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A Systematic Review on Investment Risks in Hydropower to Developing Sustainable Renewable Energy Systems

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ABSTRACT

Hydropower is regarded as one of the most important renewable energy sources for the present and the future. However, hydropower projects are exposed to various risks and uncertainties, including economic, environmental, social, geological, regulatory, political, technological, financial, climate, natural, and safety concerns. Thus, to know the existing risks in the hydropower sector, a systematic literature review is conducted to find all peer-reviewed articles in English published between 2018 and 2022 that dealt with investment risks and uncertainties associated with hydropower. This systematic review paper considers "Hydropower Investment Risk" critical to developing sustainable renewable energy systems. The keywords selected for the search are tailored to identify all the relevant articles related to "Investment Risk in Hydropower," where hydropower is referred to as mini, micro, and large hydropower. In addition, the keywords that correspond to investment risk in the hydropower sector are chosen. Two crucial databases "Scopus" and "Google Scholar" search yielded 6689 and 123,000 articles, respectively. Among 34 full texts, 31 primary source articles and 3 secondary source articles are reviewed. The many investment risks pertaining to hydropower investments obtained from the extensive review are: (1) risks related to climate change and hydrology (2) Risks related to environment and anthropogenic (3) Market risks related to credit, capital, and other financial risks (4) Risks related to substitution from renewable energy to fossil fuels (5) Risks related to socio-political and technological changes (6) Risks related to institution, policy, legality, and regulatory (7) Risks related to human capital development, and 8. Impact of climate change on hydropower's revenue generation.

Keywords: Investment Risk, Hydropower, PRISMA, Hydropower Risk
JEL Classifications: E22, G1, G32, Q42, Q43

1. INTRODUCTION

There is a sea-change in the investment patterns of investors seeking to invest in renewable energy-producing sectors as there is a global consensus among government, policymakers, and investors to create a balance between growing environmental challenges and human affairs. First, dependency on non-renewable energy, i.e., fossil fuels (coal, oil, and natural gas), is hazardous to the environment as excess greenhouse gas emissions create significant adverse environmental consequences like global warming, climate change, ozone layer depletion, melting of glaciers, and weather pattern changes (Sahoo and Sahoo, 2022). Second, human population expansion, economic development, climate change, and the need to bridge the electricity access gap have fueled the need to invest in new renewable energy sources to balance environmental degradation and sustainable economic growth (Chen et al., 2022). Massive new hydropower development programs are currently underway to substitute conventional energy sources such as fossil fuels (Andronova et al., 2022; Zarfl et al., 2015). Due to the negligible production of Green House Gases (GHGs) and other emissions subject to hydropower production, the attraction towards hydropower investment and clean energy production is gaining momentum; estimates show that two-thirds of global energy was covered by renewable energy in 2016 (Bahar, 2017).

Hydropower construction is expanding in hydro-rich economies. According to (IHA) International Hydropower Association (IHA, 2020), more than 13000 hydropower stations were established in over 150 countries, increasing the global hydropower capacity from 1334 GW to 1360 GW. As the need for electricity grows, so does concern for environmental sustainability (Cunha and Ferreira, 2014). Hydropower operations are site-specific, requiring significant investment and taking a long time for full-phase operation (Shaktawat and Vadhera, 2021). Hydropower investments' primary significance is promoting low-cost-accessible, cleaner energy production. However, hydropower projects are exposed to various risks and uncertainties, including economic, environmental, social, geological, regulatory, political, technological, financial, climate, natural, and safety concerns (Shaktawat and Vadhera, 2021). These factors also affect the process of construction, production, and management of hydroelectricity. Understanding many dimensions of risk and investment strategies is critical as the risks analysis of hydropower encourages policymakers to act rationally, allowing them to balance the demand and supply sides of the electricity market.

The uncertainties and risks associated with developing hydropower projects must be determined, studied, and analyzed. Following such studies, the project leaders, investors, and policymakers can make prudential decisions.

This study examines the investment risks and uncertainties associated with hydropower development, construction, and management. In addition, the study's goal is to look into the major factors that influence capital investment in the hydropower sector. The uncertainties and risks involved in hydropower are assessed in this manuscript. Policymakers and investors in the renewable energy production sector can use this systematic review to; identify recent contextual information and methodological advances undertaken to identify the nature of risks, prevalent investment risks, and modes of investment and navigate through reviewed methodologies to contextualize the nature of risks and investment decisions.

1.1. Hydropower Background and Context

Hydropower is regarded as one of the most important renewable energy sources for the present and the future. As of 2016, hydropower was the world's most significant renewable energy source, accounting for up to 71% of the total supply (Moran et al., 2018). In 2019, hydroelectricity generated 15.60% of the world's 27,004.70 Tera Watt (TW)-hours of energy, placing it third behind coal and natural gas, according to the BP Statistical Review of World Energy 2020 (Zhang et al., 2021). The electricity demand is also almost expected to double between 2010 and 2035, necessitating an increase in global electrical capacity from 5.20 terawatts (TW) to 9.30 TW (International Energy Agency, 2012).

Hydropower facilities can broadly be classified as small, medium, and primarily based on capital requirement and production capacity. All kinds of hydro plants contribute to sustainable energy production. Therefore, it is often necessary to figure out the best size of the hydropower plant for investors to assess capital requirements, ascertain production capacity, and analyze the prospects of energy market demand. As the study by (Hidalgo et al., 2020) mentions, economic and environmental variables are crucial in optimal size determination. Since hydropower facilities can be classified as small, medium, or large, economic and environmental variables are crucial in determining the best hydropower plant size. For instance, small-scale hydropower is the most economical and ecologically friendly energy technology that should be considered for rural electrification in developed and less developed nations (Paish, 2002). For hydro-rich economies like Nepal, investments in small and more significant hydropower projects help electrify the nation while exporting surplus through cross-border energy trade. Therefore, sizable hydroelectric power is a significant component, particularly in emerging nations (Dincer and Yuksel, 2019).

1.2. Major Investment Risks and Their Linkages with Hydropowerh2

Hydroelectric power generation suffers from many investment risks that might hinder power generation. The cost of alternative energy sources, the environmental sustainability of hydropower, and social concerns regarding equitable development are the risk factors that affect the future of hydropower development (Vaidya et al., 2021). Several papers are subject to investors' risk-return behavior; (Busse and Hefeker, 2007) have examined the relation of political risks with foreign direct investment (FDI). While (Inderst, 2009) studied the impact of investing the pension fund balance in infrastructure investment, (Gatzert and Kosub, 2017) discussed policy risks in renewable energy investment.

1.3. Research Aims

Despite increased investments in hydropower projects globally, very few papers have thoroughly examined the prevalent investment risks in hydropower projects. Thus, this systematic review intends to explore all the peer-reviewed journal articles critical to investment decisions for hydropower projects. The main research questions (RQ) for the study are as follows:

RQ 1. What are the significant risk factors affecting investment decision criteria for hydropower projects?

RQ 2. What are the significant methodological advances undertaken to identify the nature of risks critical to hydropower investment?

2. METHODOLOGY

2.1. Inclusion and Exclusion Criteria

A systematic literature review was conducted to find all peer-reviewed English articles published between 2018 and 2022 that dealt with investment risk and uncertainties associated with hydropower. Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) criteria (Liberati et al., 2009) were strictly followed throughout the literature review process. A wide range of inclusion criteria was set to identify relevant articles, expecting to remove unnecessary and irrelevant articles for an extensive review. The articles that were not in accordance with the study area were excluded. This systematic review paper reviews only peer-reviewed Scopus-indexed journal articles related to investment risks in hydropower. During the keyword search in different databases, "renewable energy" was used as one of the many synonyms for "hydropower energy." Therefore, the search results that included hydropower as a part of the many energy systems were included in the study, and those articles that were relevant to renewable energy systems that did not include hydropower were excluded.

This systematic review paper broadly considers "Hydropower Investment Risk" critical to developing sustainable renewable energy. Furthermore, both primary and secondary source articles were reviewed.

2.2. Keywords and Search Terms

The keywords selected for the search were tailored to identify all the relevant articles related to "Investment Risk in Hydropower," where hydropower is referred to as mini, micro, and large hydropower.

The keywords that correspond to investment risk in the hydropower sector were chosen. For the initial search, the keyword "investment risk" was used. To remove the chances of search biases and to ensure a robust database search, five close synonyms for the word "Investment risk," namely; dodgy investment, hazardous investment, lousy investment, dubious investment, and insecure investment, were used. Similarly, for the keyword "hydropower," other words like micro-hydropower, hydroelectric power, macro-hydropower, and hydro energy were used as synonyms (Mayeda and Boyd, 2020). Boolean operators like AND, OR, and asterisks (*) were used to identify the searches that are closely relevant to the aforementioned keywords. Different keywords were used to search the databases: (((Investment Risk*) OR (Dodgy Invest*) OR (Bad Invest*) OR (Hazardous Invest*) OR (Doubtful Invest*) OR (Dubious Invest*) OR (Insecure Invest*)) AND ((Hydro*) OR (Hydroelct* Power) OR (Mini-hydropower) OR (Micro-hydro*))). The word "AND" represents all the essential keywords, whereas the word "OR" represents synonyms for the identified keywords, and the use of asterisks (*) searched for the plurals and other suffixes.

2.3. Literature Search Process

The search process adopted by this systematic review is a four steps process by (Khan et al., 2003) and, as used in the study by (Mayeda and Boyd, 2020), to identify the factors influencing "public perceptions of hydropower projects."

The major four stages, as discussed in (Mayeda and Boyd, 2020), are as follows:

Step 1: Search for databases
Step 2: Identifying key journals that were not discovered in step 1.
Step 3: Reference list search for relevant articles from steps 1 and 2.
Step 4: Scopus and Google search for additional manuscript citations.

The keyword searches were conducted on two reliable databases to find the relevant literature. Google Scholar and Scopus are two of the major databases used. At the same time, as in the methodological procedures followed by (Linnenluecke et al., 2020; Mayeda and Boyd, 2020), all the reference lists of relevant articles were checked to find other articles with investment risk in the hydropower sector. Those articles, too, were considered eligible for full-text review. All the journal articles were selected based on relevance.

2.4. Scopus

The "Scopus database was searched on May 17, 2022, and the initial results obtained after the first keyword search was 6689 articles. Further, some exclusion criteria were used, and the results were limited to 1070 articles. As discussed in sections 2.1 and 2.2, the keyword search process, synonyms, Boolean operators, and wildcard asterisks were deployed to ensure the precise search for relevant results. The articles included from the Scopus for screening references were 122, where all parameters except the search period from 2018 to 2022 and the English language were used as criteria for explicit exclusion.

2.5. Google Scholar

The Google Scholar platform was searched using keywords such as "Investment," "Risk," and "Hydropower," which yielded 1, 23,000 results. An advanced search option was used to generate the relevant results. It was implied that "Investment risk in hydropower investment" was the principal phrase. Only the relevant journal articles were selected for the title and abstract screening, and the search pages were rigorously checked for all relevant articles until the searches became redundant and irrelevant. The first four pages (with ten results per page) were used for title screening before the abstract was reviewed.

2.6. Bibliometrics Study

The bibliometric study in this systematic review aims to look at the statistical aspects of the academic literature. The analytics of published documents, source titles, country of publication, number of citations, nature, and area of study are exhibited. In this systematic review, the bibliometric study ensures the robustness of the study by; ensuring the quality of the study and helping us understand the scientific impact of publication in the academic community.

Table 1 exhibits the analytics of the full-text reviewed articles where 34 documents were considered eligible for full-text data extraction. All of the journal articles are Scopus indexed, amongst which 31 were primary source articles, and 3 are secondary source articles that were published in the following influential journals; Electric Power Systems Research Energies, Energy Economics, International Journal Of Energy Sector Management, Renewable And Sustainable Energy Reviews, Applied Energy, Computers And Industrial Engineering, Earth Systems And Environment, Energy For Sustainable Development, Energy Policy, Energy Sustainability, And Society, Environment Development And Sustainability, Global Environmental Change, IIMB Management Review, International Journal Of Sustainable Energy Planning And Management, International Journal Of Water Resources Development, Journal Of Civil Engineering And Management, Journal Of Energy Storage, Journal Of Infrastructure Systems, Renewable Energy, and Water Resources Research.

Figure 1 represents the country-wise study strength of the academic papers generated from Vosviewer. Out of 19 countries, 17 met the threshold to calculate the study strength link (i.e., country-wise document publication and citation). Two countries (Chile and the United Kingdom) had zero citations until the diagram was generated from VOSviewer. The study strength link for seven countries (Chile, Colombia, Germany, Norway, Spain, Sri Lanka, and the United Kingdom) was zero. Out of the seventeen countries studied, the most extensive set of connected countries are 10(Australia, Brazil, China, Hong Kong, Iran, Italy, Switzerland, Turkey, United States, and Viet Nam). The connected set of countries represents the link strength between document publication and citation of the published documents. Figure 2 below presents the status of country-wise citations. The systematic review has incorporated articles from 19 countries and several geographical regions. Seven studies out of 34 journal publications were done in Brazil. Each of the three studies was conducted in the USA and India. Each of the three countries- Turkey, China, and Germany, respectively, have conducted two studies on investment risk in the hydropower sector. In addition, two studies were done, one of which looked at Belt and Road Initiatives (BRI) nations and the other at different regions of Europe. Five studies omitted to provide the name of the nation or areas.

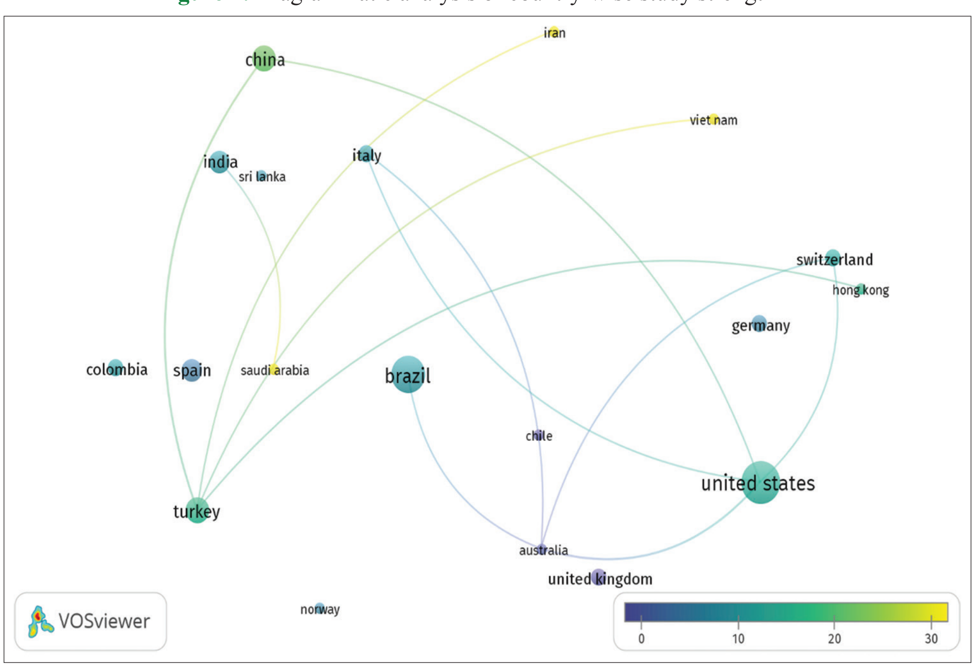
Figure 3 is a Sankey diagram with ten significant countries on the left-hand side, keywords-plus on the right-hand side, and the authors' names in the middle. The 3-field plot generated from "R" depicts the relationship between major global economies conducting the research in "Investment risk in Hydropower" with the critical areas of studies in the field ranging from "energy policy," "investment risk" to "sustainable energy development." The complex relationship between countries' authors and the major keywords-plus is appealingly displayed in the diagram where the width of the countries, authors, and keywords-plus represents their intertwined relationship and depicts how authors from different countries have individually or collaboratively worked to access the investment risk in hydropower.

The bibliometric analysis, Vosviewer analysis, and 3-field plot are based on the 34 full-text reviewed papers. The papers are thoroughly reviewed in the result section to understand the nuances of inherent risks in hydropower investments and how such risks can be adequately understood through methodological advances and the multitude of investment decision modes that can help investors and policymakers ascertain their investment decisions. These analyses portray the countries actively researching the field of hydropower investment risks, the emerging areas and scope in the field of renewable energy investment and green financing, and authors who academically contribute through their research and publications.

Table 1: Analytics of Full-text Reviewed Articles

Description	Results
Documents	34
Sources (Journals)	23
Keywords Plus (ID)	415
Author's Keywords (DE)	151
Period	2018-2021
Average citations per document	15.35
Authors	106
Author Appearances	111
Authors of single-authored documents	1
Authors of multi-authored documents	105
Single-authored documents	1
Documents per Author	0.321
Authors per Document	3.12
Co-Authors per Documents	3.26
Collaboration Index	3.18
ARTICLE	31
REVIEW	3

Figure 1: Diagrammatic analysis of country-wise study strength link



3. RESULTS AND DISCUSSIONS

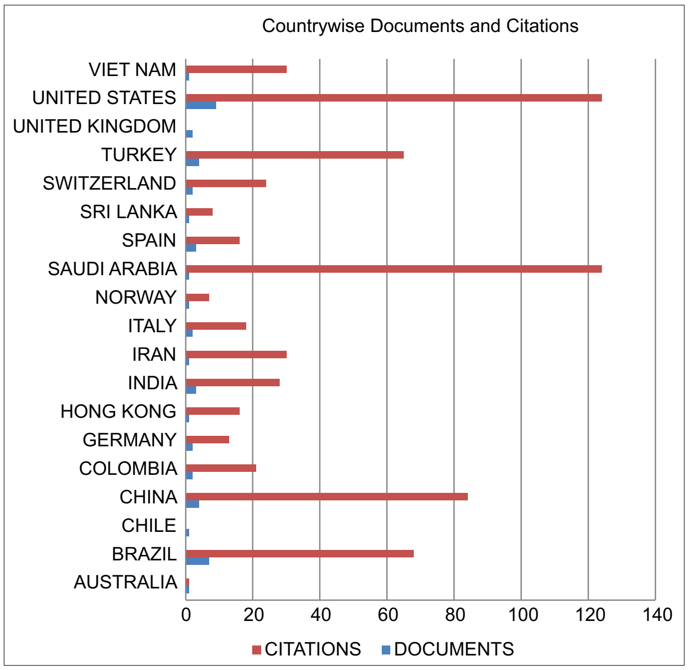
3.1. PRISMA Flow Diagram

The PRISMA flow chart in Figure 4 summarizes the significant methodological findings of this systematic review paper.

Two major databases were searched for relevant literature. 6689 initial results were identified in Scopus. Whereas 123000 initial results were identified in Google scholar. After using the exclusion criteria mentioned in 2.1, 6567 results from Scopus were excluded. On the other hand, only 40 results were assessed as eligible by excluding 122960 results from Google scholar. 122 references from Scopus, 40 from Google Scholar, and 42 additional results from reference and citation searches were identified as relevant for screening. A total of 204 studies were imported for screening. 3 duplicates were removed, and 201 studies were assessed for the title and abstract screening. Upon screening these studies, 86 were excluded because the studies were not in line with the scope of the systematic review and were thus identified as irrelevant. Furthermore, 115 studies were assessed as eligible for full-text review. However, 81 of the studies were excluded on the following grounds;

i. 19 Exclusion based on the period
ii. 35 were not relevant
iii. 13 studies were published in Scopus unindexed Journals
iv. 4 studies were considered gray literature and working papers
v. 10 studies were excluded based on other criteria

Figure 2: Country-wise journal articles and citations



3.2. Risk Factors Affecting Investment Decision Criteria for Hydropower Projects

The 34 articles employed qualitative and quantitative data collection techniques, surveys, and expert opinions to understand the risks and uncertainties in hydropower investment. Eight significant risks were identified. A multitude of investment risks pertaining to hydropower investments are listed as follows:

1. Impact of climate change on hydropower's revenue generation
2. Risks related to climate change and hydrology
3. Risks related to environment and anthropogenic
4. Market risks related to credit, capital, and other financial risks
5. Risks related to substitution from renewable energy to fossil fuels
6. Risks related to socio-political and technological changes
7. Risks related to institution, policy, legality, and regulatory
8. Risks related to human capital development

One of the significant impacts assessed in the review is the impact of climate change on the hydro energy sector's ability to generate

Figure 3: 3-Field plot analysis of countries, authors, and keywords plus

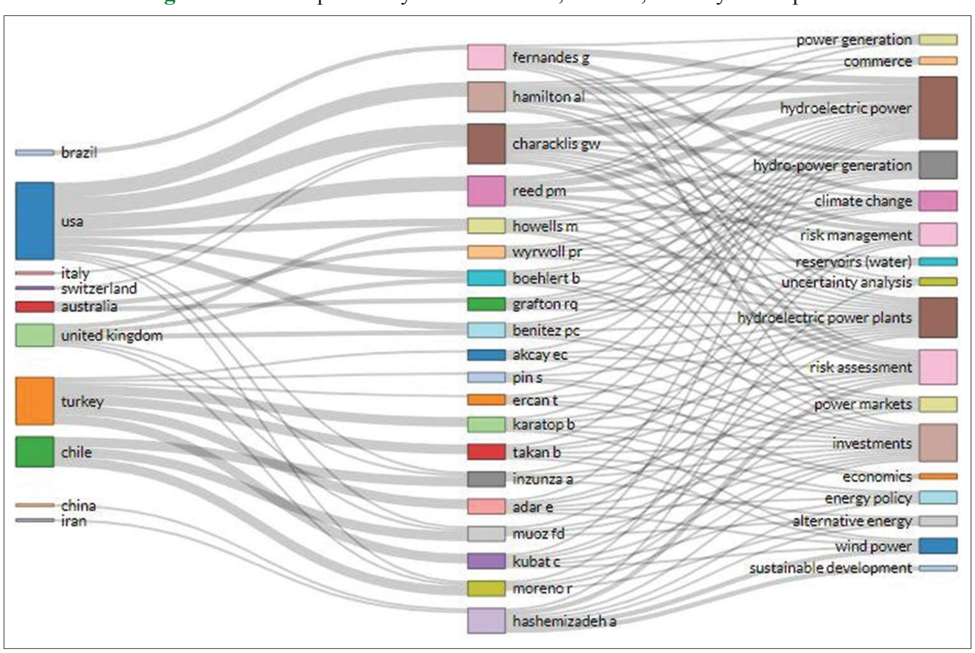
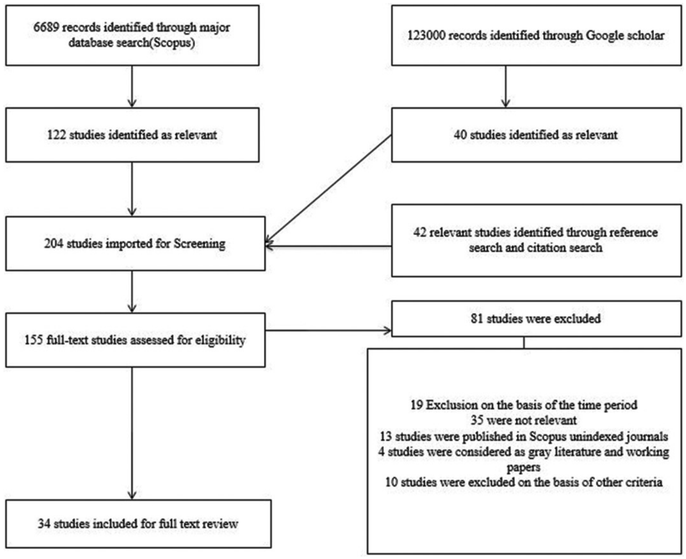


Figure 4: PRISMA flow diagram



revenue. The studies by (de Queiroz et al., 2019; Howells et al., 2021; Lucas and Mendes-Da-Silva, 2018; Ray et al., 2018) have highlighted the risk climate change will have on the hydro-energy sector's ability to generate revenue. These studies show that guaranteed energy is commonly reduced by climate change, which harms revenue generation. According to this scenario, climate factors like temperature and rainfall significantly impact the value of energy firms while seeking to meet national targets for nations like Zimbabwe.

Furthermore, (Abadie et al., 2020) identify supply-shortage risks as a prevalent risk in hydropower investment where an increase in electricity demand and possible chances for power shortages may lead to long-term insecurity in energy supply. The risks associated with the distribution of hydroelectricity are not only primarily dependent on supply shortages, infrastructural lags, or the problem of excess demand. In addition, climate change and hydrological risks are equally significant for investors in understanding the prerequisites for successful investment. (Dash and Singh, 2020) associates operational risks, cost overruns, and socio-economic risks as critical risks for sustainable hydropower development. Global warming, climate change, anthropogenic risks, and other financial risks are primary investment risks for hydropower based upon multipurpose water systems (Aly et al., 2019; de Queiroz et al., 2019; Denaro et al., 2018; Gupta et al., 2020; Hidalgo et al., 2020; Lucas and Mendes-Da-Silva, 2018). (Dincer and Yuksel, 2019)furthers its assessment by evaluating investment decision criteria for renewable energy, where market competition among renewable energy producers and institutional capacity are critical success factors. For Public-Private Partnership (PPP) investments in hydropower, institutional risk, legal risk, contractor and subcontractor risk, and operator risk are predominant risks where accountability towards stakeholders, regulatory requirements, and resource deployment assures the quality of investment (Akcay, 2021). Further, resources, energy prices, inflation, and policy risks are also evident in PPP hydropower investment (Krömer and Gatzert, 2018).

Along with other risk factors, the share of legal risk is also considered significant. In the case of other risks, the primary obstacle factors such as; statutory clearance issues, time and cost, and litigation must all be addressed. Financial hedging and contracting rules are also necessary to mitigate investment risks in hydropower. Regarding tools, modern decomposition, reference point, and reference vector algorithms are difficult to use; thus, more attention must be paid to deploying self-adaptive MOEAs. The utilities fixed cost burden and Contract for Difference (CFD) pricing significantly impact risk management techniques and outcomes, while interest rate has a minor impact. In the case of climate factors and hydropower risk, severe favorable rainfall might not hurt the hydropower plant if there is a mild change in temperature. However, pessimistic rainfall forecasts may harm the plant.

Renewable portfolio standards (RPS) can create incentives that reduce the system's risk exposure. It has been found that commercial banks are the most important source of renewable energy finance. Energy storage systems can raise the expected present value of future investment cash flows. In that case, storage systems must be efficient regarding the fixed operation, maintenance, staffing, and insurance expenses. The study by (Majid, 2020) also finds that the lack of comprehensive policies and regulatory frameworks hampers the adoption of renewable technology. Thus, clear rules and legal procedures are required. The other significant risk factor in the hydropower generation sector is freezing water during winter. When a freezing event happens, the average power price rises, and there is an inverse relationship between temperature and price (Mosquera-López et al., 2018). Subject to small hydropower, the significant investment risk factors are hydrological, technical, financial, regulatory, and socio-economic (Roy and Roy, 2020). At the same time, a study by (Salm and Wüstenhagen, 2018) claims that pension funds are preferred for large storage plants and renewable technology alternatives. To reduce schedule and expense overruns, more proactive monitoring procedures at all levels should be implemented (Shaktawat and Vadhera, 2021), particularly for developing countries.

3.3. Methodological Advances that are Undertaken to Identify the Nature of Risks Critical to Hydropower Investment

Most of the studies in this systematic review are oriented toward understanding the nature and topology of risks, and the majority of them propose robust methodologies to understand the prevalent investment risks. This review analyzed 11 major study models that help investors and policymakers navigate reviewed methodologies to contextualize the nature of risks and investment decisions. Different natures of studies require different methodological approaches to understand existing risks. Fuzzy logic, Monte Carlo simulation and Scoping-Literature-Review are the main methods used in the study. Colar Derivative, DEMATEL, Toposis Method, and MOEA are the other significant tools deployed for risk assessment (Table 2).

Most studies have employed Fuzzy logic since this model deals with hydrological problems that have imprecision, vagueness, approximations, uncertainty, or qualitative mess. Moreover, most

Table 2: Major methodologies examined with their respective studies

Methodologies	Studies
Monte Carlo simulation	(Abadie et al., 2020; Fernandes et al., 2019; Hamilton et al., 2020; Wessel et al., 2020)
Literature review	(Akcay, 2021; Dash and Singh, 2020; Denaro et al., 2018; Shaktawat and Vadhera, 2021; Wyrwoll and Grafton, 2021)
Fuzzy-Logic	(Dincer and Yuksel, 2019; Hashemizadeh et al., 2021; Karatop et al., 2021; Roy and Roy, 2020; Wu et al., 2020; Yu et al., 2018)
Monte Carlo (new wave model)	(Fernandes et al., 2019)
Global climate model	(de Queiroz et al., 2019)
Decision-making trial and evaluation laboratory (DEMATEL) and toposis method	(Dincer and Yuksel, 2019)
Colar by Difference (CBD)	(Fernandes et al., 2019)
Multiobjective evolutionary algorithms (MOEA)	(Gupta et al., 2020; Hamilton et al., 2020)
The open source energy MOdelling SYStem (OSeMOSYS)	(Howells et al., 2021)
Risk-averse planning	(Inzunza et al., 2021)
Cost-benefit approach	(Udayakumara and Gunawardena, 2018)

of the risks this study identifies as critical to investments are consolidated as variables and analyzed. Nevertheless, it is also evident that Monte Carlo Simulation has been used simultaneously to understand the risks inherent to energy system development and operation, as this model efficiently addresses the deterministic and stochastic relations between the hydrological variables. Other methods like the New Wave model, Global Climate Model, DEMATEL and Toposis Method, Colar by Difference, MOEA, OSeMOSYS, Risk averse planning, Cost-Benefit approach, and others are crucial for investors to help them understand the multitude of risks related to climate change, political and legal, technical, financial, hydrological, and anthropogenic risks.

However, (Aly et al., 2019; Fernandes et al., 2019; Gupta et al., 2020; Pedrini et al., 2020) propose fundamental financial risk hedging techniques such as energy contracts, hedging with thermal plants, the Collar-Derivative approach, and financial risk mitigation through MOEA, respectively. (Mosquera-López et al., 2018) finds exogenous shocks in the energy market as key investment risks which arise due to supply-side issues in the energy market resulting in price fluctuations and welfare loss of consumers. (Ray et al., 2018) evaluates geophysical and financial uncertainties through Multi-dimensional stress testing for quality investments in hydropower, further investigating climate and non-climate factors.

The research by (Akcay, 2021; Denaro et al., 2018; Gupta et al., 2020; Ray et al., 2018) has proposed a methodology that has created a model for risk assessment of hydropower investment and various platforms for cooperation. The effectiveness of modern multiobjective evolutionary algorithms has also been examined in papers like (Gupta et al., 2020; Ray et al., 2018). According to the analysis by (Akcay, 2021), the most significant risk cluster is stakeholders, and legal risk is a prominent risk component (in the context of investment in the PPP model). In the case of multipurpose water systems, (Denaro et al., 2018) find financial hedging technology to be an efficient, low-cost solution, whereas (Fernandes et al., 2019) demonstrates that the CBD model is more effective than the hedged mechanism. Furthermore, (Hamilton et al., 2020) show a fundamental trade-off between cash flows and debt levels. Lastly, (Ray et al., 2018) focus on other risk variables like geographical and seasonal variations as major risk factors in hydropower investment and climate change.

According to (Abadie et al., 2020), future researchers should consider improving their methodological and empirical analyses of hydropower investment risks. Decision-makers with little expertise in different models of hydropower projects can also benefit from the numerous recently offered models by (Akcay, 2021; Denaro et al., 2018; Hamilton et al., 2020). Some studies, such as (de Queiroz et al., 2019), recommend using climatic data before investing in and implementing electricity-producing projects. However, this study also suggests using sustainable energy sources, including wind, solar, biomass, nuclear power, and hydroelectricity. The hydrological and market risk problem in countries with major hydro projects, like Brazil, can be solved by adding additional availability contracts for hydropower firms. Some research suggests using CBD for estimating hydrological risks during climate change. New self-adaptive algorithms can be used to improve the consistency and effectiveness of decision-making. To maintain the environmental balance, scientific and technological developments should support future hydropower expansion.

A system's reliance on the import of fossil fuels from other regions can be reduced by encouraging the diversification of the economy's energy-generating portfolio through the employment of policies like renewable portfolio standards (RPS) and carbon taxes, which can also have economic advantages. According to (Lucas and Mendes-Da-Silva, 2018), geographic location, temperature, and rainfall should be employed as determinants of the distribution of energy firm value. (Majid, 2020) suggests that governments can execute Power Purchase Agreements (PPAs) to promote investments in renewable energy sources. In order to provide sustainable energy, project stakeholders must develop a plan early in the project planning process to reduce existing risks and handle challenges of licensing procedures.

4. CONCLUSION AND LIMITATIONS

This study is a Systematic Review of Investment risks in hydropower, where 34 full-text studies were conducted to develop the existing idea on investment risks. Two significant databases, i.e., Scopus and Google Scholar, were searched to identify the relevant results. The robustness of the study was ensured through the use of PRISMA. However, the study is not free from its limitations. Other databases, like Web of Science, Elton B. Stephens Company (EBSCO), Cochrane database for systematic review, ProQuest Central, and PUBMED, were not searched. The search biases were avoided by employing relevant keywords and their synonyms which were further used to generate precise results. However, the results that did not use our keywords or any of the used synonyms were missed on the results. Other relevant searches apart from database searching were generated from reference searching, citation searching, forward and backward searching, and critical journal searching.

The study only focused on Scopus-Indexed peer-reviewed journals from 2018 to 2022 published in English. The scope of this Systematic Review can be furthered by setting more diverse and broader search criteria regarding keywords selection and period. Including conference papers, working papers, gray literature, and other relevant literature will help researchers expand the research on investment risks in hydropower and other renewable energy systems.

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