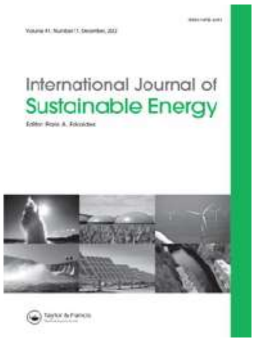

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REVIEW ARTICLE

Pricing the future: unveiling the effects of carbon pricing on socio-economic outcomes and energy poverty

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ABSTRACT

The systematic review used PRISMA guidelines to examine the impact of carbon pricing mechanisms on energy poverty and socio-economic outcomes. Furthermore, Scopus and Web of Science databases were searched for articles published between 1984 and 2023. Nine key themes emerge, including sustainable urban development, renewable energy transition, and governance challenges in energy distribution. The findings underscore the implications of the mechanisms for energy security and socio-economic aspects in developing nations. These mechanisms span multiple SDGs, including SDGs 1, 2, 4, 7, and 11. These findings have several implications, among others, (i) Strategically allocating carbon pricing revenue, e.g. targeted social programmes or investments in renewable energy, can counteract adverse effects and contribute to social equity. (ii) revenue from energy-related policies can be leveraged to alleviate energy poverty through rural electrification and infrastructural development. This study contributes insights for policymakers and practitioners emphasising the interconnectedness of environmental policies with broader development objectives.

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KEYWORDS
Carbon pricing; energy poverty; renewable energy; socio-economic outcomes; carbon emissions; Sustainable Development Goals (SDGs)

1. Introduction

The search for effective carbon pricing instruments has gained significant traction within academic, economic, and environmental policy domains (Baranzini et al. 2017; Khan and Johansson 2022; Mehling and Tvinnereim 2018). Carbon pricing mechanisms, such as carbon taxes and cap-and-trade systems, have been advanced as pivotal tools for internalising the external costs associated with carbon emissions, spurring incentives for emission reduction (Narassimhan et al. 2018; Stavins 2022; Tietenberg 2013). Carbon pricing mechanisms are a form of fiscal and taxation policy that imposes a cost on carbon emissions to limit total emissions; examples include carbon taxes and cap-and-trade systems (CICC Research, CICC Global Institute 2022; Narassimhan et al. 2017; Wang, Fu, and Zhao 2023).

The mechanisms offer a promising avenue for enhancing energy security by incentivizing investments in cleaner and more sustainable energy sources (Baranzini et al. 2017). However, poorly integrated carbon pricing mechanisms and other emissions-reduction policies can threaten energy security (Hood 2013). Internalising the external costs of carbon emissions through carbon pricing policies incentivizes the adoption of renewable energy technologies and energy efficiency measures, ultimately reducing dependence on insecure and environmentally harmful energy sources (Dahlan

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et al. 2022). Thus, integrating carbon pricing strategies with energy security initiatives presents a unified approach to addressing environmental and socio-economic challenges, ultimately leading to a more sustainable and secure energy.

In addressing the challenge of energy security, countries must seek strategies that ensure the uninterrupted availability of energy sources at an affordable price (Asif and Muneer 2007; Rafey and Sovacool 2011; Shrestha et al. 2022). The importance of energy security is magnified in countries with socio-economic fragilities, poor infrastructure, and institutional complexities (Farrell, Zerriffi, and Dowlatabadi 2004; Gregory and Sovacool 2019; Huda 2022; Jasiūnas et al. 2021; Lacher and Kumetat 2011). Socio-economic outcomes encompass various aspects such as economic growth, poverty reduction, employment, health, education, and overall well-being. Furthermore, energy security is pivotal in the people's economic growth, overall development, and livelihoods. The stability and reliability of energy supply is indispensable for fuelling various economic facets, including industries, commercial enterprises, and critical infrastructure (Alemzero, Acheampong, and Huaping 2021; de Carmoy 1986; Wang et al. 2022). Moreover, the accessibility of energy services that are both affordable and dependable is significant in reducing energy poverty levels and elevating living standards. Energy poverty occurs when individuals or households cannot adequately meet their energy needs due to a lack of access or affordability (Nussbaumer, Bazilian, and Modi 2012; Reames, Reiner, and Stacey 2018). However, the availability of clean and efficient energy sources, often made possible by renewables, extends beyond just livelihoods. It positively impacts health, education, food security, and even sectoral economic shifts (Anancharoenkij and Chinnakum 2021; Brunet et al. 2022; Koçak and Çelik 2022; Mirzabaev et al. 2018; Murshed and Ozturk 2023; Okwanya and Abah 2018; Zulu and Richardson 2013).

To address environmental concerns, many countries have implemented carbon pricing as a policy tool (Aldy and Stavins 2012; Best and Zhang 2020; Best, Burke, and Jotzo 2020; Green 2021; Narassimhan et al. 2018). As noted earlier, carbon pricing aims to internalise the external costs of carbon emissions and encourages businesses and individuals to reduce their greenhouse gas emissions. Although this can influence the cost of energy production and consumption, potentially affecting industry competitiveness, it can also drive innovation in cleaner technologies and energy efficiency measures, fostering sustainable economic development (Cui, Zhang, and Zheng 2018; Lim and Prakash 2023; van den Bergh and Savin 2021; Venmans, Ellis, and Nachtigall 2020). Notwithstanding, it is essential also to consider the potential implications of carbon pricing on poverty alleviation in developing countries. Higher energy prices resulting from carbon pricing may disproportionately affect low-income populations (Steckel et al. 2021; Telaye Mengistu et al. 2019). To mitigate this, one approach is to reinvest the revenue generated from carbon pricing mechanisms into social programmes and clean energy initiatives that directly benefit vulnerable communities. This way, the increased energy costs can be offset, and investments in clean energy can create new job opportunities and improve living conditions.

An extensive body of literature has investigated the theoretical foundations and empirical implications of carbon pricing. This body of work typically presents theoretical frameworks, numerical modelling techniques, and qualitative approaches (Köppl and Schratzenstaller 2023). While some studies aim to explain the micro and macroeconomic impacts (Best and Zhang 2020; Cui, Zhang, and Zheng 2018; Lim and Prakash 2023; van den Bergh and Savin 2021; Venmans, Ellis, and Nachtigall 2020), others focus on specific sectors, including agriculture, construction, food, energy, health, and households (Grosjean et al. 2018; Liu, Fan, and Li 2016; Springmann et al. 2018; Stepanyan et al. 2023; Xu et al. 2022). Pioneering empirical analyses in the early 1990s aimed at forecasting the potential impacts of energy and emission taxes before their implementation through ex-ante model simulations. Subsequently, studies in the early 2000s investigated the consequences of energy and emission taxes ex-post. However, these latter studies are restricted to specific jurisdictions or regions, as underscored by a recent meta-review by (Green 2021), for instance.

Despite the growing body of literature on carbon pricing mechanisms, there remains a significant gap in the systematic and comprehensive exploration of their impacts on energy security and socio-economic outcomes. While existing studies have investigated various aspects of carbon pricing, they often focus on individual mechanisms in isolation, lacking a holistic analysis that assesses and contrasts their effects on multiple dimensions. Firstly, the literature does not comprehensively examine how different carbon pricing mechanisms influence various facets of energy security, such as energy access, reliability, and affordability. This gap is particularly pronounced in vulnerable communities and developing regions, where energy security is closely intertwined with socio-economic well-being. Hence, a systematic review that thoroughly investigates the nuanced impacts of carbon pricing on energy security across diverse contexts is crucial for informing policy decisions and ensuring equitable outcomes.

Secondly, the socio-economic implications of carbon pricing remain underexplored, with limited attention given to its effects on critical indicators such as employment, poverty alleviation, and human development. While some studies (Alemzero, Acheampong, and Huaping 2021; de Carmoy 1986; Jasiūnas et al. 2021; Lacher and Kumetat 2011; Nussbaumer, Bazilian, and Modi 2012; Reames, Reiner, and Stacey 2018; Wang et al. 2022) have touched upon these aspects, a more comprehensive analysis that examines the distributional consequences of carbon pricing and its potential to exacerbate or mitigate existing inequalities is needed. Understanding the socio-economic ramifications of carbon pricing is essential for designing policies that promote sustainable development and social justice. Moreover, the variability in research outcomes regarding the effectiveness of carbon pricing policies in reducing emissions highlights the need for a systematic review that synthesises and critically appraises the existing evidence. The lack of a comprehensive review that reconciles conflicting findings and identifies the factors influencing the efficacy of carbon pricing poses a significant challenge in accurately evaluating the performance of implemented policies.

To close the gap in the literature, the systematic review adopted in the current study aims to comprehensively examine the impacts of various carbon-pricing mechanisms on energy poverty and socio-economic outcomes. Against this backdrop, the research questions of this study are as follows:

RQ1: What prevalent themes are emerging in the literature concerning the socio-economic and energy poverty consequences stemming from carbon pricing? This question aims to identify and synthesize the key themes and trends in existing literature, providing a comprehensive understanding of the socio-economic implications of carbon pricing mechanisms.

RQ2: How do carbon pricing mechanisms impact energy poverty, socio-economic outcomes, and the associated Sustainable Development Goals (SDGs)? By addressing this question, the study seeks to elucidate how carbon pricing influences energy poverty and socioeconomic outcomes while identifying the SDGs most closely linked to these impacts.

These research questions are chosen to directly address the gaps identified in the literature by focusing on the nuanced dimensions of energy poverty and socio-economic outcomes impacted by carbon pricing mechanisms. Also, it is imperative to provide a comprehensive discussion on how different carbon pricing mechanisms contribute to specific Sustainable Development Goals (SDGs). By explicitly addressing this aspect, we aim to enrich our analysis and highlight the broader societal impacts of carbon pricing policies. This discussion will explore the various ways in which carbon pricing mechanisms align with and support the attainment of specific SDGs, such as SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), and SDG 13 (Climate Action), among others. Additionally, we will explore potential synergies and trade-offs between carbon pricing policies and SDGs, considering factors such as energy access, poverty alleviation, environmental sustainability, and social equity. Through this examination, our study aims to provide valuable insights into the role of carbon pricing in advancing sustainable development objectives, thus contributing to a more holistic understanding of the implications of carbon pricing for global developmental efforts.

The systematic review conducted in this study aims to comprehensively examine the impacts of various carbon-pricing mechanisms on energy poverty, socio-economic outcomes, and their association with Sustainable Development Goals (SDGs). By synthesising existing literature and empirical evidence, the review will offer valuable insights for policymakers, researchers, and stakeholders, informing the development of effective and tailored carbon pricing policies. Moreover, the findings will shed light on the effectiveness of various carbon-pricing mechanisms in achieving emission reduction targets while assessing their influence on energy security, industry competitiveness, affordability, and poverty alleviation efforts. This comprehensive analysis will provide a more nuanced understanding of the potential trade-offs and co-benefits associated with different carbon pricing mechanisms. It will also highlight their broader societal impacts and alignment with specific SDGs. Ultimately, this research aims to aid policymakers in designing climate policies that foster sustainable economic growth while ensuring energy security, social well-being, and progress toward achieving global development goals.

2. Methodology

This study employed a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, as outlined by (Sarkis-Onofre et al. 2021). The review process comprised three sequential steps: firstly, titles of articles were screened; secondly, abstracts were examined; and finally, the full articles were scrutinised. The documents underwent an examination and analysis using the open-access Zotero software. Subsequently, a file was generated in R software, formatted in BibTeX, and exported for integration into the Bibliometrix software. Bibliometrix facilitated the execution of comprehensive bibliometric, semantic, and content analyses, mitigating the risk of result distortion. A visual representation of the PRISMA flow process can be found in Figure 1 in the PRISMA.

2.1. Data collection

- **Selection of Databases:** The study involved a systematic review of scientific articles based on two bibliographic databases, Web of Science (WoS) and Scopus. These databases are known for their extensive collections of peer-reviewed scientific literature.
- **Rationale for Choosing Databases:** Web of Science and Scopus were selected because they are considered the largest databases of peer-reviewed scientific literature. Their extensive coverage of literature makes them suitable for quantitatively examining bibliographic data to understand trends and patterns in research. Moreover, they offer extensive metadata of the literature, abstracts, citation counts, references, authorship details, affiliations, and geographical information.
- **Data Collection Date:** The data gathering process took place on October 11, 2023, i.e. all the data used for the systematic review, including the articles' bibliographic information, was collected on this date.
- **Time Frame for the Study:** The study aimed to create a dataset covering 1984 to 2023.
- **Language Inclusion:** The study exclusively considered scholarly articles and reviews published in English. This language restriction helps ensure that the dataset is consistent and manageable.

The decision to focus on Web of Science (WoS) and Scopus for our systematic review was guided by several factors. Firstly, these databases have extensive coverage of peer-reviewed scientific literature across various disciplines (Pranckutė 2021). Also, their broad reach spans various research domains, publication types, and institutions. WoS and Scopus ensure a broad and representative sample of relevant studies (Pranckutė 2021). Secondly, both databases uphold stringent standards of quality and reliability, employing rigorous selection criteria and indexing processes to include only high-calibre, peer-reviewed publications. This commitment to quality is fundamental for upholding the integrity and credibility of our systematic review.

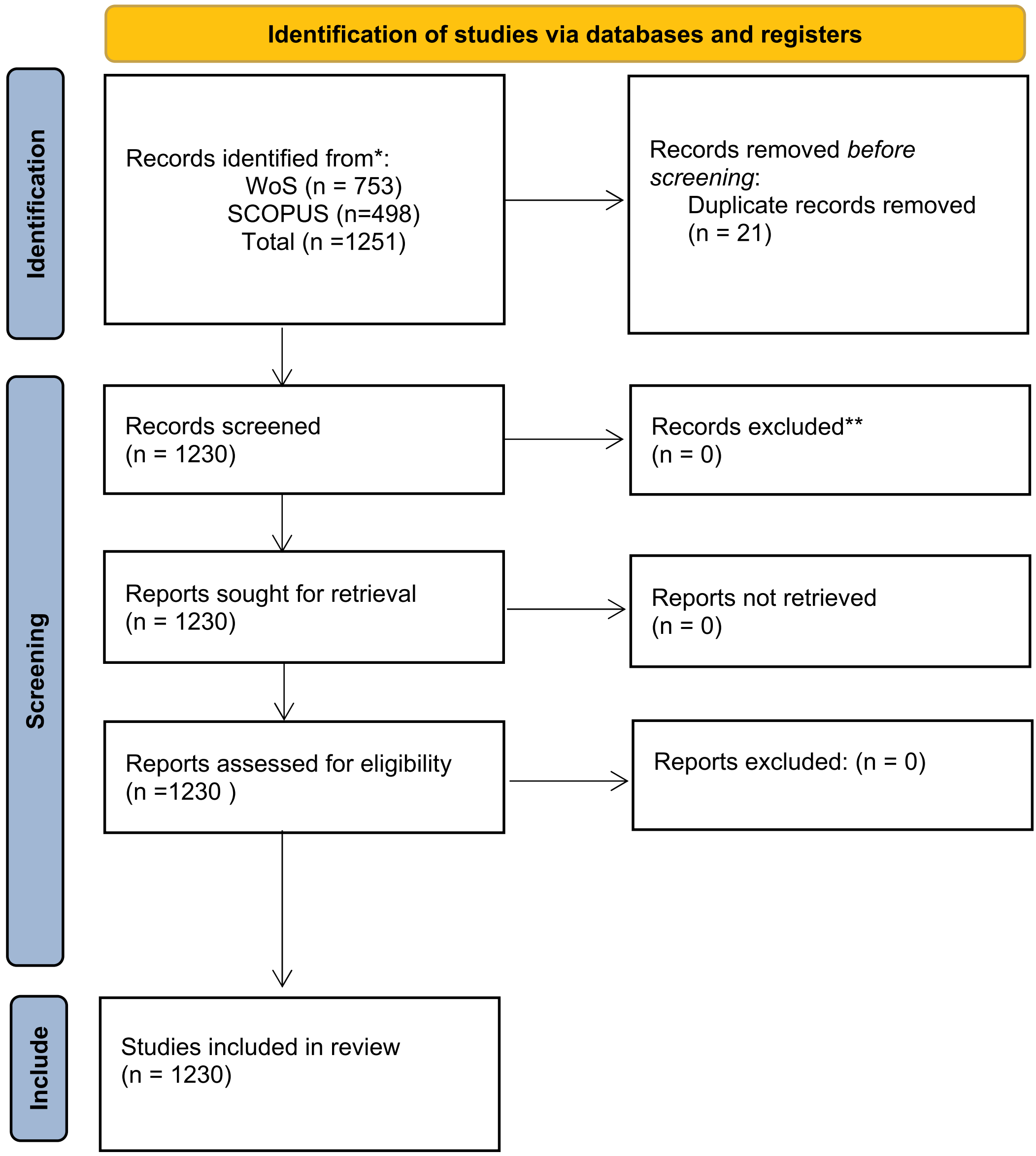

Figure 1. PRISMA flow chart. The PRISMA 2020 http://www.prisma-statement.org/.

Moreover, WoS and Scopus offer invaluable bibliometric data, such as citation counts and impact factors, which are widely utilised for research assessment and evaluation. (Pranckutė 2021). These bibliometric indicators are crucial in assessing the included studies' influence and significance, enhancing our analysis's robustness. Additionally, the decision to utilise WoS and Scopus is aligned with the methodological standards and best practices in systematic reviews and meta-analyses. Indeed, many prior studies in the domain of carbon pricing and energy economics have relied on these databases as primary data sources, ensuring comparability and consistency with existing research (Grewal, Kataria, and Dhawan 2016).

While we acknowledge the potential limitations of excluding other databases, we are confident that the extensive coverage and quality of WoS and Scopus mitigate this concern to a significant extent. Additionally, to address this issue, we have implemented supplementary search strategies, such as manual searching of key journals and reference list checking, to identify any pertinent studies that may have been overlooked in the database search (Munn et al. 2018). This multi-pronged approach ensures a thorough literature review, enhancing the reliability and validity of our findings.

2.2. Software applications

The systematic review employed two software tools to facilitate data analysis and visualisation. Firstly, bibliometrix, a specialised biblioshiny application for research in bibliometric and scientometrics, was utilised (Stepanyan et al. 2023). Bibliometrix provided essential functionalities for analysing publication patterns, citation networks, and co-authorship relationships within the literature corpus. Specifically, it enabled the extraction of bibliometric data such as citation counts, publication trends, and author collaboration networks. Additionally, bibliometrics facilitates the identification of key research themes and the visualisation of co-citation networks, offering valuable insights into the structure and dynamics of the scholarly landscape. Most metrics used in this study are already defined by the developers of the Bibliometrix package (see https://www.bibliometrix.org/home/index.php/layout/biblioshiny-2)

The second software tool utilised in the review was VOSviewer, a freely available software designed for creating, visualising, and exploring network-based maps, as developed by van Eck and Waltman (2010). VOSviewer facilitates the detection of clusters within the literature corpus, aiding in identifying distinct research themes and knowledge domains. By leveraging VOSviewer's capabilities, the review generated insightful visualisations that enhanced the understanding of the interconnections and patterns in the scholarly literature on carbon pricing and its socio-economic impacts.

The combination of bibliometrix and VOSviewer allows for comprehensive analyses of the literature corpus, enabling the identification of key trends, patterns, and relationships. These tools played a crucial role in synthesising and interpreting the systematic review's findings, providing a deeper understanding of the research landscape and contributing to the overall interpretation of the results.

2.3. Search strategy

The search strategy adopted a comprehensive approach to systematically examine the literature across three (Mehling and Tvinnereim 2018) critical fields related to carbon pricing, socioeconomic impacts, and policy implications. The search terms were carefully selected to ensure the retrieval of relevant articles from both Scopus and WoS databases. Specifically, diverse terms associated with carbon pricing, such as 'Carbon Tax,' 'Emissions Trading,' and 'Carbon Market,' were included to encompass different carbon-pricing mechanisms and their effects on environmental policy dynamics.

Moreover, terms related to socioeconomic impacts, including 'inequality,' 'welfare,' 'Poverty,' and 'Income Distribution,' were investigated to elucidate the distributional implications of carbon pricing policies and their influence on various segments of the population. The search strategy also considered assessments of regressive and progressive elements of carbon pricing to provide a nuanced understanding of its socioeconomic effects.

Additionally, the search strategy encompassed terms related to policy implications, such as 'Policy Implications,' 'Climate Change Policy,' and 'Environmental Regulation,' to explore the broader policy landscape influenced by carbon pricing. These terms were chosen to uncover insights into the recommendations and considerations emerging from the literature regarding the implementation and impact of carbon pricing policies.

While searching, efforts were made to ensure transparency and reproducibility by adhering to predefined inclusion and exclusion criteria outlined in Table 1. However, we must acknowledge

Table 1. Inclusion and exclusion criteria for the documents in the study.

	Criteria
Logical Statement Scopus	TITLE-ABS-KEY ((‘Carbon Pricing’ OR ‘Carbon Tax’ OR ‘Carbon Emissions Pricing’ OR ‘Emissions Trading’ OR ‘Carbon Market’ OR ‘Carbon Offset’) AND (distribut* OR regressive OR progressive OR inequality OR ‘household income’ OR welfare OR livelihoods OR ‘well-being’ OR ‘socio-economic impacts’ OR Poverty OR ‘Income Distribution’ OR ‘Distributional Effect’ OR ‘Equity Impact’ OR ‘Social Consequences’ OR ‘Socioeconomic Effects’ OR ‘Welfare Implications’) AND (‘Policy Implications’ OR ‘Policy Recommendations’ OR ‘Public Policy Analysis’ OR ‘Environmental Regulation’ OR ‘Climate Change Policy’ OR ‘Green Economy’ OR ‘Environmental Equity’ OR ‘Carbon Policy Assessment’)) AND NOT TITLE-ABS-KEY (‘smart grid’ OR biomass OR (distribut* W/1 (energ* OR network* OR spatial)) OR ‘power plant’ OR ‘natural gas’ OR solar OR hydropower OR software OR wireless OR computer OR forest) AND (LIMIT-TO (SRCTYPE, ‘j’)) AND (LIMIT-TO (PUBSTAGE, ‘final’)) AND (EXCLUDE (SUBJAREA, ‘COMP’) OR EXCLUDE (SUBJAREA, ‘MATH’) OR EXCLUDE (SUBJAREA, ‘CENG’)) AND (LIMIT-TO (DOCTYPE, ‘ar’)) AND (LIMIT-TO (LANGUAGE, ‘English’))
Logical Statement WoS	TS=(((‘Carbon Pricing’ OR ‘Carbon Tax’ OR ‘Carbon Emissions Pricing’ OR ‘Emissions Trading’ OR ‘Carbon Market’ OR ‘Carbon Offset’) AND (distribut* OR regressive OR progressive OR inequality OR ‘household income’ OR welfare OR livelihoods OR ‘well-being’ OR ‘socio-economic impacts’ OR ‘Poverty’ OR ‘Income Distribution’ OR ‘Distributional Effect’ OR ‘Equity Impact’ OR ‘Social Consequences’ OR ‘Socioeconomic Effects’ OR ‘Welfare Implications’) AND (‘Policy Implications’ OR ‘Policy Recommendations’ OR ‘Public Policy Analysis’ OR ‘Environmental Regulation’ OR ‘Climate Change Policy’ OR ‘Green Economy’ OR ‘Environmental Equity’ OR ‘Carbon Policy Assessment’)) NOT (‘smart grid’ OR biomass OR (distribut* NEAR/1 (energ* OR network* OR spatial)) OR ‘power plant’ OR ‘natural gas’ OR solar OR hydropower OR software OR wireless OR ‘computer’ OR forest))
Inclusion	1. Document written in English. 2. Document containing the keywords
Exclusion	1. Documents not written in English. 2. Documents not containing the keywords

that despite our best efforts, limitations have been encountered during the search process. These limitations include constraints imposed by database interfaces (the two databases do limit the number of keywords used in the search string), variations in indexing labels, and the possibility of missing relevant studies due to the complexity of the research topic synonyms and search syntax (some topics may have many synonyms).

Table 1 presents the baseline search strings used in the Web of Science (WoS) and Scopus databases to retrieve relevant documents for the systematic review. These logical statements encompass a wide array of keywords and phrases related to carbon pricing, socioeconomic impacts, and policy implications, ensuring the retrieval of relevant literature while excluding irrelevant documents. Additionally, both searches were restricted to documents written in English to maintain consistency in language and ensure comprehensibility for the reviewers.

2.4. Screening of documents

The document screening process was conducted in a sequential three-step manner: initially, by reviewing the article titles; subsequently, by examining the abstracts of the articles; and finally, by delving into the complete articles.

The systematic review utilised specific criteria for screening titles, abstracts, and full-text articles to ensure a comprehensive and rigorous selection process. The inclusion and exclusion criteria outlined in Table 1 were meticulously crafted to capture studies that directly addressed the intersection of carbon pricing, socioeconomic outcomes, and policy implications. Additionally, we included terms indicative of distributional effects, such as ‘inequality,’ ‘welfare,’ and ‘poverty,’ to encompass the breadth of relevant literature. The criteria were designed to capture relevant literature while excluding irrelevant or non-English documents.

The inclusion criteria stipulated that the documents must be written in English and contain specific keywords related to carbon pricing, socio-economic impacts, and policy implications. This ensured that the selected documents were accessible and aligned with the review’s thematic focus.

Furthermore, the logical statements presented in Table 1 offer detailed insights into the specific search terms and logical operators used for both Scopus and WoS. These logical statements represent the specific criteria employed for retrieving articles and reflect the meticulous approach taken to ensure the thoroughness and consistency of the literature search. The review process is transparent and reproducible by outlining the specific criteria for screening titles, abstracts, and full-text articles. This aligns with best practices for systematic reviews and enhances the credibility and reliability of the study's findings.

3. Results and analysis

This section presents an overview of descriptive statistics of data retrieved from Scopus and the Web of Science database, together with insights from the merged dataset. From the analysis, the section also offers insights on the following: (1) highlights the most productive authors by analysing their fractionalised articles; (2) shows the top 10 most impactful articles in the field; (3) reports on three field key plots, summarising the trends in authors, keywords, countries, and sources. Moreover, the illustration of keyword co-occurrence provides insights into the interaction among terms within the dataset; (4) uses a thematic evolution map to illustrate the temporal progression of thematic content; (5) displays results of the top 10 countries associated with corresponding authors.

3.1. Summary of descriptive statistics

Table 2 summarises the data obtained from Scopus and Web of Science (WoS) and a merged dataset spanning 1984–2023. While the WoS database includes documents from 1998 onward, Scopus covers documents from 1984 to 2023. The merged dataset with 1230 documents offers a larger pool than Scopus (498) and WoS (753) individually, indicating a more extensive set of publications in the combined data.

The annual growth rates of publication exhibit variations, with WoS presenting the highest at 20.64%, potentially indicative of an escalating scholarly output within the intersection of carbon pricing and socio-economic outcomes. Regarding document age, Scopus records an average of 5.12 years, WoS records 3.8 years, and the merged dataset records 4.3 years. The lowest average age in WoS suggests a more recent publication profile. Regarding citations, Scopus leads with an

Table 2. Main information of the Scopus, Wos, and Merged Data sets of the included studies.

	Scopus	WoS	Merged Data Set
MAIN INFORMATION ABOUT DATA			
Timespan	1984:2023	1998:2023	1984:2023
Sources (Journals, Books, etc)	170	211	338
Documents	498	753	1230
Annual Growth Rate %	11.34	20.64	14.14
Document Average Age	5.12	3.8	4.3
Average citations per doc	35.13	25.85	29.6
References	26410	1	1
DOCUMENT CONTENTS			
Keywords Plus	2845	1203	3755
Author's Keywords	1410	1991	3107
AUTHORS			
Authors	1381	2093	3249
Authors of single-authored docs	82	96	171
AUTHORS COLLABORATION			
Single-authored docs	84	101	179
Co-Authors per Doc	3.1	3.4	3.29
International co-authorships %	33.13	44.36	27.07
DOCUMENT TYPES			
Article	498	724	1197
Article			4
Article: data paper		3	3
Article: early access		15	15
Article: proceedings paper		11	11

average of 35.13 citations per document, while WoS and the merged dataset follow with 25.85 and 29.6, respectively. The merged dataset encompasses at least 3755 unique Keywords and 3107 Author's Keywords, underscoring the diverse range of topics in the nexus of carbon pricing, energy poverty, and socio-economic outcomes. Furthermore, the merged dataset involves 3249 contributors, surpassing the individual databases and indicating a more extensive network of researchers. The percentage of international co-authorships varies, with WoS displaying the highest at 44.36%, followed by Scopus (33.13%) and the merged dataset (27.07%).

The higher annual growth rate (20.64%) observed in WoS compared to Scopus (11.34%) can be significant for the field of carbon pricing research—it may suggest a more rapid increase in research output related to carbon pricing. In turn, the observation indicates growing scientific interest in the topic, potentially due to (i) Rising global awareness of climate change and the need for mitigation strategies could drive more research into carbon pricing as a potential policy tool; (ii) the implementation of carbon pricing schemes in various countries might stimulate research to evaluate their effectiveness and explore best practices; (iii) the developments in clean energy technologies and carbon capture techniques might be prompting research on how carbon pricing can incentivize their adoption.

While WoS has a higher growth rate, it also has a shorter coverage timeframe (starting in 1998 compared to Scopus' 1984). This means faster growth might capture a more recent surge in research activity. With its longer timeframe, Scopus might include more foundational studies published earlier, potentially skewing its growth rate. Since WoS captures more recent publications on average (as shown by the lower document age), the higher growth rate might reflect a focus on the latest advancements and emerging trends in carbon pricing research.

3.2. Top 10 authors ranked by article count and impact score

Table 3 presents the top 10 most influential authors, offering valuable insights into their respective contributions to carbon pricing and its impacts on socio-economic outcomes and energy poverty. The authors are ranked based on the number of articles attributed to each author and their fractionalised rank, providing a quantitative measure of their impact.

With 16 published articles and the highest fractionalised articles (7.16), Sovacool is ranked first. This implies that Savacool has authored several influential articles on the impact of carbon pricing on energy poverty and socio-economic outcomes, which aligns with the research's thematic focus. Bekun came in second place with 4.27 fractionalised articles suggesting authorship of influential articles within the broader domain of carbon pricing. Pachauri has published 14 articles and is ranked third with 4.07 fractionalised articles. The table underscores the impact and relevance of these scholars in the field. Musango occupies the tenth position with eight documents and a fractionalised rank of 3.20. In conclusion, by analysing the number of publications and the fractionalised rank, Table 3 highlights scholars who are likely making impactful contributions to the field of carbon pricing research.

3.3. Top 10 most influential articles in the field based on citation metrics

Table 4 highlights ten influential articles within the field of carbon pricing research. Several articles address the relationship between renewable energy, economic development, and carbon emissions. The study (Winzer 2012) titled 'Conceptualizing energy security' provides a foundation for discussing the impact of carbon pricing on the stability and reliability of energy sources. Similarly, the article 'Politicizing energy justice and energy system transitions,' written by (Healy and Barry 2017), emphasises the importance of just transitions, a concept integral to discussions around the socioeconomic outcomes of climate policies. The latter study underscores the importance of just energy transitions and the impact of divestment in the broader energy transition context. It

Table 3. Top 10 most influential authors (ranked by article count and impact score).

References	Authors	Articles	Authors	Articles Fractionalized	Rank
Rafey and Sovacool (2011), Gregory and Sovacool (2019), Bambawale and Sovacool (2011), Hiteva and Sovacool (2017), Park and Sovacool (2018), Sovacool (2011), Sovacool (2013), Sovacool (2020), Sovacool et al. (2019), Sovacool et al. (2013), Sovacool et al. (2017), Sovacool et al. (2019), Sovacool and Brown (2010), Sovacool and Scarpaci (2016), Sovacool and Tambo (2016), Sovacool and Walter (2019)	Sovacool B	16	Sovacool B	7.16	1
Adedoyin et al. (2020), Asongu et al. (2020 Apr 10), Azam, Gohar, and Bekun (2022), Balsalobre-Lorente et al. (2019), Bekun, Emir, and Sarkodie (2019), Bekun et al. (2022), Bekun et al. (2023), Bekun and Alola (2022), Gyamfi et al. (2021), Gyamfi et al. (2023), Joshua and Bekun (2020), Kolawole et al. (2022), Quito et al. (2023), Saint Akadiri, Bekun, and Sarkodie (2019), Steve et al. (2022)	Bekun F	15	Bekun F	4.27	2
Boza-Kiss, Pachauri, and Zimm (2021), Dagnachew et al. (2020), Doll and Pachauri (2010), Falchetta et al. (2019), Falchetta et al. (2020), Kimemia et al. (2014), Mainali et al. (2014), Pachauri et al. (2021), Pahle, Pachauri, and Steinbacher (2016), Pelz, Brutschin, and Pachauri (2021), Pelz, Pachauri, and Falchetta (2023), Poblete-Cazenave et al. (2021), Rao and Pachauri (2017), Zeyringer et al. (2015)	Pachauri S	14	Pachauri S	4.07	3
Falchetta et al. (2019), Falchetta et al. (2020 Apr 24), Pelz, Pachauri, and Falchetta (2023), Dagnachew, Choi, and Falchetta (2023), Falchetta (2021), Falchetta et al. (2021), Falchetta et al. (2022), Falchetta, Hafner, and Tagliapietra (2020), Falchetta et al. (2021), Falchetta and Mistry (2021)	Falchetta G	10	Munro *P*	4.03	4
Bazilian et al. (2011), Dhakouani et al. (2017), Korkovelos et al. (2018), Korkovelos et al. (2020), Menghwani et al. (2020), Mentis et al. (2015), Mentis et al. (2016), Mentis et al. (2017), Nerini et al. (2016), Nussbaumer et al. (2013)	Howells M	10	Urpelainen J	4.03	5
Bazilian et al. (2011), Korkovelos et al. (2018), Korkovelos et al. (2020), Mentis et al. (2015), Mentis et al. (2016), Mentis et al. (2017), Bazilian, Nakhooda, and Van de Graaf (2014), Bazilian and Onyeji (2012), Onyeji, Bazilian, and Nussbaumer (2012)	Bazilian M	9	Kusakana K	4.00	6
Aklin and Urpelainen (2021), Alkon, Harish, and Urpelainen (2016), Dugoua, Liu, and Urpelainen (2017), Dugoua and Urpelainen (2014), Lukuyu et al. (2023), Pelz and Urpelainen (2020), Urpelainen (2014), Urpelainen and Yoon (2015), Zhang et al. (2022)	Urpelainen J	9	Inglesi-Lotz R	3.70	7
Akinyele et al. (2020), Monyei et al. (2018), Monyei, Adewumi, and Jenkins (2018), Monyei et al. (2019), Monyei et al. (2022), Monyei et al. (2018), Monyei et al. (2018), Monyei and Adewumi (2017)	Monyei C	8	Falchetta G	3.42	8
Kemeny et al. (2014), Munro (2020), Munro et al. (2016), Munro (2021), Munro, Samarakoon, and van der Horst (2020), Munro and Bartlett (2019), Munro and Schiffer (2019 Apr 1), Samarakoon, Bartlett, and Munro (2021)	Munro *P*	8	Bouzarovski S	3.21	9
Batinge, Musango, and Brent (2019), Ceschin et al. (2023), Kovacic et al. (2016), Luhangala et al. (2022), Musango (2014), Smit, Musango, and Brent (2019), Strydom, Musango, and Currie (2020), van der Merwe, de Kock, and Musango (2020)	Musango J	8	Ozturk I	3.20	10

highlights the critical need to focus on the distributional impacts and the role of labour in low-carbon transitions to achieve energy justice in a democratised energy system.

The top three ranked articles (Charfeddine and Kahia 2019; Edwards et al. 2008; Inglesi-Lotz 2016) explored the potential of renewable energy technologies and their impact on emissions and economic development in regions like the Middle East and North Africa (MENA). Articles like 'A Global Perspective on Domestic Energy Deprivation: Overcoming the Energy Poverty–Fuel Poverty Binary' and 'The Political Economy of the 'Just Transition' delve into the social equity dimension of carbon

Table 4. Most influential articles in the field (based on citation metrics).

Ref	Title	Year	TC	TC per year	NTC	Rank
Edwards et al. (2008)	Hydrogen and fuel cells: Towards a sustainable energy future	2008	806	50.5	10.10	1
Charfeddine and Kahia (2019)	Impact of renewable energy consumption and financial development on CO2 emissions and economic growth in the MENA region: A panel vector autoregressive (PVAR) analysis	2019	504	100.8	13.89	2
Inglesi-Lotz (2016)	The impact of renewable energy consumption on economic growth: A panel data application	2016	491	61.4	11.21	3
Newell and Mulvaney (2013)	The political economy of the 'just transition'	2013	487	44.3	10.56	4
Bouzarovski and Petrova (2015)	A global perspective on domestic energy deprivation: Overcoming the energy poverty–fuel poverty binary	2015	482	53.6	8.25	5
Menyah and Wolde-Rufael (2010)	Energy consumption, pollutant emissions, and economic growth in South Africa	2010	417	29.8	5.91	6
Winzer (2012)	Conceptualising energy security	2012	402	33.5	4.12	7
Healy and Barry (2017)	Politicising energy justice and energy system transitions Fossil fuel divestment and a 'just transition.'	2017	376	53.7	7.67	8
Wolde-Rufael (2006)	Electricity consumption and economic growth: a time series experience for 17 African countries	2006	361	20.1	4.45	9
Inglesi-Lotz and Dogan (2018)	The role of renewable versus non-renewable energy to the level of CO2 emissions a panel analysis of sub-Saharan Africa's Big 10 electricity generators	2018	355	59.2	8.88	10

Notes: Total Citations (TC): This reflects the overall number of times other publications have cited an article. TC per Year (TCY): This indicates the average number of citations the article receives yearly since its publication. Normalized Total Citations (NTC): To compare the citation impact of research articles across different fields.

pricing. They address ensuring a just transition to a low-carbon economy that does not disproportionately burden vulnerable populations. Table 4 also encompasses broader topics in energy. The article titled 'Conceptualizing Energy Security' postulated the definition of energy security and highlighted the importance of separating other energy policy dimensions from the security of energy supply. The article 'Electricity Consumption and Economic Growth: A Time Series Experience for 17 African Countries' examined the relationship between electricity use and economic growth in Africa. The findings, however, were inconclusive and varied. While 11 countries displayed a positive unidirectional causality, with real GDP per capita driving electricity consumption per capita, three countries exhibited the opposite effect. The remaining three countries displayed bidirectional causality, suggesting a more complex interplay between the two factors.

3.4. Top 10 most productive sources in the field by number of documents

Figure 2 provides an overview of the most productive sources, i.e. those contributing the most to research on 'The differential impacts of carbon pricing mechanisms on energy security and socio-economic outcomes.' The journal 'Energy Policy' occupies the top position with 175 published documents, emphasising its role as a key publisher of scholarly articles in this field. The second and third positions are occupied by 'Energy for Sustainable Development' and 'Energy Research and Social Science,' each contributing 52 and 48 documents, respectively. The varied range of sources, including 'Energies,' 'Environmental Research and Pollution Research,' and 'Applied Energy,' highlights the multidisciplinary nature of the research topic, with contributors from both energy and environmental science domains.

Journals such as 'Energy Economics,' 'Sustainability,' and 'Renewable Energy' also underscore the multidisciplinary intersection of economic and sustainability perspectives in the domain.

3.5. Top 10 countries of corresponding authors: productivity and collaboration analysis

Table 5 shows the top 10 corresponding author's countries, which are ranked based on the productivity of corresponding authors in terms of article count, frequency (Freq), Single

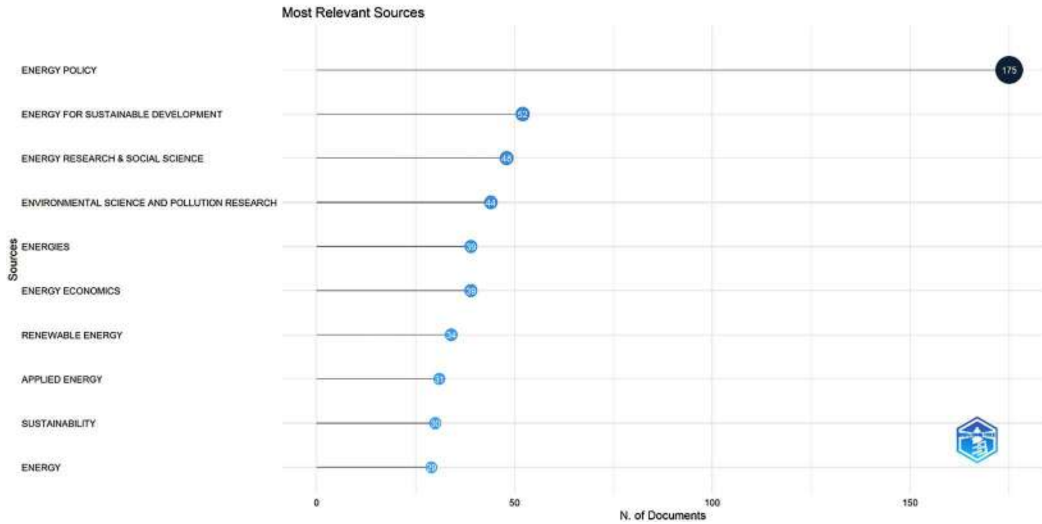

Figure 2. Most influential sources.

Corresponding Author (SCP), Multiple Corresponding Authors (MCP), and a fraction of articles with multiple corresponding (MCP ratio). The United Kingdom emerged as the top-ranked country with 141 articles, signifying its leadership in research related to carbon pricing mechanisms and their multifaceted impacts. This is because the UK has well-established universities like Imperial College London and Oxford University, both known for their vital climate science programmes. Additionally, the UK implemented a carbon pricing scheme in 2010, which could have spurred focused research efforts to evaluate its effectiveness.

Germany and the Netherlands secure positions in the top 10, showcasing their contributions to understanding the complex interplay between carbon pricing, energy security, and socio-economic outcomes within the European Union. Interestingly, while publishing fewer articles overall, countries like Nigeria and Italy have a high collaboration rate (shown by the MCP ratio). This suggests a strong focus on international collaboration. For instance, Nigeria might have research teams concentrated on the specific challenges of implementing carbon pricing in a developing nation with a rapidly growing economy. Conversely, Italy could be collaborating intensely with a select group of European partners on a joint research project. India's presence in Table 5 indicates a more comprehensive geographic range of research groups studying the topic. This might be due to India's diverse socio-economic landscape, with research teams focusing on different aspects of carbon pricing relevant to their specific regions. In summary, Table 5 provides valuable insights into

Table 5. Top 10 most productive corresponding author countries.

Country	Article Count	Freq	SCP	MCP	MCP ratio	Rank
United Kingdom	141	0.1218	99	42	0.298	1
South Africa	114	0.0984	91	23	0.202	2
USA	106	0.0915	85	21	0.198	3
China	105	0.0907	79	26	0.248	4
Germany	65	0.0561	46	19	0.292	5
Australia	48	0.0415	39	9	0.188	6
Nigeria	38	0.0328	24	14	0.368	7
Italy	33	0.0285	16	17	0.515	8
India	32	0.0276	26	6	0.188	9
Netherlands	31	0.0268	21	10	0.323	10

the global distribution of research efforts and expertise on the nuanced impacts of carbon pricing mechanisms on energy security and socio-economic outcomes.

3.6. Top collaborating countries: frequency of collaborations

Table 6 illustrates the top 10 collaborating countries based on their frequency of collaborations. Noteworthy collaborations include the United Kingdom and South Africa, which have the highest frequency of 19 collaborations, followed by South Africa and Nigeria, which have 14 collaborations.

The UK emerges as a leader in individual research output (as depicted in Table 5) and collaborative efforts. The high frequency (19 collaborations) between the UK and South Africa suggests a strong research partnership. This could be due to several factors. The UK may be providing expertise in designing carbon pricing schemes. Interestingly, South Africa features prominently, collaborating frequently with Nigeria (14 times) and the UK (19 times). This highlights South Africa's strategic approach to knowledge exchange. Collaborating with Nigeria, another African nation facing similar challenges of implementing carbon pricing in a developing economy allows for a shared perspective and the potential for jointly developed solutions. Partnering with the UK, a leader in the field, provides access to established knowledge and best practices. Several other collaborations are worth noting. China's partnerships with Ghana, Nigeria, and Turkey could reflect a focus on research related to implementing carbon pricing in rapidly industrialising countries. The collaborations between European nations like Austria, Germany, and Italy might involve joint research efforts funded by the European Union. The US also emerges as a collaborator with various countries, including South Africa, the UK, Germany, and Austria. This highlights the international nature of research in this field, with knowledge exchange happening across continents.

3.7. Analysis of keyword co-occurrence patterns in carbon pricing research

Keyword co-occurrence occurs when two or more keywords or terms appear together in a document or a set of documents. It is a measure of the frequency with which specific terms appear in proximity to each other within a document (van Eck and Waltman 2010). Moreover, it is used to identify emerging, niche, and well-established research themes (Tamasiga et al. 2023; Telaye Mengistu et al. 2023). Figure 3 shows the clusters of keywords and the links between them. The coloured nodes denote keywords belonging to the same theme/cluster. Links between nodes represent co-occurrence relationships, with colour and thickness indicating the keywords' strength and frequency of co-occurrence. The size of the coloured node signifies the frequency of occurrence of the keyword indicating its importance.

Table 6. Top 10 collaborating countries in the domain.

From	To	Frequency
UK	South Africa	19
USA	United Kingdom	15
South Africa	Nigeria	14
UK	Nigeria	12
Italy	Netherlands	10
Italy	Austria	9
UK	China	9
USA	Germany	9
Austria	Sweden	7
China	Ghana	7
China	Nigeria	7
China	Turkey	7
Germany	Austria	7
UK	Kenya	7
USA	Austria	7
USA	South Africa	7

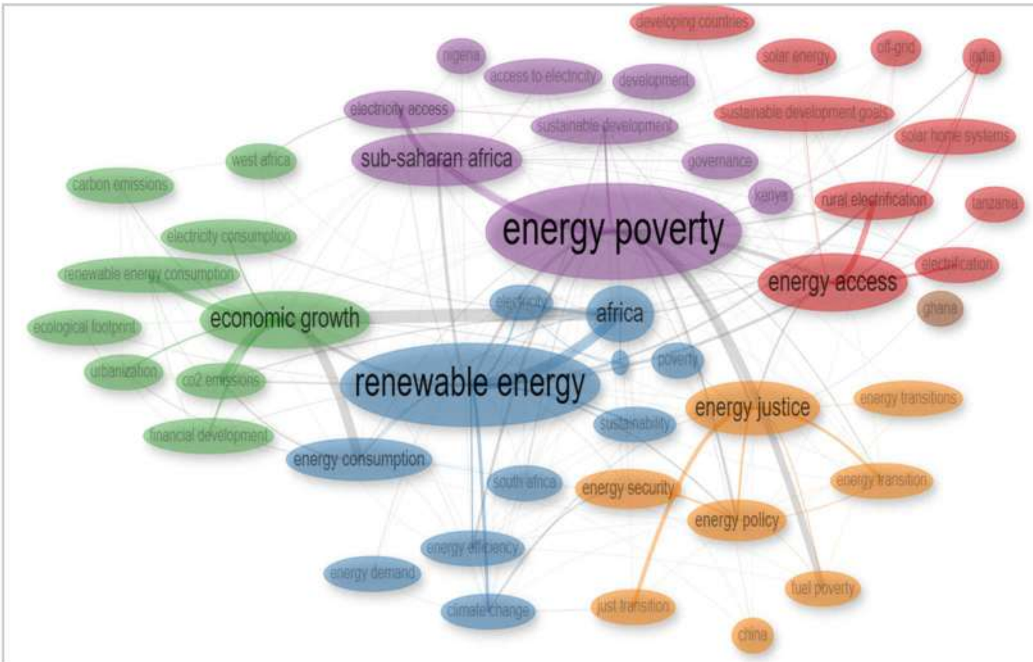

Figure 3. Keyword co-occurrence.

There are five clusters based on keyword co/occurrence. Cluster 1 (coloured blue) has renewable energy as the most frequently occurring keyword, as signified by its larger size relative to other keywords with blue-coloured nodes. Additional keywords belonging to this cluster are 'energy consumption,' 'energy demand,' 'energy efficiency,' 'climate change,' 'electricity,' 'sustainability,' 'poverty,' and 'Africa.' Cluster 2 (coloured green) shows economic growth as the most frequently used keyword. Additional keywords belonging to the green-coloured cluster include 'CO2 emissions', 'financial development,' 'urbanization,' 'ecological footprint,' 'renewable energy consumption,' 'electricity consumption,' 'carbon emissions,' and 'West Africa.' Cluster 3 (coloured purple) includes keywords such as 'energy poverty,' 'electricity access,' 'sustainable development,' 'governance,' 'development,' 'Nigeria,' and 'Kenya.' Cluster 4 (coloured red) includes the following keywords, 'energy access,' 'rural electrification,' 'solar home systems,' 'sustainable development goals,' 'solar energy,' 'developing countries,' and 'off-grid.' Cluster 5 (coloured orange) includes the following keywords: 'energy justice,' 'energy policy,' 'energy security,' 'just transition,' 'China,' 'fuel poverty,' and 'energy transition.'

The five clusters identified in Figure 3 reveal broader trends and patterns within the research domain of carbon pricing:

Cluster 1 (Blue): This cluster highlights the importance of renewable energy in achieving emission reductions and a sustainable energy future. The focus on Africa suggests a research interest in its potential to leapfrog fossil fuel dependence. This trend emphasises the need for research on effective policy design and financing mechanisms to accelerate renewable energy adoption, particularly in developing countries.

Cluster 2 (Green): This cluster explores the potential for carbon pricing to achieve a 'win-win' by promoting economic growth alongside emission reductions, particularly in urbanising areas. The focus on West Africa suggests a specific regional interest in this approach. Further research is needed on how carbon pricing policies can be tailored to foster sustainable economic development pathways, especially in rapidly growing economies.

Cluster 3 (Purple): This cluster highlights the importance of addressing energy poverty when designing carbon pricing policies. Including specific developing countries like Nigeria and Kenya suggests ongoing research on their unique challenges. Developing equitable carbon pricing schemes that consider social equity and alleviate energy poverty requires further investigation, particularly in developing nations.

Cluster 4 (Red): This cluster emphasises expanding electricity access, mainly through decentralised renewables, in achieving SDGs related to energy and development. The focus on developing countries reflects the critical need to address this challenge. Research is needed on innovative financing models and policy frameworks to support large-scale rural electrification using renewable energy solutions in developing countries.

Cluster 5 (Orange): This cluster explores the importance of ensuring a fair and transition to a low-carbon economy. The focus on China suggests a particular interest in the challenges of balancing energy security and social equity in a major developing economy. Developing practical policy tools and social safety nets is crucial to addressing concerns about fuel poverty and ensuring a just transition for vulnerable populations impacted by carbon pricing.

In conclusion, analysing these clusters helps identify critical research gaps and priorities within the domain of carbon pricing. Further research that delves deeper into these themes and explores the specific contexts of different countries can inform the development of more effective and equitable carbon pricing strategies for a sustainable future.

3.8. Thematic evolution from 1984–2023

Over the years, the thematic focus has shifted from a broad consideration of energy policy, encompassing aspects like biomass and renewable energy, to exploring specific issues (see Figure 4). The evolution includes a period emphasising policy in general, focusing on rural electrification and electricity consumption. The most recent theme revolves around the urgent concern of carbon dioxide emissions, with additional attention to energy policy and storage solutions.

1984 to 1995 – Formulating Energy Policy: This initial period focused on formulating and shaping broad energy policies. This likely reflects the early stages of research in carbon pricing, laying the groundwork for future exploration of specific issues within the domain. Rising global energy demand and concerns about energy security might have also contributed to this initial focus.

1998 to 2010 – Broadening Policy Considerations and Rural Electrification: The thematic landscape shifted towards broader policy considerations, emphasising rural electrification efforts

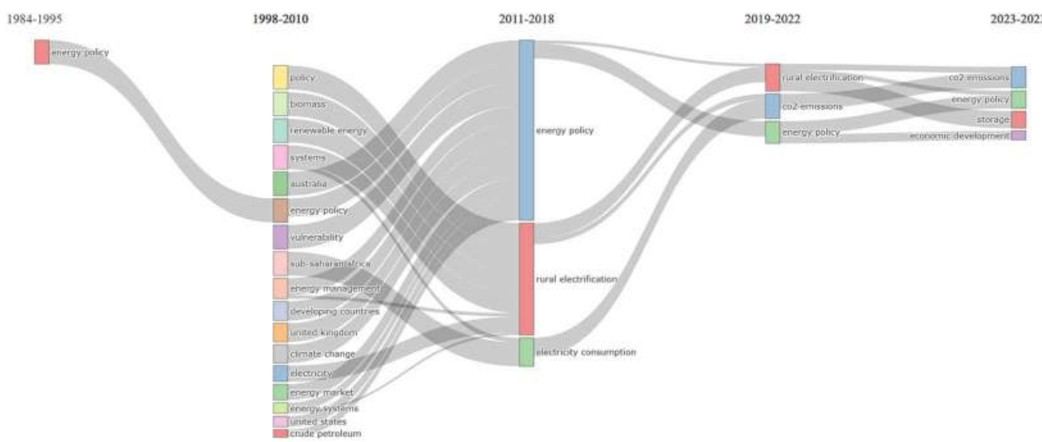

Figure 4. Evolution of themes.

strongly. This period coincided with the Millennium Development Goals (MDGs) gaining international traction—with Goal 1 aiming to eradicate extreme poverty and hunger. Energy access emerged as a critical factor in poverty reduction, prompting research on expanding electricity access to rural populations.

2011 to 2018 – Energy Policy, Consumption Patterns, and Efficiency: The theme of energy policy persisted, but with an added focus on electricity consumption patterns. This shift might be attributed to two key factors:

- Growing Awareness of Climate Change: Scientific evidence on the impacts of climate change became increasingly compelling during this period. Researchers began exploring how carbon pricing could incentivize energy efficiency and reduce greenhouse gas emissions.
- Technological Advancements: Advances in monitoring and metering technologies have facilitated a more detailed analysis of energy consumption patterns, allowing researchers to identify areas for efficiency improvements.

Rural electrification remained a prominent theme, potentially reflecting ongoing efforts to bridge the energy gap in developing countries.

2019 to 2022—Rural Electrification, Economic Development, and the Rise of Climate Change Concerns. This period witnessed a continued focus on rural electrification but with a new emphasis on its role in fostering economic development. This shift aligns with the adoption of the Sustainable Development Goals (SDGs) in 2015, with Goal 7 focusing on ensuring affordable and clean energy access for all. Research likely explored how electrification can power economic activity in rural regions.

The most recent thematic shift in 2023 -2024 centres on carbon dioxide emissions, indicative of a heightened awareness of climate change concerns. This is a significant turning point, reflecting the urgency of addressing climate change and the growing consensus on the role of carbon pricing as a mitigation strategy. The Paris Agreement 2015 further solidified this focus by urging countries to implement effective strategies to reduce greenhouse gas emissions. The focus on energy storage systems also highlights a growing emphasis on developing sustainable and resilient energy infrastructure to support a low-carbon future.

4. Discussion

This section discusses the emerging themes from the retrieved studies (sub-section 4.1), followed by an exposition on the socio-economic and energy poverty outcomes of carbon pricing (sub-section 4.2).

4.1. Emerging themes

Based on co-occurring keywords, the study used content analysis to synthesise emerging themes, which include: (i) Balancing sustainable urban development and environmental sustainability; (ii) Energy transition, environmental impact and economic growth; (iii) Equitable energy transition and justice; (iv) Renewable energy consumption and carbon emissions reduction; (v) Energy policy and security in a transitioning world; (vi) Energy access, poverty alleviation, and electricity equity; (vii) Addressing energy poverty in sub-Saharan Africa for sustainable development; (viii) Governance and policy challenges in energy access; (ix) Solar-powered rural electrification and off grid solutions.

Theme 1: Balancing sustainable urban development and environmental sustainability

This theme explores the relationship between urbanisation, economic growth, and sustainability. It delves into how cities can achieve economic prosperity while minimising their ecological footprint, reducing carbon emissions, and transitioning to renewable energy sources. Key aspects of this theme include urban planning strategies, green infrastructure, and policies to promote sustainable urbanisation (Pauleit et al. 2019). The study by (Van Oijstaeijen, Van Passel, and Cools 2020) evaluated ten existing valuation tools for urban green infrastructure investment decisions, focusing on urban planning and decision-making. Criteria included biophysical and socio-economic aspects, revealing challenges like limited economic case support and inadequate adaptation to urban contexts. The recommendations of (Van Oijstaeijen, Van Passel, and Cools 2020) emphasised co-development between scientists and local authorities for tailored tools addressing urban ecosystem specifics. Furthermore, (Chen 2015) investigated the role of urban green infrastructure in the carbon balance of significant cities in China. Their study showed that urban green spaces significantly store about 18.7 million tons of carbon. This indicates a potential for increased carbon sequestration with appropriate policies and management practices in urban spaces.

Theme 2: Energy transition, environmental impact and economic growth

This theme focuses on the shift towards renewable energy consumption and its impact on carbon emissions and overall ecological footprints. It investigates the challenges and opportunities in transitioning to cleaner energy sources, emphasising the importance of reducing fossil energy consumption and promoting sustainable energy practices to achieve economic growth while mitigating environmental harm (Han and Wu 2018; Khan et al. 2022; Pachauri and Jiang 2008). Transitioning to low-carbon pathways is a complex process influenced by a confluence of factors, amongst others, the social, technological, and organisational dimensions (Gui and MacGill 2018). Institutional change, interactions and interconnections with existing systems and actors shape the path and pace of transition.

Theme 3: Equitable energy transition and justice

This theme focuses on the intersection of energy policy, justice, and the transition to cleaner energy sources. The authors in (Heffron and McCauley 2017) explain the concept of energy justice, examine energy justice frameworks, advocate for its integration into education, and make a vital policy contribution to a balanced energy trilemma. Furthermore, this theme explores how energy policies can be designed to ensure that the benefits of this transition are distributed fairly among all members of society. As highlighted by (Carley and Konisky 2020), the shift to low-carbon energy creates winners with cleaner sources, reduced emissions and new opportunities. The authors asserted that losers face burdens and limited access to benefits, perpetuating existing inequalities in the energy transition. The authors in (Mundaca, Busch, and Schwer 2018) analysed the energy justice implications of successful low-carbon transitions in Samsø (Denmark) and Feldheim (Germany). In examining community perspectives, the authors underscored the role of procedural justice amid identified tensions, emphasising intensive local involvement. Their study found positive perceived distributive justice outcomes, especially in social and environmental domains. The authors also highlighted the significance of compensation schemes in fostering a sense of energy justice during the energy transitions.

Theme 4: Renewable energy consumption and carbon emissions reduction

Studies on this theme emphasise the importance of policymakers actively promoting the research and development of low-carbon technologies and encouraging the adoption of renewable energy. The financial sector is urged to prioritise funding for environmentally friendly firms utilising energy-efficient technologies (Henriques and Catarino 2016). Implementing strict measures on low-energy-intensive imports can effectively mitigate embodied carbon, reducing dependence on non-renewable resources and fostering sustainable economic growth in the face of climate change challenges (Kirikkaleli, Güngör, and Adebayo 2022). In addition, (Hu et al. 2018) identified bidirectional causal relationships between economic growth, renewable energy consumption, commercial services trade, and carbon emissions across 25 developing countries. The findings from (Hu et al. 2018) corroborate the Environmental Kuznets Curve, highlighting the importance of fostering trade and scaling up renewable energy to facilitate low-carbon economic growth. Their study showed that while a higher proportion of renewable energy diminishes emissions, an increase in the overall consumption of renewable energy can paradoxically elevate emissions.

Theme 5: Energy policy and security in a transitioning world

This theme focuses on the intersection of energy policy and security during the ongoing energy transition. It explores how governments and organisations can create policies that enhance energy security while simultaneously supporting the shift to renewable and sustainable energy sources (Li, Zhang, and Li 2023; Nuttall and Manz 2008; Pollitt 2012; Tongsopit et al. 2016). Key considerations within this theme include strategies for diversifying energy sources, reducing dependence on fossil fuels, and ensuring energy systems are resilient in the face of external shocks. In the same frame of mind, (Li and Jiang 2019) asserted that the energy transition fosters energy security by moving from resource to technology dependence, promoting economic vitality through equipment manufacturing, and ensuring sustainability through the electrification of conventional energy consumption. A particular case study country is Denmark, which stands out as the most energy-secure and sustainable OECD country, having achieved self-sufficiency in energy production. Lessons from Denmark's success include a dedication to energy efficiency, persistent taxes on energy fuels, and incentives for combined heat and power (CHP) and wind turbines.

Theme 6: Energy access, poverty alleviation, and electricity equity

This theme examines efforts to bring electricity to underserved populations, improve energy efficiency, and develop policies that promote social and economic well-being while ensuring a sustainable energy future. For example, (Li, Zhang, and Li 2023) considered government, enterprise, and household in examining the challenges impeding China's Photovoltaic poverty alleviation programme. Their study emphasized the importance of government monitoring, active participation of enterprises and households, government leadership, and conflict resolution for achieving successful outcomes in photovoltaic projects. Similarly, (Murshed and Ozturk 2023) highlighted that enhancing energy efficiency, transitioning to renewable energy, and fostering financial development contribute to alleviating energy poverty by reducing the rates of electricity inaccessibility in African nations.

Theme 7: Addressing energy poverty in Sub-Saharan Africa for sustainable development

There is an urgent need to tackle energy poverty in Sub-Saharan Africa to promote sustainable development. It encompasses efforts to expand electricity access, especially in rural and underserved areas and explores the role of effective governance in implementing policies and programmes aimed at alleviating energy poverty (Nalule 2019). The study by (Haldar et al. 2023) examined governance and renewable energy's impact on energy poverty in sub-Saharan Africa. Their study showed that government expenditure reduces energy poverty, and a rising renewable energy share mitigates it. (Monyei et al. 2022) suggested that power pools in Sub-Saharan Africa could solve energy poverty, arguing for improved regional cooperation to address energy poverty and achieve universal energy access, emphasising the need for national energy security.

Theme 8: Governance and policy challenges in energy access

This theme emphasises the significance of governance and policy frameworks in ensuring inclusive and equitable access to electricity (Bazilian, Nakhooda, and Van de Graaf 2014). The development of regulatory mechanisms, governance structures, and policy initiatives are needed to support the expansion of electricity access while aligning with principles of sustainability and social equity (Fraser, Chapman, and Shigetomi 2023; Johnson et al. 2020). Research on this theme indicated that institutional quality affects energy access as such countries should prioritise digital public services and enhance the quality of governance and institutional structures (Kwilinski, Lyulyov, and Pimonenko 2023). In contrast, (Acheampong 2023) showed that in sub-Saharan Africa, access to credit and governance do not boost clean cooking tech adoption, but economic and regional factors significantly influence its uptake.

Theme 9: Solar-Powered Rural Electrification and off-grid solutions

This theme revolves around the adoption of solar home systems and off-grid solutions in developing countries to achieve rural electrification and support sustainable development goals (Asuamah, Gyamfi, and Dagoumas 2021; Baurzhan and Jenkins 2016; Feron 2016). Solar energy technologies can be harnessed to provide reliable electricity access in remote areas, contributing to economic growth, improved quality of life, and environmental sustainability (Wagner et al. 2021).

These findings have far-reaching implications, particularly in the context of policymaking. The themes identified underscore the need for a multifaceted approach to carbon pricing and energy transition. For instance, the balance between sustainable urban development and environmental sustainability suggests that urban planning strategies must incorporate carbon pricing mechanisms to incentivize green infrastructure (Cheng et al. 2019). This could manifest in policies promoting renewable energy sources or reducing carbon emissions (Linares, Santos, and Ventosa 2008).

Similarly, the theme of equitable energy transition and justice highlights the importance of considering socioeconomic disparities in policy-making (Heffron, McCauley, and Sovacool 2015). Carbon pricing policies should be designed not disproportionately to burden economically disadvantaged communities but instead contribute to poverty alleviation and electricity equity (Zhang et al. 2022).

In terms of research and practice, these themes provide a roadmap for future investigations and interventions in energy transition and carbon pricing. For example, the link between renewable energy consumption and carbon emissions reduction warrants further exploration to quantify the potential impact of different carbon pricing mechanisms on promoting renewable energy use (Kok, Shang, and Yücel 2015). Additionally, the theme of governance and policy challenges in energy access points to the need for more research on overcoming these obstacles (Gunningham 2012; Nwokolo et al. 2023). This could involve studying successful case studies of solar-powered rural electrification and off-grid solutions and identifying the factors that made these initiatives successful (Liang et al. 2023). Ultimately, the findings of this systematic review underscore the complexity of the energy transition and carbon pricing landscape, and the need for comprehensive, nuanced approaches to address these challenges.

4.2. Energy poverty and socio-economic impacts of carbon pricing

This section discusses the impact of carbon pricing mechanisms on energy security in developing countries and the associated socio-economic implications and sustainable development goals (SDGs). The introduction of carbon pricing presents a complex interplay of factors that can influence poverty, food security, industrial production, education, employment, trust in government institutions, and inequality through multiple channels. For example, increased costs for goods and services with high carbon footprints may disproportionately affect low-income households, potentially exacerbating economic disparities and affecting consumption patterns (Golub et al. 2013).

Furthermore, some industries may face economic shifts due to the higher cost of carbon, while others may benefit from emerging opportunities in the transition to a low-carbon economy (Lin and Wesseh 2020). Striking a balance that ensures fair treatment of workers in carbon-intensive sectors and supports job transitions becomes crucial. Additionally, carbon pricing, by incentivizing emissions reduction, can positively affect public health through improvements in air quality. Yet, attention must be paid to whether these health benefits are equitably distributed across socio-economic groups. Table 7 summarises the socioeconomic outcomes and effects of energy poverty and shows the associated studies and SDGs.

How revenue from carbon pricing is recycled into the economy and the distributional impacts and disparities is a critical factor (Chen 2022;

Cornwell and Creedy 1996; Rezai and Van der Ploeg 2016). Governments can strategically allocate these funds to implement progressive policies, such as targeted social programmes or investments in renewable energy, to counteract the potential regressive impacts of carbon pricing and contribute to social equity. While carbon taxes are accepted in Sweden, resistance persists due to factors like education, location, and political views. Distrust in government is a crucial concern. The general population and protesters favour directing tax revenues towards climate initiatives (Ewald, Sterner, and Sterner 2022).

Table 7. Summary of socio-economic outcomes and impacts on energy poverty.

Outcome	Dimensions/ Category	Studies examining the outcome	Associated SDGs
Social Outcomes	Poverty and livelihoods	Benessaiah (2012), Dorband et al. (2019), Franks et al. (2018), Klenert et al. (2018), Vorster, Winkler, and Jooste (2011), Zhao et al. (2022)	SDG 1: No Poverty SDG 10: Reduced Inequality
	Impact on Food Security	Anser et al. (2021), Caillavet, Fadhuile, and Nichèle (2019), Frank et al. (2017), Frank et al. (2017), Isbasoiu, Jayet, and De Cara (2021 Apr 1), Jansson et al. (2024), Rosenberg and Scott (1994)	SDG 2: Zero Hunger SDG 12: Responsible Consumption and Production SDG 13: Climate Action SDG 1: No Poverty SDG 8: Decent Work and Economic Growth
	Jobs and employment	Casey et al. (2022), Erdoğan (2023), Fragkos and Fragkiadakis (2022), Zhang and Cross (2020)	Goal 7: Affordable and Clean Energy Goal 8: Decent Work and Economic Growth Goal 13: Climate Action
	Inequality and distributional impacts (income, spatial, gender)	Baranzini, Goldemberg, and Speck (2000), Cornwell and Creedy (2022), Cornwell and Creedy (1996), Dissou and Siddiqui (2014), Farrell (2017), Fremstad and Paul (2019), Rezai and Van der Ploeg (2016)	SDG 10: Reduced Inequalities SDG 13: Climate Action SDG 7: Affordable and Clean Energy SDG 12: Responsible Consumption and Production
	Trust on government	Ewald, Sterner, and Sterner (2022), Kitt et al. (2021), Levi, Flachsland, and Jakob (2020), Lo et al. (2013), Muhammad et al. (2022)	SDG 13: Climate Action
	Education/Human Capital benefits	Borissov, Brausmann, and Bretschger (2019), Lee and Lee (2021)	SDG 4: Quality Education SDG 13: Climate Action
Economic Outcomes	Impact on industrialisation/ firm productivity	Venmans, Ellis, and Nachtigall (2020), Cloete and Robb (2010), Kim and Bae (2022), Liu, Fan, and Wang (2017), Ulrich, Trench, and Hagemann (2022)	Goal 7: Affordable and Clean Energy Goal 9: Industry, Innovation, and Infrastructure Goal 12: Responsible Consumption and Production Goal 13: Climate Action
	Impact on Agricultural produce	Stepanyan et al. (2023), Rosenberg and Scott (1994), Hartell (2004), Pradhan et al. (2017)	SDG 2: Zero Hunger SDG 10: Reduced Inequalities
	Innovation	van den Bergh and Savin (2021), Lin and Wesseh (2020), Khurshid et al. (2023), Lilliestam, Patt, and Bersalli (2022)	SDG 7: Affordable and Clean Energy SDG 13: Climate Action
	Impact on economic growth/ GDP of the country	Alton et al. (2014), Conefrey et al. (2013), Fang et al. (2013)	SDG 8: Decent Work and Economic Growth SDG 10: Reduced Inequalities SDG 13: Climate Action SDG 16: Peace, Justice, and Strong Institutions
Energy Poverty	Access and affordability of electricity services, Stability of Electricity	Dagnachew et al. (2017), Jakob et al. (2016), Kelly et al. (2020), Nong (2020), Winkler (2017)	SDG 7: Affordable and Clean Energy SDG 11: Sustainable Cities and Communities SDG 13: Climate Action SDG 1: No Poverty

The interconnection of carbon taxes and inequality was further investigated by (Fremstad and Paul 2019) who illustrated that a \$50/ton CO2 tax could worsen inequality, but allocating revenue to a carbon dividend makes it progressive, benefiting the majority and mitigating disparities. Additionally (Dissou and Siddiqui 2014) makes a significant contribution showing that carbon taxes impact inequality positively (via factor prices) and negatively (through commodity prices), i.e. in a U-shaped relationship. Therefore, assessing only commodity prices for inequality can be misleading since both channels are shown to be essential. To improve distributional impacts (Baranzini, Goldemberg, and Speck 2000) argued that implementing carbon taxes requires a reform of the fiscal system. The reform involves ending energy subsidies, discouraging environmental degradation and reallocating carbon tax revenues to reduce other taxes, aiming for an economic double dividend (economic growth and emission cuts).

Introducing a greenhouse gas emission price can mitigate climate change risks and generate significant public revenues (Klenert et al. 2018). These funds could address infrastructure needs, enhancing access to water, sanitation, electricity, telecommunications, and transport, fostering sustainable socio-economic development. This approach supports cost-efficient emission reductions and aids human development objectives over traditional project-based financing (Jakob et al. 2016). Furthermore (Bento and Gianfrate 2020) highlighted that urgent climate action requires firms to internalise carbon costs. They found that firms' adoption of internal carbon pricing (ICP) is influenced by national policy, development, industry, and governance. They also underscored that uncertainties in climate policies hinder widespread business carbon pricing.

Rising energy expenses due to carbon pricing can heighten production costs, which might prompt companies to elevate product prices. This leads to reduced product demand and, subsequently, lower employment levels. Secondly, efforts to reduce emissions could enhance the demand for labour compared to the standard business practices (Venmans, Ellis, and Nachtigall 2020). Carbon policies raise fossil fuel prices, contracting/reducing industry employment. A model by (Zhang and Cross 2020) reveals that the impact depends on market responsiveness to price changes. In a study by (Brown, Li, and Soni 2020), a \$25/tCO2 carbon tax on U.S. electricity increased employment by 511,000 jobs by 2030. While reducing CO2 emissions, carbon tax raises utility bills, with regional variations requiring inclusive policy features. Other evidence is from a study by (Casey et al. 2022), where subnational carbon pricing (\$10/ton) was shown to reduce employment in regulated regions by 2.1% but boosted nearby states by 0.8%.

The effects of carbon taxes on food security have also been documented in the literature. For example, (Caillavet, Fadhuile, and Nichèle 2019) concluded that a carbon tax on food can reduce emissions but poses equity concerns due to its regressive nature. The authors, analysing French household data, evaluated emission impacts, nutritional changes, and distributional effects of carbon taxes. A key result of their study is a proposal to tax animal protein-rich foods while subsidising plant-based ones. Similarly, Jansson et al., (Jansson et al. 2024) investigated the impact of five carbon tax scenarios on agriculture's greenhouse gas emissions. Their study showed that a global tax of EUR 120/ton CO2-eq cuts emissions by 19% but risks food security. On the contrary, a lower global tax at EUR 12 achieves a 3.2% reduction in emissions, while a unilateral EU tax with a border adjustment only cuts emissions by 0.15%. Moreover, a study by (Rosenberg and Scott 1994), showed that rising energy costs due to carbon taxes adversely affected agricultural productivity.

Carbon prices have also affected education and human capital and sectoral shifts. For instance, (Borissov, Brausmann, and Bretschger 2019) showed that a temporary carbon policy can facilitate a transition to a cleaner economy by influencing technology choices and encouraging human capital development. Additionally, their study showed that global knowledge spillovers suggest that northern carbon policies benefit southern human capital formation and drive the south toward a clean, steady state. The education outcomes were also highlighted by (Lee and Lee 2021), whose study proposed that higher education institutions can lead in climate mitigation through carbon pricing on waste emissions. Their study estimated emission costs and suggested that carbon pricing revenues can be used for carbon reduction within campuses.

Carbon prices have also been documented to promote research and development (R&D) but do not necessarily increase sales or profits. This is because high-energy industries innovate more in the distribution and marketing stages of the value chain (Lin and Wesseh 2020). The authors evaluated carbon pricing's impact on China's cement industry. While cement production growth is slowing, full technology adoption will likely take 10–20 years, with a mitigation potential of around 10% by 2030. Carbon pricing's effect is limited, reducing emissions marginally—emphasising the need for integrated policy approaches (Liu, Fan, and Wang 2017). Using seven years of firm-level data, a study by (Kim and Bae 2022) assessed Korea's Emission Trading Scheme (ETS) on carbon pricing effects across industries. While the ETS significantly influenced carbon reduction, responses varied: manufacturing improved energy efficiency, while electricity generation shifted from fossil fuels to low-carbon sources. Based on the examples of China and Korea, carbon pricing effectively promotes decarboniation tailored to industry characteristics. Another noteworthy study by (Best and Zhang 2020) found that coal reserves per capita negatively impact carbon pricing; good governance and political globalisation enhance it. On the other hand, domestic credit was shown to aid carbon pricing, but perceptions of climate change seriousness can hinder it.

Regarding the economic effects of carbon pricing, carbon taxes in Ireland revealed a double dividend with revenue from reduced income taxes. The tax disproportionately affects capital over labour, significantly impacting the competitiveness of manufacturing and market services sectors. Using Lyapunov exponents and neural networks for the case of China, (Fang et al. 2013) studied the introduction of an optimal carbon tax. Their results suggested that a higher carbon tax can control energy intensity, but it is essential to consider its impact on economic growth. How carbon tax revenues are recycled significantly affects distributional outcomes, posing trade-offs between growth and equity. For example, (Alton et al. 2014) showed that a reduction in welfare and employment losses in South Africa is possible by implementing domestic border carbon adjustments.

In the context of energy poverty (Dagnachew et al. 2017) showed that combining grid extension with off-grid solutions optimises access, especially in Sub-Saharan Africa, where there is limited access to electricity. The potential of carbon pricing to simultaneously tackle development and climate change challenges was investigated by (Winkler 2017). Their study underscored the potential benefits of channelling carbon tax revenue towards electrification, free basic energy, sustainable housing, and rooftop solar subsidies. In assessing the distributional impacts of France's carbon tax, (Berry 2019) proposed a revenue redistribution that targeted low-income households to alleviate fuel poverty effectively.

The discussion around the socio-economic impacts of carbon pricing highlights the need for a nuanced approach that considers distributional effects, equity concerns, and the importance of a just transition. Below are some additional considerations:

The success of carbon pricing policies depends on public understanding and support. Policymakers must effectively communicate the rationale behind carbon pricing and ensure a fair and transparent implementation process. Research can explore strategies for building public trust and social acceptance of carbon pricing policies. While carbon pricing can incentivize low-carbon behaviour, it is essential to consider complementary policies that promote energy efficiency and sustainable consumption patterns. Policymakers can implement awareness campaigns, invest in energy education programmes, and encourage lifestyle changes. Research can explore practical strategies for promoting behaviour change in energy transition.

Potential carbon leakage occurs when industries relocate to countries with less stringent regulations. To address these concerns, policymakers can explore border carbon adjustments or international cooperation mechanisms. Research can analyse the potential economic impacts of carbon pricing on different sectors and develop strategies to mitigate competitiveness concerns.

Connecting the emerging Themes and Socio-Economic Outcomes

This analysis of emerging themes highlights the intricate relationships between carbon pricing, energy transition, and socio-economic outcomes. While themes like 'Energy Transition, Environmental Impact, and Economic Growth' (Theme 2) emphasise potential economic benefits, concerns arise regarding how these benefits are distributed (Theme 3: Equitable Energy Transition and Justice). Carbon pricing (Theme 4: Renewable Energy Consumption and Carbon Emissions Reduction) can incentivize a shift to cleaner energy sources but also disproportionately burden low-income households. Themes like 'Energy Access, Poverty Alleviation, and Electricity Equity' (Theme 6) and 'Addressing Energy Poverty in Sub-Saharan Africa' (Theme 7) underscore the need for targeted policies to ensure a just transition that no one is left behind in a just energy transition.

4.3. Implications and limitations in the context of existing literature

The studies reviewed provide valuable insights but also present limitations to consider. Many emphasise the potential benefits of carbon pricing for emissions reduction (Klenert et al. 2018). However, research by (Caillavet, Fadhuile, and Nichèle 2019) highlights the potential for regressive impacts if not designed carefully. Similarly, studies on job impacts (Venmans, Ellis, and Nachtigall 2020) showcase uncertainties and a need for sector-specific analysis. Furthermore, most research focuses on national or regional levels (Dissou and Siddiqui 2014) with limited exploration of local contexts and community-level impacts. Future research should address these limitations by: (i) Distributional analysis tools are employed to assess the equity implications of carbon pricing policies across different income groups and communities.; (ii) Conducting longitudinal studies to track the energy transition's long-term economic and social impacts; (iii) Investigating the effectiveness of different policy mixes that combine carbon pricing with complementary measures like social safety nets and energy efficiency programmes. Acknowledging these complexities and incorporating them into policy design, the energy transition and carbon pricing can be instruments for achieving a sustainable, equitable, and inclusive future as envisioned in the Sustainable Development Goals (SDGs).

4.4. Future research and policy directions

This discussion section has explored the complex relationships between carbon pricing, energy transition, and socio-economic outcomes. The analysis of emerging themes underscores the need for a comprehensive approach that considers environmental sustainability, economic growth, energy security, affordability, and equity.

To further strengthen our understanding and inform effective policy design, several areas warrant future research endeavours:

i **Distributional Impacts and Equity**

Research should employ distributional and social assessment analysis tools to assess the fairness of existing and proposed policies. This will guide the development of targeted measures to mitigate potential regressive effects and ensure a just transition.

ii **Long-Term Socio-Economic Impacts**

The long-term economic and social consequences of the energy transition remain understudied. This necessitates longitudinal studies to track the evolution of jobs, income distribution, and energy access patterns over time. This will inform policy interventions to maximise the benefits and minimise the disruptions associated with the transition.

iii **Policy Mixes**

Future research should investigate the effectiveness of different policy mixes incorporating carbon pricing, social safety nets, energy efficiency programmes, and investments in clean energy infrastructure. Evaluating the synergies and trade-offs between these policies will guide the development of robust policy frameworks for a sustainable energy future.

Addressing these research gaps can help us better understand the challenges and opportunities related to energy transition and carbon pricing. Incorporating these insights into policy design can facilitate the development of effective instruments for achieving the Sustainable Development Goals (SDGs).

5. Conclusions

This systematic review, conducted in adherence to PRISMA guidelines, provides a comprehensive synthesis of literature spanning the period from 1984 to 2023. It uses two databases, Scopus and WoS, and then merges the two. It studies the relationship between carbon pricing, energy security, and socio-economic outcomes. The systematic review is carried out alongside a bibliometric and content analysis.

A comprehensive content review identified nine (Wang, Fu, and Zhao 2023) key themes, including sustainable urban development, the shift towards renewable energy, fair energy policies, the relationship between renewable energy use and carbon emissions, energy security amidst global changes, the crucial link between energy accessibility and poverty reduction, governance issues in energy distribution, and the promise of solar-driven rural electrification. Carbon pricing mechanisms have profound implications for developing nations' energy security and socio-economic aspects. These mechanisms impact various factors, including poverty, food security, and employment. An emerging key concern from this systematic review is the potential exacerbation of economic and social inequalities. As carbon pricing increases the costs of goods and services with high carbon footprints, low-income households may bear a disproportionate burden. This implies that the distributional impacts of carbon pricing revenue become a critical factor in mitigating potential regressivity. Studies highlight that strategic allocation of these funds, such as targeted social programmes or investments in renewable energy, can counteract adverse effects and contribute to social equity. However, public acceptance and trust in government institutions are essential, as demonstrated by resistance to carbon taxes in certain regions, emphasising the need for transparent and inclusive policymaking.

Furthermore, the socio-economic ramifications span multiple Sustainable Development Goals (SDGs) and extend to education and human capital development. Temporary carbon policies can influence technology choices and spur human capital development, potentially benefiting northern and southern regions. This aligns with SDG 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth), underlining the interconnectedness of environmental policies with broader development objectives. Economic outcomes, including impacts on industrialisation, agricultural production, and innovation, also underscore the effects of carbon pricing. While some industries may face economic shifts due to higher carbon costs, others may find opportunities in the transition to a low-carbon economy. Rising energy costs resulting from carbon taxes have been shown to adversely affect agricultural productivity and food security, hence affecting SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 1 (No Poverty). Energy poverty affects multiple dimensions, including access to and affordability of electricity services, stability of electricity, and the broader socio-economic implications. Energy poverty intersects with various SDGs, such as SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities) and SDG 1 (No Poverty). The systematic review has shown that revenue from energy-related policies, such as carbon pricing, can be recycled into the economy and be used to mitigate energy poverty through rural electrification and infrastructural development.

This research is not without limitations. The reliance on Scopus and Web of Science databases may introduce publication bias, as these databases may not encompass all relevant literature, particularly from non-English sources. Building on the insights gained from this study, future research can explore several promising avenues to deepen our understanding of the complexities surrounding carbon pricing. Firstly, panel data studies could offer valuable insights into the evolving dynamics of carbon pricing impacts over time. Furthermore, an exploration of regional variations and the influence of contextual factors on the effectiveness of carbon pricing mechanisms could enhance the precision of policy recommendations. Lastly, investigating the potential synergies and trade-offs between carbon pricing and other policy instruments could shed light on comprehensive and effective strategies for addressing environmental sustainability and socio-economic equity.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article.

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