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Review

Exploring the nexus of gender and energy transitions: A systematic literature review

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ABSTRACT

Against the backdrop of the growing emphasis on gender aspects in the energy transition within the scientific community, this Systematic Literature Review provides a comprehensive analysis of the current state of scientific literature on the interconnection between gender issues and energy transitions. Unlike other SLRs on the topic, the primary contribution of this paper is to comprehensively analyze the gender-energy transitions nexus, encompassing all its facets, rather than concentrating on specific dimensions. After reviewing a sample of 152 scientific publications extracted from the Web of Science Database, this paper identifies and categorizes the key dimensions of the gender-energy nexus into distinct clusters, systematically organizes the existing knowledge within these categories, and pinpoints specific research gaps, offering a clear foundation for future investigations in this area. The results are presented in two sections: the first provides a quantitative overview of the research landscape and the second provides a qualitative analysis of the publications' results. The scientific evidence considered in this work reveals that the gender issues related to energy transitions can be clustered within seven categories: Empowerment, Employment/Work, Attitudes/Behaviors, Transitions to modern energy, Knowledge/Awareness, Perception, and Health. Just energy transitions require sensibilization, and thorough planning and direction across all these clusters. This work serves as a valuable tool for future research and informs policy-makers in developing just policy recommendations for energy transitions.

1. Introduction

The interconnection between gender and energy studies has gained increasing attention in the academic world within the past years. Scholars from different disciplines such as sociology, anthropology, gender and feminist studies, as well as science and technology studies have all pointed out the social impact of energy production, infrastructure and consumption on sex and gender. Energy systems and energy policies are not gender-neutral, they are in fact permeated by deep-rooted social and economic inequalities. This holds true not only for traditional, fossil-fuel based energy systems, but equally for modern, indeed even renewable, energy systems. However, given this growing recognition, only a small proportion of literature in energy studies deals with gendered inequalities in the energy system [1–5]. This research gap has far-reaching implications, not only for the pursuit of gender equality, but for the successful realization of genuinely sustainable energy transitions. To thoroughly understand the gendered dynamics of gender and sex within the energy system, a more comprehensive and nuanced analysis remains to be conducted. In response to this, the project "Transforming Gendered Interrelations of Power and Inequalities in Transition Pathways to Sustainable Energy Systems" (gEneSys) has been initiated. In order to assess the state of the art and systematize the available results concerning the nexus between gender and energy transitions, in the context of the gEneSys Project, a systematic literature review (SLR) has been carried out. The SLR comprehensively analyzed the current state of knowledge on the interaction between gender and energy transitions, aiming to improve our understanding of gender power relations in the context of current energy transitions.

When we refer to this gender-energy nexus, we mean the interplay of gender roles and relations with access and control over energy resources and how energy policies and practices in turn affect gender equality. The

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gender-energy nexus highlights the differences in energy demand, access and use according to societal gender roles and emphasizes the socio-cultural, economic and political factors that shape these inequalities [6,7].

Certainly, this is not the first systematic literature review (SLR) assessing the nexus between gender and energy transitions. However, previous SLRs tend to be limited in scope. Some of them are only focused on the effect of the transitions on women, not considering the other side of the coin, namely how women contribute to the transitions. For instance, while analyzing a sample of 90 publications, Lieu et al. [8] uncovered the extent to which the adoption and diffusion of low-carbon technologies impact gender and social equity, leaving aside the role that women can actively have in the energy transitions. On the other side, Dall-Orsoletta et al. [9] systematically reviewed the literature to identify the impacts of social innovations and bottom-up initiatives on sustainable energy transitions; but in doing so they considered the gender dimension solely as one dimension among others. Furthermore, other research has a limited country or regional focus; for instance, Manjon, Merino and Cairns [10] investigated the intersection between energy poverty, social innovation, and social entrepreneurship but focused only on the Global North. Guta et al. [11], on the other hand, focused their analysis on low- and middle-income countries while looking at household decision-making and the factors that influence decisions to adopt, or not, the use of clean fuels or improved biomass stoves.

In principle, the SLRs cited generally have a very narrow focus on specific aspects of the gender-energy nexus. They either looked at individual sectors or regions or focused on gender roles exclusively in relation to individual aspects, such as consumption, production, participation or what it means to be affected by certain energy policies. As a result, often rather small bodies of literature were considered.

The ambition of the SLR carried out as part of the gEneSys Project was to offer a comprehensive examination of the gender-energy nexus by identifying and synthesizing the various research perspectives that have been explored in this field. In doing so, the paper attempts to connect the various research communities gathered under the gender-energy umbrella with each other. Cacophony arises in unconnected research communities, including the confusion of different voices and assessments. An illustrative example is research into the impact of photovoltaic technology on women. Photovoltaic development has been shown to improve the health of women and communities, while women's engagement in this process stimulates their curiosity and creativity, contributing to their psychological and intellectual development [12]; however, the construction of photovoltaic systems can have negative impacts in other contexts, such as fencing off public wastelands and depriving resource-dependent women of access to firewood and pasture [13]. Such diversity of research perspectives can be fruitful if integrated.

Furthermore, one key objective of this study is to explore the nexus of both gender and sex with regard to the energy transitions. Although gender and sex represent distinct categories, each grounded in different theoretical perspectives, sex and gender are frequently used interchangeably in the literature. Our research sought to examine how both concepts are employed within the energy context. Another central objective was to examine how the energy transitions both create new gender-related challenges and reinforce existing inequalities, offering a nuanced perspective on how the shifting dynamics of the energy sector intersect with gender.

In principle, the concept of the gender-energy nexus is strongly related to research on energy justice [7,14–16], aiming to attain just energy transitions [17,18]. Even though the objective of just energy transitions is well beyond the scope of the present paper, our study enriches the discourse on social and gender impacts of energy justice by analyzing the three main tenets of energy justice (distributive, procedural, and recognition justice) [19] through a gendered lens, following suggestions provided by McCauley and Heffron [18], who argue that just energy transitions "must seek fairness and equity with regards to the major global justice concerns such as (but not limited to) ethnicity, income, gender within both developed and developing contexts".

In the next section, the procedure for the SLR is described. This is followed by an explanation of the analyzed text corpus, using descriptive statistics, along with a discussion of the literature clusters identified through qualitative analysis. Based on these findings, conclusions about future research on the gender-energy nexus are drawn.

2. Materials and methods

The method developed for the present SLR is the result of a collaborative, interdisciplinary process among the researchers of the gEneSys' partner institutions. In the first step, data about publications assessing the nexus between gender and energy transitions were extracted from the Web of Science (WoS) (all databases). In the construction of the database, we explored the possibility of extracting data from SCOPUS as well to have a more complete set of publications, however, this was discarded because merging the different sets of variables offered by WoS and SCOPUS would have required renouncing relevant information. Compared to SCOPUS, in fact, WoS offers more information about the author, such as the full name and affiliation of all the authors as well as more information about citation patterns, which are useful to perform different analyses. Data were retrieved from the year 2000 to April 12, 2023. The choice to start the analysis in the year 2000 was due to the fact that before 1990 no publication was retrieved, while between the period of 1990 and 2000 only 13 publications were retrieved. For this reason, we decided to focus on more recent literature and exclude the 13 publications published before the year 2000.

A specific syntax was developed in order to maximize the highest number of publications that could be retrieved:

(TI = ((((gender OR women OR woman OR female OR feminis* OR sex) AND ("energy transition" OR "green transition" OR "energy transformation" OR "sustainable energy" OR "renewable energy")))) OR AB = ((((gender OR women OR woman OR female OR feminis* OR sex) AND ("energy transition" OR "green transition" OR "energy transformation" OR "sustainable energy" OR "renewable energy")))) OR AK = ((((gender OR women OR woman OR female OR feminis* OR sex) AND ("energy transition" OR "green transition" OR "energy transformation" OR "sustainable energy" OR "renewable energy"))))).

The syntax employed to search the WoS database gave us 647 results. At this stage, we excluded the works published before the year 2000, the types of publications that were deemed not relevant for the present SLR (editors' commentaries, reviews, etc.), the publications in languages other than English, and those publications without an abstract, thus obtaining 419 results.

Then we proceeded with the selection further by reading the abstracts. At this stage, a team of researchers filtered out the abstracts based on the following exclusion criteria: A) The publication does not have a clear gender focus; B) The publication does not address a topic related to energy transitions.

To assess the validity and coherence of the two criteria selected, we performed a consistency check. The consistency check was performed using CADIMA. In detail, we set up CADIMA by adding 9 reviewers participating in the abstract screening to the CADIMA project and by assigning each reviewer to evaluate 5 abstracts. CADIMA randomly selected the 5 abstracts, to be reviewed by the 9 reviewers, among the database of 419 publications' abstracts imported in CADIMA. To evaluate the consistency of the reviews we calculated the level of agreement resulting in an 86 % level of agreement, meaning that the strength of agreement among the reviewers was good. For this reason, we confirmed the list of criteria created and proceeded with the actual evaluation of the 419 abstracts included in our database.

The abstract screening applying the exclusion criteria explained above resulted in the selection of a total of 302 publications and the exclusion of 117 publications. The preliminary analysis of the abstracts selected revealed the presence of 3 publications that were duplicated

and 1 that was an editorial material (type of publication preliminarily excluded from the present SLR). Further, the publications remaining included 9 databases, that were also excluded from the analysis. In the process of downloading the remaining 289 publications, 1 publication was not available to be downloaded by any of the institutions within the consortium remaining beyond a paywall. After unsuccessfully requesting the publication by the corresponding author, we decided to eliminate the paper from the analysis. Therefore, the total number of publications considered and downloaded ultimately was 288.

The 288 publications included have been analyzed by a pool of 18 reviewers. To allow homogeneous information extraction, a research template to use for gathering information has been elaborated. Table A1 in Appendix 1 reports the categories included for the extraction of the information, and the related explanation.

The reading of the full texts allowed us to further exclude 136 publications that, despite passing the abstracts' screening, did not actually assess the nexus between gender and energy transitions. The total number of publications analyzed was therefore 152. Fig. 1 summarizes the process of extraction of the final dataset.

The data have been analyzed with a mixed quali-quantitative method. In particular, the first part of the analysis involved descriptive statistics of the variables reported in Table A1 in Appendix A. The second part of the analysis consisted of a thematic analysis of the variables related to the publications' results, as well as the research gap identified for future exploration.

For completeness, it is worth mentioning that for the sake of analyzability, some of the categorical variables included in the analysis were re-coded (see Table A2 in Appendix A).

2.1. Data analysis

The systematic literature review's findings are presented in two sections: The first section provides an overview of the research landscape, showcasing specific descriptive statistics. The second section follows on from this and provides a qualitative analysis of the literature reviewed.

2.2. Descriptive results

The publication of scientific literature on the energy-gender nexus has gained momentum in recent years. Our data shows that the number of papers published in this area has increased considerably since the year 2020. While between 2005 and 2019 a total number of 54 papers within our sample have been published, in the short timeframe between 2020 and April 12, 2023, this number has almost doubled. Fig. 2 reports the number of publications by year.

The papers included in the sample were published in several scientific journals. The journal with the most sampled publications and thus the most engagement with research on the gender-energy nexus is Energy Research & Social Science with 26 articles, followed by Renewable Energy with 12 papers. The most comprehensive category with 58 publications, however, is “Other”, meaning that 58 journals have published just one article included in our sample. Besides these, there are 16 other journals that have published between 2 and 8 papers each from our sample.

The 152 articles analyzed are almost exclusively research articles published in specialist journals (92 %). In addition, five proceeding papers and a few other types such as reviews, early access articles or book chapters with isolated publications are included.

After analyzing the metadata of our sample, our research team classified the content. We first wanted to know which topics the publications dealt with. Two-thirds (67 %) of the publications evaluated did not evaluate one specific technology but rather investigated the renewable energy (RE) sector as a whole or more than one specific technology at once. The remaining publications were centered around bio-energy (29 publications) and fossil fuels (17). In comparison, the focus on gender and grids, nuclear energy, and stoves is limited.

In terms of spatial context, nearly all studies on the gender-energy nexus (93 %) focus on a specific country or a set of countries, demonstrating a clear regional focus. The classification of the countries into regions was performed following the World Bank regional and wealth classification of countries. Most of the publications in our sample analyzed cases within Sub-Saharan Africa (39), Europe and Central Asia (31), East Asia and Pacific (21), and South Asia (19). Only 13 publications simultaneously analyze multiple regions. Of these, only seven bridge the gap between the Global North and South. Most of the studies clearly focus on the Global South. Two-thirds of the studies (94) analyze the gender-energy nexus in low-income countries. Just under one-third (42) look at middle-income countries. And only ten sampled studies deal with the gender-energy nexus in high-income countries.

Most of the papers, around a third (55 publications), deal with issues at the national level. Further, the rural context is addressed in approximately a quarter of the studies (45 publications). In contrast, studies examining nationally comparative or urban contexts are much less common (19 and 17 publications respectively).

In terms of methodology, the majority of authors approach the gender-energy nexus using quantitative studies (81 publications), as shown in Fig. 3. One in three studies is qualitative (48) and 19 apply mixed methods. We were also able to identify four purely theoretical contributions including one mathematical model. Looking more closely, the survey is the preferred method employed by 76 publications. Also, interviews (35) and secondary data analysis (25) are largely employed. Less used and residual appear to be the employment of focus groups (15), ethnography (14), literature reviews (13), case study analysis (8), and document analysis (7).

3. Qualitative analysis of the publications' results

The gender-related results of the sampled papers have been scrutinized to assess the presence of common macro-themes, upon which to build the clusters for analysis. Due to the high number of publications analyzed and their heterogeneity in terms of subjects covered, the clustering process was essential to make sense of this extensive corpus of knowledge on the relationship between gender and energy transitions. Such analysis allowed us to divide the publications into seven clusters: 1. Empowerment; 2. Employment/Work; 3. Attitudes/Behaviors; 4. Transitions to modern energy in the Global South[2]; 5. Knowledge/Awareness; 6. Perception; 7. Health.

Table 1 shows the content structure of the clusters in a simplified cross-tabulation. The cross-tabulation is taken up in the cluster descriptions below. As shown the clustered articles sometimes have different content profiles, e.g.: in high-income countries, research on gendered attitudes, behaviors, and perceptions are the most frequent topics of articles; studies of health effects of energy are exclusively focused on low-income countries, and the studies that deal with transitions to modern energy study this predominantly in a rural setting.

Furthermore, the table presents the distribution of the publications by clusters. Most articles (41) were therefore assigned to the Empowerment cluster. The fewest articles dealt with the gendered health effects of energy.

In the next subsections, we will summarize the results by cluster as well as the research gaps for future research identified and the policy recommendations proposed.

3.1. Cluster 1 – empowerment

The concept of empowerment is a multifaceted concept assuming

[2] The category “transition to modern energy in the Global South” contains those papers that analyze the ongoing transformation of energy systems in rural contexts of the Global South and the gender impacts of this transformation.

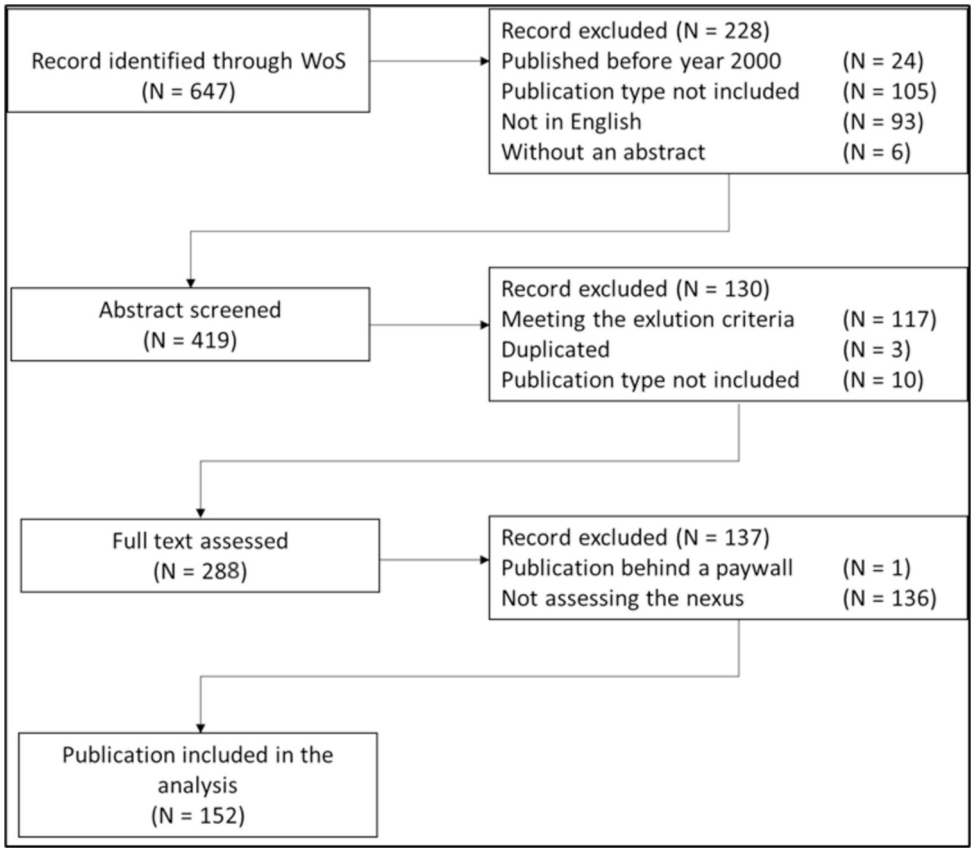

Fig. 1. Steps for the exclusion/inclusion of publications to be analyzed.
Source: Authors' elaboration

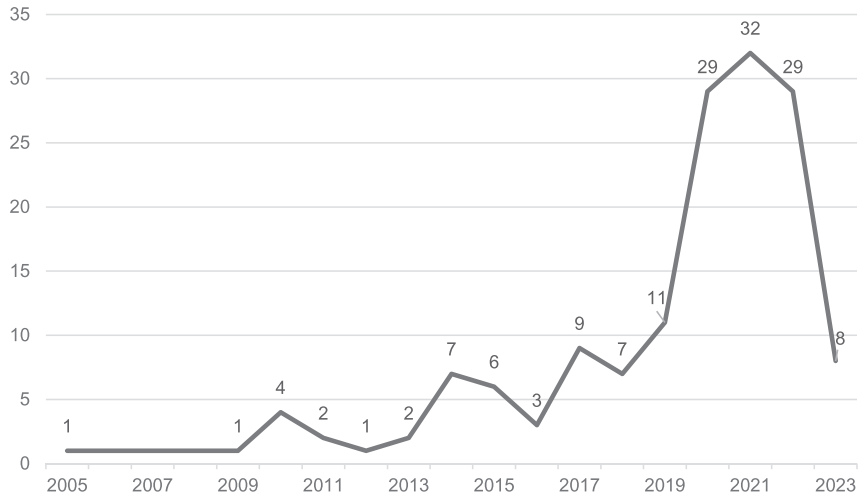

Fig. 2. Number of publications by year.
Note: Data have been extracted on April 14, 2023, so the year 2023 is incomplete.
Source: Authors' elaboration

different meanings according to the different research contexts in which it is employed. Therefore, we do not present a specific definition of empowerment since this is beyond the aim of the present review. Rather we analyze the effects of energy transitions on women's empowerment (in its different dimensions), which can be divided up by various sub-streams. Since women are under-represented, compared to men, in the energy transitions sectors, the considered literature focuses exclusively on women's empowerment.

Studies in the Empowerment cluster mostly focused on low-income countries, renewable energies and referred to national, international, or local levels.

By looking at the content of the papers, a first stream of the literature makes the point that, in various regions of the world, the transitions to RE can be a **double-edged sword for women**. On the one hand, it can increase energy access bringing socio-economic benefits, which potentially translate into higher levels of empowerment. On the other hand, it

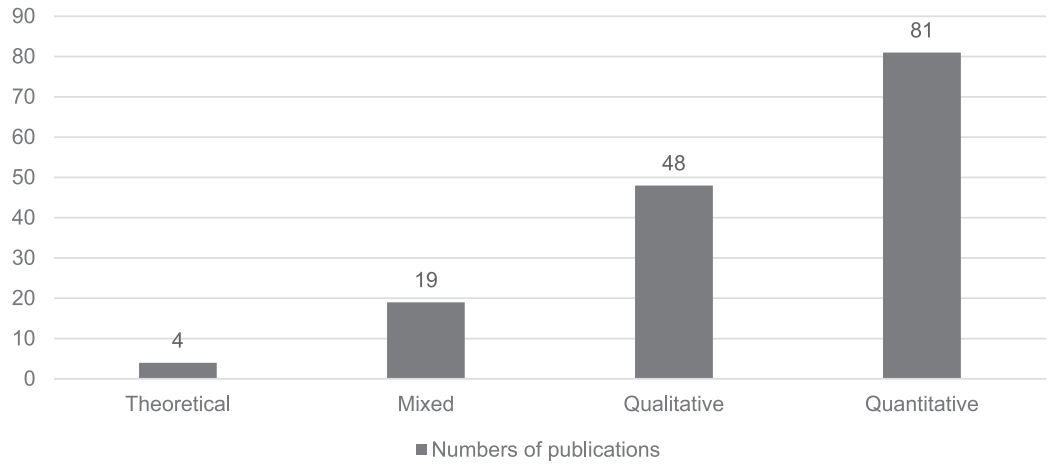

Fig. 3. Number of publications by research method.
Source: Authors' elaboration

Table 1
Condensed cluster profiles.

CLUSTER	Attitudes/ Behaviors	Employment/ work	Empowerment	Health	Knowledge/ awareness	Perception	Transitions to modern energy	Overall result
Methodology								
Mixed	4 %	21 %	7 %	14 %	0 %	18 %	30 %	13 %
Qualitative	16 %	34 %	59 %	29 %	11 %	9 %	25 %	32 %
Quantitative	76 %	41 %	29 %	57 %	89 %	73 %	45 %	53 %
Theoretical	4 %	3 %	5 %	0 %	0 %	0 %	0 %	3 %
Country-Category								
High-income	64 %	31 %	17 %	0 %	16 %	64 %	0 %	28 %
Middle-income	0 %	7 %	12 %	0 %	16 %	0 %	0 %	7 %
Low Income	36 %	55 %	61 %	100 %	68 %	36 %	100 %	62 %
No answer	0 %	7 %	10 %	0 %	0 %	0 %	0 %	4 %
Renewable energy								
Mentioned	76 %	86 %	68 %	43 %	63 %	55 %	45 %	67 %
Not mentioned	24 %	14 %	32 %	57 %	37 %	45 %	55 %	33 %
Spatial Context								
International	4 %	17 %	20 %	14 %	21 %	0 %	0 %	13 %
National	56 %	31 %	32 %	29 %	42 %	64 %	10 %	36 %
Rural	16 %	31 %	24 %	43 %	11 %	9 %	55 %	26 %
Urban	20 %	10 %	2 %	0 %	21 %	27 %	5 %	11 %
Other	4 %	11 %	22 %	14 %	5 %	0 %	30 %	14 %
Total number of articles	**25**	**29**	**41**	**7**	**19**	**11**	**20**	**152**

disrupts traditional livelihood activities, such as grazing livestock and collecting firewood, making those not benefiting from the new employment opportunities opened by the RE power plants more vulnerable [20]. Women often find themselves wrestling with this. Solar electrification projects in West Africa, for instance, have shown positive impacts on women's empowerment, allowing them to seize new job opportunities [21]. Another study in Mexico and Arizona also shows the positive impact of small-scale solar energy projects on urban and rural women's livelihood and savings [22]. On the other hand, in Karnataka, India, large-scale solar projects resulted in the loss of autonomous income for landless women and thus increased their dependence on their husbands [23]. Furthermore, while women take the brunt of the repercussions of change, they remain excluded by the decision-making processes guiding the energy transitions [20,23]. For instance, large-scale projects do not always distribute the energy produced across local territories, generating energy injustice which has a greater adverse effect on women. A study on the impact of Utility-Scale Wind Energy projects in indigenous territories in southern Mexico, showed that small agrarian producers have not benefited from the energy produced and that communities lacked proper public lighting, which exposed the most vulnerable people, including women, to the risk of aggression [24]. In addition, sometimes projects can reproduce and therefore reinforce prejudices against women as incapable leaders, as identified in a study conducted in Sub-Saharan Africa about small scale electrification projects in rural contexts [25].

Linked to the above, another body of evidence highlights that **women are often excluded or marginalized in the decision-making processes** and that this is a critical component of gendered energy injustice. In Gujarat, India, for instance, while the Solar Park's development presents gender-positive policies, it does not necessarily translate into equitable outcomes, often creating a surplus population of landless peasants who do not find employment within the solar park

[26]. Other works address gender relations in political participation and the impact of women's participation on energy policies. An examination of citizen participation schemes in renewable electricity production reveals how the gender investment gap can be greater than the wealth gap itself. Institutional and cultural factors can either accelerate or mitigate this gap, emphasizing the crucial interplay of these dimensions in shaping gender relations within energy transformations [27]. Interestingly, evidence suggests that greater female representation in national parliaments correlates positively with improved access to electricity and potential increases in sustainable energy consumption and energy efficiency [28,29]. Despite some women managing to exert their agency at local levels, they often remain marginal actors with limited decision-making authority [30]. A Mexican study on gender impacts of land privatization for RE (Green Grabbing) found women leaders excluded from decision-making by government, companies, and community leaders, despite land rights and common land use [31]. Even in cases where there is a willingness and commitment among the population to voluntarily participate in programs or activities that can help reduce energy poverty, there is a limited involvement of women in the decision-making process, as in the case studied in rural Niger [32]. Similar conclusions are presented by a study on energy transitions in the Colombian coal sector, where women are change agents at local level, yet there are still obstacles hindering their participation in formal decision-making spaces [33].

When women are included or lead the energy transitions better outcomes can be observed. For example, in Canada, grassroots women's networks, such as Women in Renewable Energy (WiRE) and Women and Inclusivity in Sustainable Energy Research (WISER), are recognized as having an important role in reducing the gender gap in the energy sector [34]. A modeling-based study in South Africa revealed that mainstream gender in the RE sector can be improved by ethical leadership and broad-based black economic empowerment [35]. Sometimes women lead energy transition projects. This is explored in a case study in the United States of how women-led non-profit organizations are advancing the transitions to RE, operationalizing the concept of energy democracy, and contributing to the energy justice movement [36].

Access to resources is another theme emerging as relevant to understand the nexus between gender and energy from an empowerment perspective. For instance, technology uptake brings to light the gender dynamics at play: men predominantly own radios and mobile phones in many contexts, potentially widening the gender digital divide and affecting women's ability to access information related to energy development and therefore limiting their empowerment, as well as increasing the knowledge gap, including on energy [37]. At the household level, the bargaining power of women can influence energy choices, particularly the shift towards cleaner fuels [38]. This power dynamic seems more pronounced in urban areas, underlining the influence of local socio-economic conditions and access to resources on the gender-energy nexus [38]. Some studies demonstrate that access to clean fuels and electricity can be a solid driver for women empowerment [39]. For instance, homes' lighting has been found to increase the number of activities performed throughout the day but, at the same time, the activities performed are often very different between genders in those contexts where a strong patriarchal structure of society is present. In those contexts, it has been noted how men tend to extend their time spent on leisure activities, while women extend their working time [40]. This could be considered a way of reinforcing traditional gender roles and preserving gender inequalities, but from the point of view of women interviewed in research conducted in Cajamarca, Peru, having more time available to work for the well-being of the family due to homes' lighting is perceived as a positive change [40].

The analyzed literature features some **possible solutions** to the challenges identified above **in terms of alternative research or policy paradigms**. Energy transitions can both reinforce and challenge existing gender inequalities, contingent on a variety of factors such as local socio-economic conditions, cultural norms, policy environments, and the technologies and energy sources involved. Thus, context-specific and gender-responsive frameworks in energy transitions policies and strategies need to be promoted to generate a more equitable energy future [41], not only for the Global South but also for the Global North [42]. In this regard, Maduekwe and Factor [43] present the role of the Economic Community of West African States (ECOWAS) in assessing energy projects from a gender perspective. ECOWAS is the first regional organization, globally, to have a Directive on Gender Assessment in Energy Projects, which provides a framework for Member States to ensure that women and marginalized groups in project-affected communities are adequately protected from adverse impacts of energy projects [43].

Some authors question approaches that consider women as targets of energy policies. Instead, they suggest adopting a feminist perspective and epistemology towards energy, especially to integrate the analysis of power dynamics within energy research [15,44]. This perspective offers a crucial framework for comprehending the factors that perpetuate unsustainable energy practices along four intersecting coordinates: the political, economic, socio-ecological, and technological [15]. Another contribution, drawing on feminist standpoint theory, develops a feminist contextual empiricist approach to scientific knowledge with which the RE, together with the geoengineering strategy of ocean fertilization, as climate change mitigation strategies, are examined [45]. Some authors use ecofeminist and feminist political ecology lenses to reveal the nexus between oppression and extractivism, as well as the opposite nexus between empowerment and the healing of the earth [46]. A further contribution presents the empowering role of performative arts, in particular theater, for marginalized women by including them in public discussions about energy improvement at household level [47]. Finally, Lieu et al. [8] call for the need of transitions including diverse voices to ensure fair decision-making processes in energy transitions.

A last stream of research presents some **normative considerations** about the changes that should be made in order to ensure just and fair energy transitions. To build more resilient, sustainable, and equitable energy systems, it is essential to deal with the gendered realities that shape energy experiences worldwide. Energy democracy remains incomplete if gendered perspectives are not incorporated [44]. Recognizing the diverse gendered aspects of everyday energy use practices and securing energy services is crucial, especially for improving energy security in poor urban environments [48,49]. The gendered aspects of energy transitions and justice shed light on the need for greater attention to the neglected socio-cultural and political dimensions of sustainable energy access [50,51].

3.2. *Cluster 2 – employment/work*

The Employment/Work cluster does not have a clear methodological profile and comprises roughly equal numbers of quantitative, qualitative, and mixed-method studies. The studies are more often concerned with a national, rural, or international level of analysis in low-income countries and somewhat less often in high-income countries. Particularly typical of these studies is a focus on renewable energies.

The data collected presents a multifaceted narrative about gender and employment in the context of energy transitions, particularly emphasizing the need for active efforts at the policy level towards achieving gender equity [52]. The literature reviewed focuses on three main issues, namely, (i) the participation of women in the energy transitions workforce, (ii) the participation of women in energy transitions entrepreneurship, and (iii) the factors that hinder such participation. In this context, it is important to highlight that, as pointed out by [53], sex-disaggregated data on the energy labor market, especially in the coal sector, are still scarce and often do not allow correlating them with social and gender indicators.

Concerning **women's participation in the energy transitions workforce**, the RE sector exhibits greater gender diversity and can potentially boost job creation and economic growth provided that gender equity considerations are accounted for [54]. Inclusion of

women is particularly important as workforce diversity correlates with better R&D performance [55]. However, gender imbalances persist in the broader energy sector, with greater male participation in the mining industry [56].

Further, while gender biases against women in renewables can be observed in industrialized, emerging, and developing economies, inequality patterns manifest differently in these contexts [57]. In developing and emerging economies, female job opportunities are expanding but are concentrated in the lower-paid and more precarious positions, far removed from creative design, management, and policy-making roles. Such evidence has been found in Kazakhstan's [58], and India [52]. This segregation is pervasive in technology-oriented employment patterns, which could impact the RE sector too [52]. Also, research indicates a link between female employment and positive energy outcomes at the national level such as greater RE consumption and lower CO2 emissions in China, Pakistan, India, Bangladesh, and Sri Lanka [59–61].

Studies focusing on the Global North yielded similar findings. For example, in Canada, it has been seen that the socio-technical transitions of the recent past did not lead to more gender-equal employment patterns [62]. In the UK a strong gender imbalance against women has also been found in the RE sector [63]. Re-skilling the female workforce and opening up new job prospects for women is recognized as fundamental for achieving a just transitions and reducing energy poverty in Poland, considering that single unemployed women are the most vulnerable to this phenomenon [64]. This could bring about significant changes in the labor market, particularly in regions that rely heavily on mining, an industry that is still male-dominated [64].

Concerning **energy transitions entrepreneurship**, research points out the need to look at it through the gendered lens to gauge whether the inclusion of women as entrepreneurs is actually advancing the cause of sustainable development [65].

There is evidence that women entrepreneurs in rural Rwanda can compete and even outperform men [66,67]. ENERGIA's WEE Program shows women entrepreneurs to be effective in last-mile distribution of affordable clean energy technologies through their social networks. Furthermore, the study reveals gender differences regarding participation in cooperation and solution-finding instruments [68].

The inclusion of gender concerns in the push for productive use of electricity and in RE policy can promote sustainable value chain creation and inclusive business model development [69]. The potential of RE in fostering women's empowerment, particularly in rural areas, is quite evident. The availability of RE encourages members to develop eco-friendly businesses, and the green loan conditions of microfinance institutions favor women's participation in the labor market [70].

Despite the positive outcomes described above, **barriers such as gender-based discrimination against women** and existing power structures still hinder women's participation and advancement in this field [54]. Studies in Kenya mention the existence of a masculine representation of the entrepreneur. This male-dominated idealization reproduces gender inequalities also in the sustainable energy industry [71].

Therefore, despite some advancements, it is vital to note that structural impediments still exist. Investment risks and barriers are still prevalent for women entrepreneurs [65]. Therefore, efforts to create livelihoods for women in this sector need to be supported by wider socially progressive pro-women policies and societal shifts in gender roles. Cultural barriers and changing market conditions can also affect the effectiveness of training programs on the Solar Home System value chain in developing countries, in terms of the eventual integration of women into the related job market [72].

3.3. Cluster 3 – attitudes/behaviors

The cluster has a clear quantitative profile. It is also characterized by most studies in high-income countries and a focus on the national level. Many studies in the Attitudes/Behaviors' cluster deal with renewable energies.

Several studies have focused on female and male attitudes and behaviors in relation to the adoption of RE sources. A crucial insight is that the adoption of RE technologies does not automatically equate to positive experiences for all. A literature review on the rise of Solar Home Systems in Sub-Saharan Africa shows that for women and other marginalized groups adopting this technology does not necessarily report positive experiences [73]. Class, age, and geographical location, intersecting with gender, significantly shape the adoption experience [73]. Older, richer, and urban sections of women's population seem to show more positive adoption experiences.

Regarding attitudes, multiple studies show the **gender-differentiated attitudes towards the use of RE and green services** [74,75]. This support can manifest in various ways, such as a preference for the use of renewable and clean energy [76,77], eco-friendly behaviors [78,79], and willingness to pay extra taxes for the sake of the environment [74,80], as well as accepting RE production facilities locally [81]. Studies reveal female consumers express greater environmental concern than men, particularly opposing nuclear and coal power [76,82]. This can be reflected into strong political stances, as the case of higher support for nuclear phase-out observed in Switzerland among female parliamentary candidates compared to male parliamentary candidates [83]. The case of hydrogen fuel, on the other hand, shows a different trend in a study conducted in Norway, from which it emerges that women are less likely to support this energy source compared to men [84].

Attitudes have recently been studied for the first time from the perspective of customers' intention to adopt green banking services [85]. This study reveals that the effect of perceived behavior control, namely the degree to which a person perceives to be able to perform a given behavior, is significant and positive for females and insignificant for males [85]. In other words, women's eco-friendly attitudes translate into their striving for eco-friendly behavior, even when faced with challenges like self-belief, limited time, and financial constraints. A study conducted in Lithuania showed that in addition to gender, other factors influence the intention to use RE sources, such as age, living place, and usage of RE sources. Individuals who are young, female, from smaller towns or villages, and already using some RE sources tend to show a higher intention to adopt RE [86]. Most of the studies, therefore, seem to agree about the existence of different attitudes towards RE sources between men and women. Nevertheless, such a conclusion is not universal, and other studies have found no gender difference [87,88].

Evidence shows that, although female consumers may hold more frequently pro-RE attitudes, **social and cultural factors may influence their behavior in relation to energy** [89]. Gender, together with other socio-economic factors, can impact how households adopt and manage RE technologies, like rooftop solar and grid electricity [87,89–91]. There is a need to understand how different socio-economic relationships, including gender, but also race, ethnicity, and class, shape energy transitions [92]. Research and policies have not yet fully integrated knowledge of energy practices from a gender and marginality perspective, such as communities with a migrant background or living in remote locations, as in the case of Sweden considered in the perspective article published by Ring et al. [92]. Socio-cultural factors and stereotypes also shape how women and men interact with energy systems at home [89]. Women often coordinate housework-related tasks that involve energy use while men take up more of the physical refurbishment work and monitoring energy systems [89]. The technical aspects of energy production and consumption are often seen as masculine, though results are mixed [87,93].

When we consider the **willingness to adopt new energy-saving behaviors and pay for RE initiatives**, the picture gets even more complex, and the results are mixed. Some studies found that women are more prone to adopt energy-saving behaviors [74], other studies found no differences among genders [80,94], yet another study in Ethiopia

found that female heads of households express greater willingness to pay for green electricity [95]. On the other hand, a case study assessing the effects of urban energy policy interventions on household energy consumption and gendered measures in South Africa, showed that in households in informal settings, women are often the household heads deciding on energy consumption [96]. In this context, the energy subsidy policy increased energy consumption and resulted in socio-environmental impacts that might increase inequality and impair human health [96]. Also, when looking at to what extent differences between men and women in environmental support translates into gender differences in willingness to pay for green energy, Hojnik et al. [75] found no relation. In other words, while women tend to have a higher level of environmental consciousness, they do not seem to be more willing than men to pay for RE.

Lastly, attitudes and behavioral intentions towards renewable energies can be influenced by the way content is conveyed. Environmental issues can be addressed in terms of their severity or the possibilities of overcoming them. A study conducted in Belgium shows that the frame used to convey content influences women more, along with people younger than 35 years old and older than 55 years old, those with lower education levels, and those less inclined towards environmentalism [97]. Meanwhile, higher-educated men, people between 35 and 54 years old, and those with the most pro-environmental attitudes are less affected by the message frame [97].

3.4. Cluster 4 – transitions to modern energy in the Global South

This cluster analyzes those studies that offer a description of the ongoing transformation of energy systems in rural contexts of the Global South and the gender impacts of this transformation. This definitional focus is also reflected in its quantitative description: all studies deal with low-income countries in the Global South, usually at a rural level. One special feature is that the majority focus on non-renewable energies (such as LPG, methane, etc.). In terms of methodology, the studies in this cluster are of a quantitative, qualitative, and mixed-methodology nature in comparable proportions.

In this cluster, research findings have been consolidated to investigate energy transitions within contexts of the Global South, where the concept of transitions is not necessarily tied to the abandonment of fossil fuels in favor of renewable energies. Instead, the concept of transitions to modern energy primarily pertains, at least in rural contexts within the Global South, to the shift from biomass to energy forms, including gas and hydrocarbons, considered cleaner, particularly with regard to indoor pollution and efficiency in a strict sense.

In these contexts, two pathways of the energy transitions can be observed: 1) Transitions from traditional to modern energy, which refers to the transitions from solid fuels - such as wood, charcoal, and animal residue - towards cleaner modern energy resources, such as gas and centralized electricity; 2) Transitions to RE, which refer to the shift from lack of access to modern energy to access and consumption of energy from renewable sources through various technologies (solar, photovoltaic, biodigesters, hydropower, etc.).

Firstly, studies on **the transitions to modern energy** fit into two different theoretical frameworks: a) the energy ladder hypothesis, which states that improved financial well-being of households tends to increase the uptake of modern and efficient energy; and b) the stacking hypothesis, which suggests that as households' income rises, they adopt modern fuels, but also continue using traditional fuels ‘mixing’ various energy sources [98]. A study conducted in Kenya validated the energy ladder hypothesis, showing that the likelihood of choosing modern lighting fuel increases in female-headed households, as well as with improvements in income, wealth, and education [99]. Built upon the energy ladder hypothesis, a study conducted in Ghana on the relationship between access to financial services and lighting energy consumption showed that men have access to financial services more than women [100].

In contrast, based on the energy stacking hypothesis, a study conducted in Tanzania investigated the relationships between the intra-household bargaining power of women and households' fuel choices [98]. The level of education, age, and labor market access of women is positively correlated with transitions from firewood and animal residue towards charcoal, but also towards modern lighting fuels [98]. A study conducted in rural China emphasizes the comfort of using non-solid fuel for elderly people since they are able to perform daily activities with greater ease if they cook with non-solid fuels [101].

Indeed, as shown by Vyas, Gupta, and Khalid [102] despite policies pushing for the adoption of modern energy sources, fuel choice seems to be also influenced by patriarchal norms leading women to continue using solid fuels. In fact, even when modern sources are preferred it is often due to norms of seclusion preventing women from leaving the home to collect solid fuels [102]. Bhallamudi and Lingam [103] pointed out that policies should aim for transitions to renewable rather than non-renewable modern energy sources. To achieve this goal, the authors suggest the implementation of region-specific policies taking into account rural contexts and needs, including the relatively lower incomes, and gender and class-based power structures. Furthermore, these interventions are more likely to succeed if they offer a basket of alternatives that can meet multiple energy needs [103]. Also, to increase acceptance among women the energy sources must reduce household workload [103].

A study conducted in Botswana shows that wood is used as fuel because connection to the electrical grid is not economically accessible [104]. The authors recommend economic diversification and subsidies to make electricity connection possible and consider solar energy and low-cost technologies complementary to centralized electricity [104,105]. In contrast to papers stating that modern energy allows for saving time for other activities [106,107], the authors show that wood collection is not a waste of time because it serves important social functions for women [104]. They consider it a moment of social interaction, social learning, friendship bonding, and emotional problem-solving space.

The second stream of studies on energy transitions in the rural Global South concerns the **transitions from solid fuels to RE**. In these areas, in addition to the expansion of national grids as the dominant strategy for extending access to electricity, the provision of decentralized, off-grid, small-scale electricity supplies is becoming a useful alternative to the national grid, and solar PV technology is the most widespread [105]. As mentioned in [105], according to the International Energy Agency, 220 million people in sub-Saharan Africa might be difficult to reach with centralized grids and will need decentralized solutions [108]. Such solutions are often promoted by private sector companies, research organizations, NGOs, and single departments within energy ministries and utilities [105].

In remote rural areas, such as rural Senegal, where grid connection is non-existent, photovoltaic (PV) renewable technologies provide suitable solutions for delivering energy services [107]. The best way through which access to modern energy could impact equity issues is by reducing time spent collecting biomass [107]. In Kenya and Senegal, decentralized solar power is making a difference in terms of gender equality, both in the supply and use of electricity [105]. For instance, this has occurred through the provision of solutions for people with very low incomes, a group in which women are overrepresented. The author argues that in these contexts women sometimes benefit even more than men from gaining access to light, better communication, information, and security because they are less free than men to spend time away from the home, and more at risk than men of experiencing violence outdoors at nighttime [105]. Decentralized small-scale solar power technology also opens some new opportunities for women to make decisions and act independently [105]. Similarly, a case study in rural India showed how the engagement of local illiterate and semi-literate women in the energy technology training program contributed to their empowerment and increased gender equality [12].

Another important fuel for the RE transitions in the Global South is biogas (methane) produced through biodigesters from animal waste. In Nepal, biogas technology has proven to be one of the most successful models of RE [106]. Utilizing biogas saves women time from collecting firewood, allowing them to engage in other empowering activities such as remunerated activities, education, and social involvement [106]. In line with these results, other studies concluded that the reduction in workload for women is one of the most significant benefits of switching to biogas [98,109]. They argue that not only do these technologies reduce time spent on cooking and collecting fuelwood and solid biofuels, but they also enhance women's health by reducing exposure to indoor smoke pollution [110]. However, the time saved does not necessarily translate into increasing leisure or empowerment, as it often results in more unpaid labor for women rather than an equal division of household labor between genders. A study conducted in Peru found that while men tend to extend their leisure time women often tend to do other working activities [40]. Research conducted in Nigeria showed that female-headed households prefer biofuel gel over traditional fuels for cooking [111]. The authors suggest that this may happen because women are more likely than men to be the decision-makers with regard to the choice of cooking fuel to be used at home [111]. Despite several studies suggesting biogas to have great potential, a study conducted in South Africa among smallholder and mixed farmers identified that women are less favorable than men to adopt biodigesters [112].

A study conducted in India, however, shows a very different situation where the transitions to RE reproduce the infrastructural violence in which poor rural women are immersed [13]. The case studied by Stock and Birkenholtz [13], hosts a world-class solar park (the Gujarat Solar Park), which is serviced by infrastructures and networks to facilitate flows of electricity, water, capital, information, and labor. Paradoxically, the hosting village remains under-equipped with infrastructure improvements as promised by the project commissioners. Furthermore, poor lower-caste women were displaced from previously accessible spaces for firewood procurement; and they were also excluded from corporate social responsibility schemes that boosted female empowerment through workshops and market opportunities related to artisanal handicrafts [13].

Micro-Hydro Power (MHP) projects are another source of RE driving the energy transitions in rural areas of the Global South. However, research in Ethiopia highlights ongoing gender inequalities in these projects, with women facing unequal distribution of benefits, limited involvement, and a lack of recognition for their energy needs and knowledge [114]. This study demonstrated the existence of rules of entry, social norms, and behavior hindering women's participation in community-based micro-hydropower projects [114]. Similarly, in rural Indonesia, Micro-Hydro Power is providing benefits to many households and is empowering women through skills training and enabling them to earn additional income [115]. Income also facilitates women's access to and control over other resources. Since they have their income, women can raise their living standards by buying electronic appliances for their household, smartphones, and even motorbikes or vehicles they did not have before when electricity was not available in the area [115].

In conclusion, the studies on energy transitions in the rural Global South reveal both differences and similarities to the Global North. While the energy transition pathways in the Global South are distinct in certain aspects, such as the shift from traditional to modern energy, the gendered division of household labor and the persistence of gender inequalities in access to and use of energy show significant commonalities with the Global North. In both regions, modern energy does not necessarily reduce women's workload or challenge established gender norms.

3.5. Cluster 5 – knowledge/awareness

The research cluster Knowledge/Awareness collects papers on three main aspects: 1) gender differences in the understanding and awareness of RE sources both in the scientific/academic community as well as among lay citizens; 2) gendered impacts on education attainments of access to energy and electrification; and 3) gender considerations in just energy education programs and tools. These are primarily quantitative studies in low-income countries at national and in some cases international and urban levels. The majority of the studies address renewable energies.

As for the **understanding and awareness of RE technologies,** the literature found that men tend to be more informed and knowledgeable than women concerning RE technologies, whereas women have been found to be more aware of RE impact and sustainability. Studies show that men seem to have greater knowledge about RE among university students [116–118] and high school students [119], as well as laymen citizens [120]. This seems to hold true for both developed and developing countries [121]. In this respect in educational contexts, studies conducted in Malaysia, Jordan, and Palestine, as well as a cross-national study conducted in 33 countries, found that both female students and teachers, are more aware of sustainability issues and RE impacts than their male counterparts [118,121–123]. Furthermore, there is evidence from a survey dataset from 31 European Countries that women exhibit higher levels of awareness, readiness, and action than men in the context of smart energy systems [124]. A study conducted in Jordan highlights that younger women have higher levels of awareness about RE [122], while another study conducted in India stresses the importance of intra-household power relations in shaping women's awareness of energy [125]. These findings point to the complexity of the gender-energy nexus, indicating it might not be related solely to the individual's knowledge and awareness but also to the domains and contexts in which knowledge is applied, developed, or valued. It is important to stress that knowledge about RE does not necessarily entail more positive attitudes in terms of support and consumption [119,126,127].

The second aspect analyzed in this SLR regarding the cluster Knowledge/Awareness is the **impacts of access to energy sources on educational outcomes**. A gendered pattern emerges in rural India, where the use of household solid fuel has more significant adverse impacts on the education opportunities for girls than for boys [128]. In the same vein, RE projects-enabled electrification in indigenous rural communities of Venezuela have proved to generate more positive outcomes for women's education than for men's [129].

Lastly, the literature presented insights into effective and **just energy education**. One study stresses the importance of mainstreaming gender into the energy Master's programs in Africa [130]. Another study proposes an interesting insight into gamification in massive open online courses (MOOC) on energy [131]. This study observes that there is no significant difference in the participation and completion of men and women, showing that this educational tool can be used for just energy education [131].

3.6. Cluster 6 – perception

The publications examined cover a range of aspects related to the perceptions of energy and energy transitions differentiated by gender: 1) physical perceptions and thermal sensations; 2) perceptions of environmental impacts of energy technologies and sources; 3) gender perception in STEM fields.

Although cluster 6 has a different thematic focus than the Attitudes/Behaviors' cluster, it is comparable in terms of the type of articles. Similar to cluster 1, the focus of this cluster is on quantitative studies, mostly conducted in high-income countries and at the national and urban level.

It is interesting to note that research on construction engineering and thermodynamics is studying **people's thermal sensations to low-temperature heating systems** at a gender-disaggregated level. This suggests that the standard and reference models of research, which by default refer to men, are changing to account for differences between women and men, as encouraged among others by Stanford University [132] and in line with the gendering research principles. In this respect,

a study on construction and building technology in Nordic European countries came to the conclusion that gender influences thermal sensation and draft acceptability and that it can be correlated to clothing preferences differentiated by gender. [133].

Gender differences and similarities in **the perceptions of environmental impacts of RE technologies** can be found in the literature. A study in rural South Africa shows that more men than women perceived energy practices as the main factor influencing climate change. Interestingly, the study found a lack of awareness in both women and men about the pollution associated with the use of fuelwood [134]. A study conducted in Indonesia found that while male respondents see RE as safer and inclusive, female respondents express concerns about serious environmental issues arising from its use in the future [135]. On the other hand, in South Korea, males appear more concerned about the effects of global warming, while women tend to have a lower preference for nuclear energy than men, perceiving a higher level of risk [136]. A particular case of technological innovation shows how gender influences the reception of innovations in the energy field. In fact, a study conducted in a college in Uganda on the Pee Power toilet technology, which generates light from human urine, shows that it is perceived positively especially among female students [137]. According to the study, the safety and convenience provided by the lighting enhanced their experience and indirectly improved educational outcomes and social empowerment thus highlighting the benefits that access to energy and electrification measures can have for women [137]. Lastly, a study in the US shows that women tend to give more importance to the positive outcomes of emission reductions than men [138].

A study conducted in Nigeria also explored how socially constructed **perceptions about gender affect attitudes** towards science, technology, engineering, and mathematics (STEM) fields [139]. There seems to be a prevailing stereotype associating masculine characteristics with science professions, which is reflected in the belief that male students outperform female students in STEM disciplines.

3.7. Cluster 7 – health

Gender differences regarding productive and reproductive activities play a pivotal role in determining the health outcomes associated with various energy sources and is therefore a fundamental aspect to consider when assessing the relationship between gender and energy transitions. It is worth stressing that all the literature included in the analysis considered the health dimensions of energy assessments specifically in low-income countries. These tend to be quantitative studies, but often also qualitative and mixed-method studies. Of all the clusters, the Health cluster contains the smallest proportion of articles on renewable energies. The analyses are often carried out at the rural, but also at the national and international levels.

From a gender perspective, the papers addressed health issues associated with energy by focusing on the use of solid biomass fuel for cooking. The literature identified two different streams: a) health issues related to air pollution due to burning solid biomass; and b) health issues associated with biomass collection.

Concerning **health issues related to air pollution due to burning solid biomass**, several studies highlight that household air pollution disproportionately impacts women and children, who typically spend more time in cooking and food preparation [140]. Women, who are primarily involved in cooking tasks in many societies, bear the brunt of biomass combustion, which is still one of the main energy sources employed especially in rural areas of low- and middle-income countries. This exposes them to health risks related to indoor air pollution (IAP). The toxic fumes they inhale lead to a range of health conditions, including chronic obstructive pulmonary disease, tracheal/bronchial/lung cancers, and even an increased risk of stillbirth during pregnancy [140–143]. Health issues related to the use of solid biomass fuel are sometimes also associated with women's paid working activities outside the household, as shown for instance in the coffee processing sector in Colombia [144]. However, awareness concerning the non-communicable diseases associated with the air pollution resulting from burning solid biomass is often insufficient, underlining the necessity for initiatives to educate about the adverse health effects of household air pollution, thereby fostering transitions towards cleaner fuels [145].

With regard to **health issues associated with biomass collection,** the literature agrees that transitions from traditional to RE sources, such as biogas, solar stoves, and biomass stoves, bring tangible benefits for women in wide-ranging dimensions. For instance, Chinese as well as Tibetan women reported a significant decrease in disease incidence after the introduction of cleaner and more efficient energy stoves, which also relieved them from the strenuous task of energy-sources collection [142,146]. Apart from health benefits, a study conducted in rural Colombia demonstrated that women noticed an improvement in their quality of life when shifting to biodigesters fed by waste, yielding not only environmental advantages but also time savings and reduced energy costs [144]. Furthermore, the use of RE sources frees up time for schooling and work opportunities and reduces the risk of injuries or attacks [140].

In summary, therefore, the reviewed papers demonstrated that transitions to cleaner fuels, such as shifting from solid fuel to clean fuel for cooking, is not only an environmental concern but a pressing health and gender issue. However, further research needs to be carried out to assess to what extent transitions from traditional to modern cooking fuels can also positively affect women's daily activities and independence. In fact, while Presta-Novello et al. [144] found a positive effect, Wu [146] reported no significant effects. Despite all the studies in our sample focused on the Global South, studies outside our sample found that health issues related to residential wood combustion for heating and cooking are present also in the Global North [147,148].

4. Discussion

Energy transitions, with its promise of a cleaner and sustainable future, present a complex mix of opportunities and challenges for women. The presented SLR, drawing insights from 152 scientific publications, delves into the multifaceted relationship between gender and energy transitions. Based on the subject and content of their results, the analyzed body of literature has been grouped into seven clusters: Transitions to modern energy, Employment/Work, Knowledge/Awareness, Perception, Attitudes/Behaviors, Health, and Empowerment.

Indeed, the SLR also presents some limitations. In particular, it is worth stressing that the methodology relies on a sample that is strongly dependent on the syntax and the database used for the extraction of the papers. In more precise terms, our search focused exclusively on peer-reviewed English-language academic literature from the WoS database, potentially omitting valuable insights from grey literature and other databases. Furthermore, our study echoes conclusions of prior research, which argue that gender and sex are often used interchangeably within the literature meaning that current studies on gender and energy oftentimes fall short by focusing solely on energy and a biological understanding of sex, or by reductively equating gender with a masculine/feminine binary [6,16]. Even though feminist [6,14–16] as well as masculinities theories [149–151] that seek to deconstruct oversimplified notions of gender and challenge traditional power relations are gaining traction in energy studies, they remain underrepresented in our study, inevitably shaping the direction and depth of our conclusions, potentially constraining a more nuanced understanding of how gender dynamics intersect with energy issues.

The SLR presented here underscored the complex relationship between gender and energy transitions. Such complexity is highlighted also by the heterogeneity of the publications collected in terms of methodologies, social and geographical contexts, disciplinary fields and aspects analyzed.

From a quantitative perspective, our analysis shows how the

relationship between gender and energy transitions is a relatively new strand of research and the academic interest in it sharply increased in recent years. In our sample, the majority of publications was published in the years between 2020 and April 2023. Despite the increased interest in the subject, most of the literature pointed out how the paucity of gender-disaggregated data [7,152,153] on the different aspects of energy transitions still makes it difficult to assess both the different repercussions it has had on men and women and the contribution that women can bring to favoring and advancing the transitions itself. This represents a very urgent issue to be addressed since just transitions should be grounded in robust data and analysis. The quantitative analysis also unveiled a marked imbalance in the geographical distribution of the countries and regions studied and a lack of comparative studies. Most of the publications included in our sample analyzed the Global South with a focus on Sub-Saharan Africa. Only 13 publications simultaneously analyzed multiple regions. Of these, only seven bridge the gap between the Global North and South and only ten consider gender-energy nexus in high-income countries. It seems that the gender dimension of energy has not sufficiently been studied in rich countries; those countries that can guarantee a reliable and secure energy supply across the board [154]. Despite the undoubtedly higher level of energy access and supply, the literature emphasizes that the Global North has its specific challenges related to the gender-energy nexus [7,154,155]. For instance, concerning energy poverty, as shown by Eurofound [156], the share of women who were late in paying their energy bills surged in the spring of 2022, and single women and single mothers were more likely than other groups to struggle to pay their energy bills.

The studies demonstrate the usage of diverse methodologies and themes across various clusters. The analysis shows a series of typical approaches depending on the respective topic in relation to the gender-energy nexus. Particularly pronounced correlations are, for example, the focus on quantitative studies in the Knowledge/Awareness cluster, the exclusive focus on low-income countries in both the Health and Transitions to modern energy clusters, the strong focus in the Employment/Work cluster on renewable energies or the generally rather rare consideration of the urban or international level as a unit of analysis. A deviation from the methodological and analytical mainstream of the respective thematic clusters could enable additional in-depth perspectives on the problem areas underlying the clusters - e.g. in an investigation of sex and gender-related health effects of energy or the gender dimension in transitions to modern energy in middle- or high-income countries or a stronger consideration of the urban context in empowerment- or transitions-related studies.

From a qualitative point of view, the analysis' results highlight some general findings. Firstly, compared with the traditional energy sector, the green energy sector may offer, across all the dimensions analyzed, significantly greater opportunities for women's empowerment and well-being. However, the green energy sector is not intrinsically more inclusive and equitable than the traditional energy sector. Secondly, energy-related gender inequalities are often linked to and reinforced by cultural norms, and gender roles and stereotypes [157] that still permeate many national contexts. Thirdly, most of the research carried out on the nexus between gender and energy does not employ an intersectional approach, often considering women as a homogeneous social group. On the contrary, other identities and characteristics (such as ethnicity, religious beliefs, economic status, level of education, etc.) must be jointly considered to have a precise and realistic picture of the issues examined. Fourthly, it is crucial that energy transitions are duly guided by gender-tailored policies aimed at eliminating the gender inequalities that persist in the energy sector. Otherwise, energy transitions will end up replicating the same gender distortion as the traditional energy sector [158]. Lastly, our analysis suggests a lack of research on the nexus between gender and energy in the Global North in all the clusters identified.

5. Conclusions

From the qualitative analysis of the publications' results investigated in the present SLR emerges how moving towards a just and equitable energy future requires a gender-inclusive approach that prioritizes the following aspects:

5.1. Gendered policy framework

Varying among countries and regions, from the analysis, a general insufficiency of gender-tailored policies concerning energy transitions emerged. Even in those contexts where such tailored policies exist, the literature pointed out how they are often insufficient for reaching just and inclusive transitions. This is confirmed, for instance, by several studies assessing European policies on energy transitions [7,159–161].

Therefore, at national as well as international levels, policymakers need to design and implement policies addressing the specific needs and challenges faced by women concerning energy access and energy poverty [162], employment [163], education [61,164], and decision making [165]. This includes allocating resources for targeted training programs, promoting women-led clean energy initiatives, and ensuring women's participation in energy governance structures. Also, the literature highlighted the importance of including women's voices in the policy-making process.

5.2. Investing in education on sustainability

Education plays a crucial role in empowering women to be active participants in every aspect of energy transitions [166]. Integrating gender considerations into STEM in general and energy education and sustainability programs in particular could help to increase women's participation [164]. Knowledge concerning RE should also be enhanced by integrating RE-related topics and projects into university, school curricula and vocational training that may involve “learning-by doing” approaches [122]. The level of awareness should be increased through various channels and by presenting the information in different and appealing formats (e.g., laboratories, movies, scenario simulation). The topics addressed in the curricula should also be adapted based on the trends in industry and requirements of the region and regularly updated to include the latest technology [167].

Also, in addition to school curricula, awareness raising should be realized through educational and outreach campaigns aimed at the public at large and by combining traditional mass media channels such as newspapers, television, and radio with community-based initiatives [168].

5.3. Fostering women's participation in the energy workforce and entrepreneurship

It is essential to break down those structural barriers that hinder women's entry and advancement in the RE sector, as workers as well as entrepreneurs, such as cultural gender norms and stereotypes, prevalent male-biased hiring practices, access to credit, and lack of STEM education. Ad hoc gender-sensitive orientation and training programs, mentorship initiatives, and access to tailored financing mechanisms can give women the necessary instruments to thrive in the clean energy industry [68].

5.4. Adapting communication strategies

It is of utmost importance to develop communication strategies and campaigns that consider gender knowledge gaps and perceptions regarding RE. Communication campaigns considering the typical different social roles distributed between men and women as well as average knowledge and perceptions of men and women can improve the participation of women along the value chain of the energy sector and

can increase awareness on the subject [124,127]. Additionally, tailoring communication strategies to consider the specific contexts and needs of different communities, including active involvement of indigenous communities during the implementation of low-carbon energy projects [169]. For instance, in rural areas where women are primarily responsible for fuel collection, highlighting the health and time-saving benefits of clean cooking/heating/lighting solutions can be a powerful motivator for adoption.

5.5. Ensuring equitable benefits

In order to be fair and just, energy transitions must provide equitable benefits for all. The SLR suggests that this is not happening everywhere and there are still the risks of disruption to traditional livelihood activities and displacement for those whose livelihoods depend on fossil and other traditional fuels [20,170]. To address this risk, it is essential to ensure that women have equal access to the opportunities arising from transitions to greener and renewable forms of energy. This could be done through implementing social safety nets and upskilling and reskilling programs for displaced workers, with a specific focus on empowering women to participate in the energy transitions economy [63].

5.6. Increasing women's energy access and reducing energy poverty

The publications analyzed highlighted how access to energy and energy poverty are issues disproportionately affecting women. With different degrees and specificities, in both the Global South and the Global North, women have resulted in being more exposed than men to energy poverty, adverse health impacts, and more affected by lack of energy access [51,57,114]. Especially focusing on the Global South, the publications analyzed underscored the significance of economic diversification and subsidies as tools to empower women in transitions away from traditional energy sources [104,146]. Governments should aim to enhance women's access to the national electric grids and diminish reliance on firewood and other traditional energy sources [146]. Empowering women's access to energy services is a crucial factor contributing to the broader objective of Sustainable Energy for All (SDG7), and subsidies can play a pivotal role in enabling women to access energy resources.

5.7. Recommendations for future research

Addressing the **gender perspective in energy research**: Through the SLR, research gaps that can guide future energy studies based on a gender perspective emerged. Within the scope of employment, it is essential to strengthen sex-disaggregated data on employment in renewables to document gender gaps in energy employment and make evidence-based comparisons [53]. Future research could delve into the role of women's professional networking organizations in reducing the gender gap in professions related to energy transitions [54]. Furthermore, future studies could address the economic benefits of closing the gender gap in the energy sector [124], through for example, counterfactual analyses. Regarding entrepreneurship, it is necessary to study the factors that could influence business performances of female entrepreneurs [124]. Among these factors, literature suggests experimental studies on how women perform when competing exclusively against other women or against men and women [124]. Furthermore, it is important to study the mechanisms that cause the underrepresentation of female entrepreneurs in the energy sector. Studies are needed to delve into gender-based discrimination in access to financing, such as the gender effect on the cost of bank financing [65,170]. Also, further studies are needed to understand the business models of successful female-led enterprises as well as the benefits of entrepreneurship for women and their families [172].

The research gaps related to the dimensions of behavior, knowledge, and perceptions intersect on multiple levels, showing that it is necessary to analyze the sociodemographic factors, but also the subjective factors such as emotions, culture, norms, preferences, place identities, values which influence knowledge and acceptability of renewable and clean energy sources. Other factors to be explored concern the influence of political ideology, memories, representations of the localities, and levels of trust in public and private sector organizations in supporting local energy projects [173]. The relationship between traditional gender roles, which associate energy with the male gender, and the low organizational participation and engagement of women in local energy transitions initiatives should also be studied more thoroughly [174]. Research is also recommended on gender differentiated perceptions and insights of top management and policymakers about energy transition issues.

The role of women in shaping energy agendas and influencing energy policies in different social and political contexts still needs to be studied more extensively and in-depth. It would be worthwhile to study the institutional, cultural, and political barriers women face in influencing environmental and energy policies [29]. Further studies are needed to analyze and compare the impact and benefits of different national programs, policies, and electrification initiatives in rural contexts [25,77]. Further studies could address the social implications of sustainable electrification projects in remote and rural areas of the Global South. In particular, comparative studies could be conducted to highlight the differentiated gender impacts and benefits of electrification projects based on centralized and decentralized energy models [25]. Few studies so far have addressed the issue of traditional practices that are abandoning women with the introduction of new forms of energy, and the impacts of this transformation on their daily practices of socialization and resistance.

Finally, concerning the nexus between energy and health from a gender perspective, further studies are needed regarding the impact of energy poverty on women's health (both in the Global North and the Global South), but also on other groups such as children and the elderly [145,146]. Moreover, when assessing the gendered relation between health and energy, men should also be considered since it has been observed that they are often exposed to the pollution derived from cooking (especially boys in some specific contexts) and they are also likely to develop pulmonary disease since men are more likely to have underlying health issues due to smoking that increase the risk of mortality from pollution [175] It is also necessary for research to focus on creating indicators to establish relationships between gender and processes of social appropriation of clean energy technologies [144].

In conclusion, the SLR has shown how energy transitions can bring many different advantages for women and reduce those gender inequalities characterizing the traditional energy sector. To do so, however, the transitions need to be properly guided to reach the goal of justice. Providing insights about the gender-energy nexus, highlighting the gaps still affecting its knowledge, and offering policy recommendations, the present work could represent a useful tool for defining the agenda for future research on the nexus between gender and energy transitions, as well as for elaboration of informed and tailored policies.

CRediT authorship contribution statement

Marco Cellini: Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Sabine Loos:** Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Cloe Mirenda:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Lucio Pisacane:** Writing – review & editing, Writing – original draft, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Clemens Striebing:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Serena Tagliacozzo:**

Writing – review & editing, Writing – original draft, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Lucio Pisacane reports financial support was provided by European Union's Horizon Europe - Culture, creativity and inclusive society. The work presentend in this paper generated from the gEneSys Project. The project has received funding from the European Union's Horizon Europe - Culture, creativity and inclusive society - under grant agreement no. 101094326. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2024.103887.

Data availability

I have shared the link to the dataset in the "attach files" step gEneSys Project - Systematic Literature on the Nexus between Gender and Energy Transition Database (Original data) (ZENODO)

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