to be abandoned, and which are still developing and worth researching; and (iii) through SLNA, future work can be taken related to REOL.

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