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REVIEW ARTICLE

Labor Market and Ecological Implications of the Shift from Fossil Fuels to Renewable Energy: A Systematic Literature Review

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Abstract – The global transition from fossil fuels to renewable energy is reshaping labor markets while simultaneously offering significant environmental benefits. This study provides the first Systematic Literature Review (SLR) that integrates evidence across diverse geographic contexts, a broad range of renewable energy technologies, and multiple labor market outcomes, including job creation, job quality, skills development, and distributional effects, while explicitly incorporating associated environmental co-benefits and trade-offs. The review assesses key labor market implications of the energy transition, including sectoral employment shifts and workforce reskilling needs. The findings indicate that renewable energy deployment generally leads to net job gains, particularly in solar, wind, and hydropower sectors, and supports more inclusive labor market opportunities, including marginalized groups. However, the distribution of these gains remains uneven across regions, with fossil fuel–dependent areas facing employment risks and requiring targeted support. Beyond the socioeconomic dimension, the review shows that the expansion of green jobs contributes to broader sustainability goals by reducing carbon emissions, improving air quality, and enhancing ecosystem resilience. The study further highlights the critical role of education systems, skills development, and policy instruments, such as carbon pricing and local employment incentives, in enabling a just and environmentally restorative energy transition.

Keywords – Energy transition, employment, labor market institutions, Renewable energy, Systematic Literature Review.

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1. INTRODUCTION

The transition from fossil fuels to renewable energy is accelerating as concerns about environmental damage and climate risks grow. While this shift is seen as crucial for cutting greenhouse gas emissions and improving ecosystem health, it also affects more than just the environment. The energy transition is changing labor markets by creating new jobs, causing job losses, requiring workers to learn new skills, and altering job quality.

Despite the growing body of research on the labor market implications of the energy transition, existing evidence remains fragmented and incomplete. Recent review studies tend to focus on specific regions, technologies, or social dimensions, without providing an integrated assessment of how the energy transition reshapes labor markets across countries, renewable energy technologies, and employment dimensions, or how these labor outcomes interact with environmental results. Consequently, there is still no comprehensive and up-to-date synthesis that jointly examines job creation, job quality, skills development, and distributional effects alongside environmental co-benefits and trade-offs at the global level.

International climate governance has been instrumental in shaping the global response to environmental challenges. Early achievements, such as the Montreal Protocol (1987), demonstrated the effectiveness of coordinated policy action by phasing out nearly 99% of ozone-depleting substances and delivering substantial climate and health benefits, including preventing significant additional global warming (UNEP, 2021). Building on this foundation, subsequent frameworks, including the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, and the Paris Agreement, have progressively broadened the scope of international climate cooperation, culminating in commitments to limit global warming to well below 2°C and to pursue net-zero emissions in the latter half of the century (UNFCCC, 2015). While these agreements mainly focus on environmental and technological goals, putting them into practice also brings. major economic and social changes. Moving from fossil fuels to renewable energy is not just about the environment; it also means big changes for labor markets. As industries relying on carbon shrink and cleaner sectors grow, jobs shift between sectors and regions. This creates new opportunities but also leads to job losses in traditional energy fields. These changes in the workforce are closely tied to environmental outcomes: having enough skilled workers can accelerate decarbonization, but if workers are unable to adapt, the energy transition may slow or become less effective.

The shift to clean energy is now a major force changing today's job market. The International Energy Agency estimates that up to 14 million new jobs could be created worldwide by 2030, but about 5 million jobs in the fossil fuel industries may disappear (IEA, 2023). Besides the overall job numbers, the transition also raises important questions about job quality, retraining workers, job security, and regional differences. Ensuring that new green jobs offer fair pay, good working conditions, and equal opportunities is key to ensuring a fair transition that supports both social and environmental goals.

To address these challenges, governments and organizations are changing labor policies to help workers learn new skills, encourage green job growth, and support fair transition plans for those affected. However, research on how energy transition affects jobs remains scattered across regions, technologies, and topics. Many studies focus on separate issues and rarely combine information about job outcomes, job quality, and environmental benefits.

Although more research is examining how labor markets are changing, significant gaps remain. A recent search of the Web of Science database for review articles published after 2023 found no new studies that provide a comprehensive and up-to-date overview of how the energy transition is affecting jobs. Current reviews tend to focus on specific areas. For example, Das and Patil (2025) look at labor market changes in certain countries or regions, Gachi (2025) studies specific renewable energy technologies, and May et al. (2025) examine social inequalities and how impacts are shared. These studies are helpful, but none of them bring together different locations, technologies, job-market issues, and environmental outcomes at once.

Moreover, the research also has other gaps. Most of the evidence comes from Europe, China, and North America, while regions like Sub-Saharan Africa, the Middle East, and Southeast Asia are rarely studied, even though they may face serious climate risks and job losses. There are also a few long-term or worker-level studies, so we do not know much about whether workers who lose fossil fuel jobs move into green jobs, what they earn, or what their working conditions are like. Few studies examine how job changes and environmental outcomes are connected, such as whether places with more green jobs also see better air quality or lower emissions. Research on jobs in the circular economy, like recycling and repairing renewable technologies, is also limited, even though these jobs are important for long-term sustainability. Finally, policy research is scattered, and there is little evidence comparing which policies best support both fair jobs and environmental goals.

This study addresses these gaps by conducting a systematic literature review that integrates evidence across diverse geographic contexts, a broad range of renewable energy technologies, and multiple labor market outcomes, including job creation, job quality, skills development, and distributional effects, while explicitly incorporating associated environmental co-benefits and trade-offs. The review is based on a systematic search of the Web of Science database covering the period from 2000 to 2025 (last accessed in May 2025), following the PRISMA protocol for study selection and employing VOSviewer for bibliometric analysis. By synthesizing the rapidly expanding literature, whose publication volume and citation intensity peaked in 2024, this study provides an integrated assessment of how the energy transition reshapes labor markets and contributes to environmental sustainability.

The paper is organized as follows. Section 1 presents the introduction, research gaps, and the study's originality. Section 2 reviews the theory and research on energy transitions and labor markets. Section 3 explains the methods, data sources, and analysis techniques. Section 4 shows the results of the literature and discusses the main findings and policy implications, and Section 5 provides the conclusion, policy recommendations, and limitations.

2. LITERATURE REVIEW

2.1. Theoretical background

The link between renewable energy development and employment is explained by several theories in labor economics, institutional economics, and sustainability studies. Keynesian theory suggests that investing in renewable energy creates jobs directly and indirectly, as well as through increased economic spending (Moreno & López, 2006b; Tourkolias & Mirasgedis, 2011b). Other theories, such as those on structural change and creative destruction, suggest that while new green jobs are created, jobs in fossil-fuel industries may be lost, so the overall effect depends on how workers move between sectors rather than solely on new technology (Lambert & Silva, 2012c). The way researchers measure these effects also matters. Results can differ depending on whether they use input–output models, general equilibrium models, or case studies, since each method makes different assumptions about aspects such as productivity, labor movement, and imports (Lambert & Silva, 2012; Simas & Pacca, 2013). Institutional economics shows that policies, labor laws, and training systems shape job outcomes, while human capital theory explains that workers' ability to adapt depends on education and retraining (Becker, 1964; J & Majid, 2020). Overall, these theories show that the job impacts of the energy transition depend on policy and context, supporting the view that changes in jobs and the environment happen together.

2.2. Overview of the literature

Empirical literature on renewable energy and employment has developed along several complementary strands. Early regional studies focused on localized labor impacts of renewable deployment. Moreno and López (2006b), examining Asturias in Spain, demonstrate that renewable energy investments can generate employment at the regional level, particularly during construction and installation phases. However, their findings also underscore that employment intensity varies significantly across technologies and project lifecycle phases.

Later studies looked at renewable energy and jobs in emerging and developing countries. Research on India, for example, highlights renewable energy as key to sustainable development, connecting job creation to better energy access, more investment, and industrial growth (J & Majid, 2020b). This research also links renewable energy jobs to goals such as reducing poverty and building long-term economic strength, but notes challenges including funding, infrastructure, and the need for skilled workers.

Studies focusing on specific technologies show that job impacts vary across locations. Simas and Pacca (2013) studied wind power in Brazil and found that job creation depends not only on the amount of installed wind power, but also on the amount of equipment manufactured locally and on the configuration of the supply chain. In Greece, Tourkolias & Mirasgedis (2011b) measured the job benefits of renewable energy and found that policies and the country's economic structure play a big role in shaping job outcomes.

These studies all show that renewable energy does not have the same effect on jobs everywhere. The number of jobs created depends on the technology, the region, the project stage, and national policies, economic conditions, and institutions. As a result, researchers agree that we cannot judge the job impacts of renewable energy solely by looking at how much is installed or invested. Instead, we need to consider the specific social and economic context.

Even though research on renewable energy and jobs is increasing, there is still no complete review that brings together evidence from different technologies, regions, job outcomes, and environmental benefits. Most earlier studies focus on a single region, a single technology, or just a few aspects of employment, making it hard to see the full picture of how the energy transition affects society and the environment. This study aims to fill that gap by providing a broad, evidence-based overview of how renewable energy impacts jobs, fairness, and the environment, and by setting the stage for the framework discussed in Section 4.

3. METHODOLOGY & ANALYTICAL FRAMEWORK

This study used a Systematic Literature Review to examine how moving from fossil fuels to renewable energy affects labor markets and the environment. The SLR method was chosen because it provides a clear, repeatable approach to identifying, reviewing, and summarizing relevant studies, accounting for both social and environmental aspects of the energy transition (Kitchenham & Charters, 2007). The review covers research published between 2000 and May 2025, including both older and newer studies. Data was gathered from the Web of Science database, which provides a broad selection of peer-reviewed sources and useful analytical tools.

The study's framework examined how the transition to renewable energy reshapes labor markets across sectors and regions. It focused on job creation, shifts in employment, workforce retraining, changing skill needs, regional differences, and policy responses to the energy transition. The review paid special attention to employment rates, job quality, and worker well-being in both growing green industries and shrinking fossil fuel sectors. The framework also included an assessment of the indirect environmental benefits of green jobs, such as lower greenhouse gas emissions, improved air and water quality, and stronger ecosystems. By examining both labor market and environmental issues, this study aimed to identify the opportunities and challenges of decarbonization. The analysis also aimed to offer practical policy recommendations, showing how energy transition plans can support fair job outcomes, help workers adjust, and ensure a just transition that balances economic growth with environmental protection.

3.1. Research questions

This study addresses the following research questions:

- What opportunities and challenges do the energy transition present for labor markets, and how do these changes interact with environmental outcomes?
- How does the transition from fossil fuels to renewable energy affect job creation, job quality, and employment outcomes across sectors and regions, while contributing to environmental co-benefits?
- How can policymakers ensure that the energy transition is both socially equitable and ecologically restorative, providing new job opportunities while supporting workers' adaptation and sustainability objectives?

3.2. Planning phase

The PICOC framework was employed to structure the research approach by clearly defining the Population, Intervention, Comparison, Outcome, and Context. This ensured a systematic and focused roadmap for data collection and analysis, aligning the study with its objectives and scope (Table 1):

Table 1. PICOC framework

PICOC element	Description
Population	Workers and labor markets affected by the transition from fossil fuels to renewable energy.
Intervention	The shift from fossil fuels to renewable energy and its labor market implications.
Comparison	Traditional fossil fuel-based employment versus emerging renewable energy job opportunities.
Outcome	Changes in job creation, employment transitions, regional disparities, skill development, and policy responses.
Context	Global labor market dynamics, with a focus on sectoral employment shifts, socioeconomic challenges, and policy interventions.

Source: author's own contribution, 2025

3.3. Search phase

A structured keyword search was conducted in WoS using the Topic Search (TS) and Author Keywords (AK) fields, with terms capturing both labor market and environmental dimensions. This ensured that the review captured studies linking labor outcomes to ecological effects (Table 2):

Table 2. Search summary

Databases	Searching terms	Number of articles
Web of Science	TS= (("labor market" OR "employment") AND ("energy transition" OR "renewable energy"))	1,660
	TS= (("labor market" OR "employment" OR "Skill transition" OR "workforce") AND ("energy transition" OR "energy shift" OR "renewable energy" OR "fossil fuel" OR "green energy" OR "clean energy"))	2,172
	TS= (("labor market" OR "employment" OR "Skill* transition*" OR "workforce") AND ("energy transition*" OR "energy shift*" OR "renewable energy" OR "fossil fuel" OR "green energy" OR "clean energy"))	2,193
	TS= (("labor market" OR "employment" OR "Skill* transition*" OR "workforce") AND ("energy transition*" OR "energ* shift*" OR "renewable energ*" OR "fossil fuel" OR "green energ*" OR "clean energ*" OR "low carbon transition*")) AND AK=(("labor market" OR "employment*" OR "workforce" OR "Skill* transition*" OR "job market*") AND ("energy transition*" OR "energ* shift*" OR "renewable energ*" OR "fossil fuel" OR "green energ*" OR "clean energ*" OR "low carbon transition*"))	160

Source: author's own contribution, 2025

3.4. Critical mapping

Following the search phase, the retrieved studies were critically assessed to determine their eligibility for inclusion in the review. Predefined inclusion and exclusion criteria guided this assessment, ensuring that only relevant, methodologically robust studies were retained.

Table 3. Inclusion/ exclusion criteria

Criteria type	Decision
Papers written in English.	Inclusion
Papers that are not freely and fully accessible.	Exclusion
Papers that are duplicated within the search.	Exclusion
Papers that are not relevant to at least one research question.	Exclusion

Source: author's own contribution, 2025

We used a Quality Assessment (QA) checklist to review the selected studies, focusing on how they addressed the socio-environmental aspects of the energy transition. This process helped us include only studies that provided reliable information about labor market changes and environmental effects. The checklist had seven criteria: clear research objectives, sound methods, enough data, transparent results, relevance to jobs and the environment, publication quality, and contribution to existing knowledge. Each was scored as 0 (not addressed), 0.5 (partially addressed), or 1 (fully addressed), for a total possible score of 7. Studies with scores below 4 were left out because they did not meet the standards for academic rigor or relevance to the socio-environmental aspects of energy transition. This approach made our selection process more transparent and ensured that our final dataset included only peer-reviewed, reliable, and relevant studies.

Table 4. Quality Assessment Checklist

Questions
Does the study explicitly explore the relationship between energy transition and the labor market?
Is the study's methodology clearly described and appropriate for the research questions?
Is the data used in the study sufficient to support the conclusions?
Are the results presented clearly, with appropriate use of tables, graphs, or statistics?
Is the impact of the energy transition on the labor market dynamics clearly explained?
Is the study published in a peer-reviewed journal or another high-quality academic outlet?
Does the study contribute new insights or build on existing research in a meaningful way?

Source: author's own contribution, 2025

3.5. Data extraction and analysis

The data extraction and analysis focused on important social and environmental aspects of the energy transition. The review examined labor market outcomes, including job creation, employment changes, new skill requirements, and impacts across sectors and regions. It also looked at environmental outcomes such as reduced emissions, improved air and water quality, and ecosystem restoration, as well as policy measures including workforce adaptation, reskilling, and just transition strategies. Performance analysis was used to track publication and citation trends, and science mapping methods were applied. Keyword co-occurrence analysis with VOSviewer helped identify main themes and new trends, especially those connecting labor market changes to ecological outcomes. This method provided a broad overview of how workforce changes and environmental benefits are linked in the energy transition.

3.6. Synthesis phase

The study used the PRISMA framework to ensure articles were selected in a clear and systematic way. The process began with a search of the Web of Science database, which returned 160 records. Studies that could not be accessed or were not in English were excluded, leaving 77 for further screening based on title, keywords, and discipline. After reviewing abstracts, the selection was narrowed again. Full-text articles were then assessed using a Quality Assessment Checklist, and only methodologically strong and relevant studies were included. The PRISMA diagram shows that this process resulted in a final group of 71 studies, ensuring the synthesis is based on high-quality evidence aligned with the research goals.

4. Results and Discussion

4.1. Descriptive statistics

Between 2000 and 2025, 71 studies were published in this field, reflecting steady research activity. These studies have been cited 1,943 times, averaging 28.28 citations per study, indicating strong academic influence. Excluding self-citations, the total remains high at 1,890, indicating that other researchers are actively citing this work. There are 1,741 citing articles (1,708 without self-citations), so many studies build on this research. The H-index is 21, so at least 21 papers have been cited 21 or more times. These numbers show the research is visible and influential, but there is still potential for greater impact (Table 5).

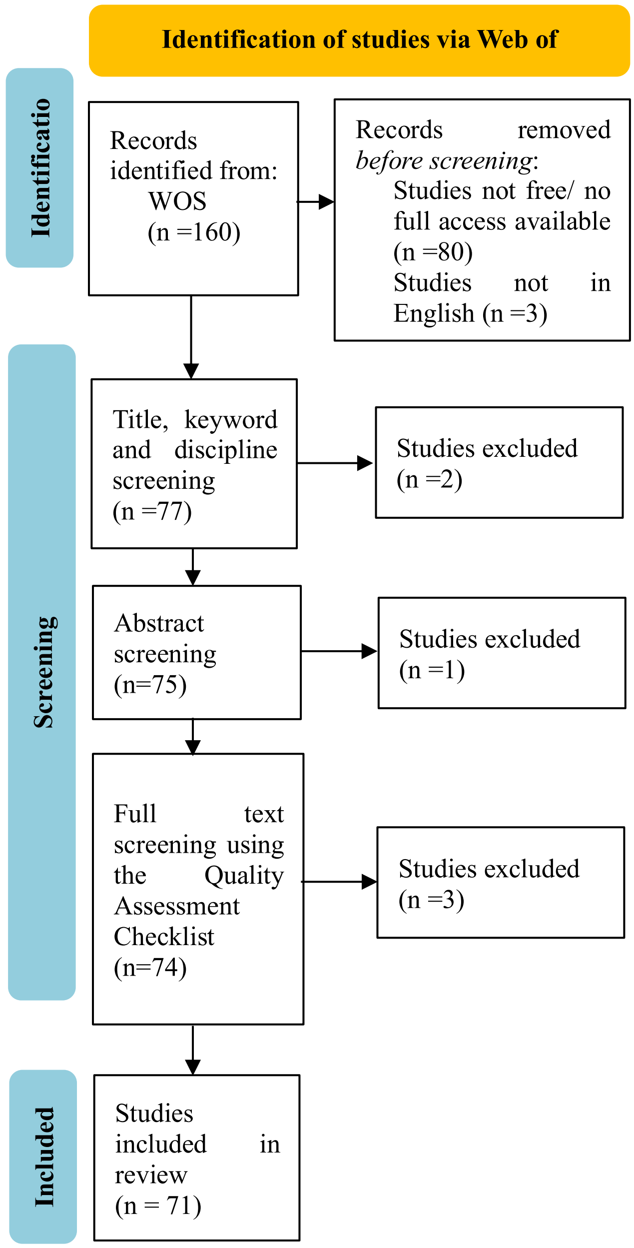

Figure 1. PRISMA Flow Diagram of the SLR

Figure 2 illustrates the evolution of publications and citations over time, starting from 2012 to May 2025. This starting point was deliberately chosen to focus on recent developments in the field, as the number of publications prior to 2012 remained relatively stable and limited. Extending the figure to earlier years would therefore reduce visual clarity without providing substantial additional insight. From 2012 to 2015, both publications and citations remained low with minimal variation. After 2016, the number of publications increased rapidly, reaching a peak in 2024. Citations followed a similar upward trend, also peaking in 2024. The observed decline in 2025 is likely attributable to incomplete data for that year. Overall, these trends indicate growing research activity and increasing relevance of this topic in recent years.

Table 5. Descriptive statistics

Publication	Citing articles	Times cited		H-Index: 21
71 From 2000 to 2025	Total: 1,741	Total: 1,943	27.37 Average per item	
	Without self-citations: 1,708	Without self-citations: 1,890		

Source: author's own contribution, 2025

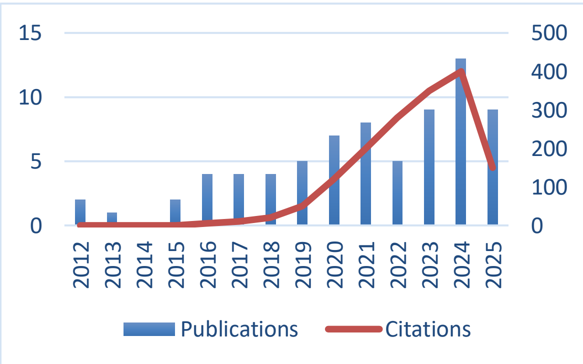

Figure 2. Publications and citations trend

Figure 3 shows that most publications are articles, with nearly 60 papers. There are about 6 conference papers and around 3 review articles. Editorial material is rare. This means most research in the field is original, including both empirical and theoretical studies.

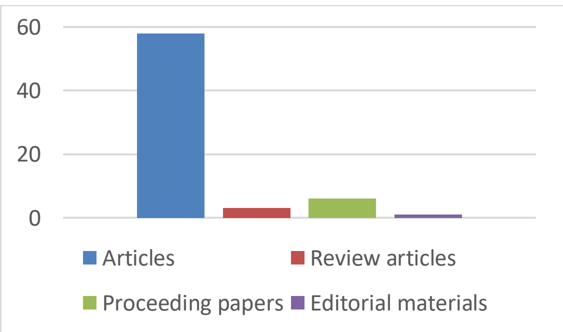

Figure 3. Document types

4.2. Sources analysis

Table 6 shows that most top publishers in this field focus on sustainability, environmental economics, and business research. Elsevier leads with 34 articles, about 48% of the total. MDPI has 18 articles (25%), and Taylor & Francis has 7 articles (10%). Springer Nature and IEEE each contribute about 3%.

Table 6. Publisher analysis

Journal	Record count	%
Elsevier	34	47.887%
MDPI	18	25.352%
Taylor & Francis	7	9.859%
Springer Nature	2	2.817%
IEEE	2	2.817%

Source: author's own contribution, 2025

Figure 4 presents the distribution of publications by country, based on the authors' institutional affiliations, indicating which countries contribute most actively to this research field. The figure does not reflect the empirical studies' geographical focus, but rather the countries in which the research is conducted. The results show that the United States leads with eight publications, followed by China, Germany, Spain, and England, reflecting strong research activity in North America, Europe, and China. This concentration highlights where scholarly interest and research capacity in this area are most prominent.

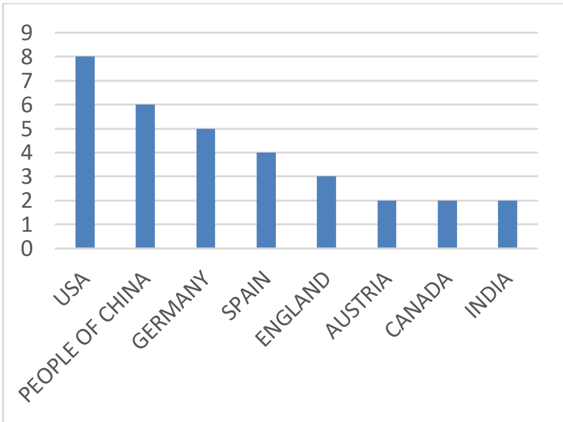

Figure 4. The distribution of publications by country

Figure 5 presents a VOSviewer keyword co-occurrence map based on author-provided keywords from publications between 2020 and 2023, a period selected to capture the most recent and dynamic developments in the field. It should be noted that keyword-based analyses are subject to limitations, as authors may differ in their attention to keyword selection and may not consistently follow emerging trends. To mitigate this issue, the analysis relies on aggregated patterns of keyword co-occurrence rather than individual keyword choices, allowing dominant themes and their evolution to be identified more robustly.

To improve clarity and transparency, the four-year period is explicitly divided into three sub-periods based on publication years: 2020–2021, 2022, and 2023. In the 2020–2021 period, research primarily focused on the socioeconomic implications of the energy transition, with frequently occurring keywords such as “employment,” “labor,” “innovation,” and “model,” reflecting concerns about job creation, reallocation, and competitiveness under decarbonization policies.

In 2022, attention shifted toward integrating renewable energy into broader sustainability and management frameworks. This is reflected in the increased prominence of keywords such as “renewable energy,” “sustainable development,” “growth,” “management,” and “performance,” indicating a transition from impact assessment toward linking renewable energy deployment with sustainable economic growth and organizational performance.

More recently, in 2023, the literature exhibits a stronger emphasis on technical, strategic, and methodological refinement, as shown by the emergence of keywords such as “classification,” “strategies,” and “impacts.” This suggests a maturing research field that increasingly employs data-driven methods, advanced analytical tools, and policy-oriented frameworks to optimize and guide the energy transition.

The largest and most interconnected nodes, particularly “renewable energy” and “impact”, confirm their central role across all sub-periods, while strong linkages with terms such as “employment,” “health,” “performance,” and “management” highlight the integrated economic, social, and environmental perspective adopted in recent studies. Overall, the keyword map reveals a clear thematic progression from broad socio-economic concerns toward strategic integration and refined policy and methodological applications, while acknowledging the inherent limitations of keyword-based analyses.

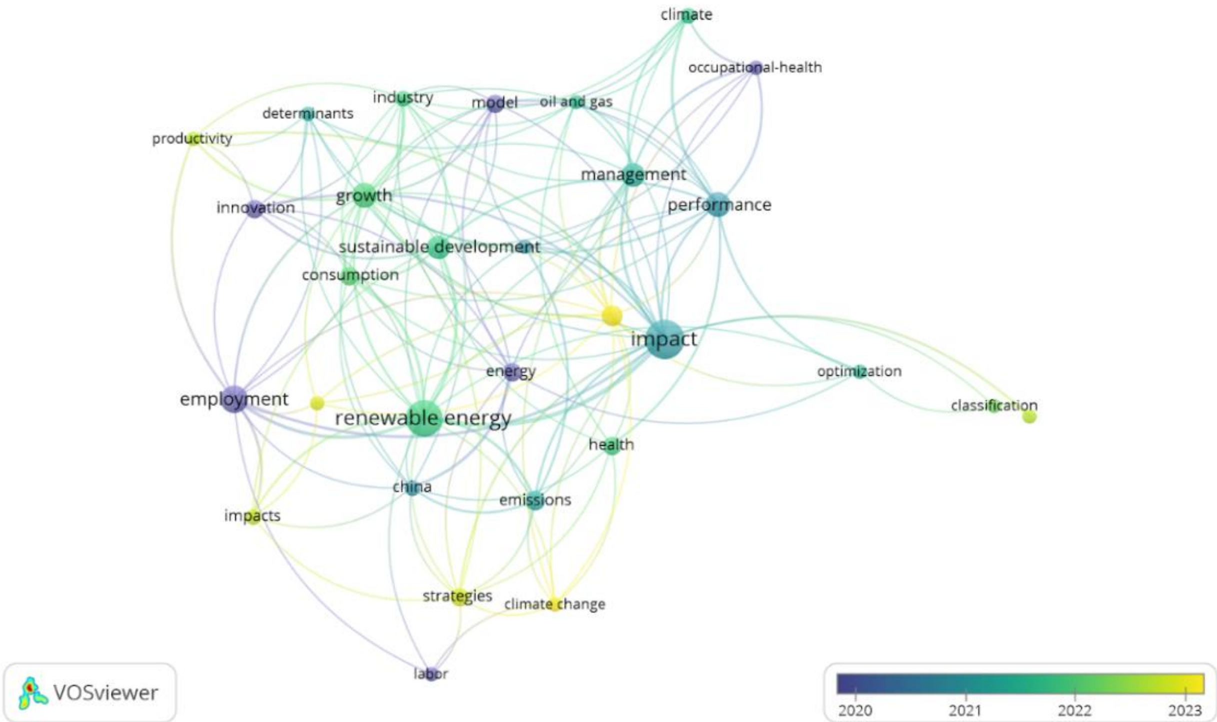

Figure 5. The VOSviewer keyword co-occurrence map

4.3. Evidence mapping and gap analysis

Over the past decade, research on how the energy transition affects the labor market has grown rapidly, as policymakers and academics have paid closer attention to the socioeconomic impacts of decarbonization. Many studies examine employment effects, but results vary widely across sectors, regions, and institutional settings. The research generally focuses on three main debates: (i) net job creation versus just transition risks, (ii) skill biases and workforce transformation in green jobs, and (iii) the geography of winners and losers. Across these themes, a smaller subset of studies has examined the environmental co-benefits of green employment, although such links remain under-explored.

This section brings together the main findings from the literature and presents the evidence-mapping results from the SLR. Instead of listing results separately, it points out where studies agree or disagree, and these points are later summarized in Table 8, which shows where outcomes differ across studies. In this way, the review serves as both a summary of key themes and a basis for subsequent analysis.

4.3.1. Net Job Creation versus Just Transition Risks

Many studies find that the energy transition leads to more jobs overall, especially in renewable energy sectors. Research shows significant job growth in solar, wind, and hydropower, mainly during manufacturing, installation, and maintenance. For instance, Osorio-Aravena et al. (2025) estimate that Chile's move to fully renewable energy could create over 351,000 new direct energy jobs by 2050. Liu et al. (2023) also highlight hydropower, wind, and solar as key sources of job growth, especially in manufacturing and technical services. Similar positive results are seen in Europe, including Switzerland and Poland, where renewable energy and energy efficiency have helped expand the labor market (Füllemann et al., 2019; Dvořák et al., 2016).

Research from developing and emerging economies also shows that investing in renewable energy can create jobs. Studies in Africa find that renewable energy projects can generate jobs cost-effectively (Cantore et al., 2017). Projections for India and Uzbekistan suggest that expanding clean energy will increase employment and economic growth (J & Majid, 2020; Xolmurotov et al., 2025). Globally, Ram et al. (2021) estimate that energy-related jobs could rise from 57 million in 2020 to 134 million by 2050, mainly due to solar, battery, and wind technologies. These technologies also require more workers per dollar invested than fossil fuels (Chen, 2018). Some studies note that renewable energy can also create job opportunities for marginalized groups (Ragmoun & Alfalih, 2024).

However, not all studies find positive job outcomes. Some research shows that in certain regions or during specific phases, job losses in the fossil fuel industry can exceed the number of new jobs created in renewables. For example, Oei et al. (2020) report that phasing out coal in Germany led to short- and medium-term job losses. Hanto et al. (2021) find that in South Africa, new renewable energy jobs did not fully offset coal job losses. Table 8 summarizes these mixed results, showing that net job effects depend on local economies, the speed of the transition, and policy support. Barros et al. (2017) also show that job outcomes differ widely by energy technology, highlighting the need for targeted policies to support a just transition.

4.3.2. Skill Biases and Workforce Transformation in Green Jobs

Another key debate concerns the skills required for the energy transition and whether current workers are prepared for these changes. Many studies emphasize that job benefits depend on how well education and training align with labor market needs. Pilipczuk (2024) points out that gaps between what schools teach and the skills needed for renewable energy can limit job growth, especially in countries facing fast technological change. Müller et al. (2024) also note that good training and working conditions are important for helping workers adapt.

Evidence from Poland illustrates how these dynamics unfold in practice. Szydło et al. (2021) show that employers increasingly prioritize soft skills, such as teamwork, communication, and organizational abilities, often valuing them as much as, or even more than, technical expertise, including in high-tech occupations. Digital skills are often required, and work experience can sometimes substitute for formal qualifications. However, job advertisements rarely mention skills specific to renewable energy, suggesting a gap between employers' needs and the skills listed in job requirements. Table 8 shows that studies have mixed results about job quality and workforce development. While renewables create new jobs, Chen (2018) estimates that more than 70% of these jobs worldwide are in the informal sector, which raises concerns about pay, job security, and social protection. This means that simply counting jobs is not enough to measure the success of the transition; improving job quality and skills is also important.

4.3.3. Geography of Winners and Losers

A third theme examines how the energy transition affects employment differently across regions. Employment outcomes depend on local economic structures, institutional strength, and the type of renewable technology used. For example, Mori-Clement and Bednar-Friedl (2018) found that hydropower projects in Brazil boosted commercial jobs but reduced agricultural ones, showing trade-offs at the local level. Similarly, Fabra et al. (2024) reported that solar projects in Spain created more jobs than wind projects during construction, but many of these jobs went to people from outside the area, limiting local benefits.

Spatial disparities are further reinforced by infrastructure and workforce constraints. Larkin et al. (2023) demonstrate that regional benefits from offshore wind development in Australia depend heavily on existing industrial bases and workforce readiness. Matsumoto and Matsumura (2022) identify limited investment and skill shortages as barriers to renewable energy deployment in Japan's remote islands. These contrasting outcomes are explicitly mapped in Table 8, which illustrates how regional context shapes labor market impacts.

Inequalities also persist across demographic groups. Some studies show progress in inclusion, but gender gaps and wage disparities remain common in renewable energy jobs (Santos, 2025). The evidence suggests that improved inclusion depends on specific policies, not merely on sector growth.

4.3.4. Environmental Co-Benefits and Trade-Offs of Green Employment

Many studies connect the growth of green jobs to wider environmental benefits. More jobs in renewable energy are linked to lower greenhouse gas emissions, better air and water quality, and less damage from fossil fuel extraction. IRENA (2024) reports that in 2023, there were 16.2 million renewable energy workers worldwide, with solar photovoltaic accounting for 44% of these jobs. In the United States, clean power is estimated to prevent approximately 240 million tons of CO_2 emissions annually (Clean Power Association, 2024).

However, evidence mapping reveals a significant gap. Few studies measure labor and environmental outcomes simultaneously, and ecological benefits are often assumed rather than empirically tested. Potential trade-offs, including land-use pressures, raw-material extraction, and renewable waste streams, remain underexplored (Chen, 2018; Oei et al., 2020). These limitations are explicitly highlighted in Table 8, which identifies the absence of integrated socio-ecological analysis as a key research gap.

4.3.5.Gap analysis

Research on renewable energy and labor markets is expanding, but important gaps remain. Table 9 summarizes these gaps and lists the supporting studies.

Geographic coverage in the literature remains uneven. Most studies focus on Europe, North America, China, and a limited number of developing countries. In contrast, regions facing high climate vulnerability and significant labor market disruptions, such as Sub-Saharan Africa, the Middle East and North Africa (MENA), Southeast Asia, Central Asia, and Pacific Island states, are substantially underrepresented (Moreno & López, 2006; J & Majid, 2020; Simas & Pacca, 2013). This geographic bias limits the global applicability of existing findings and reinforces a Global North–centric perspective.

Sectoral coverage is also imbalanced. Research largely concentrates on energy production, while sectors such as transport, agriculture, construction, manufacturing, and services receive considerably less attention, despite their importance for indirect and induced employment effects (Tourkolias & Mirasgedis, 2011). Similarly, most studies focus on mature renewable energy technologies, whereas geothermal, tidal, biomass, and hybrid systems remain insufficiently explored (Lambert & Silva, 2012; J & Majid, 2020). This gap limits our understanding of employment dynamics associated with emerging or region-specific technologies.

Regarding job quality and informality, the literature predominantly emphasizes employment quantity, often overlooking critical dimensions such as wages, job security, working conditions, and the prevalence of informal work, particularly in developing economies (Chen, 2018; Simas & Pacca, 2013).

Although some studies address gender and disability, limited attention is paid to other vulnerable groups, including youth, older workers, rural populations, and informal workers. Moreover, despite growing policy interest in just transition frameworks (Müller et al., 2024), there is a lack of systematic evidence on the effectiveness of labor market and social policies across different institutional and regional contexts. Few studies assess whether education and training systems align with labor market needs or evaluate the effectiveness of reskilling and upskilling programs (Szydło et al., 2021; Moreno & López, 2006).

Finally, data availability and methodological consistency remain major challenges. Many studies rely on projections or isolated case studies rather than real-time labor market data, and definitions of green jobs and employment metrics vary widely across studies (Lambert & Silva, 2012; Simas & Pacca, 2013). Addressing these gaps requires more interdisciplinary research that integrates labor economics, environmental science, and political economy, and explicitly links employment outcomes with equity and environmental objectives. Table 9 summarizes these research gaps and outlines directions for future studies.

Table 7. Evidence mapping: Topics with conflicting evidence

Topic	Evidence
Job Creation in the Renewable Sector	Positive: Renewables (solar, wind, hydro) generate significant new jobs (Osorio-Aravena, 2025; Liu, 2023; Hlongwane & Khobai, 2025). Conflicting: Fossil-fuel sector losses may not be fully offset, especially short-term (Oei et al., 2020; Hanto et al., 2021).
Economic Benefits for Local Communities	Positive: Renewables enhance local economies and reduce poverty, particularly in rural/developing areas (Liu, 2023; Oteng et al., 2024). Conflicting: Construction-phase jobs may be awarded to non-residents, thereby limiting local benefits (Fabra et al., 2024).
Equity & Inclusion (Gender, Disability, Regional)	Positive: Renewable shift supports diverse worker groups; gender inclusion policies are emerging (Ragmoun & Alfalih, 2024; Santos, 2025). Conflicting: Gender equity and wage gaps persist; inclusion is not guaranteed without targeted policies.
Sector-Specific Employment Shifts	Positive: New roles created in services, manufacturing, and construction (Liu, 2023; Mori-Clement & Bednar-Friedl, 2018). Conflicting: Shifts away from agriculture or legacy sectors may lead to sectoral job losses (e.g., hydropower projects).
Policy Impact on Employment Outcomes	Positive: Supportive policies increase jobs and economic performance (Diniz & Couto, 2024; Timmer et al., 2015). Conflicting: Without targeted policies, transitions can lead to GDP or employment losses (e.g., Brazil).
Ecological Co-Benefits and Trade-Offs	Positive: Green job expansion is associated with reduced emissions, improved air quality, and lower fossil-fuel extraction impacts (IRENA, 2024; Clean Power Association, 2024). Conflicting: Few studies empirically measure environmental outcomes alongside labor impacts; potential trade-offs include land use, raw material extraction, and renewable waste streams (Chen, 2018; Oei et al., 2020).

Source: author's own contribution, 2025

Table 8. Gap analysis

Category	Findings	Gaps identified	Implications for Future Research
Geographic Coverage	Strong evidence from Europe, North America, China, and selected developing countries such as Brazil and India (Moreno & López, 2006; Simas & Pacca, 2013; J & Majid, 2020).	Underrepresentation of regions such as Southeast Asia, Central Asia, MENA, and Pacific Islands.	Develop regional case studies to capture context-specific labor market dynamics and policy needs.
Sectoral Focus	Predominant focus on energy production activities; limited references to industrial and service sectors (Tourkolias & Mirasgedis, 2011).	Limited evidence on non-energy production sectors such as transport, agriculture, construction, and services.	Expand scope to capture indirect employment and sectoral effects beyond energy generation.
Types of Renewable Energy	Research primarily focuses on solar, wind, and hydropower (Lambert & Silva, 2012; J & Majid, 2020).	Insufficient study on geothermal, tidal, biomass, and hybrid technologies.	Encourage studies assessing the labor impacts of less common or emerging renewable technologies.
Job Quality and Informality	Employment effects are often measured in terms of job numbers (Simas & Pacca, 2013).	Limited discussion on job quality (wages, benefits, security), informality (Chen, 2018b), and working conditions.	Future research should assess not just how many jobs are being created, but also what kinds of jobs are being created.
Vulnerable & Marginalized Groups	Some attention to gender and disability inclusion (Ragmoun & Alfalih, 2024; Santos, 2025).	There is a lack of comprehensive data on how the transition affects youth, older workers, rural populations, and informal workers.	Include equity-focused assessments to guide just transition policies.
Policy Analysis	Policy relevance is frequently acknowledged (Diniz & Couto, 2024; Müller et al., 2024).	Lack of evaluation of existing transition plans and the identification of which policies work best and under what conditions.	Systematic policy effectiveness evaluations are needed.
Skills and Education Alignment	Recognition of skill gaps and training needs (Szydło et al., 2021).	Few empirical evaluations of the education system's readiness or of reskilling outcomes (Moreno & López, 2006).	Research should link labor needs with educational outputs and evaluate training program outcomes.
Data Availability	Use of projections and case studies is common (Lambert & Silva, 2012).	Limited real-time labor market data; inconsistent job definitions and methodologies across studies.	Need for standardized data collection and comparable indicators across countries and sectors.

Source: author's own contribution, 2025

4.4. Theoretical implications

This review goes beyond identifying employment patterns to highlight key structural factors that determine whether the energy transition leads to fair and meaningful labor outcomes. The findings show that labor impacts depend not just on technology, but also on how policies are designed, the strength of institutions, and the quality of education and skills systems. This means that the employment effects of decarbonization are guided more by policy decisions than by market forces alone, a point that has not been fully explored in current research. The review introduces a socio-ecological framework in which labor and environmental outcomes co-evolve, influenced primarily by policy choices rather than technological change alone.

Figure 6 presents a socio-ecological framework illustrating how the transition from fossil fuels to renewable energy alters the labor market and affects the environment. As the transition moves forward, changes in structure and technology alter job patterns, create new industries, and require different skills from workers. These developments, such as more green jobs, stronger local job markets, and new green skills, are important for environmental progress. When workers adapt by learning new skills, innovating, and moving into new industries, the labor market helps deliver benefits such as lower greenhouse gas emissions, better air quality, and a stronger circular economy. Policies, training programs, and cooperation between the labor and energy sectors influence how well these labor changes support sustainability. In this framework, the labor market can either accelerate or slow environmental progress, underscoring the need for well-coordinated policies.

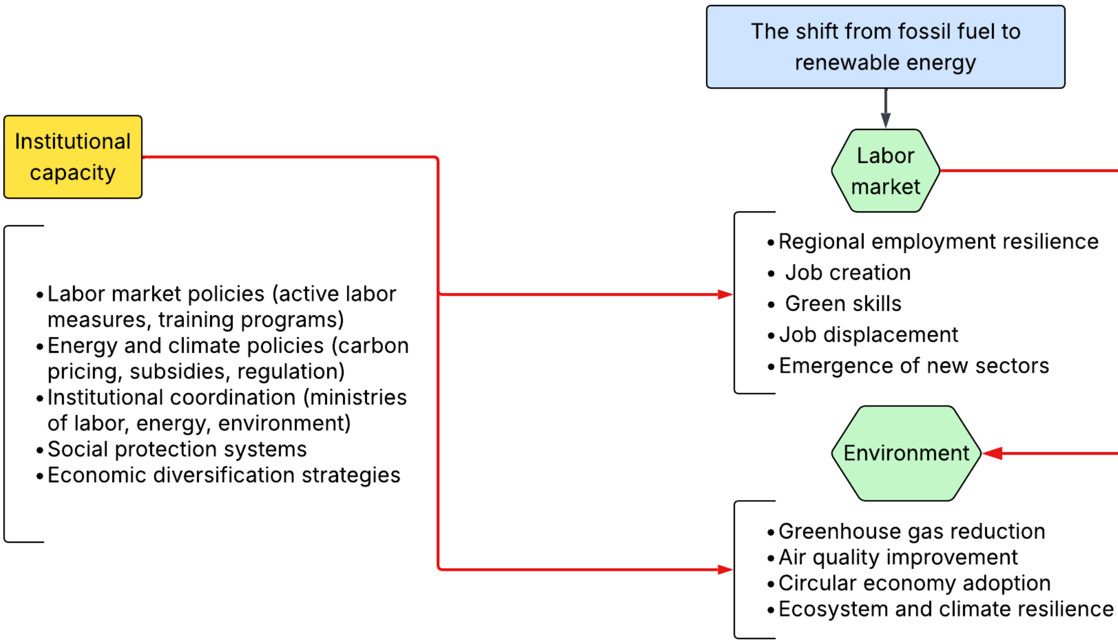

Figure 6 A Socio-Ecological Framework for Labor Market Effects of Energy Transition

5. CONCLUSIONS

This study is the first to provide a comprehensive review of how the worldwide move to renewable energy affects labor markets. It combines results from 71 peer-reviewed studies that examine different regions, technologies, worker types, and environmental issues. The study develops a framework linking energy transitions to labor market outcomes and environmental impacts. This helps address a major gap in prior research, which often focuses on a single region, technology, or job outcome and overlooks the connections between labor and environmental effects.

The review finds that growing the renewable energy sector can create more jobs, especially in manufacturing, installation, operation, and maintenance for solar, wind, and hydropower. These jobs can help lower poverty, support local economies, and improve the environment by cutting CO_2 emissions and cleaning the air. However, the benefits are not shared equally. Areas that depend on fossil fuels, informal workers, and marginalized groups often face more challenges. It is also important to pay attention to job quality and stability, and to make sure people have the right skills for these jobs to achieve real progress.

Policies, strong institutions, and good education systems are key to making labor-market changes fair and lasting. This study recommends five main policy actions: (i) provide training programs that fit the needs of renewable energy jobs, including soft, digital, and technical skills; (ii) develop labor policies that support women, young people, informal workers, and marginalized groups; (iii) plan renewable energy projects by region and sector to meet local needs; (iv) link job programs with environmental goals, like circular economy efforts; and (v) offer funding and local support to help regions that depend on fossil fuels handle job losses.

The main limitation of this study is that it relied exclusively on the Web of Science database, potentially excluding relevant studies indexed in other databases, repositories, or grey literature sources. As a result, some regional studies, industry reports, or publications in non- English journals may not have been captured, potentially biasing the geographic and sectoral representation of the findings. While the systematic approach and bibliometric analysis provide a robust overview of trends and evidence, these constraints should be considered when interpreting the results.

Future research should draw on more databases, include long-term and sector-specific studies, and consider intersectional perspectives to better understand job trends, equity, and environmental benefits. In summary, transitioning to renewable energy could significantly reshape global job markets, but success will depend on well-designed, inclusive, and evidence-based policies. To ensure a fair and lasting transition, it is important to provide good jobs, ensure that everyone can participate, and protect the environment.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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