Evaluating Work Environment and Gender Barriers in Energy R&I: Insight From gEneSys survey

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Research and Innovation (R&I) play a pivotal role in advancing renewable energy technologies and facilitating the transition towards more equitable and sustainable energy systems. However, significant gender inequalities persist within R&I, with women markedly underrepresented in research teams, leadership positions, and decision-making processes. This study contributes to the understanding of a yet under-investigated field by examining the existing gender barriers in public/private R&I organisations engaged in energy research.

Based on a survey conducted across multiple European countries, including the United Kingdom and Norway – as part of the Horizon gEneSys project – the study assesses job satisfaction, organizational culture, work-life quality, collaboration dynamics, and persistent gender inequalities within the R&I workforce. Findings reveal pronounced job insecurity among women in R&I, linked to greater challenges in career advancement, formal recognition, and workplace respect. Moreover, women report a heightened awareness of gender inequalities, highlighting the interplay between gender, job insecurity, professional roles, and both overt and covert discrimination.

Achieving gender equity in energy-related R&I is a key strategic objective, essential to valorise talents and expertise and incorporate diverse perspectives in energy research agendas. This ensures that the energy transition is not only technologically advanced, but also socially just.

Keywords: gender inequalities, research and innovation workforce, renewable energy sector.

1. Introduction

Recent studies show that the energy sector—both fossil and renewables —faces major socio-economic inequalities (Baruah & Gaudet, 2022; Lazoroska et al., 2024), with a

predominantly male workforce (Cellini et al., 2025). This is due to two main factors: the gender imbalance in STEM pipelines and work environments that fail to support female participation (European Commission, 2024; Striebing et al., 2024).

Nevertheless, the renewable energy (RE) sector offers substantial opportunities to boost women's employment and narrow gender gaps in technical, scientific, and commercial areas (IRENA, 2023; Webb et al., 2021). According to 1.5° scenario, by 2030, 85 million additional jobs related to the energy transition would be created compared to 2019 (IRENA, 2022), yet women currently make up a small portion of the RE workforce. For instance, women in senior positions account for 25.2% in the solar sector, 25.6% in the wind sector, and 19.3% in the hydropower sector (IEA, 2024).

Research and Innovation (R&I) in energy is crucial for advancing RE potential, as well as storage and distribution for new energy systems. The energy transition's success hinges on skilled, committed R&I professionals (Soriano & Mulatero, 2011).

Studies supporting the integration of a gender perspective across labor markets, including R&I, show women often exhibit stronger environmental and sustainability awareness than men, turning that sensitivity into tangible action (Allison et al., 2019). Their participation also enhances research performance and fosters more inclusive workplaces (Lazoroska et al., 2024). Women's involvement in energy research is therefore essential for tackling emerging challenges, yet they remain underrepresented: in the engineering and technology field, which includes the majority of researchers in the energy sector, women hold 17.9% of full professor positions (European Commission, 2024).

Although extensive research addresses women's underrepresentation in STEM, the energy-related research fields remain overlooked. Existing work considers women in boards and management of large energy companies (Carlsson-Kanyama et al., 2010), decision-making in renewables (IRENA, 2023; IEA, 2024) and energy policymaking.

However, gender roles, stereotypes, and inequalities within energy research organizations remain underexplored, with few exceptions (Sánchez-López et al., 2024). These dynamics often impede women's entry, retention, and career progression in STEM (Wentling & Thomas, 2009).

The organizational level is therefore critical to encourage women's contribution in scientific development, yet the lack of indicators often stems from intrinsic challenges in gender monitoring. Such monitoring frequently relies on quantitative data by sex. Capturing gender dynamics, however, requires qualitative indicators, such as perceptions, which are harder to operationalize, gathered through surveys or focus groups (Sánchez-López, 2024).

Commentato [CM1]: Questo paragrafo eliminerei/ridurrei perché dice quello che intende fare sempre la ricerca con prospettiva di genere

Commentato [CF2R1]: Concordo! Può essere rimosso

This paper presents findings from a survey targeting researchers, technicians, experts, and academics involved in energy R&I. The survey was designed in the context of the EU funded gEneSys project, to gauge employees' job satisfaction and assess the organizational culture and workplace dynamics. In particular, the aim of the survey was to understand to what extent gender barriers and stereotypes still permeate the R&I sector in the context of the energy transition and assess the presence or absence of an inclusive working climate within public and private R&I organization engaged in energy transition related research.

The survey builds on a recent study commissioned by CINEA, European Climate, Infrastructure and Environment Executive Agency, to assess gender balance in the R&I field in the energy sector (European Commission, 2024). It was distributed to professionals engaged in R&I activities across energy-related fields within public and private organizations including research centres, academic departments, national/local agencies, companies, and businesses.

The paper is structured as follows: Section 2 reviews the available literature and

situates our contribution within it. Section 3 outlines the questionnaire's design, administration, and the methodology used for data analysis. Section 4 presents the analysis results. Section 5 concludes with a discussion of the findings, their implications, and policy recommendations.

2. Literature Review

Women's persistent underrepresentation in R&I arises from a complex interplay of structural, cultural, and economic factors. Studies identify universal barriers to women's advancement, especially during transitions to stable positions rooted in competitive, individualized progression systems (Kinahan et al., 2020; Ghaempanah & Khapova, 2023). In Canada, for example, women are less likely to secure permanent roles and more prone to perceiving hiring and promotion practices as inequitable (Uppal & Hango, 2022). Similar trends appear in New Zealand, where men are over twice as likely to attain full or associate professorships with equivalent qualifications (Brower & James, 2020).

Gender inequalities in research careers emerge from several factors, including gender biased evaluations, limited mentoring, workplace discrimination, and disparities in promotion and pay, exacerbated by caregiving challenges (Kinahan et al., 2020; Harris et al., 2024). The "leaky pipeline"—women's gradual exit from scientific careers—worsens after childbirth, as family obligations clash with high productivity demands (Weisgram & Diekman, 2017; Sebastián-González et al., 2023).

In addition, there is the impact of barriers resulting from the interaction between situated socio-cultural practices and gender (Saifuddin et al., 2019), which reinforce bias and further limit women's career opportunities in research. Notably, Prozesky and Beaudry (2019) question the conventional assumption that caregiving responsibilities are the primary obstacle to African women researchers' mobility. Instead, they highlight the influence of gender-based restrictions, including patriarchal norms that limit women's

social interactions and freedom of movement.

Gender disparities are also prominent in Northern European countries, with segregation affecting fields, networks, and work environments (Griffin, 2022). Analyzing and addressing these inequalities requires context-specific solutions at both national (e.g., research investment) and organizational (e.g., departmental equity policies) levels (Griffin, 2022).

These issues intensify in energy-system research, historically STEM-dominated, where women's representation is notably lower than average (Smith et al., 2019). Inequities extend beyond structural barriers to power dynamics: few women occupy senior or leadership roles, limiting their decision-making influence, and their participation as principal investigators or co-investigators remains significantly below that of men (Sánchez-López et al., 2024).

Despite a marginal increase in the last few years, the share of women seeking energy-related research grants remains low, and funds allocated to them generally lag behind those for men. Barriers include the size and timing of funding calls and the broader academic culture and evaluation criteria. Additional challenges involve minimal support for those with caregiving responsibilities or fragmented career paths, as well as difficulties forming industry partnerships in a male-dominated sector (Smith et al., 2019).

As a result, "gender blindness" in energy R&I has a dual impact: it wastes talent by confining women to subordinate roles with slow career progression or pushing them to leave the field, and it weakens research quality. Gender perspectives are often dismissed as irrelevant, as illustrated by studies on photovoltaic cell placement (Sánchez-López et al., 2024).

However, a growing body of research emphasizes the importance of adopting inclusive approaches incorporating gender and minority considerations into energy

research agendas (Cannon & Chu, 2021; Ryan, 2014; Sovacool, 2014). This shift represents both a crucial transformation of society and a substantial challenge for entire epistemic communities, as energy systems-including production, access, and governance-need to systematically address inherent issues of equity and justice. Failure to tackle these issues perpetuates existing systemic inequalities, evident in disparities in energy access and use and the persistent underrepresentation of women in decision-making arenas and labor markets.

Against the backdrop of such critical issues, scientific literature agrees that the transformation of energy systems toward sustainability can only be achieved by drawing on a broad talent pool that embraces gender inclusion and other forms of diversity (Pearl-Martinez & Stephens, 2017). In this regard, Hoicka (2023) argues for the need to strengthen energy research programs through a multi-level approach. First, integrating equity principles into all stages of the research process is critical not only to ensure more equitable access to scientific and professional opportunities, but also to incorporate the social dimensions of the most vulnerable populations into STEM agendas. Second, creating inclusive environments – through targeted recruitment strategies that engage researchers from different backgrounds and the adoption of mentoring practices that support the experiences of historically underrepresented groups – fosters greater equity in the field (Hoicka, 2023).

This transformation requires a deep cultural shift in research institutions, which are still marked by structural barriers and discrimination. Such barriers manifest in unequal access to publication and funding, as well as in recruitment, retention, and promotion processes, disproportionately affecting women and other underrepresented groups (Smith et al., 2019; Wilgosh et al., 2022).

Prevailing cultural norms also shape the work environment, creating mixed

experiences for women in energy research (Smith et al., 2019). While Gender Equality Plans and diversity commitments mark progress, actual implementation often misaligned with the best practices they theoretically promote (Lazoroska et al., 2024). Unwelcoming conditions persist where long hours are valued, contracts are short-term, and caregiving needs go unmet. Consequently, "invisible women" remain a reality in energy research (Smith et al., 2019).

3. Data and methods

3.1. Survey and data collection

This study investigates how far gender barriers and stereotypes permeate energy-related R&I, and evaluates whether an inclusive working climate exists in public and private academic or research organizations.

The survey was designed by the CNR Team, then reviewed by gEneSys partners. A pilot version was tested on eleven individuals selected for diversity in gender, nationality, and employer type. Their feedback informed the final survey.

Because identifying all energy researchers in public and private institutions proved challenging, we employed stakeholder mapping and snowball sampling. Stakeholder mapping allowed distributing the survey to contacts in Italy, Germany, the UK, and Poland, who were then asked to circulate it within their networks.

The survey on R&I Workforce in Energy Transition includes three main sections:

- Sociographic characteristics: gender, age, employer, type of employment contract, care responsibilities, career level, and educational attainment (7 questions).
- Organizational features: energy sector, country, and company size (3 questions).

- Psychometric scales: agreement or disagreement with various constructs (43 questions), assessed using the following validate scales:

(1) Work-Related Quality of Life (WRQoL). Adapted from Easton and Van Laar (2018), assessing perceived quality of life at work (12 questions).
(2) Perceived Subtle Gender Bias Index (PSGBI). Elaborated by Tran et al. (2019), it measures individual perceptions of subtle, gender-related experiences (21 questions).
(3) Perspective for just energy transition knowledge production (PJETKP). We created this scale to understand individual opinions on policies for a more inclusive energy sector (6 questions).
(4) Workplace Diversity Climate (WDC). Adapted from Ward et al. (2022), this scale measure individual's perceptions about the diversity climate in their workplaces (4 questions).

Administered via LimeSurvey between September and November 2024, the survey yielded 484 responses, with 14.15% partially completed.

Due to snowball sampling, geographical coverage was uneven. Most responses came from EU countries, the UK, and Norway, so the analysis focused on those regions, limiting the sample to 357. Among them, three identified as non-binary and eleven who declined to disclose gender, were analyzed separately. The final sample included 342 respondents from 21 countries.

3.2. Gender variable treatment

Before designing the questionnaire, we aimed to go beyond a binary view of gender in quantitative research. Though not targeting trans or non-binary identities specifically, we

acknowledged non-binary possibilities and offered four options: Female, Male, Non-Binary/Other, and “I prefer not to answer.”.

Unfortunately, even using "non-binary" as an umbrella term did not yield enough data to conduct analyses beyond the binary understanding of gender. Among the 356 respondents, only 3 identified as non-binary, and 11 chose not to answer the gender question.

Given the low non-binary response (0.8%), we conducted analyses using a binary variable (Female, Male). As Fraser (2018) suggests, when subgroups lack statistical power, descriptive data should still acknowledge them. Annex 2 details respondents who chose “non-binary” or “I prefer not to answer.”

3.3. Method of analysis

After cleaning the dataset and conducting descriptive statistics, multidimensional analyses were performed. These centered on categorical items from the four psychometric scales, aiming to detect response patterns and their links with respondents’ attributes (gender, age, professional role, contract type, care responsibilities, and energy sector).

First, Exploratory Factor Analysis (EFA) explored latent structures in the question batteries, identifying key dimensions. Next, Confirmatory Factor Analysis (CFA) validated these structures and evaluated model fit. Finally, Cluster Analysis (CA) leveraged the extracted factors to group respondents and revealed differences for each latent construct1.

For factor synthesis, the PSGBI underwent CFA following Tran et al. (2019),

[1] For a comprehensive methodology description, refer to Annex 1 – Methodology full description, which details the full Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and clustering processes, along with the statistics used to assess them.

using the full set of questions per the authors' guidelines. By contrast, WRQoL, WDC, and PJETKP began with EFA prior to CFA, as WRQoL and WDC used only selected items from existing scales, and PJETKP was newly created for this survey. As Suhr (2006) explains, EFA clarifies underlying factor structures and determines the number of latent constructs.

Through EFA and CFA, the number of variables was reduced, resulting in the identification of nine factors. Table 1 presents the extracted factors for each set of questions, along with their corresponding items and identified construct2.

Table 1. List of the extracted factors, constructs and constructs' items

Extracted factor	***Construct's Items***	***Construct***
WRQoL_F1	influence; abilities; goals	*Empowerment and Goal Clarity in the Workplace*
WRQoL_F2	aknowledgement; skill_development; decision_involvement; career_opportunity; needs_met; safe_environment	*Workplace Support and Professional Development Opportunities*
WRQoL_F3	working_hours; flexibility	*Work-Life balance and Flexibility*
Discrimination_F1	biases; verbal_prevarication; respect; ambitiousness; subordination; treat_women; support_male; meeting; bias_aknowledgement	*Perceptions of Gender-Based Inequality*
Discrimination_F2	feedback; collegial; relationship; ideas; support_people; feel_valued	*Perceived Workplace Support and collegiality*
Discrimination_F3	mentoring_informal; mentoring_formal; mentoring_senior	*Mentorship and Professional Guidance*
Discrimination_F4	attuned; support_balance; policy_equity	*Support and Work-Life Balance*
Policy_F1	diversity; culture; favoring_groups; society_representation; male_domination; minorities	*Policy Advocacy for Inclusivity in the Energy Sector*

[2] For a detailed description of the identified constructs, refer to refer to Annex 1 – Methodology full description.

Organization_F1	managing_backgrounds; accepted_backgrounds; hiring_practices; retain_diversity	*Commitment to Diversity and Inclusion*

Tests for EFA's validity (see Annex 1) showed adequate sample adequacy and robust inter-variable correlations, supported by strong KMOs and Bartlett's tests. Eigenvalues and parallel analysis justified factors count, while fit statistics (RMSR, RMSEA, TLI) fell within acceptable ranges. For CFA, CFI, TLI, RMSEA, and SRMR indicated good data fit, except for the PJETKP model (RMSEA=0.1). All other RMSEA confidence intervals were below 0.08, confirming an acceptable fit. Overall, the CFA results strongly validate the proposed factorial structures, with most indices meeting standard thresholds.

The final analytical step involved Cluster Analysis (CA) on each factor to identify distinct respondent profiles, conducted as follows:

(1) Data preparation: Missing data within extracted factors were imputed using gender-stratified means.
(2) Standardization: Data was standardized via z-scores for alignment with distance metrics (e.g., *k-means*) and minimizing outlier impact.
(3) Determination of optimal cluster: The Elbow method consistently indicated three clusters for each factor.
(4) Clustering Methods: K-means clustering was applied to group observations into homogeneous clusters by minimizing within-cluster variance. The algorithm assigned respondents to clusters based on their similarity within each latent construct.

(5) Evaluation of cluster quality: Silhouette scores (-1 to 1) measured within-cluster cohesion and between-cluster separation, with higher values indicating better-defined clusters.

For the nine clustering processes conducted, average scores ranged from 0.51 to 0.69, as shown in Table 2, indicating a reasonably well-defined cluster structure (Rousseeuw, 1987).

Table 2. Silhouette score by clusterized factor

Clusterized factor	Number of clusters	Average Silhouette score
WRQoL_F1	3	0.61
WRQoL_F2	3	0.55
WRQoL_F3	3	0.69
Discrimination_F1	3	0.55
Discrimination_F2	3	0.60
Discrimination_F3	3	0.59
Discrimination_F4	3	0.51
Policy_F1	3	0.56
Organization_F1	3	0.61

Cluster means for the variables of interest were calculated to characterize each cluster. Averages for key demographic and contextual variables (e.g., gender, age, education, seniority, contract type, and research profile) were computed and discussed in section 5.

4. Analysis and results

4.1. Respondent profile

4.1.1. Demographic characteristics

The sample includes 55.9% men, 40.2% women, and 3.9% non-binary or unspecified. These results align with She Figures (European Commission, 2021), which reports similar

proportions of women in higher education (42.3%) and government research (43.9%).

Age distribution peaks at 41–45 and 51–55 (16% each). Younger (22–25) and older (≥70) groups are less represented, at 2.2% and 0.8%, respectively. These age patterns reflect career stages: 74.7% are senior (7+ years' experience), while 13.8% are early-career and 11.5% mid-career.

Most respondents are Researchers or Technologists (68.3%), followed by Team Leaders/Supervisors (16.6%) and Directors/Board Members (5.6%). Support roles—assistants (3.4%) and technicians (2.5%)—are less common. Other categories include PhD candidates (1.4%), administrative staff (0.6%), and private-sector professionals (1.5%).

In this highly specialized R&I sector, 70.2% hold a doctoral degree, 23% a master's or equivalent, and 6.8% lower-level qualifications, often in administrative or support roles.

Regarding contract type, 75.6% have permanent positions, 14.9% are on fixed-term contracts, and 1.7% hold temporary agency roles. Another 4.8% are in apprenticeship or training programs, including doctoral research, scholarships, and internships.

Finally, 92.1% are employed in academic or research organizations (including state-controlled agencies). Another 4.8% work in private companies or corporations, and 3.1% are self-employed in academic or industrial sectors.

4.1.2. Organization and Energy sector

The survey also examined the specific energy sectors where respondents work. Findings show a promising shift toward sustainable solutions: 56.2% are in renewables, followed by energy efficiency and demand response (39.6%), hydrogen (28.4%), energy storage (28.9%), transmission/distribution (15.7%), energy policies (19.7%), and nuclear (9.6%).

Meanwhile, fewer respondents focus on fossil fuels: oil and gas (9.8%) and coal (3.7%).

Focusing on RE sector, principal research areas include solar (68%), wind (50.5%), and energy economics, society, and management (46%), with bioenergy and heat pumps (35.5%), geothermal (32.5%), waste (29.5%), and marine energy (18.5%), opening the way to more sustainable scenarios.

From a gender standpoint, consistent with other studies (Baruah & Gaudet, 2022), the renewable energy sector is still male dominated, though women are increasingly focusing on solar (18.8%), wind (11%), energy economics/social/management (11%), bioenergy (9.8%), and energy policy (9.4%).

4.1.3. Care responsibilities

A central challenge for women's careers in R&I is balancing professional commitment with caregiving responsibilities. Many women find themselves managing this dual roles, often postponing motherhood or leaving their careers for childcare (Mendez & Watson, 2024; Thébaud & Taylor, 2021).

Within our sample, 57.5% reported caregiving responsibilities, while 42.7% had none. Reasons for having no caregiving duties may range from not having children to receiving support from partners or relatives, although the survey did not delve into these details. Future research should delve into this aspect.

Gender-based distribution of care appears relatively balanced, likely due to flexibility in R&I. Men (30.5%) and women (29.4%) care for children aged 7–17, and 18.5% of men vs. 18% of women care for children under 6. However, men (7%) more often care for disabled relatives than women (3%), while women (14.7%) more often care for the elderly than men (11%).

Particularly concerning is the fact that 40% of women have no care responsibilities, possibly reflecting the "spectre of motherhood," where the prospect of

motherhood is seen as incompatible with career advancement (Thébaud & Taylor, 2021). This phenomenon is especially pronounced in R&I, where professional stabilization coincides with peak reproductive years (Ecklund & Lincoln, 2016), so cultural beliefs penalizing motherhood likely influence women's career aspirations and life choices (Thébaud & Taylor, 2021).

4.2. Cluster analysis

As outlined in the methodology section, EFA and CFA were conducted to distil information into principal explanatory factors derived from the linear combination of scale items. This approach effectively captures key trends with minimal information loss and provides a robust basis for CA to identify groups of respondents with similar traits.

The next subsections present the results of the CAs performed on the various identified factors: Work-related Quality of Life (WQRoL_F1, WQRoL_F2, WQRoL_F3); Perceived Subtle Gender Bias Index (Discrimination_F1, Discrimination_F2, Discrimination_F3, Discrimination_F4); Perspective for Just Energy Transition Knowledge Production (Policy_F1); and Workplace Diversity Climate (Organization_F1).

4.2.1. Work-Related Quality of Life (WRQoL) Clusters

Cluster Analysis (CA) for WQRoL_F1—Empowerment and Goal Clarity—yielded three groups (Table 3), each reflecting different levels of dissatisfaction with clarity of objectives, the opportunity to fully utilize one's abilities, freedom of expression, and influence on decision-making processes.

Cluster 1 (-1.955) and Cluster 3 (-0.196) exhibited higher levels of disagreement with the factor WQroL_F1, while Cluster 2 reported positive evaluations.

Socio-demographic data reveal a larger share of women in Clusters 1 (50%) and

3 (43%) than in Cluster 2 (39%), indicating that women often face greater obstacles in workplaces that undervalue their contributions and limit their capacity to voice opinions.

Only 40% of Cluster 1 participants work in renewables, suggesting that traditional energy research areas may uphold conservative practices that undervalue individual skills and constrain professional expression.

Table 3. Average Characteristics by Cluster – WQRoL_F1 – Empowerment & Goal Clarity.

Empowerment and Goal Clarity in the Workplace identified		**Demographic**		**Care responsibility**				**Energy sector**
Cluster	*WRQoL_F1*	*Gender_F*	*Age*	*Child < 6*	*Child 7_17*	*Elderly*	*None*	*Renewable*
1	-1.955	0.50	46.1	0.11	0.24	0.11	0.55	0.40
2	0.752	0.39	47.4	0.19	0.28	0.12	0.43	0.58
3	-0.196	0.43	46.5	0.19	0.32	0.13	0.40	0.59

WQRoL_F2—Workplace Support and Professional Development— assess key aspects of workplace climate (Table 4), evaluating recognition, skill enhancement, employer support, decision-making involvement, and career growth satisfaction. A supportive environment is crucial for employee well-being and strengthens R&I performance.

While Clusters 2 and 3 report some workplace satisfaction, Cluster 1 shows negative scores, indicating a less inclusive climate. Here, gender differences are less pronounced, whereas contract type and the energy sector play a bigger role.

Examining Clusters 1 and 2, which display differences in satisfaction with WQRoL_F2, provides key insights. Cluster 1 has 50% women (average age 48), 84% on permanent contracts, and half in renewables. Meanwhile, Cluster 2 includes 41% women (average age 45), 78% on permanent contracts, 13% on fixed-term, and over 60% in renewables.

Two insights emerge. First, renewables often foster an inclusive and stimulating environment. Second, younger workforce compositions—even with precarious contracts—tend to promote inclusivity, engagement, and innovation, enhancing job satisfaction and adaptability.

Table 4. Average characteristics by cluster WRQoL_F2 - Workplace Support & Professional Opportunities

Workplace Support and Professional Development Opportunities		***Demographic***		***Employment contract***		***Energy sector***
Cluster	*WRQoL_F2*	*Gender_F*	*Age*	*Fixed term contract*	*Permantent contract*	*Renewable*
1	-1.269	0.50	47.8	0.11	0.84	0.51
2	0.998	0.41	45.2	0.13	0.78	0.62
3	0.042	0.39	47.3	0.19	0.75	0.55

WRQoL_F3—Work-Life Balance and Flexibility—reflects employers' accommodation of caregiving needs and overall work-life balance (Table 5). A supportive approach fosters healthier, more inclusive workplaces. However, the R&I sector often provides limited flexibility, resulting in long working hours.

Cluster 1, where flexibility is present, has 34% women, an average age of 46, and 52% working in renewables. These workplaces also report higher caregiving for children under six (20%), children aged 7–17 (27%), and elderly relatives (12%).

By contrast, Clusters 2 and 3, which perceive less flexibility, have higher shares of women (39% and 49%) and greater caregiving for children aged 7–17 (24% and 33%). They also feature a larger share of respondents without caregiving duties (51% in Cluster 2, 43% in Cluster 3), possibly indicating reliance on external support or a smaller pool of caregivers in these workplaces.

Table 5. Average characteristics by cluster WRQoL_F3 - Work-Life balance & Flexibility

Work-Life balance and Flexibility		***Demographic***		***Care responsibility***				***Energy sector***
Cluster	*WRQoL_F3*	*Gender_F*	*Age*	*Child_6<*	*Child 7_17*	*Elderly*	*None*	*Renewable*
1	0.772	0.34	46.2	0.20	0.27	0.12	0.40	0.52
2	-2.003	0.39	46.2	0.12	0.24	0.06	0.52	0.55
3	-0.258	0.49	47.5	0.17	0.33	0.15	0.43	0.60

4.2.2. Perceived Subtle Gender Bias Index (PSGBI) Clusters

Discrimination_F1—Perceptions of Gender-Based Inequality—evaluates workplace gender bias, including differential treatment, lack of recognition, and insufficient support for women-specific challenges (Table 6). It captures both overt and covert inequalities in interactions and decision-making.

Cluster 2 registers positive scores (1.207), indicating acknowledgment of discrimination, whereas Clusters 1 and 3 have negative scores, denying such practices. Renewables are prominent in Clusters 1 (61%) and 3 (55%), suggesting more inclusive environments with lower perceptions of gender bias.

Socio-demographics reveal Cluster 2 has the highest percentage of women (77%) compared to Cluster 3 (33%) and Cluster 1 (21%), indicating stronger awareness of discrimination. Cluster 2 also shows greater job insecurity (17% fixed-term) and fewer researchers (59%) than Clusters 1 and 3. Even with more women in management/supervisory roles (23%), gender bias persists, suggesting leadership positions do not prevent discrimination.

Table 6. Average characteristics by cluster Discrimination_F1 - Perceptions of Gender-Based Inequality

Perceptions of				

Gender-Based Inequality		***Demographic***		***Employment contract***	***Research profile***		***Energy sector***
Cluster	*Discrimination_F1*	*Gender_F*	*Age*	*Fixed term contract*	*Researcher/ Technologist*	Team Manager, *Supervisor*	*Renewable*
1	-1.150	0.21	45.2	0.16	0.75	0.11	0.61
2	1.207	0.77	45.5	0.17	0.59	0.23	0.54
3	-0.096	0.33	48.3	0.14	0.70	0.16	0.55

Discrimination_F2 – Perceived Workplace Support and Collegiality factor (Table 7) explores workplace relationships, including ideas exchange, received support, and sense of value. Clusters responses vary from very positive (cluster 3: 0.594), neutral (cluster 1: 0.007), to negative (cluster 2: -0.727).

Cluster 2 shows little proactivity, minimal support, and fewer exchange opportunities. Women form 55% of this group, with an average age of 47, primarily researchers (75%) and lower renewable-sector participation (42%). These findings point to systemic barriers and persistent gender disparities in accessing more collaborative work environments.

Cluster 3 indicates a collaborative environment, with 40% women, an average age of 44, roles spanning research assistants (3%), researchers (62%), and team managers/supervisors (15%).

This cluster suggests that workplace diversity and the renewable sector's relatively inclusive culture foster collaboration. However, the underrepresentation of women in renewables aligns with prior research, indicating that, despite expanding opportunities, scientific and leadership roles remain male-dominated (García-Baños et al., 2023).

Table 7. Average characteristics by cluster Discrimination_F2 - Perceived Workplace Support and Collegiality

Perceived Workplace Support	***Demographic***	***Employment contract***	***Research profile***	***Energy sector***

and collegiality										
Cluster	*Discrimination_F2*	*Gender F*	*Age*	*Fixed term*	*Permanent*	*Director / Board mem.*	*Research assistant*	*Researc./ Technolog.*	*Team Man/ Super.*	*Renew.*
1	0.007	0.37	47.8	0.16	0.80	0.05	0.04	0.69	0.19	0.57
2	-0.727	0.55	47.3	0.15	0.79	0.05	0.01	0.75	0.13	0.42
3	0.594	0.40	44.3	0.14	0.74	0.08	0.03	0.62	0.15	0.66

Discrimination_F3—Mentorship and Professional Guidance—assesses formal and informal mentoring, especially vital for entry-level and less structured R&I careers (Table 8). Clusters display varied dynamics.

Clusters 2 and 3 largely provide neutral or negative scores, reflecting senior profiles (average age 48, 80% permanent contracts, ~70% in research, and a small director share). For these well-established individuals, mentoring seems less relevant.

By contrast, Cluster 1 reports higher mentoring support. Its average age is 42, with 70% on permanent contracts and 17% on fixed term. Roles are 65% researchers and 20% team managers/supervisors, who often need mentoring for career progression. Notably, 63% work in renewables—the highest share—which appears to value mentoring. Gender differences are minimal, emphasizing professional and sectoral factors in mentorship.

Table 8. Average characteristics by cluster Discrimination_F3 - Mentorship and Professional Guidance.

Mentorship and Professional Guidance		***Demographic***		***Employment contract***		***Research profile***				***Energy sector***
Cluster	*Discrimination F 3*	*Gender F*	*Age*	*Fixed term*	*Permanent*	*Direc/ Board mem.*	*Research assistant*	*Researc./ Technol.*	*Team Man., Super*	*Renew.*
1	0.805	0.40	42.5	0.17	0.70	0.03	0.04	0.65	0.20	0.63
2	0.016	0.43	48.6	0.14	0.81	0.08	0.04	0.69	0.12	0.53
3	-0.691	0.42	48	0.15	0.80	0.05	0.02	0.70	0.20	0.54

Discrimination_F3—Support and Work-Life Balance—evaluates institutions' support for women's vocational needs and caregiving responsibilities (Table 9). Scores vary notably across clusters: Cluster 1 (-0.091), Cluster 2 (-1.159), and Cluster 3 (0.0736).

Clusters 1 and 2 reported poor satisfaction with support and work-life balance. Women represent 42% and 65% respectively, compared to 29% in Cluster 3. In cluster 2, where 60% are researchers and 22% are team managers, the lack of institutional support is particularly pronounced for caregiving, especially for young children (26%) and elderly relatives (14%). Cluster 1 shows similar trends, with 30% caring for children and 16% for elderly relatives. These findings highlight inadequate institutional measures to address work-life balance, especially for women with caregiving roles.

This situation underscores the significant challenges R&I workers face in balancing research demands and family responsibilities. The absence of support disproportionately affects women's career progression and work-life harmony. As studies indicate, work-life balance measures are crucial for women's career development in research and for enhancing their wider participation in R&I (Sánchez-López et al., 2023).

Cluster 3 positively perceived support and work-life. It should be noted that women constitute only 29%, managerial roles remain limited (16%), and 61% work in the RE. Care responsibilities primarily involve children (22% under 6 years and 30% aged 7-17).

This result should be considered with caution. The positive evaluations may reflect the favorable environment of the renewable sector and reduced pressure associated with managerial roles, but they may also hide the limited integration of gender perspectives, potentially due to the underrepresentation of women in this cluster.

Table 9. Average characteristics by cluster Discrimination_F4 - Support & Work-Life Balance.

Support and Work-Life Balance		Demographic		Employment contract		Research profile		Care responsibility				Energy sector
Cluster	*Discrimination_F4*	*Gender F*	*Age*	*Fixed term*	*Permanent*	*Research./Techn.*	*Team Man., Superv.*	*Child < 6*	*Child 7-17*	*Elderly*	*No*	*Renew*
1	-0.091	0.42	47.9	0.17	0.78	0.71	0.14	0.16	0.30	0.16	0.46	0.55
2	-1.159	0.65	46.1	0.15	0.75	0.61	0.23	0.14	0.27	0.14	0.45	0.51
3	0.736	0.29	45.9	0.14	0.79	0.70	0.16	0.22	0.30	0.08	0.37	0.61

4.2.3. Perspective for just energy transition knowledge production (PJETKP) Cluster

Clusters associated with Policy Advocacy for Inclusivity in the Energy Sector reveal a clear gender-based division in perspectives (Table 10).

In Cluster 3, with the highest agreement on inclusivity policies (0.55), women comprise 66% of respondents and are younger (average age 45). This group mostly includes researchers and technologists (66%), plus more managers and supervisors (18%). Employment conditions vary, with fewer permanent and slightly more fixed-term contracts. Additionally, they report significant caregiving responsibilities, especially for children and elderly relatives. These factors likely drive strong support for inclusive policies, as they directly face structural barriers hindering equal opportunities. Their positive stance reflects recognition of gendered workplace challenges and a demand for systemic change.

In contrast, Cluster 2 opposes inclusivity (-1.88). Women form just 12% of this group, dominated by senior leaders, including directors and board members (11%). Most hold permanent contracts (80%); 67% have no caregiving responsibilities. Professional stability and seniority may shape their view that inclusive measures are unnecessary. Furthermore, this reluctance may reflect a belief that meritocratic principles alone suffice for advancement, ignoring others' structural barriers.

Notably, 54% of Cluster 3 respondents work in the renewable energy sector, widely seen as progressive. Their strong advocacy suggests the sector, despite its advancements, falls short of full inclusivity. This gap underscores the need for targeted interventions to ensure equitable workplace policies.

Table 10. Average characteristics by cluster Policy_F1 - Policy Advocacy for Inclusivity in the Energy Sector.

Policy Advocacy for Inclusivity in the Energy Sector		**Demographic**		**Employment contract**		**Research profile**				**Care responsiblity**				**Energy sector**
Cluster	*Policy_F1*	*Gender_F*	*Age*	*Fixed term*	*Permanent*	*Director / Board member*	*Research assistant*	*Researcher/ Technologist*	*Team Man./ Supervisor*	*Child < 6*	*Child 7_17*	*Elder*	*No*	*Renew,*
1	-0.319	0.27	47.7	0.14	0.78	0.05	0.03	0.70	0.17	0.23	0.29	0.10	0.37	0.59
2	-1.882	0.12	50.5	0.11	0.78	0.11	0.06	0.67	0.06	0.06	0.28	0.11	0.67	0.44
3	0.554	0.66	45.2	0.16	0.73	0.06	0.04	0.66	0.18	0.14	0.30	0.15	0.46	0.54

4.2.4. Workplace Diversity Climate (WDC) Cluster

Commitment to Diversity and Inclusion (Table 11), defined as workforce diversity and inclusivity, received negative ratings in Cluster 2 (-1.513). Notably, 60% of respondents here are women who perceived limited inclusivity for diverse backgrounds. Considering care responsibilities, this suggests discriminatory practices disproportionately affecting women. In this cluster, 46% have no family care responsibilities, while 15% care for children under six, and 30% for children aged 7–17.

Cluster 2 has a slightly higher proportion of fixed-term contracts (16%) and a lower proportion of permanent contracts (76%) than Clusters 1 and 3. This suggests weak diversity management may undermine inclusion and limit career advancement, especially for women and underrepresented groups.

In contrast, Cluster 3 reports positive ratings, though women comprise only 31% of respondents. Sector influence appears significant, with 60% working in renewable

energy, which promotes inclusivity through fair hiring and cultural diversity. However, low female representation suggests that while inclusivity is improving, gender-specific challenges remain insufficiently addressed.

Table 11. Average characteristics by cluster Organization_F1 - Commitment to Diversity and Inclusion.

Commitment to Diversity and Inclusion		**Demographic**		**Employment contract**		**Research profile**		**Care responsiblity**			**Energy sector**
Cluster	*Organization_F1*	*Gender F*	*Age*	*Fixed term*	*Permanent*	*Researc. /Techn.*	*Team Man., Superv*	*Child < 6*	*Child 7-17*	*No*	*Renew.*
1	0.027	0.41	47.5	0.15	0.78	0.70	0.15	0.18	0.28	0.44	0.58
2	-1.513	0.60	46.1	0.16	0.77	0.64	0.17	0.15	0.31	0.46	0.46
3	1.066	0.31	45.4	0.15	0.78	0.66	0.20	0.21	0.33	0.37	0.58

5. Discussion and conclusions

The analysis of the Research and Innovation (R&I) workforce survey provides key insights into gender dynamics in the energy research sector, with notable implications for policymakers seeking to increase women's participation in the energy transition. It also guides public and private research organizations toward a more inclusive environment. Results reveal that R&I experiences are shaped by gender, contractual conditions, and sector affiliations.

Across WRQoL dimensions, women report structural barriers in traditional energy research environments, including fewer opportunities to apply their skills, influence decisions, or clarify working objectives. This aligns with longstanding concerns that male-dominated contexts undervalue women's contributions and reinforce stereotypes (Etzkowitz et al., 2000; Moss-Racusin et al., 2012).

By contrast, renewables research, often linked to younger and more dynamic workplaces, appears more open to inclusivity and career advancement. However, it also has more precarious contracts, complicating long-term stability for women. This finding aligns with research on women's greater job insecurity in R&I (O'Keefe & Courtois, 2019; Sim & Bierema, 2025), which hinders professional advancement, recognition, and workplace respect (Palomba & Menniti 2001; Blackwell & Glover 2008). Furthermore, women exhibit a heightened awareness of gender inequalities, emphasizing how gender, job insecurity, professional roles, and overt or covert discrimination interconnect. This echoes evidence showing women are likelier to recognize and report workplace gender discrimination, especially in male-dominated fields (Parker, 2018).

A recurring theme in gender studies is mentorship's role in advancing women's careers in R&I (Kiopa et al., 2009). Mentorship and guidance are crucial for women's advancement, confidence in research paths, and building professional networks (Shen et al., 2022). Our analysis shows that those receiving formal or informal mentorship are usually earlier in their careers, on fixed-term contracts, or in transitional leadership, indicating a need for structured support amid uncertain trajectories. Notably, respondents' gender did not correlate with receiving formal or informal mentorship, suggesting that the gender gap in mentorship access may have narrowed. However, this finding should be interpreted with caution, as our sample is largely composed of senior researchers. Additionally, the RE sector provides higher mentorship support than other energy fields. Future studies should focus on early-stage researchers in the RE sector, going beyond the assessment of gender-differentiated access to mentoring, and examining the relational dynamics within mentoring activities, whether they foster positive change or reinforce discrimination against women.

Another pivotal factor is the interplay between caregiving responsibilities, work-life balance and perceived workplace support. The results highlight how women tend to be less satisfied than men with institutional support and work-life balance. It is interesting to note that the cluster of respondents who are more satisfied is composed predominantly by men (about 71%), and respondents who declare higher care responsibilities toward children, compared to the other clusters. This could be explained by previous studies' findings that highlight how male researchers are less engaged in family and caring activities than female ones (Misra, Lundquist and Templer, 2012; Rosa, 2022). Being less engaged in family and caring activities, men tend to spend less time thinking about work-life balance issues (Bonache et al., 2022) and this could lead men to misperceive the level of institutional support and work-life balance provided by their employer. This aspect will need a closer examination since broader evidence show that, when work-life policies are absent or tenuous, women disproportionately bear the cost, either reducing their working hours or sacrificing career progression (European Commission, 2021). Yet the data also point to nuanced differences between younger renewables-focused environments and more conventional energy sectors. Renewables' researchers report higher levels of support and work-life balance than other energy related research fields, possibly reflecting the values of an emergent research sector that embraces new modes of work.

Perceptions of gender bias vary by rank and workplace composition. Women in precarious contracts or managerial roles often sense stronger biases. Research suggests senior women face heightened bias, and female managers receive more negative evaluations (Lyness and Heilman, 2006). Thus, as women advance, they may encounter intensified biases. In contrast, men and less senior staff often do not perceive bias,

possibly due to limited exposure or norm benefits. This aligns with findings that men tend to perceive greater gender equality (García-González et al., 2019).

The analysis provides insights into how demographic characteristics shape attitudes toward inclusive policy advocacy in R&I organizations. Younger employees and women generally support policies fostering inclusion, while men and senior researchers on permanent contracts often oppose them. Job security may thus influence openness to systemic changes.

Observed disparities in organizational diversity management perceptions between men and women reflect prior research on workplace inclusivity. Studies show women often perceive less inclusive work environments (Pinho and Colston, 2024). Cluster compositions reinforce this: those viewing their workplace as inclusive are mostly men in permanent managerial roles, suggesting secure and authoritative positions foster positive diversity perceptions. Conversely, the cluster seeing less inclusivity consists mainly of women, with more fixed-term contracts and fewer supervisory roles. Notably, renewable energy researchers report more inclusive management.

Across the cluster analysis, the renewable energy research sector appears more inclusive and equality-oriented than other fields, offering better work-life balance. Indeed, IRENA (2019) notes women comprise 32% of renewables' workforce versus 22% in oil and gas, which aligns with our data showing a higher share of women in renewable research. Literature indicates employees perceive their workplaces more positively when they are more gender diverse (Islam, Alam and Penalba, 2024). Therefore, future studies should explore whether renewable research has inherent features that foster this positive perception, or if it simply reflects greater gender diversity compared to traditional sectors.

This study acknowledges certain methodological limitations that offer insights for future R&I workforce research. The survey, distributed across public and private research

institutions worldwide, struggled to engage private companies, underrepresenting their perspective. Given their crucial role in energy research, future work should find strategies to ensure a more balanced representation to capture gender dynamics comprehensively. Beyond academic goals, the survey served as a reflective tool for organizations to foster inclusive, gender-sensitive, and collaborative environments. While some stakeholders utilized it, others did not fully leverage its potential for assessment and improvement. Future studies might adopt tailored communication to highlight the dual benefits of participation: contributing to broader research and gaining actionable internal insights. Additionally, despite comprehensive stakeholder mapping, reliance on snowball sampling limited sample diversity, reducing internal variability. Still, the data provided meaningful perspectives on gender dynamics in energy research. Future efforts could aim for greater sample diversity to strengthen data robustness and allow more nuanced, generalizable analyses.

This study highlights both strengths and challenges in the R&I sector for energy systems. The findings emphasize the renewable energy sector's potential to foster inclusivity and equity through fair hiring, diversity promotion, and mentorship. However, despite its dynamism and innovation, gender barriers persist. Work environments often prove hostile to women, fueling insecurity beyond contractual precariousness, including inadequate recognition, respect, and gender discrimination.

Specifically, our sample reveals a persistent gender gap, driven by women's under-representation in both the broader sector and leadership, alongside inadequate diversity management. These challenges intensify when care responsibilities disproportionately burden women.

Addressing these unresolved issues will require a comprehensive approach, including institutional reforms, targeted mentorship, and proactive diversity policies.

Achieving gender equity in R&I related to energy systems is a strategic priority, essential not only for leveraging the full spectrum of talent and expertise but also for integrating diverse perspectives into energy research agendas. This would ensure that the energy transition is not only technologically innovative but also socially equitable and just.

Declaration of interest

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Involvement of human participants

The authors confirm the data collection received an ethic approval by the Commission for Research Ethics and Integrity of the Italian National Research council (Protocol 122584/2024). They also confirm that all the subjects involved have provided appropriate informed consent. In particular, informed consent forms has been signed and stored properly before starting the survey.

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