sustainability

MDPI

Review

A Bibliometric and Scientometric Network Analysis of Occupational Safety and Health in the Electric Power Industry: Future Implication of Digital Pathways

Ka Po Wong [1] and Xiangcheng Meng [2,*]

[1] Department of Applied Social Sciences, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong; portia.wong@polyu.edu.hk

[2] Sub-Institute of Public Security, China National Institute of Standardization, Zhichun Road, Haidian District, Beijing 100191, China

* Correspondence: xcmeng3-c@my.cityu.edu.hk

Abstract: (1) Background: The demand for electricity in rural and urban areas has given rise to numerous related industries, resulting in perilous working conditions and a significant number of safety accidents for workers. In recent years, there has been an increasing focus on improving occupational safety and health in the electric power industry. However, the lack of a systematic review or the integration of disaggregated studies has hindered our understanding of the state of the development of this research field. This study aims to provide bibliometric and scientometric network analyses and explore the untapped potential of digital pathways. (2) Methods: A bibliometric analysis focused on the research cooperation, author keywords, and journal co-citation patterns of studies was carried out, while a temporal trend analysis was employed to identify topical focuses and trends for further research on the occupational safety and health of electrical workers. Papers were searched for across three databases, namely Web of Science, Scopus, and Google Scholar. Using "occupational safety and health" and "electric power industry" as keywords, the articles published from 1991 to 2022 were retrieved. (3) Results: A total of 608 articles published from 1991 to 2022 were collected for the bibliometric analysis. Four clusters were successfully recognized in the search results after adopting the process of cluster analysis based on a total of 608 articles. As for the countries, most of the publications and citations came from the United States. The most frequent keywords were safety, exposure assessment, electrocution, and electrical injury. (4) Conclusions: This is the first study to highlight occupational safety and health in the electric power industry and provides valuable insights into the knowledge structure, emerging trends, and future directions through the lens of digital pathways. This study sheds light on the importance of digital pathways in enhancing occupational safety and health practices within the industry. The findings contribute to the fields of occupational safety management and health promotion, providing a foundation for future research and interventions aimed at improving safety conditions and promoting the well-being of personnel in the electric power industry.

Keywords: occupational safety and health; bibliometric analysis; scientometric network; electric power industry; digital technologies; internet of things

Citation: Wong, K.P.; Meng, X. A Bibliometric and Scientometric Network Analysis of Occupational Safety and Health in the Electric Power Industry: Future Implication of Digital Pathways. *Sustainability* **2024**, *16*, 5358. https://doi.org/10.3390/su16135358

Academic Editors: Tianan Yang, Jianwei Deng and Ran Liu

Received: 20 May 2024
Revised: 18 June 2024
Accepted: 20 June 2024
Published: 24 June 2024

1. Introduction

The electric power industry poses significant risks to workers, with a wide range of hazards such as electrocution, electric shock, burns, and falls [1,2]. These hazards have resulted in severe injuries and fatalities, making electricity a leading cause of occupational injuries and deaths. For instance, in the United States, electricity is the fifth leading cause of occupational injury death (7% of all workplace fatalities), posing a particular hazard to workers who regularly work in proximity to power sources [3]. Liu et al. [4] reported that electrocution accounted for 14.6% of all fatal accidents in Taiwan and was the second leading cause of occupational fatalities after falls (30%). Additionally, the Occupational Safety and Health Administration reports data showing an average of 12,976 lost workday accidents and 86 fatal accidents per year related to workers in the power generation, transmission, and distribution industries [2]. The economic costs associated with poor health records and electrical accidents are substantial, impacting workers, employers, insurance companies, and society at large [5,6].

In recent years, there has been a growing recognition of the importance of occupational safety and health in the electric power industry for the sustainable development of organizations [7,8]. Previous studies have accumulated knowledge of hazard scenarios and effective management measures to address these hazards [9,10]. Narine [11] highlighted four key risk scenarios associated with serious accident triggers: direct contact with live power sources; improper wearing of protective equipment; improperly installed or damaged equipment; and unsafe operation and unconsciousness of personnel. Safety interventions, such as the "Knowledge-driven Recognition Methodology" and the "Improved Bode Accident Causation Model", have been implemented to mitigate hazards in the electrical power industry [1,12]. Additionally, various occupational health studies have identified key causes of accidents and occupational diseases, such as unsafe equipment or installation, undesirable environment, and improper work practices [13], leading to interventions like the "Workplace Wellness Program" and the "Health in Working Life Program" [14] to mitigate and reduce health hazards affecting the electrical workforce.

Occupational safety and health aim to prevent workplace hazards, eliminate diseases, and ensure the well-being of individuals [15,16]. In the electric power industry, occupational safety and health is a significant issue, both legally and economically. It requires a comprehensive understanding of the scientific developments in the area. While narrative analyses are commonly used in literature reviews related to this aspect, they can be subjective and biased [17]. On the other hand, scientometric analysis approaches provide a transparent, reproducible, and principled assessment of research areas [18]. However, these approaches have not been used yet in the assessment of electrical safety and occupational health. Furthermore, despite the advancements in digital technologies that have revolutionized various industries, their potential impact on enhancing safety and health practices in the electric power sector remains relatively unexplored.

To address these concerns and gaps, this study conducted a bibliometrics-based systematic review using scientific mapping and scientometric network approaches to analyze the research field of occupational safety and health in the electric power industry. The specific objectives of this study are (1) to analyze the influential journals, keywords, regional cooperations, and research states using a scientific mapping approach; (2) to uncover existing trends, patterns, and interconnections of relevant research themes; (3) to discuss the existing research limitations or gaps; and (4) propose a research framework to guide future implications of digital pathways. This review-based study aims to provide researchers and practitioners with a systematic and quantitative overview of potential research frontiers and recommendations for future research in the field of occupational safety and health in the electric power industry.

2. Materials and Methods

This study adopted a three-part analytical approach to conduct a systematic literature review, summarize the research areas, and identify promising research trends in and perspectives of occupational safety and health studies related to the electric power industry. The scientific mapping approach was used to achieve bibliometric analysis and scientometric visualization. The review process followed a three-step approach, namely, literature collection, scientometric analysis, and qualitative discussion.

2.1. Literature Collection

The first step of the review was a bibliometric search across three different databases, namely Web of Science, Scopus, and Google Scholar. Bibliometrics is a research method that uses quantitative analysis and statistics to study and measure patterns within academic publications, such as journals, articles, and citations. By employing bibliometric techniques, the researchers were able to systematically identify and retrieve relevant literature for the study [19]. Using "occupational safety and health" and "electric power industry" as keywords, the articles published from 1991 to 2022 were retrieved, and a total of 1091 articles were retrieved. These articles were further screened by removing conference papers with low-value or non-useful information [19]. Afterwards, 827 papers remained in the literature sample. The scope of collected papers was further narrowed as this review mainly deals with people-centered safety and occupation health issues in the electric power industry. Some papers involving irrelevant issues, such as grid structural safety and material safety for power station construction, were excluded. Ultimately, a total of 608 journal articles were selected as literature samples for the subsequent scientometric analysis.

2.2. Scientometric Analysis

The next step involved a scientometric analytic method, applying four powerful text-mining tools for co-citation and co-occurrence analysis to visualize and explore the current states and emerging trends in the research domain, i.e., VOSViewer version 1.6.3, Gephi version 0.9.2, Pajek 64, and CiteSpace version 5.7.R2 [20,21]. The scientometric analysis combined two key methodological approaches: scientific mapping and scientometric network analysis. Scientific mapping techniques, such as co-citation and co-occurrence analysis, were used to create distance-based visualizations of the knowledge structure. These visualizations, generated through VOSViewer and Gephi, depict the relationships between influential publications, authors, and research themes, with the distance between nodes representing the degree of similarity [17]. In parallel, scientometric network approaches were applied using Pajek and CiteSpace to examine the temporal evolution and research milestones within the domain. The main path detection functions in these tools allowed the researchers to trace the development of prominent research topics and their interconnections over time [22]. Additionally, HistCite (version 2.0) was utilized to perform basic statistical analyses on the publication metadata, such as publication years, countries, and journals in terms of key indicators of knowledge domain development. The study applied the global citation index to represent the impact of cumulative publications on a topic.

2.3. Qualitative Discussion

Although bibliometric analysis can analyze a large set of data and provide general publication trends in a specific domain, it does not provide detailed information on research content [23]. Therefore, a content analysis was further performed to gain insight and explore the temporal evolutions of research topics [18]. Based on the scientometric analysis conducted in the previous step, the subsequent qualitative discussion aims to provide an in-depth evaluation of the main research objectives related to the mainstream research topics, current research gaps or limitations, and recommendations for future work in the field of occupational safety and health in the electric power industry. Finally, a research framework linking the identified research topics to future perspectives and directions is proposed for researchers and practitioners in academia to continue related research work. Figure 1 shows a flow diagram of the scientometric network analysis.

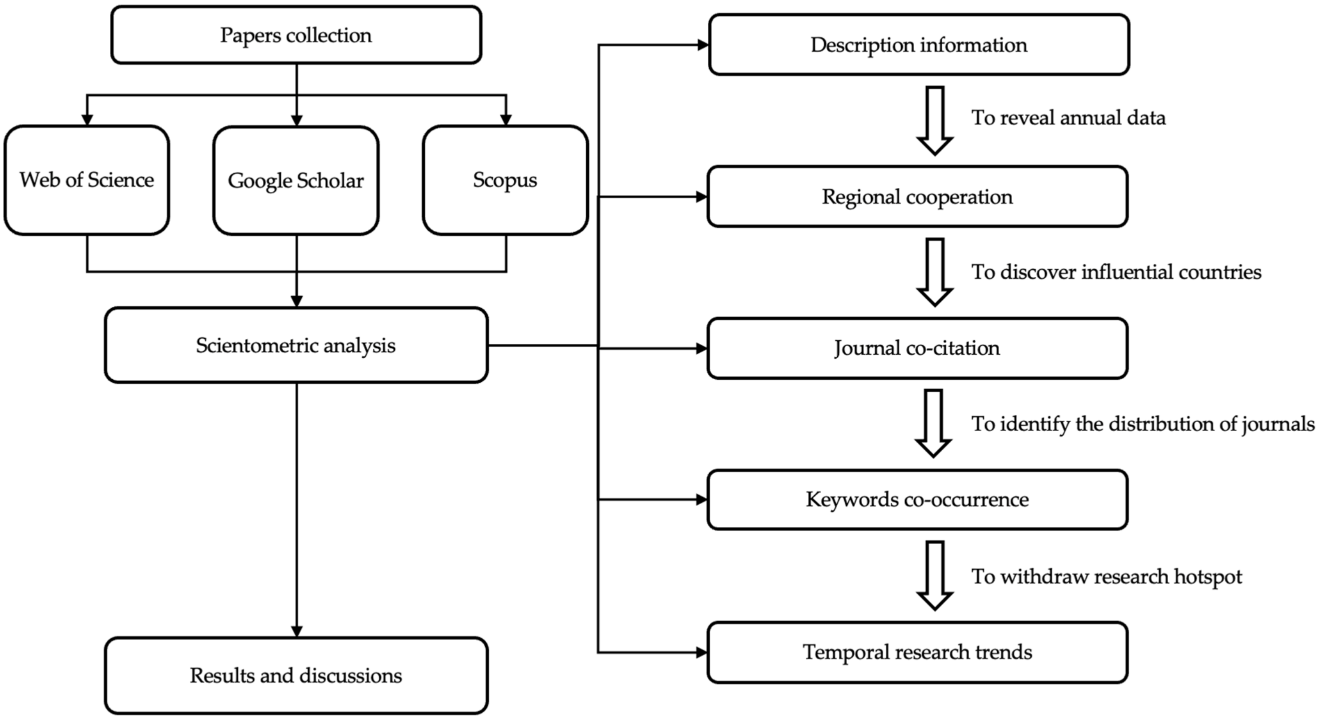


Figure 1. Flow diagram of the scientometric network analysis.

3. Results

3.1. Descriptive Data Analysis

The distribution of the annual publication of papers from 1991 to 2022 is shown in Figure 2, which shows that, since 1991, scholars have gradually paid more attention to the occupational safety and health of personnel in the electric power industry. A remarkable development was observed between 2015 and 2019, with an incredible increase in publications over this period. The highest number of publications was observed in 2019, with 40 articles published in one year. The increase in the number of papers indicates that the research on occupational safety and health in the electric power industry has attracted widespread attention from scholars and has become an important part of electric power safety research.

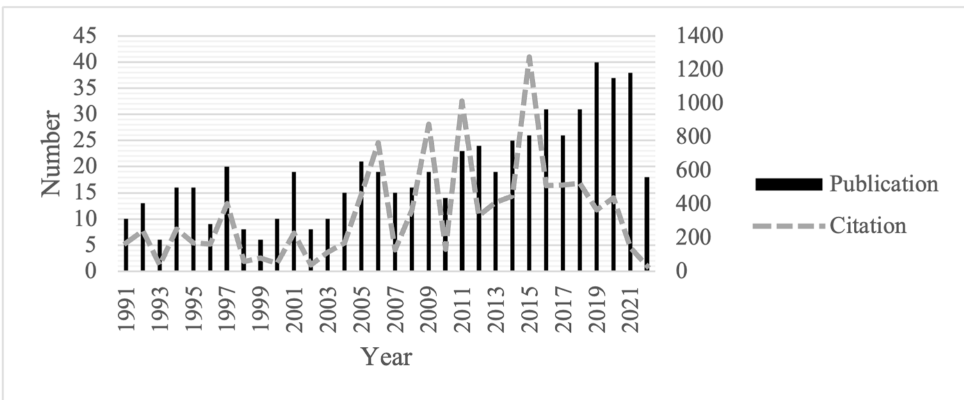


Figure 2. Distribution of paper publications and global citations between 1991 and 2021.

The high number of citations worldwide is a testament to the flourishing nature of this excellent research. A total of 608 articles were collected which received 18,974 citations worldwide, with an average of 32 citations per article. Despite some fluctuations, global citations are on the rise. The average number of citations per paper peaked at a record of 50 in 2015, before arguably decreasing due to the time it takes for the cumulative effects of new publications to take effect (shown in Figure 2).

3.2. Countries/Regions Cooperation Analysis

The scope of research cooperation between countries and regions demonstrates the global attention to and international influence of occupational safety and health research related to the electric power industry. A total of 70 countries/regions were represented by the 608 papers, of which 68.57% published more than one paper between 1991 and 2022. Figure 3 shows the top 17 countries with the most prolific paper publications (at least 10 papers) and their global citations, indicating the number of times all papers have been cited worldwide. Productive countries that contribute more papers contributions tend to perform higher in global citations. For instance, the United States leads the research field with 180 articles published and is also the highest in terms of global citations (3964), indicating its dominance in the field of occupational safety and health research in the electric power industry.

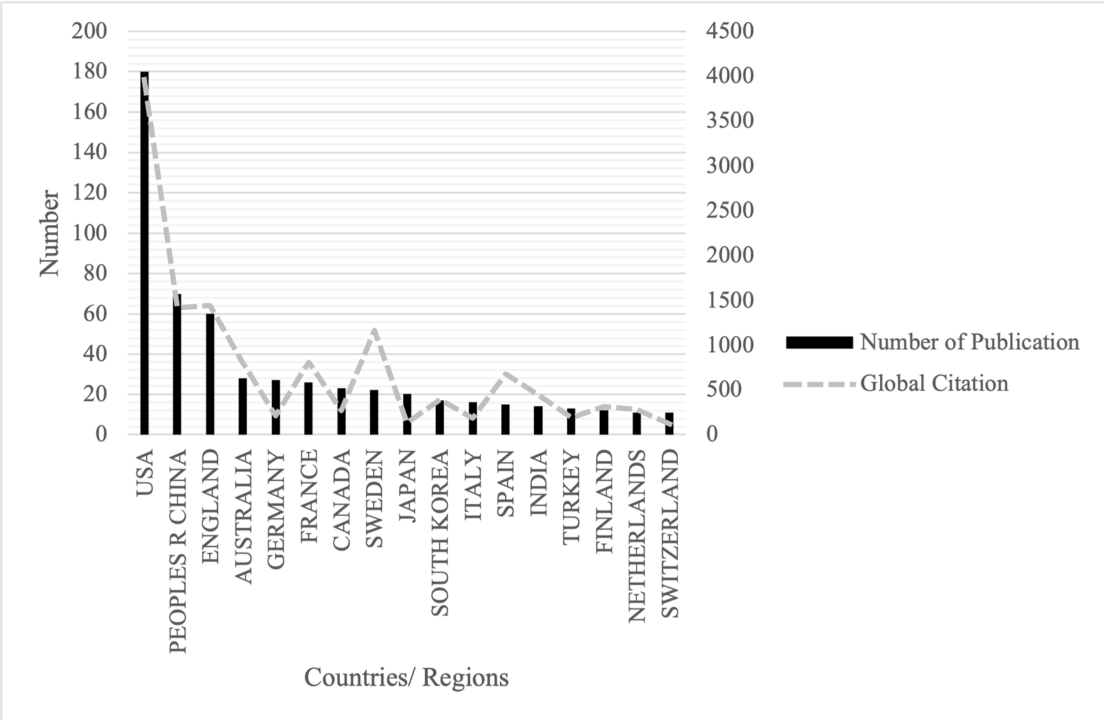


Figure 3. Top 17 most productive countries for paper publication in global range.

Gephi was applied to visualize the cooperative relationships between countries and regions. The threshold was set to six, which meant that countries or regions with less than six papers were not included in the cooperation analysis. Finally, 26 countries remained in the scientometric network, as shown in Figure 4. The size of the nodes and the thickness of the edges were determined by the software-generated weighting degree, consistent with the citation relationships between countries [24]. As indicated by larger node sizes and thicker edges, the United States, China, and England were identified as three influential countries with frequent international cooperation with other countries such as Canada, Switzerland, Spain, France, Sweden, etc. China is one of the developing countries that can be seen to be among the leading contributors and active cooperators given the remarkable node size and edge thickness. With rapid economic development and the huge growth in the demand for electricity and electricity consumption in the past few decades, the Chinese government and society have attached great importance to the occupational safety and health of labors in the electric power industry to obtain a sustainable and robust workforce in specific industries [25]. Meanwhile, most developing countries, such as Nigeria, Turkey, India, Brazil, and Iran, play a smaller role, as can be seen from their ties in the cooperation network, and have less impact on outcomes. However, considering the development background of energy consumption, population explosion and electricity supply demand, the occupational safety and health of electrical personnel is worthy of attention.

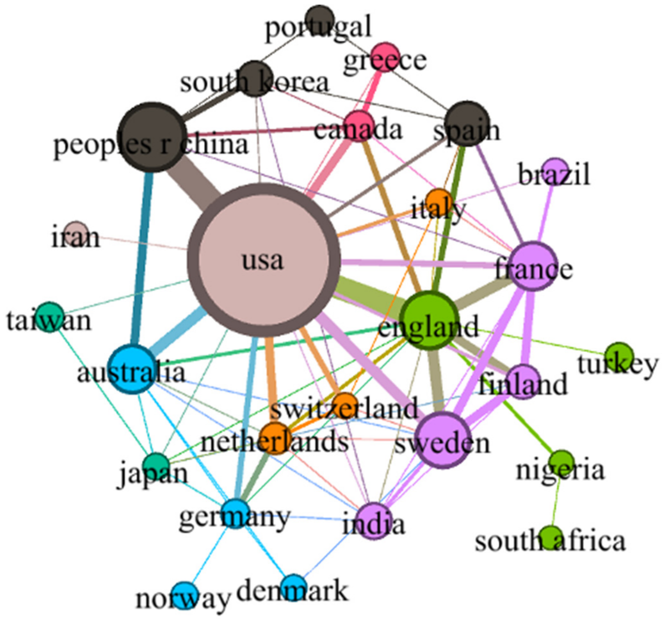


Figure 4. Countries' cooperation network in occupational safety research of electricity personnel.

3.3. Journal Co-Citation Analysis

The 608 selected articles were published in 257 different journals, most of which published only one paper (61.74%). The visualization of the journal co-citation network was implemented using Gephi, and only the top 20 journals with the most co-citation relationships were included in the co-citation network. Table 1 lists the top ten productive journals according to weighted link strength. The weighted degree yielded by Gephi reflects the centrality of each node in the network, which is equal to the sum of the edge weights associated with a given node [26]. The higher the weight, the greater the influence of a node in the research field.

Table 1. Top 10 productive journals in co-citation network.

Name of Journal	Impact Factor (2021)	Global Citation	Weighted Link Strength
International Journal of Environmental Research and Public Health	4.614	168	10
Safety Science	6.392	694	8
American Journal of Industrial Medicine	2.214	165	8
Occupational And Environmental Medicine	4.948	460	5
Journal of Occupational and Environmental Hygiene	3.359	264	5
IEEE Transactions on Industry Applications	4.079	190	5
Journal of Safety Research	4.264	124	4
Work-A Journal of Prevention Assessment & Rehabilitation	1.169	34	4
Journal of Cleaner Production	11.07	352	2
Energy	8.857	26	2

Figure 5 shows the co-citation network layout for two clusters grouped by the theme of the journals, namely safety engineering in industrial practice (10 papers in red) and occupational health and treatment of the personnel (10 papers in blue). Each node represents a particular journal, and its size was determined by the strength of the link with the corresponding publications.

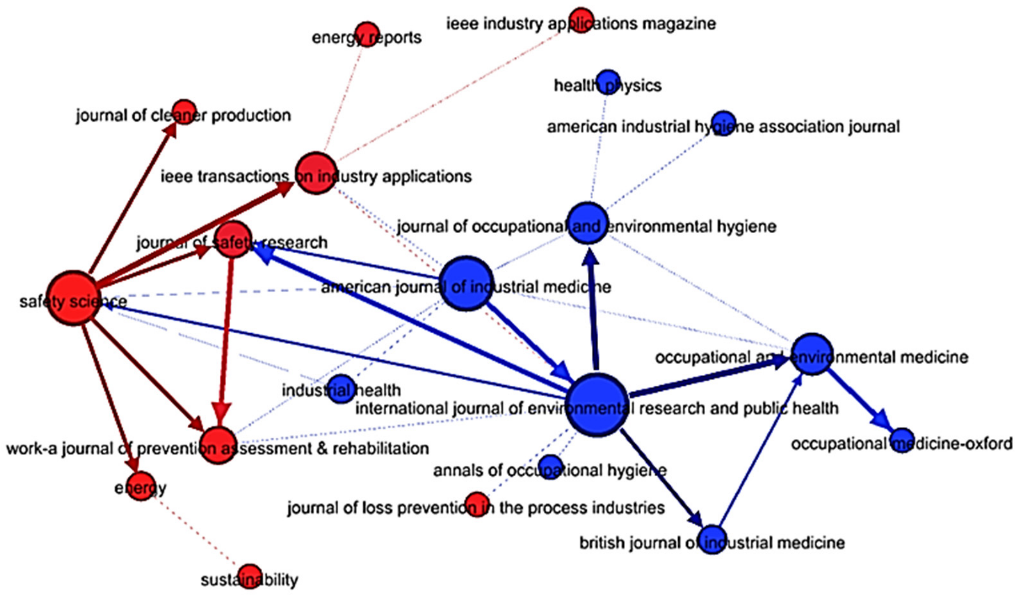


Figure 5. Journal co-citation network of occupational safety and health of electrical personnel.

As shown in Figure 5, *Safety Science* is the leading journal in cluster 1 (red), consistent with the strength of its links with other journals. The significant citation relationships between *Journal of Safety Research*, *Work-A Journal of Prevention Assessment and Rehabilitation*, *IEEE Transactions on Industry Application*, *Journal of Clean Production*, and *Energy* indicate that there are further research topics related to safety engineering combined with the new energy revolution, industrial injuries prevention assessment, and rehabilitation and its application in industrial management.

In cluster 2 (blue), *International Journal of Environmental Research and Public Health* is the core journal given its substantial information outflows (through citation relationships) to *Occupational and Environment Medicine*, *British Journal of Industrial Medicine*, *American Journal of Industrial Medicine*, and *Journal of Occupational and Environmental Hygiene*. The existing co-citation relationships highlighted promising research topics in the field of occupational treatment, specific drug development, and environmental hygiene management in the electric power industry.

The role of *International Journal of Environmental Research and Public Health* and *American Journal of Industrial Medicine* should be emphasized as they created information outflows between the two clusters by linking to the significant co-citations of *Safety Science* and *Journal of Safety Research*.

3.4. Keywords Co-Occurrence Analysis

Keyword co-occurrence helps us to examine the internal correlations between studies and discover promising research topics using VOSViewer and Gephi. The co-occurrence of the author's keywords constituted the network linkage between different nodes. A total of 217 author-specified keywords were extracted from 608 papers based on bibliometric data. The threshold of keyword co-occurrence was set to more than three times to remove insignificant correlations, and eventually, 76 keywords remained. Figure 6 depicts the layout of the keywords co-occurrence network drawn by VOSViewer. Four clusters were generated based on the proximity of various topics related to the occupational safety and health of electrical personnel. The four clusters are shown in Figures 7–10.

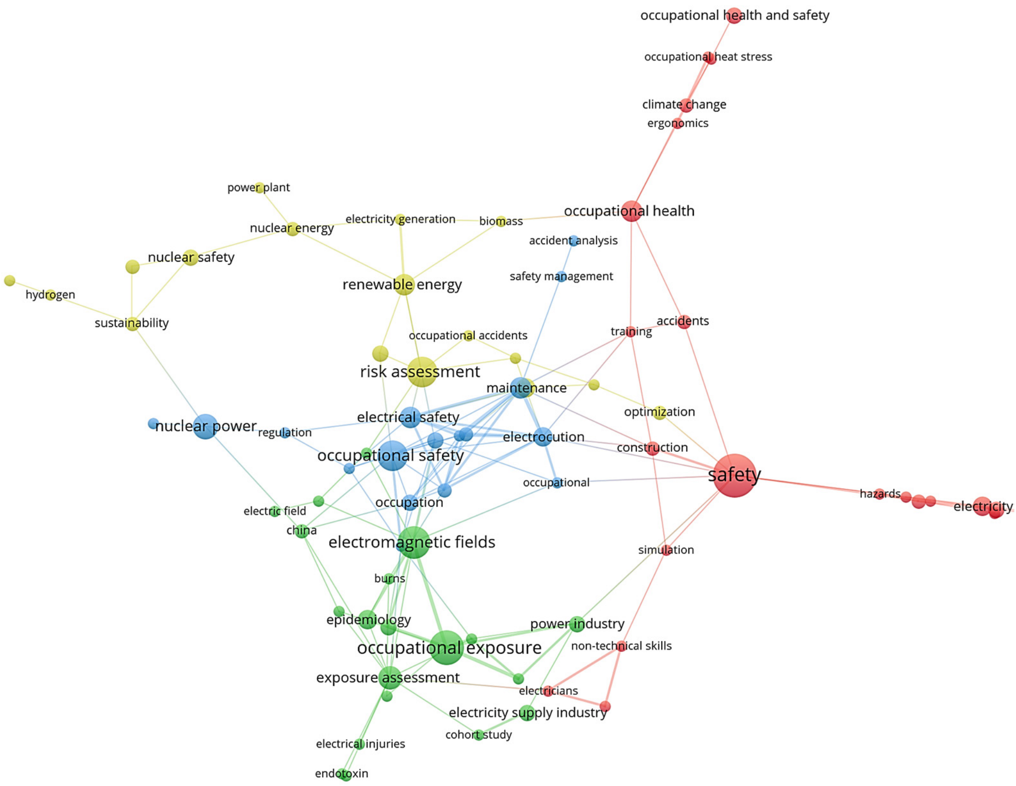


Figure 6. Co-occurrence network for author keywords of collected papers.

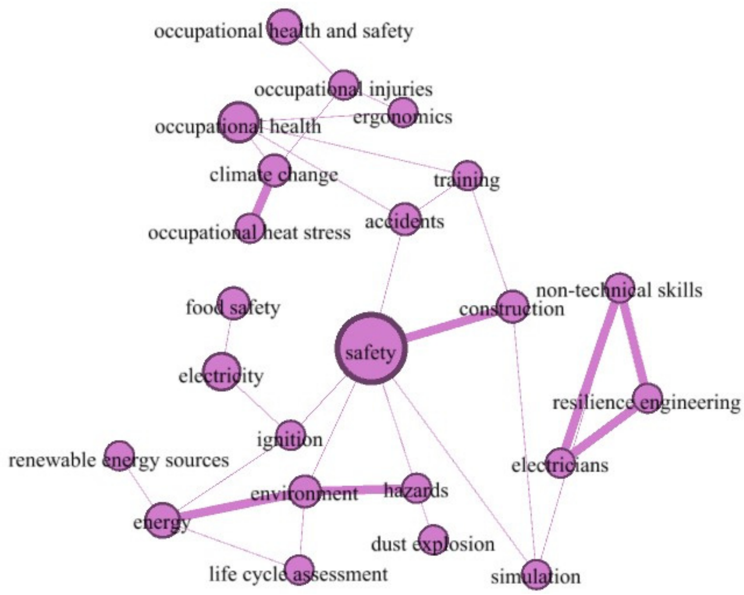


Figure 7. Cooccurrence network of author keywords in cluster 1.

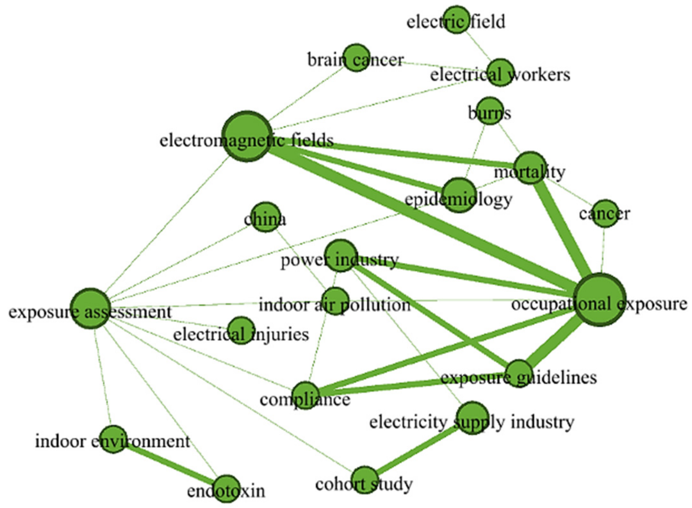


Figure 8. Cooccurrence network of author keywords in cluster 2.

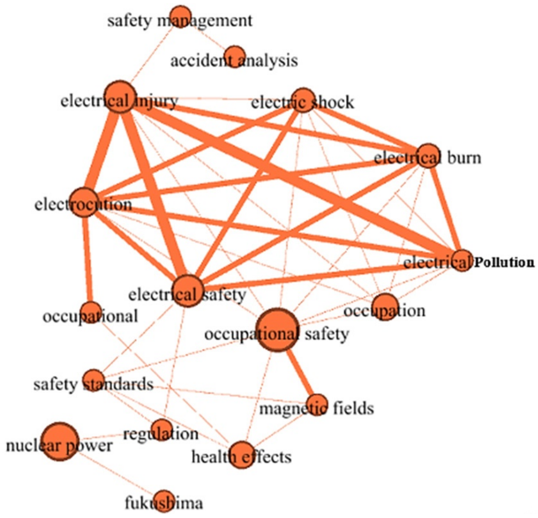


Figure 9. Cooccurrence network of author keyword in cluster 3.

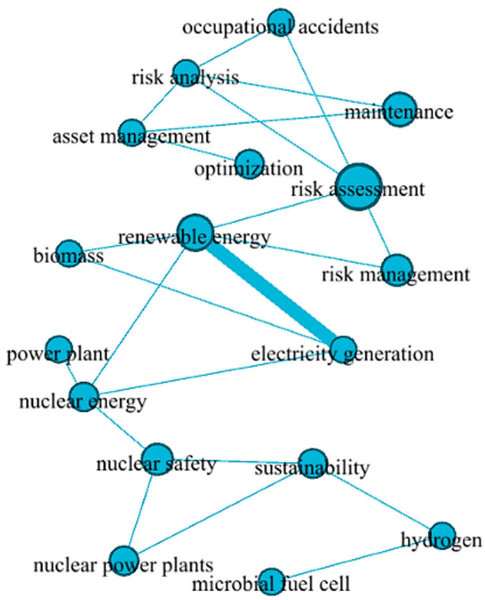


Figure 10. Keywords cooccurrence network in cluster 4.

Gephi was further applied to subdivide the entire network based on clustering. Figure 7 shows the keywords in cluster 1, which are mainly related to safety, accidents, and hazards in the electric power industry. Specifically, the research topics covered by the cluster highlighted the focus on the dominant factors in the subjectivity of and possible solutions to safety accidents in the electric power industry. For instance, occupational heat stress caused by adverse climate change and insufficient technical skills can lead to personnel accidents and illness among indoor and outdoor electricians. Ignition and dust explosions during power generation can cause personnel injuries. Furthermore, within this cluster, "ergonomic simulation," "safety training", "life cycle assessment", and "resilience engineering" represent potential solutions that can mitigate the occurrence of safety accidents in the electricity industry.

As shown in Figure 8, cluster 2 mainly covers studies related to occupational exposure and the major diseases in the electric power industry. Epidemiological research has demonstrated there are correlations between unhealthy occupational exposures of electrical workers to air pollution, toxicity, the electromagnetic environment and negative body injuries and diseases, such as cancer, burns, endotoxin contamination, and brain disease. Considering the severity of occupational diseases (cardiovascular and respiratory diseases, lung cancers, diabetes) among electricians in China, the regional situation in China is highlighted. Workers in the power supply industry typically perform a significant amount of outdoor circuit operation and maintenance during shift time and are therefore more vulnerable to unsafe occupational exposures. Previous studies have proposed some key points to eliminate negative occupational exposures to risk sources, namely exposure assessment, cohort studies, exposure guidelines, etc.

The keywords in cluster 3 are shown in Figure 9, which can be further summarized as electrical accident management, including "electrocution", "electrical shock", "magnetic field radiation", "electrical burn", and "electrical pollution". Specifically, fatal and nonfatal electric shocks are often the result of improper procedures and inadequate protective equipment. Magnetic field radiation from adverse occupational exposure often causes serious illnesses such as dizziness, fatigue, palpitation, and anemia. Electric shock burns caused by common reasons such as voltage fluctuation, short circuits, and poor heat dissipation can cause huge amounts of damage to property and risk human safety. Electrical pollution from arcing, dust, and toxic radioactive substances can cause irreversible damage to the lungs, trachea, blood, skin, eyes and nervous system. Scholars have proposed a variety of ideas and solutions to mitigate the occurrence of electric shock injuries. Safety management through accident analysis has attracted the attention of researchers. Establishing safety standards and regulations is an effective way to avoid occupational safety accidents in the electric power industry.

Figure 10 demonstrates that the keywords included in cluster 4 are related to risk management in the renewable energy revolution, especially in the power generation industry. Safety management in the nuclear power industry has been emphasized many times. Nuclear pollution is impalpable, irreversible, and extremely harmful to human organs. For instance, nuclear radioactivity produced by improper waste disposal cannot be eliminated by ordinary physical, chemical, and biological methods, thus causing irreversible damage to the blood system, reproductive system, and digestive system. The key processes within risk management include risk assessment, risk analysis, optimization, and maintenance. The authors also focus on the sustainability and renewability of electricity energy applications. In recent years, biomass, microorganisms, and hydrogen power generation have shown a growing trend in industrial applications. Considering the uniqueness of these two fields, that is, the explosiveness and vulnerability of leakage, the occupational safety and health issues affecting electrical personnel should be highly valued.

3.5. Temporal Trend Analysis

To further verify the temporal evolution of the research topics implied in the keywords analysis, the burst detection program provided by the CiteSpace software was carried out to examine the strength of the burst terms extracted from the four clusters. Terms with a strong burst strength represent a significant short-term growth and often herald the emerging trends of research topics. Pajek 64 was adopted to pre-identify key research topics within each cluster. The weight of the strength of each keyword was calculated using the equation below [27]:

$$\mathrm{Weight_{ij}} = \frac{\mathrm{TP_{ij}}}{\mathrm{TSS_j}}$$

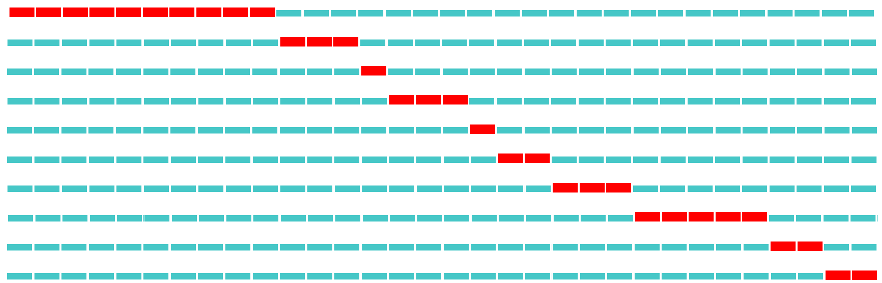
where $\mathrm{TP_{ij}}$ is the aggregate of paths in network j, including keyword i, and $\mathrm{TSS_j}$ is the sum of paths between the origins and terminuses in network j. Specifically, 10 strong burst terms were identified in each cluster.

Table 2 presents the burstiness of key research topics in cluster 1 from 1991 to 2022. In the field of safety and ergonomics in the electric power industry, scholars have paid great attention to the safety issues of electricians, given the explosive dominance of the keywords "Safety" and "Electricians" from 1991 to 2003. Key issues and underlying dominant factors were identified by previous studies from 2004 to 2008, namely, "Occupational heat stress" (2004), "Ignition" (2005–2007), and "Dust explosion" (2008). Accordingly, researchers began to consider the combination of "Ergonomic" theories and techniques with the safety development of electrical personnel during 2009–2010, and frequently developed safety intervention programs. Among the terms with a high burst strength are "Simulation (2011–2013) and "Training (2014–2018)". Over the past few years, there has been increased interest in innovative technologies to improve the accuracy and efficiency of electrical safety intervention training and education. This was consistent with the strong burst terms "Life cycle assessment (2019–2020)" and "Resilience engineering (2021–2022)".

Table 3 shows the temporal trend of research topics in cluster 2 and the top 10 research topics involved in the keywords network. The outbreak of the keyword "Epidemiology" from 1991 to 1993 and the keyword "Cancer" in 1994 made the trend of occupational exposure issues relevant started the trend for epidemiological research on the occupational health of and diseases affecting electrical workers. Shortly after, researchers found the impact of adverse "Occupational exposure" (1998–2002) on electrical workers in environments as affected by "Indoor pollution" (1995–1996) and "Endotoxin" environments (1997). Therefore, given the burstiness of the terms "Exposure assessment" (2003–2010) and "Exposure guideline" (2011–2012), researchers set out to find solutions to eliminate unsafe occupational exposure using quantitative assessments and work guidelines. The specific vulnerability to exposure of personnel in "Electromagnetic" work fields was highlighted (2014–2021) given the negative impact of radiation on the human body. In addition, considering the strong outbreak of the keywords "Electricity supply industry" in 2022, workers in the power supply industry were proved to suffer from a significant amount of occupational exposure in hazardous environments.

Table 2. Burstiness of key research topics in cluster 1.

Keywords	Strength	Start Year	End Year	Burstiness (from 1991 to 2022)
Safety	10	1991	2000	
Electrician	3	2001	2003	
Occupational heat stress	1	2004	2004	
Ignition	3	2005	2007	
Dust explosion	1	2008	2008	
Ergonomic	2	2009	2010	
Simulation	3	2011	2013	
Training	5	2014	2018	
Life cycle assessment	2	2019	2020	
Resilience engineering	2	2021	2022	



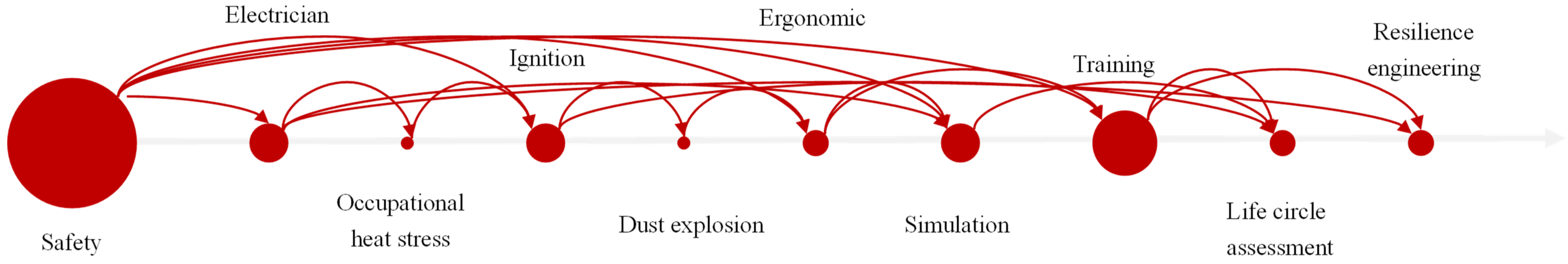
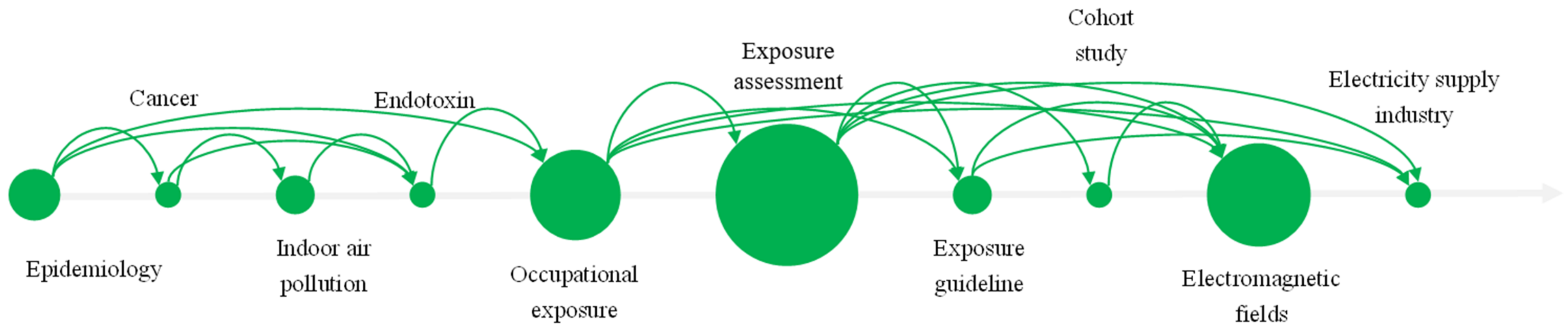


Table 3. Burstiness of key research topics in cluster 2.

Keywords	Strength	Start Year	End Year	Burstiness (from 1991 to 2022)
Epidemiology	4	1991	1993	
Cancer	2	1994	1994	
Indoor air pollution	3	1995	1996	
Endotoxin	2	1997	1997	
Occupational exposure	7	1998	2002	
Exposure assessment	11	2003	2010	
Exposure guideline	3	2011	2012	
Cohort study	2	2013	2013	
Electromagnetic fields	8	2014	2021	
Electricity supply industry	2	2022	2022	



For cluster 3, Table 4 describes the burstiness of the keywords from research topics related to the causality and prevention of critical electrical injuries. Previous studies have already focused on eliminating fatal electric shock injuries among industrial workers from 1991 to 1995, given the outbreak of the keywords "Electrical injuries" and "Electrocution" over the corresponding period. Three hazardous factors were identified from 2002 to 2013, namely "Electric shock" (2002–2005), "Electrical burns" (2006–2009), and "Electrical pollution" (2010–2013). To eliminate these negative problems, scholars began to formulate a safety management system for the electrical industry based on the accident analysis of essential injuries and unsafe issues, which was consistent with the strong burst terms "Accident analysis" (2014) and "Safety management" (2015). The necessity of "Regulation" (high burstiness during 2016–2017) and "Safety standard" development (2018–2020) has recently attracted considerable interest among scholars to facilitate the efficiency and feasibility of electrical safety management and injury prevention, especially in the "Nuclear power industry", with high risks of potential radiation hazards to personnel (2021–2022).

Finally, Table 5 lists the 10 most important research topics and their burstiness during the period 1991–2022 in cluster 4, mainly focusing on risk management within the renewable energy generation revolution. The concept of "risk management" in the "Electrical generation industry" has been attracting scholars' attention since 1991. Due to the periodic burstiness of corresponding keywords, it did not appear to experience large-scale proliferation until 1996. Since 1997, research on renewable energy innovation in electricity generation has further become an academic hotspot, followed by the application of emerging energy resources like "Nuclear energy" (2003), "Hydrogen energy" (2007), "Biomass energy" (2009), and "Microbial fuel" (2012). In view of the above-mentioned characteristics of renewable energies, the hazard assessment and sustainable optimization of renewable energy power generation were then frequently explored, as shown by the strong burst terms "Risk analysis (2013–2018)", "Optimization (2019–2020)", and "Sustainability (2021–2022).

Table 4. The burstiness of key research topic in cluster 3.

Keywords	Strength	Start Year	End Year	Burstiness (from 1991 to 2022)
Electrical injury	10	1991	1995	
Electrocution	12	1996	2001	
Electric shock	8	2002	2005	
Electrical burns	8	2006	2009	
Electrical pollution	7	2010	2013	
Accident analysis	2	2014	2014	
Safety management	1	2015	2015	
Regulation	3	2016	2017	
Safety standard	5	2018	2020	
Nuclear power	4	2021	2022	

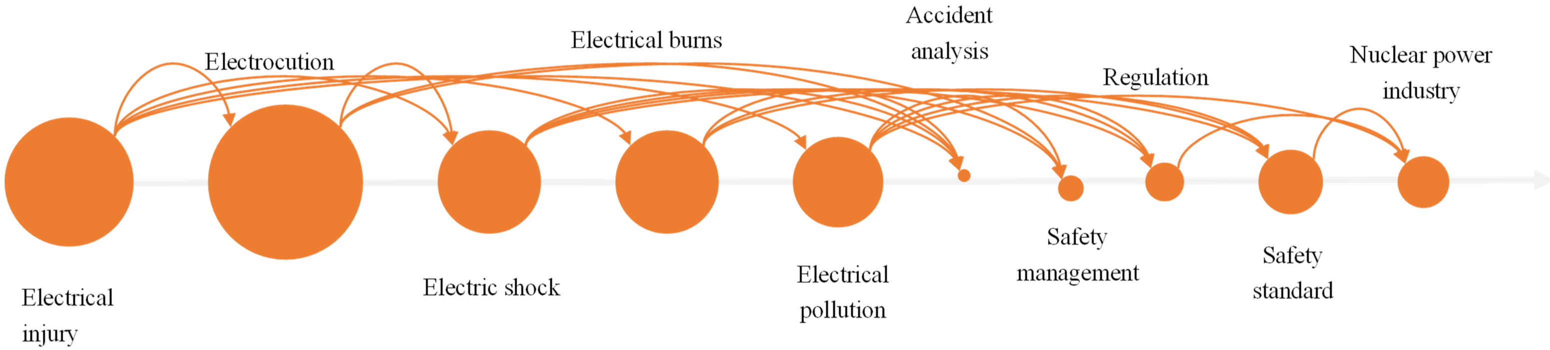
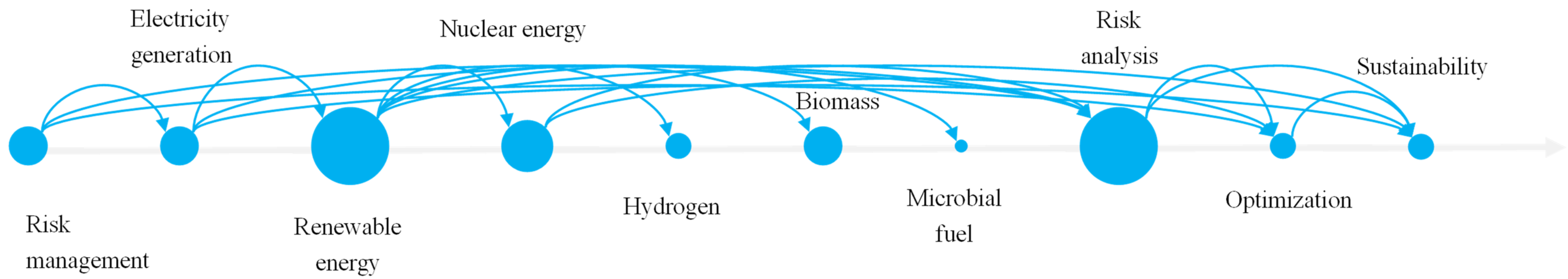


Table 5. The burstiness of key research topic in cluster 4.

Keywords	Strength	Start Year	End Year	Burstiness (from 1991 to 2022)
Risk management	3	1991	1993	
Electricity generation	3	1994	1996	
Renewable energy	6	1997	2002	
Nuclear energy	4	2003	2006	
Hydrogen	2	2007	2008	
Biomass	3	2009	2011	
Microbial fuel	1	2012	2012	
Risk analysis	6	2013	2018	
Optimization	2	2019	2020	
Sustainability	2	2021	2022	



4. Discussion

Following the bibliometric analysis and scientific mapping of the selected literature, an in-depth qualitative discussion was conducted, focusing on summarizing the main research themes and trends within the topics of occupational safety and health in the electric power industry, identifying the existing research gaps and limitations, and proposing a framework that establishes meaningful connections between the existing research topics and the future implications of digital pathways aimed to safeguard workers, mitigate risks, and revolutionize safety management in the electric power industry. This framework serves as a valuable resource for guiding future research endeavors and informing the development of effective strategies for implementing digital pathways to enhance safety and health outcomes.

4.1. Emerging Research Topics and Trends

The results for the regional cooperation, co-citation networks, and the four clusters identified from the keywords co-occurrence analysis are not separated. In contrast, all the quantitative retrospective outcomes involved strong correlations. For instance, risk assessments and ergonomic safety were ways of mitigating electrical hazards and injuries and were interrelated to be applied in electrical safety management, although a risk assessment is the process of hazard identification, risk evaluation and analysis, hazard elimination and risk control, while ergonomic safety is the design of the tools, methods, and environments workers use to suit their job requirements and capabilities. Continuing from the scientometric mapping and temporal trends analysis, the mainstream research topics related to the occupational safety and health of electrical personnel are summarized below.

4.1.1. Safety Management: Causes and Prevention

Multiple studies have focused on identifying the accidents and hazards in different workplaces and exploring the root causes of these accidents and hazards [28,29]. Scholars commonly categorized these causes into three levels, including individual, organizational, and environmental factors [30–33]. Individual determinants, such as gender, age, level of education, salary, and work experience, have been examined for their influence on safety outcomes. Organizational determinants, including job demands, resources, workplace policies, and safety culture and climate, have also been investigated. Environmental determinants encompass a range of factors, such as peer influences, ergonomic hazards, chemical hazards, electrical hazards, and unseen hazards. Dust explosions have been consistently highlighted as a serious hazard in the workplaces of electricity personnel [34–36]. Studies have identified various ignition sources for dust explosions, including electrostatic ignition, friction, electric arcs, hot surfaces, open flames, and spontaneous combustion [37–40]. Additionally, occupational heat stress caused by climate change has been found to have detrimental effects on the safety and health of workers in the electric power industry [41,42].

Numerous studies have examined the application of ergonomics to create a safer work environment, leading to the formulation of different interventions for monitoring and evaluation, e.g., [2,43–45]. For instance, Seeley and Marklin [44] proposed battery-operated presses and cutters as ergonomic interventions to mitigate the risks associated with musculoskeletal disorders. Janackovic et al. [43] identified the ergonomic factors that are important for enhancing safety systems in power companies, including an analysis of the criteria for choosing safety levels (technical indicators), the application of working procedures (human indicators), higher-risk workplace assessment (organizational indicators), and the evaluation of technological solutions currently available on the market (environmental indicators). According to ergonomics and safety-related research in the electric power industry, strictly adhering to operating procedures, defining appropriate levels of safety, surveilling and reporting errors and omissions in work, providing safety training, effectively managing safety resources, and applying first-rate safety technologies may reduce occupational accidents and injuries.

4.1.2. Occupational Exposure in the Electricity Industry

Occupational exposure assessment is a critical aspect of ensuring the safety and health of workers in the electric power industry [46]. It involves identifying and characterizing the various types of exposures that workers may encounter, developing exposure estimates for risk assessment, and evaluating the effectiveness of intervention strategies aimed at mitigating health risks [46]. One emerging trend of concern is the potential health effects of electromagnetic fields, particularly due to the increased use of wireless communication systems [47]. Extensive research has been conducted to investigate the long-term health risks associated with occupational exposure to electromagnetic fields in the electric power industry [46,48,49]. These studies have reported increased risks of breast cancer, brain cancer, and lung cancer in male electric workers exposed to electric and magnetic fields [50–52]. Moreover, Jalilian et al. [53] conducted a meta-analysis specifically focusing on the association between occupational exposure to magnetic fields and the risk of Alzheimer's disease among electric utility workers. Their findings suggested an increased likelihood of this relationship, highlighting the importance of further research in this area.

Recent studies have also examined the effects of occupational exposure to extremely low-frequency magnetic fields [54–56]. These investigations have revealed potential adverse impacts on the nervous and cardiovascular systems. Additionally, electromagnetic pollution can affect indoor air quality, leading to biological and psychological risks to human health and an increased risk of cancer and various diseases [57]. Recognizing the significance of occupational exposure assessment, the electric power industry has developed and validated various assessment and measurement techniques to anticipate and evaluate potential health risks [55,58,59]. Exposure guidelines have been designed and regularly updated to protect workers in the industry, encompassing process improvements, exposure elimination, and good management practices [60,61].

4.1.3. Electrical Incidents Management

Effective management of electrical incidents is crucial for ensuring the safety of workers in the electric power industry. Extensive research has been carried out to understand the causality of electrical shock injuries [62–64]. For example, Ichikawa [65] investigated electric shock injury accidents in Japan from 2013 to 2015 and identified that the failure to use insulating guards, such as insulating rubber gloves, was a common cause of these injuries. Electrical injuries often result from accidental contact with electrical outlets, power cords, exposed parts of appliances or cords, arc flashes on high-voltage power lines, mechanical or occupational-related exposures, and lightning incidents [66]. Waldmann et al. [67] highlighted the range of shock injuries, which can vary from minor skin burns to life-threatening visceral damage. For individuals who appear to be stable after electrical shocks, a significant concern is the potential delayed onset of arrhythmias. Therefore, the monitoring and management of electrical injuries, particularly their cardiac effects, are essential in the intensive care unit.

Occupational electrocution is a fatal incident that poses a significant risk to electrical personnel. Liu et al. [68] investigated the epidemiological characteristics of electrocution deaths in Guangdong Province and discovered 71 electric shock accidents between 2001 and 2010. The leading cause of death was exposure to power lines and live machinery. Massey et al. [69] emphasized that electrocution deaths predominantly affect young male workers who are exposed to high-voltage currents on the job. Linemen and electricians are among the most common occupations associated with electrocution injuries, and these incidents often involve young men at the peak of their careers [70]. To protect electrical personnel from electrical injuries and fatalities, several measures have been recommended. These include avoiding working near power lines whenever possible, protecting cables with conduit, using well-insulated cables, promptly detecting and reporting potential electrical hazards, wearing shock-resistant personal protective equipment, and providing comprehensive electrical safety-related training [71,72].

4.1.4. Risk Analysis and Management in the Renewable Energy Revolution

The growth of renewable energy sources in the global electricity system has brought attention to the importance of risk analysis and management in ensuring the occupational safety and health of electric workers [73]. While renewable energy technologies offer promising benefits, they also introduce new risks. Several studies have explored the impact of renewable energy on workers and have found potential reductions in injuries, illnesses, and deaths compared to traditional energy sources [74,75]. For example, Gerassis et al. [75] reported a decrease in neurological disorders and skin problems among workers in renewable generation due to the absence of pollutants associated with new technologies. However, it is important to acknowledge that the development of renewable energy can also pose health risks to workers [76–79]. For instance, in the context of biomass resources, workers may be exposed to significant amounts of dust, which can negatively impact their health [77]. Additionally, as electricity generation is at the core of renewable energy, workers are exposed to the risks associated with electricity, including burns and shocks. Consequently, risk assessment, analysis, and management practices have been implemented to identify and mitigate potential hazards that could affect workers' health [80–82].

Nuclear energy is another important component of the sustainable energy mix, accounting for over 11% of the world's electricity supply [83]. Following the nuclear accident at the Fukushima nuclear power plant in 2011, concerns and debates surrounding nuclear facilities have grown [84]. Numerous studies have shown that human errors are often the primary cause of nuclear accidents [85–87]. Suh and Yim [87] emphasized the significance of workers' fitness for duty (FFD), which refers to their mental and physical ability to safely perform their jobs, in reducing human errors. Implementing effective FFD management programs in plant operations can mitigate human errors and foster a positive safety culture. Multiple studies have suggested that policymakers should prioritize improving work regulations and promoting positive attitudes towards safety to enhance the overall safety and health performance in the electric power industry [88–90]. By addressing these factors, the industry can better manage risks and ensure the well-being of workers in the renewable energy revolution.

4.2. Research Gaps and Future Implications of Digital Pathways

4.2.1. Analysis, Prevention, and Emergency Planning for Electrical Accidents

Previous studies have identified various types of electrical accidents, such as electric shock injuries, electrical burns, and electrocution deaths, with a primary focus on investigating the causes and implementing preventive measures [62,67]. However, there is a notable dearth of research on emergency preparedness and planning for incidents and accidents in relation to the utilization of digital technologies and innovative solutions. It is imperative to address this research gap by exploring effective emergency response strategies, evacuation procedures, coordination with emergency services, the provision of medical treatment and assistance, communication protocols, and comprehensive instruction and training for electrical workers in implementing emergency procedures.

Digital technologies can play a significant role in enhancing these aspects, such as leveraging mobile applications or wearable devices to facilitate real-time communication and provide step-by-step guidance during emergencies [91]. Moreover, there is a need to continue to conduct risk assessments, analysis, and management within the electricity industry, which serve as valuable tools for safety management practitioners to evaluate the efficacy of measures and policies in safeguarding workers from injuries. Future research should investigate how ergonomics can be applied to optimize work tools, personal protective equipment, and emergency planning, thereby enhancing the safety and health of electrical workers. Additionally, effective methods of imparting safety knowledge to electrical workers through training and education should be explored, considering the integration of digital platforms and innovative learning techniques.

In the context of digital technologies, risk communication is of the utmost importance as a critical step in providing real-time information to personnel in the electric industry to prevent hazardous threats in the workplace [92]. Future research should focus on identifying and evaluating effective risk communication strategies that harness digital platforms, social media, and innovative tools to ensure the timely and accurate dissemination of information [93]. Furthermore, investigating the occupational safety and health of electricians, specifically in developed countries, is recommended, considering the potential influence of imperfect safety systems on the heightened probability of occupational injuries [94]. Exploring the impact of digital technologies, innovative interventions, and technological advancements on occupational safety and health outcomes in developed countries can provide valuable insights and support the development of targeted interventions and policies.

4.2.2. Hazards in Electric Power Work Environments

It is essential to comprehensively cover different types of electric power work environments as they present varying electrical hazards [95,96]. While electrocution, electrical burns, electric shock, and falls are prevalent injuries in the electric power industry, the emergence of renewable energy sources may introduce new safety and health challenges that pose risks to workers. These challenges include nuclear pollution, biomass hazards, and nuclear radioactivity resulting from improper waste disposal practices [97,98]. To effectively address occupational risk exposure, research should incorporate advanced science, technologies, and equipment management related to two crucial aspects: the work environment and employee safety. This entails developing monitoring and early warning systems to detect the concentration of invisible and odorless substances that may be harmful in the workplace [99]. Establishing an alarm or unlocking system can also help to ensure the proper usage and appropriate wearing of personal protective equipment among employees in the electric power industry [100].

Moreover, the management of personnel safety in the electric industry should consider different demographic variables, including the specific needs and vulnerabilities of certain groups such as women and older workers. Currently, the focus on occupational safety and health in the electric industry has not given adequate attention to these vulnerable groups. Employing a multilevel analytical framework that incorporates the perspectives of different workers, employers, and relevant stakeholders can optimize overall occupational safety and health protection for electric workers. To bridge these research gaps, future studies should explore the integration of advanced tools and technologies. For instance, the application of Internet of Things (IoT) sensors and data analytics can enhance real-time monitoring of workplace conditions, facilitating the early detection of potential hazards [101]. Additionally, wearable devices and smart personal protective equipment can provide real-time feedback and alerts to workers, ensuring their safety and compliance with safety protocols [102]. The utilization of digital platforms and innovative training approaches, such as virtual reality simulations and interactive modules, can enhance safety training and education for electric workers. These technologies can provide immersive learning experiences, improve knowledge retention, and foster a culture of safety [103].

4.2.3. Barriers and Facilitators of Safety Climate Improvement

The safety climate is a crucial factor influencing worker injuries, exposure, and adherence to safe work practices, as it provides insights into workers' safety performances before accidents occur [104]. It encompasses the psychological safety and health aspects that reflect the management's approach to balancing productivity and the occupational health of workers [105,106]. Therefore, enhancing and promoting a positive safety climate within an organization can significantly increase employees' safety awareness, which is a critical factor influencing their work safety behaviors [107]. Continued evaluation is necessary to assess the permeation of safety policies throughout organizations and their impact on individual workers, aiming to develop a positive and proactive safety climate. It is important to explore the barriers and facilitators that affect the implementation of safety policies and the creation of a safety climate in the electrical power industry. Additionally, examining the effects of current safety policies and strategies among workers can provide valuable insights into their effectiveness.

Future studies can explore how digital tools and platforms can contribute to enhancing the safety climate [108]. For instance, data analytics and sentiment analysis can be utilized to assess and monitor safety climate indicators in real time. Mobile applications or wearable devices can facilitate timely and interactive communication between workers and management, fostering a culture of safety and enabling workers to report hazards or safety concerns more effectively. The integration of digital technologies can support the dissemination of safety information and training materials, ensuring accessibility and engagement among workers. Virtual reality simulations and augmented reality tools can create immersive training experiences, allowing workers to practice safety procedures in realistic virtual environments.

4.2.4. Safety and Health of Renewable Energies

There is a lack of comprehensive risk identification and risk perception studies within the current research that are specifically focused on electric workers in the new energy power industry. Existing studies on risk analysis primarily concentrate on the traditional power industry [109,110]. However, renewable energy sources like wind power generation, new energy power generation, and bio-energy power generation present unique risk sources based on their energy characteristics, and there is a need for the identification and analysis of these risks in the context of the new energy power industries. Furthermore, the development of renewable energies and technologies may lead to an increase in electric power industry-related diseases. As safety management and regulations might not be adequately designed to prevent accidents associated with these new technologies, there is a potential for more injuries and uncertain hazards that have not yet been discovered [111]. Therefore, it is crucial to explore and investigate these potential risks to ensure the safety and well-being of workers in the new energy power industry. Future studies should focus on conducting in-depth risk identification and risk perception analyses specific to the new energy power industry. This includes identifying and analyzing the unique risk sources associated with renewable energy technologies. Additionally, research should explore the potential occupational diseases and health risks that may arise in the context of these new energy sources.

To enhance risk perception and promote safety awareness among personnel in the new energy power industry, it is recommended to provide more comprehensive information and training related to risk identification in the field of renewable energies. This can involve developing targeted training programs that highlight the specific risks and hazards associated with different renewable energy technologies. Leveraging digital technologies, such as e-learning platforms, virtual reality simulations, and interactive modules, can enhance the effectiveness and accessibility of such training programs [112]. Moreover, collaboration between researchers, industry stakeholders, and regulatory bodies is crucial to developing appropriate safety management measures and regulations that address the specific risks posed by new energy technologies. It is important to continuously monitor, and update safety practices as new technologies emerge, and potential hazards are identified.

4.3. Research Trends in Occupational Safety and Health in the Electrical Industry

Based upon the keyword analysis, the qualitative analysis of the mainstream research areas related to workers' occupational safety and health in the electrical industry, and the research gap analysis, a research framework recommending future research implications related to the utilization of digital technologies is proposed (see Figure 11). Several future research suggestions can be anticipated, including:

1. Strengthening robust emergency preparedness, planning strategies, and effective risk communication strategies.

2. Identifying and evaluating strategies that facilitate real-time communication of occupational risks to workers.
3. Exploration of the integration of advanced technologies to enhance the accuracy and efficiency of assessing and monitoring occupational risk exposures in the electrical power industry.
4. The development of early warning systems to detect and alert workers about potential safety hazards or incidents.
5. The enhancement of safety policies and strategies through digital technologies by evaluating their implementation and identifying barriers and facilitators.
6. Leveraging real-time monitoring to enhance safety climate.
7. The utilization of digital technologies for comprehensive risk analysis and developing targeted risk mitigation strategies.
8. Designing digital platforms, interventions and safety training related to the electrical power industry, particularly the renewable energy sector, to enhance workers' risk perception and safety culture.

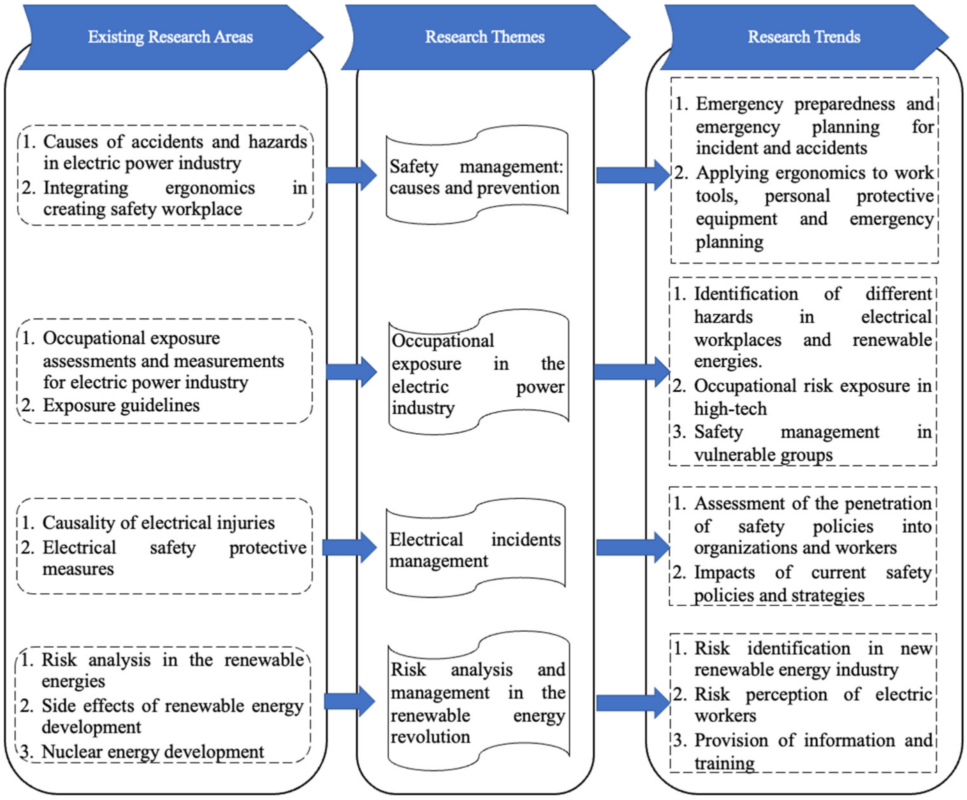


Figure 11. Research framework linking existing study areas on occupational safety and health of personnel in the electric power industry for future research suggestions.

This comprehensive discussion of occupational safety and health within the electric power industry, particularly focusing on the integration of digital pathways for enhanced safety management, offers invaluable insights for a broad spectrum of stakeholders. Industry practitioners and safety managers can derive practical strategies for mitigating risks and improving workplace safety through targeted interventions and ergonomic solutions. Policymakers and regulators can utilize these findings to refine safety guidelines and adapt regulations to the evolving landscape of renewable energy technologies. Researchers and academics are provided with a clear direction for future studies, identifying critical gaps in the current body of knowledge. Workers and their representatives can gain awareness of occupational risks, empowering advocacy for improved safety measures. Technology developers and vendors can identify market needs and opportunities for innovation in safety technologies. Lastly, investors and financial analysts can make informed decisions based on the potential risks and benefits associated with the renewable energy sector.

A key limitation of this study pertains to the temporal scope of the literature analyzed. The bibliometric and scientometric analysis was conducted on articles published from 1991 to 2022. However, the field of occupational safety and health in the electric power industry is rapidly evolving, particularly with the increased adoption of digital technologies. The exclusion of literature from the most recent two years may inhibit our ability to fully capture the latest trends and developments within this dynamic research domain. Consequently, the future implications of digital pathways derived from this analysis may not entirely reflect the most up-to-date situation and advancements in the industry. To address this limitation, future research efforts would benefit from expanding the temporal scope of the analysis to encompass literature published up to the present day. This would enable a more comprehensive and current understanding of the research landscape and its prospective trajectories.

5. Conclusions

This paper provided a science mapping analysis and in-depth qualitative discussion of more than 600 journal articles on the global occupational safety and health of personnel in the electric power industry from 1991 to 2022. The topic of electricity safety and health has been an area of extensive research over the past decade, with an exponential increase in publication output. The development of this study field is hampered by the lack of reviews, which may lead to a declining trend in publication output in the coming years. Thus, the current review is essential for identifying trends in the occupational safety and health of workers in the electric power industry to alleviate the risks related to the working environment in this field and to reduce the number of employees that are absent from work due to illness or injury and improve work efficiency. This study included 608 articles on occupational safety and health in the electric power industry covering 70 countries or regions and 257 journals. Four main research areas were distinguished: (1) safety management: causes and prevention; (2) occupational exposure in the electric power industry; (3) electrical incidents management; (4) risk analysis and management in the renewable energy revolution. The scientometric analysis offered insights into the future implications of harnessing the potential of digital technology to create a safer and more resilient work environment in the electrical power industry. These proposed research trends could benefit academics and industry practitioners in improving the safety climate and enhancing occupational safety and health among workers in electric power industries. However, the present review is limited to the literature published in Web of Science, Scopus, and Google Scholar, and includes journal articles published in English only. Some of the latest articles published on other types of databases and in other languages may be excluded.

While some of the occupational safety and health issues in the electric power industry, such as hazards related to high-voltage equipment, confined spaces, and work at heights, may be shared with other safety-critical domains like transportation, oil and gas, or mining, there are likely to be some unique factors as well. For example, the electric power workforce may face psychological stresses related to on-call duties, shift work, and responding to emergencies—circumstances that may be less prevalent in industries with more standardized work schedules and operating environments. Additionally, the ongoing transition towards renewable energy sources like solar and wind power introduces new occupational health and safety challenges around the installation, maintenance, and decommissioning of these technologies, which workers in the electric power industry may need specialized training and safety protocols to address.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Qu, Z.; Zhang, Z.; Liu, S.; Cao, J.; Bo, X. Knowledge-driven recognition methodology for electricity safety hazard scenarios. *Energy Rep.* **2022**, *8*, 10006–10016. [CrossRef]
2. Rahmani, A.; Khadem, M.; Madreseh, E.; Aghaei, H.A.; Raei, M.; Karchani, M. Descriptive study of occupational accidents and their causes among electricity distribution company workers at an eight-year period in Iran. *Saf. Health Work.* **2013**, *4*, 160–165. [CrossRef]
3. Brenner, B.; Cawley, J.C.; Majano, D. Electrically hazardous jobs in the US. *IEEE Trans. Ind. Appl.* **2020**, *56*, 2190–2195. [CrossRef]
4. Liu, H.C.; Cheng, Y.; Ho, J.J. Associations of ergonomic and psychosocial work hazards with musculoskeletal disorders of specific body parts: A study of general employees in Taiwan. *Int. J. Ind. Ergon.* **2020**, *76*, 102935. [CrossRef]
5. Araújo Vila, N.; Fraiz-Brea, J.A.; Toubes, D.R. Degree of Integration of Risk Preventive Measures in the Management System of Companies in the Electricity Sector. *J. Sci. Ind. Res.* **2022**, *81*, 663–670. [CrossRef]
6. Ugwu, F.I. The effect of workplace safety on the performance of Enugu state electricity distribution company. *Eur. J. Financ. Manag. Sci.* **2021**, *5*, 10–27.
7. Hromada, M.; Rehak, D.; Walker, N. Electricity infrastructure technical security: Practical application and best practices of risk assessment. *Saf. Secur. Issues Technol. Infrastruct.* **2020**, 1–30. [CrossRef]
8. Rezaei Dizghah, M.; Ajalli, M.; Homayounfar, M. The effect of organizational culture on employees' safety performance in electricity distribution organization of Gilan Province. *Occup. Hygine Health Promot. J.* **2022**, *6*, 98–110. [CrossRef]
9. Floyd, H.L. A systems safety approach to occupational electrical safety. In Proceedings of the 2014 IEEE-IAS/PCA Cement Industry Technical Conference, Washington, DC, USA, 13–17 April 2014; pp. 1–17. [CrossRef]
10. Gammon, T.; Lee, W.J.; Intwari, I. Reframing our view of workplace "electrical" injuries. *IEEE Trans. Ind. Appl.* **2019**, *55*, 4370–4376. [CrossRef]
11. Narine, G. Causes and Prevention of Electric Power Industry Accidents: A Delphi Study. Doctoral Dissertation, Walden University, Minneapolis, MN, USA, 2019. Available online: https://www.proquest.com/openview/06e98e9074daf04d39143dda897d4f6f/1?pq-origsite=gscholar&cbl=18750&diss=y (accessed on 19 May 2024).
12. Qian, Y.Y.; Xu, J.; Mi, C.M.; Peng, Q.W. Research on electricity falling accident based on improved bode accident causation model. In *Smart Service Systems, Operations Management, and Analytics*; Yang, H., Qiu, R., Chen, W., Eds.; INFORMS-CSS 2019; Springer Proceedings in Business and Economics; Springer: Cham, Switzerland, 2020. [CrossRef]
13. Song, Y. Safety management principles in electric power industry based on human factors. In Proceedings of the International Conference on Applied Human Factors and Ergonomics, Orlando, FL, USA, 21–25 July 2018; Springer: Cham, Switzerland, 2018; pp. 541–550. [CrossRef]
14. Song, Z.; Baicker, K. Effect of a workplace wellness program on employee health and economic outcomes: A randomized clinical trial. *JAMA* **2019**, *321*, 1491–1501. [CrossRef]
15. WHO. Global Strategy on Occupational Health for All: The Way to Health at Work Recommendation of the Second Meeting of the WHO Collaborating Centres in Occupational Health. 1994. Available online: https://www.who.int/publications/i/item/WHO-OCH-95.1 (accessed on 19 May 2024).
16. Goetsch, D.L.; Occupational Safety and Health. Pearson India. 2010. Available online: https://www.pearsonhighered.com/assets/preface/0/1/3/4/013469581X.pdf (accessed on 19 May 2024).
17. Hosseini, M.R.; Martek, I.; Zavadskas, E.K.; Aibinu, A.A.; Arashpour, M.; Chileshe, N. Critical evaluation of off-site construction research: A Scientometric analysis. *Autom. Constr.* **2018**, *87*, 235–247. [CrossRef]
18. Abedinnia, H.; Glock, C.H.; Schneider, M.D. Machine scheduling in production: A content analysis. *Appl. Math. Model.* **2017**, *50*, 279–299. [CrossRef]
19. Butler, L.; Visser, M.S. Extending citation analysis to non-source items. *Scientometrics* **2006**, *66*, 327–343. [CrossRef]
20. Bastian, M.; Heymann, S.; Jacomy, M. Gephi: An open source software for exploring and manipulating networks. *ICWSM* **2009**, *8*, 361–362. [CrossRef]
21. Waltman, L.; Van Eck, N.J.; Noyons, E.C.M. A unified approach to mapping and clustering of bibliometric networks. *J. Informetr.* **2010**, *4*, 629–635. [CrossRef]
22. Waltman, L.; Van Eck, N.J. A new methodology for constructing a publication-level classification system of science. *J. Am. Soc. Inf. Sci.* **2012**, *63*, 2378–2392. [CrossRef]
23. Esen, M.; Bellibas, M.S.; Gumus, S. The evolution of leadership research in higher education for two decades (1995–2014): A bibliometric and content analysis. *Int. J. Leadersh. Educ.* **2020**, *23*, 259–273. [CrossRef]
24. Prell, C. *Social Network Analysis: History, Theory and Methodology*; Sage: Southern Oaks, CA, USA, 2012.
25. Chen, C.; Ao, Y.; Wang, Y.; Li, J. Performance appraisal method for rural infrastructure construction based on public satisfaction. *PLoS ONE* **2018**, *13*, e0204563. [CrossRef]
26. Feng, S.; Hu, B.; Nie, C.; Shen, X. Empirical study on a directed and weighted bus transport network in China. *Phys. A Stat. Mech. Its Appl.* **2016**, *441*, 85–92. [CrossRef]
27. De Nooy, W.; Mrvar, A.; Batagelj, V. *Exploratory Social Network Analysis with Pajek*; Cambridge University Press: Cambridge, UK, 2005.
28. Lombardi, M.; Fargnoli, M.; Parise, G. Risk profiling from the european statistics on accidents at work (ESAW) accidents' databases: A case study in construction sites. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4748. [CrossRef]

29. Wong, F.; Chan, A.; Wong, A.; Hon, C.; Choi, T. Accidents of electrical and mechanical works for public sector projects in Hong Kong. *Int. J. Environ. Res. Public Health* **2018**, *15*, 485. [CrossRef]
30. Basahel, A.M. Safety leadership, safety attitudes, safety knowledge and motivation toward safety-related behaviors in electrical substation construction projects. *Int. J. Environ. Res. Public Health* **2021**, *18*, 4196. [CrossRef]
31. Chen, Y.; Feng, W.; Jiang, Z.; Duan, L.; Cheng, S. An accident causation model based on safety information cognition and its application. *Reliab. Eng. Syst. Saf.* **2021**, *27*, 107363. [CrossRef]
32. Khan, R.U.; Yin, J.; Mustafa, F.S.; Ahmad Farea, A.O. A data centered human factor analysis approach for hazardous cargo accidents in a port environment. *J. Loss Prev. Process Ind.* **2022**, *75*, 104711. [CrossRef]
33. Oliver, A.; Cheyne, A.; Tomás, J.M.; Cox, S. The effects of organizational and individual factors on occupational accidents. *J. Occup. Organ. Psychol.* **2002**, *75*, 473–488. [CrossRef]
34. Li, G.; Yang, H.-X.; Yuan, C.-M.; Eckhoff, R.K. A catastrophic aluminium-alloy dust explosion in China. *J. Loss Prev. Process Ind.* **2016**, *39*, 121–130. [CrossRef]
35. Randeberg, E.; Eckhoff, R.K. Initiation of dust explosions by electric spark discharges triggered by the explosive dust cloud itself. *J. Loss Prev. Process Ind.* **2006**, *19*, 154–160. [CrossRef]
36. Yuan, Z.; Khakzad, N.; Khan, F.; Amyotte, P. Dust explosions: A threat to the process industries. *Process Saf. Environ. Prot.* **2015**, *98*, 57–71. [CrossRef]
37. Ji, M.; Sun, Z.; Guo, H. The application of the foam technology to the dust control for reducing the dust injury of coal mines. *Appl. Sci.* **2022**, *12*, 10878. [CrossRef]
38. Man, C.K.; Harris, M.L. Participation of large particles in coal dust explosions. *J. Loss Prev. Process Ind.* **2014**, *27*, 49–54. [CrossRef]
39. Pak, S.; Jung, S.; Roh, C.; Kang, C. Case studies for dangerous dust explosions in South Korea during recent years. *Sustainability* **2019**, *11*, 4888. [CrossRef]
40. Wei, M.C.; Cheng, Y.C.; Lin, Y.Y.; Kuo, W.K.; Shu, C.M. Applications of dust explosion hazard and disaster prevention technology. *J. Loss Prev. Process Ind.* **2020**, *68*, 104304. [CrossRef]
41. Flouris, A.D.; Ioannou, L.G.; Notley, S.R.; Kenny, G.P. Determinants of heat stress and strain in electrical utilities workers across North America as assessed by means of an exploratory questionnaire. *J. Occup. Environ. Hyg.* **2022**, *19*, 12–22. [CrossRef]
42. Spector, J.T.; Sheffield, P.E. Re-evaluating occupational heat stress in a changing climate. *Ann. Occup. Hyg.* **2014**, *58*, 936–942. [CrossRef]
43. Janackovic, G.; Stojiljkovic, E.; Grozdanovic, M. Selection of key indicators for the improvement of occupational safety system in electricity distribution companies. *Saf. Sci.* **2020**, *125*, 103654. [CrossRef]
44. Seeley, P.A.; Marklin, R.W. Business case for implementing two ergonomic interventions at an electric power utility. *Appl. Ergon.* **2003**, *34*, 429–439. [CrossRef]
45. Zwetsloot, G.; Leka, S.; Kines, P.; Jain, A. Vision zero: Developing proactive leading indicators for safety, health and wellbeing at work. *Saf. Sci.* **2020**, *130*, 104890. [CrossRef]
46. Hartwig, V.; Virgili, G.; Ederica Mattei, F.; Biagini, C.; Romeo, S.; Zeni, O.; Scarfì, M.R.; Massa, R.; Campanella, F.; Landini, L.; et al. Occupational exposure to electromagnetic fields in magnetic resonance environment: An update on regulation, exposure assessment techniques, health risk evaluation, and surveillance. *Med. Biol. Eng. Comput.* **2022**, *60*, 297–320. [CrossRef]
47. Serafeim, I.; Apostolidis, C.; Athanasios, M.; Samaras, T. Electromagnetic fields exposure assessment in Europe utilizing publicly available data. *Sensors* **2022**, *22*, 8481. [CrossRef]
48. Politański, P.; Aniołczyk, H.; Gadzicka, E.; Bortkiewicz, A.; Zmyślony, M. Electromagnetic fields exposure assessment among workers at broadcast centers in Poland. *Med. Pr.* **2018**, *69*, 477–482. [CrossRef]
49. Vila, J.; Turner, M.C.; Gracia-Lavedan, E.; Figuerola, J.; Bowman, J.D.; Kincl, L.; Richardson, L.; Benke, G.; Hours, M.; Krewski, D.; et al. Occupational exposure to high-frequency electromagnetic fields and brain tumor risk in the INTEROCC study: An individualized assessment approach. *Environ. Int.* **2018**, *119*, 353–365. [CrossRef]
50. Carpenter, D.O. Extremely low frequency electromagnetic fields and cancer: How source of funding affects results. *Environ. Res.* **2019**, *178*, 108688. [CrossRef]
51. Rodrigues, N.C.P.; Dode, A.C.; de Noronha Andrade, M.K.; O'Dwyer, G.; Monteiro, D.L.M.; Reis, I.N.C.; Rodrigues, R.P.; Frossard, V.C.; Lino, V.T.S. The effect of continuous low-intensity exposure to electromagnetic fields from radio base stations to cancer mortality in Brazil. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1229. [CrossRef]
52. Sorahan, T.M. Cancer incidence in UK electricity generation and transmission workers, 1973–2015. *Occup. Med.* **2019**, *69*, 342–351. [CrossRef]
53. Jalilian, H.; Teshnizi, S.H.; Röösli, M.; Neghab, M. Occupational exposure to extremely low frequency magnetic fields and risk of Alzheimer disease: A systematic review and meta-analysis. *Neurotoxicology* **2018**, *69*, 242–252. [CrossRef]
54. Baaken, D.; Dechent, D.; Blettner, M.; Drießen, S.; Merzenich, H. Occupational exposure to extremely low-frequency magnetic fields and risk of amyotrophic lateral sclerosis: Results of a feasibility study for a pooled analysis of original data. *Bioelectromagnetics* **2021**, *42*, 271–283. [CrossRef]
55. Huss, A.; Peters, S.; Vermeulen, R. Occupational exposure to extremely low-frequency magnetic fields and the risk of ALS: A systematic review and meta-analysis. *Bioelectromagnetics* **2018**, *39*, 156–163. [CrossRef]
56. Jalilian, H.; Najafi, K.; Khosravi, Y.; Röösli, M. Amyotrophic lateral sclerosis, occupational exposure to extremely low-frequency magnetic fields and electric shocks: A systematic review and meta-analysis. *Rev. Environ. Health* **2020**, *36*, 129–142. [CrossRef]

57. Pavlík, M.; Melnykov, V. Measurement of Reflection and Shielding Effectiveness of Electromagnetic Fields in Construction Materials with Subsequent Calculation of Absorption. In Proceedings of the IEEE 5th International Conference on Modern Electrical and Energy System (MEES), Kremenchuk, Ukraine, 27–30 September 2023; pp. 1–4.
58. Bracken, T.D.; Patterson, R.M. Variability and consistency of electric and magnetic field occupational exposure measurements. *J. Expo. Anal. Environ. Epidemiol.* **1996**, *6*, 355–374.
59. Mohammadyan, M.; Moosazadeh, M.; Borji, A.; Khanjani, N.; Rahimi Moghadam, S. Investigation of occupational exposure to lead and its relation with blood lead levels in electrical solderers. *Environ. Monit. Assess.* **2019**, *191*, 126. [CrossRef]
60. Mild, K.H.; Alanko, T.; Decat, G.; Falsaperla, R.; Gryz, K.; Hietanen, M.; Karpowicz, J.; Rossi, P.; Sandström, M. Exposure of workers to electromagnetic fields. A review of open questions on exposure assessment techniques. *Int. J. Occup. Saf. Ergon.* **2009**, *15*, 3–33. [CrossRef] [PubMed]
61. Modenese, A.; Gobba, F. Occupational exposure to electromagnetic fields and health surveillance according to the European Directive 2013/35/EU. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1730. [CrossRef] [PubMed]
62. Biering, K.; Vestergaard, J.M.; Nielsen, K.J. Contacts with general practitioner, sick leave and work participation after electrical injuries: A register-based, matched cohort study. *Occup. Environ. Med.* **2021**, *78*, 54–60. [CrossRef] [PubMed]
63. Dechent, D.; Emonds, T.; Stunder, D.; Schmiedchen, K.; Kraus, T.; Driessen, S. Direct current electrical injuries: A systematic review of case reports and case series. *Burns* **2020**, *46*, 267–278. [CrossRef] [PubMed]
64. Fordyce, T.A.; Kelsh, M.; Lu, E.T.; Sahl, J.D.; Yager, J.W. Thermal burn and electrical injuries among electric utility workers, 1995–2004. *Burns* **2007**, *33*, 209–220. [CrossRef] [PubMed]
65. Ichikawa, N. Electrical injury rate and epidemiology in Japan, 2013–2015. *IEEE Trans. Ind. Appl.* **2020**, *56*, 4319–4323. [CrossRef]
66. Koumbourlis, A.C. Electrical injuries. *Crit. Care Med.* **2002**, *30*, S424–S430. [CrossRef] [PubMed]
67. Waldmann, V.; Narayanan, K.; Combes, N.; Jost, D.; Jouven, X.; Marijon, E. Electrical cardiac injuries: Current concepts and management. *Eur. Heart J.* **2018**, *39*, 1459–1465. [CrossRef] [PubMed]
68. Liu, S.; Yu, Y.; Huang, Q.; Luo, B.; Liao, X. Electrocution-related mortality: A review of 71 deaths by low-voltage electrical current in Guangdong, China, 2001–2010. *Am. J. Forensic Med. Pathol.* **2014**, *35*, 193–196. [CrossRef]
69. Massey, B.K.; Sait, M.A.; Johnson, W.L.; Ripple, M.; Fowler, D.R.; Li, L. Deaths due to electrocution: An evaluation of death scene investigations and autopsy findings. *J. Forensic Sci. Med.* **2018**, *4*, 179–183. [CrossRef]
70. Arnoldo, B.D.; Purdue, G.F.; Kowalske, K.; Helm, P.A.; Burris, A.; Hunt, J.L. Electrical injuries: A 20-year review. *J. Burn Care Rehabil.* **2004**, *25*, 479–484. [CrossRef] [PubMed]
71. Rabban, J.T.; Blair, J.A.; Rosen, C.L.; Adler, J.N.; Sheridan, R.L. Mechanisms of pediatric electrical injury. New implications for product safety and injury prevention. *Arch. Pediatr. Adolesc. Med.* **1997**, *151*, 696–700. [CrossRef] [PubMed]
72. Mebarki, B.; Bengharbi, M.; Mokdad, M.; Bouabdellah, L. Burning and electrocution risk's evaluation and prevention procedures: A case study in a production work shop. In *Advances in Safety Management and Human Factors. AHFE 2017. Advances in Intelligent Systems and Computing*; Arezes, P., Ed.; Springer: Cham, Switzerland, 2018; Volume 604. [CrossRef]
73. Garcia, D.; Bruschi, D. A risk assessment tool for improving safety standards and emergency management in Italian onshore wind farms. *Sustain. Energy Technol. Assess.* **2016**, *18*, 48–58. [CrossRef]
74. Mulloy, K.B.; Sumner, S.A.; Rose, C.; Conway, G.A.; Reynolds, S.J.; Davidson, M.E.; Heidel, D.S.; Layde, P.M. Renewable energy and occupational health and safety research directions: A white paper from the Energy Summit, Denver Colorado, April 11–13, 2011. *Am. J. Ind. Med.* **2013**, *56*, 1359–1370. [CrossRef] [PubMed]
75. Gerassis, S.; Abad, A.; Giráldez, E.; Taboada, J. The impact of renewable energy for occupational health in the smart grid era. *J. Clean Energy Technol.* **2018**, *6*, 405–410. [CrossRef]
76. Dhar, A.; Naeth, M.A.; Jennings, P.D.; El-Din, M.G. Geothermal energy resources: Potential environmental impact and land reclamation. *Environ. Rev.* **2020**, *28*, 415–427. [CrossRef]
77. Qin, Z.; Zhuang, Q.; Cai, X.; He, Y.; Huang, Y.; Jiang, D.; Lin, E.; Liu, Y.; Tang, Y.; Wang, M.Q. Biomass and biofuels in China: Toward bioenergy resource potentials and their impacts on the environment. *Renew. Sustain. Energy Rev.* **2018**, *82*, 2387–2400. [CrossRef]
78. Wu, Y.; Zhao, F.; Liu, S.; Wang, L.; Qiu, L.; Alexandrov, G.; Jothiprakash, V. Bioenergy production and environmental impacts. *Geosci. Lett* **2018**, *5*, 14. [CrossRef]
79. Al-Shetwi, A.Q. Sustainable development of renewable energy integrated power sector: Trends, environmental impacts, and recent challenges. *Sci. Total Environ.* **2022**, *822*, 153645. [CrossRef]
80. Sui, Y.; Ding, R.; Wang, H. A novel approach for occupational health and safety and environment risk assessment for nuclear power plant construction project. *J. Clean. Prod.* **2020**, *258*, 120945. [CrossRef]
81. Mohandes, S.R.; Zhang, X. Developing a holistic occupational health and safety risk assessment model: An application to a case of sustainable construction project. *J. Clean. Prod.* **2021**, *291*, 125934. [CrossRef]
82. Rantala, M.; Lindholm, M.; Tappura, S. Supporting occupational health and safety risk assessment skills: A case study of five companies. *Int. J. Environ. Res. Public Health* **2022**, *19*, 1720. [CrossRef] [PubMed]
83. Mu, R.; Zuo, J.; Yuan, X. China's approach to nuclear safety—From the perspective of policy and institutional system. *Energy Policy* **2015**, *76*, 161–172. [CrossRef]
84. Wada, K.; Yoshikawa, T.; Hayashi, T.; Aizawa, Y. Emergency response technical work at Fukushima Dai-ichi nuclear power plant: Occupational health challenges posed by the nuclear disaster. *Occup. Environ. Med.* **2012**, *69*, 599–602. [CrossRef] [PubMed]

85. Heo, G.; Park, J. A framework for evaluating the effects of maintenance-related human errors in nuclear power plants. *Reliab. Eng. Syst. Saf.* **2010**, *95*, 797–805. [CrossRef]
86. Jeong, K.; Choi, B.; Moon, J.; Hyun, D.; Lee, J.; Kim, I.; Kim, G.; Kang, S. Risk assessment on abnormal accidents from human errors during decommissioning of nuclear facilities. *Ann. Nucl. Energy* **2016**, *87*, 1–6. [CrossRef]
87. Suh, Y.A.; Yim, M.S. A worker's fitness-for-duty status identification based on biosignals to reduce human error in nuclear power plants. *Nucl. Technol.* **2020**, *206*, 1840–1860. [CrossRef]
88. Sovacool, B.K. A critical evaluation of nuclear power and renewable electricity in Asia. *J. Contemp. Asia.* **2010**, *40*, 369–400. [CrossRef]
89. Zhang, T.; Liu, Z.; Zheng, S.; Qu, X.; Tao, D. Predicting errors, violations, and safety participation behavior at nuclear power plants. *Int. J. Environ. Res. Public Health.* **2020**, *17*, 5613. [CrossRef]
90. Tao, D.; Liu, Z.; Diao, X.; Tan, H.; Qu, X.; Zhang, T. Antecedents of self-reported safety behaviors among commissioning workers in nuclear power plants: The roles of demographics, personality traits and safety attitudes. *Nucl. Eng. Technol.* **2021**, *53*, 1454–1463. [CrossRef]
91. Shimura, T.; Yamaguchi, I.; Terada, H.; Robert Svendsen, E.; Kunugita, N. Public health activities for mitigation of radiation exposures and risk communication challenges after the Fukushima nuclear accident. *J. Radiat. Res.* **2015**, *56*, 422–429. [CrossRef] [PubMed]
92. Ding, H.; Huang, M.; Li, D.; Lin, Y.; Qian, W. Epidemiology of electrical burns: A 10-year retrospective analysis of 376 cases at a burn centre in South China. *J. Int. Med. Res.* **2019**, *48*, 300060519891325. [CrossRef] [PubMed]
93. Simon, T.; Goldberg, A.; Adini, B. Socializing in emergencies—A review of the use of social media in emergency situations. *Int J. Inf. Manag.* **2015**, *35*, 609–619. [CrossRef]
94. Sadeghain, M.; Farid, R.A.; Dormohammadi, A.; Aghaei, H.A.; Rahmani, A.; Farhadi, R.; Eskandari, R.; Karchani, M. Assessment of the prevalence of occupational accidents and their influential actors in an electricity distribution company during a five-year period. Electron. *Physician* **2013**, *5*, 643–650. [CrossRef] [PubMed]
95. Noreen, U.; Ahmed, Z.; Khalid, A.; Di Serafino, A.; Habiba, U.; Ali, F.; Hussain, M. Water pollution and occupational health hazards caused by the marble industries in district Mardan, Pakistan. *Environ. Technol. Innov.* **2019**, *16*, 100470. [CrossRef]
96. Wang, B.; Dehghanian, P.; Wang, S.; Mitolo, M. Electrical safety considerations in large-scale electric vehicle charging stations. *IEEE Trans. Ind. Appl.* **2019**, *55*, 6603–6612. [CrossRef]
97. Bakhiyi, B.; Labrèche, F.; Zayed, J. The photovoltaic industry on the path to a sustainable future—Environmental and occupational health issues. *Environ. Int.* **2014**, *73*, 224–234. [CrossRef] [PubMed]
98. Karanikas, N.; Steele, S.; Bruschi, K.; Robertson, C.; Kass, J.; Popovich, A.; MacFadyen, C. Occupational health hazards and risks in the wind industry. *Energy Rep.* **2021**, *7*, 3750–3759. [CrossRef]
99. Wiss, J.; Fleury, C.; Onken, U. Safety improvement of chemical processes involving azides by online monitoring of the hydrazoic acid concentration. *Org. Process Res. Dev.* **2006**, *10*, 349–353. [CrossRef]
100. Jiang, S.W.; Chen, S.Y.; Chen, W.E.; Wu, H.T. Development of personnel epidemic prevention monitoring access control system. In *International Computer Symposium*; Springer Nature: Singapore, 2022; pp. 223–229.
101. Da Xu, L.; He, W.; Li, S. Internet of things in industries: A survey. *IEEE Trans Ind Inform.* **2014**, *10*, 2233–2243. [CrossRef]
102. Nikulin, A.; Ikonnikov, D.; Dolzhikov, I. Smart personal protective equipment in the coal mining industry. *Int. J. Civ. Eng. Technol.* **2019**, *10*, 852–863.
103. Acar, E.; Wall, J.; McNamee, F.; Carney, M.; Öney-Yazici, E. Innovative safety management training through e-learning. *Archit. Eng. Des. Manag.* **2008**, *4*, 239–250. [CrossRef]
104. Yule, S.; Flin, R.; Murdy, A. The role of management and safety climate in preventing risk-taking at work. *Int. J. Risk Assess. Manag.* **2007**, *7*, 137. [CrossRef]
105. Dollard, M.F.; McTernan, W. Psychosocial safety climate: A multilevel theory of work stress in the health and community service sector. *Epidemiol. Psychiatr. Sci.* **2011**, *20*, 287–293. [CrossRef]
106. Omidi, L.; Karimi, H.; Pilbeam, C.; Mousavi, S.; Moradi, G. Exploring the relationships among safety leadership, safety climate, psychological contract of safety, risk perception, safety compliance, and safety outcomes. *Front. Public Health* **2023**, *11*, 1235214. [CrossRef]
107. Fugas, C.S.; Silva, S.A.; Meliá, J.L. Another look at safety climate and safety behavior: Deepening the cognitive and social mediator mechanisms. *Accid. Anal. Prev.* **2012**, *45*, 468–477. [CrossRef]
108. Bronkhorst, B.; Tummers, L.; Steijn, B. Improving safety climate and behavior through a multifaceted intervention: Results from a field experiment. *Saf. Sci.* **2018**, *103*, 293–304. [CrossRef]
109. Volberg, V.; Fordyce, T.; Leonhard, M.; Mezei, G.; Vergara, X.; Krishen, L. Injuries among electric power industry workers, 1995–2013. *J. Safety Res.* **2017**, *60*, 9–16. [CrossRef]
110. Roberts, D.T. Applying Risk Assessment at the Worker Level: Applications to Electrical Safety. *IEEE Ind. Appl. Mag.* **2019**, *25*, 18–24. [CrossRef]

111. Li, R.; Chen, Y.; Ritchie, M.D.; Moore, J.H. Electronic health records and polygenic risk scores for predicting disease risk. *Nat. Rev. Genet.* **2020**, *21*, 493–502. [CrossRef]
112. Vukićević, A.M.; Mačužić, I.; Djapan, M.; Milićević, V.; Shamina, L. Digital training and advanced learning in occupational safety and health based on modern and affordable technologies. *Sustainability* **2021**, *13*, 13641. [CrossRef]