

Bridging the gender gap in the energy transition: addressing unmet aspirations and repellent effect in education and career pathways in Italy, Germany and UK

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Abstract

The global energy transition demands not only technological innovation but also systemic change in education and research cultures. Drawing on qualitative data from focus groups conducted with university students and faculty from various STEM and non-STEM disciplines in Italy, Germany, and the United Kingdom, this study reveals how gender gaps persist in energy-related higher education. These gaps are shaped by various dynamics, categorized and discussed in this paper in terms of unmet aspirations and repelling effects. The first refers to the failure to meet students' expectations regarding the resolution of issues related to the socio-technical changes of the energy transition, as well as gender blindness in teaching content. The second dynamic refers to practices linked to persistent cultural norms and gender stereotypes that effectively generate barriers, especially to the detriment of women. We argue that bridging these gaps requires rethinking curricula, pedagogy, and underlying epistemology, as well as workplace cultures, to foster equitable and socially engaged pathways for the next generation of energy transition researchers and innovators.

Introduction

The energy transition can be understood as a complex multidimensional process, revealing the intrinsic interconnections between societal, economic, political and technological spheres that mutually reinforce each other. The interdisciplinary and systemic nature of the challenges it addresses necessitates solutions that are, in turn, both interdisciplinary and systemic (Eu Commission, 2021; Steg et al. 2021; Foulds et al. 2022). In recent years, although the role of energy-related social sciences and humanities (energy-SSH) in energy transitions has gained greater recognition, significant challenges remain especially in integrating these fields into STEM disciplines (Krupnik et al, 2022 and Foulds & Robison, 2018). This has significant implications for knowledge production, higher education and the power relations shaping research agendas among subjects driving the energy transition.

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The emerging configuration in the production of knowledge and higher education on sustainability and energy transitions, rather than bridging scientific and disciplinary silos, risks reproducing mechanisms of exclusion and devaluation of certain categories of knowledge and expertise – a pattern deeply embedded in modern positivist science. This concern leads to the core of feminist literature on science. Feminist epistemologies have highlighted the historical and social constructs underlying scientific postulates and objectives (Keller 1985; Harding, 1986). A relevant construct for this work is the polarization of knowledge according to gendered binary schemes, with the masculine pole being associated with valued, precise, and relevant knowledge, methodologies, themes, and competencies; while the feminine pole is conversely associated with devalued, secondary, and inconsequential counterparts (Schiebinger 2000; Allegrini, 2015). This binary framework produces fragmented, sectorialized knowledge that proves insufficient to adequately address the underlying systemic complexity of global energy systems.

In this paper, we explore how the reproduction of this binary framework in higher education programs aimed at training future professionals in energy transition research and innovation creates a dual gendered form of exclusion.

On the one hand, it results in individuals (predominantly women) who do not conform to the above mentioned masculine pole due to a combination of socialization, societal norms, individual interests, personal inclinations as well as structural barriers being less attracted to traditional STEM pathways and are instead drawn to programs offering interdisciplinary training aimed at solving concrete socio-environmental problems (communal goals). On the other hand, it fosters biases, misogynistic attitudes, and microaggressions that function as barriers to entry, retention, and career advancement in fields directly related to the energy transition, particularly for women.

Several studies have addressed disciplinary segregation by sex and the role of gender stereotypes both on women's educational choices and on their retention within STEM career paths (Buquet Corleto, 2011; McKinnon & O'Connell, 2020; Dunlap & Barth 2023; Miller et al., 2024; McGuire et al., 2022; Shenouda, Patel, and Danovitch, 2024). Miller et al. (2024) showed that by age six, children already hold strong stereotypes favoring boys in computer science, engineering, and physics while demonstrating only mild male bias in general math and concurrently robust pro-female verbal stereotypes—a pattern that intensifies with age. McGuire et al. (2022) found that children and adolescents believe boys to be more skilled than girls in engineering and technology—but not in science or mathematics—and that these domain-specific biases predict a greater likelihood of selecting male peers for help on science questions. Shenouda, Patel, and Danovitch (2024) showed that children aged 5–9 judge men as more competent than women across both STEM and non-STEM fields - whereas girls only favor women in non-STEM - while perceiving girls as less capable learners of STEM subjects despite no link between these beliefs and their own subject preferences or career aspirations. Collectively, these findings underscore how early emerging, domain-specific stereotypes and

structural barriers converge to influence competence judgments, participation, and retention in STEM contexts.

The literature has focused on gender dynamics in engineering (Phipps, 2002; Ihlen 2005; Faulkner, 2009, Buquet & Moreno, 2021; Pascual et al. 2021). For at least two decades, the approach of Gender Studies in Engineering has had the goal of integrating more women into engineering and implementing changes in the male-dominated engineering culture, among others (Ihlen, 2005). Recently, the literature has been developing the theme of how to integrate the gender dimension within the curricula on energy access and energy transition (Pailman & de Groot, 2022). To the best of our knowledge, no studies have analyzed gender disparities in energy transition education and career development through this lens—combining STEM experiences with social sciences and interdisciplinary trajectories. With this paper, we aim to contribute to the literature by offering an analysis that engages with the complexity of the phenomenon, moving beyond the quantitative focus on gender gap in the energy transition education (e.g., increasing the number of women in STEM). Instead, we propose a qualitative approach that critically examines the binarism and biases that make energy transition education unattractive, exclusionary, and unwelcoming in both educational and professional contexts. The empirical research is based on focus group interviews (FGIs) conducted as part of the *gEneSys – Transforming Gender Interrelations of Power and Inequalities in Transition Pathways to Sustainable Energy Systems* project in Germany, Italy, and the United Kingdom (UK) during 2024 and 2025.

The paper is organized as follows: i) looking at the relevant literature and feminist theories on educational choices and academic cultures, we propose an original lens of analyses on structural and systemic inequalities in energy-related educational; ii) we describe the methodological steps for the collection of qualitative data collected in the focus groups organized in Italy, Germany, and the UK; iii) we discuss the main results highlighting the persistent gender inequalities in education and professional pathways. We conclude with a call for a fundamental rethinking of curricula, pedagogy, and institutional cultures to foster a more inclusive, socially engaged, and gender-just energy sector.

Beyond Numbers: Feminist Theories on Educational Choices and Academic Cultures

In our critical analysis of structural and systemic inequalities in energy-related educational contexts, we draw upon theoretical frameworks that will inform the interpretation of our findings. We focus on the factors influencing educational choices in tertiary education, genderizing teaching and on the organizational climate in academic and workplace.

Factors influencing tertiary educational choices

The issue of women's quantitative access to science has traditionally been defined as "woman question in science" (Harding, 1986). However, today's primary concern is not merely the

numerical presence of women in STEM but their unequal distribution across scientific fields (Allegrini, 2015). Indeed, a significant gender heterogeneity persists, with women being overrepresented in life and health sciences while remaining underrepresented in disciplines such as physics, mathematics, computer science, and engineering. The *She Figure* report, the main gender analysis on the EU R&I system, highlighted that women in Information and Communication Technologies (ICT) represent only 22% of doctoral graduates, while in Engineering, Manufacturing, and Construction women account for less than 40% of doctoral graduates. On the opposite, in sectors such as Health and Welfare, women are well represented, making up 59% of doctoral graduates. The same report highlights the persistent "leaky pipeline" effect that although women account for nearly half of early-career researchers (48%), they make up only 36% of senior-level researchers. This shows that not only are women underrepresented in certain disciplines, but their numbers also decline as they progress in academia and research (EU Commission 2025)

This gender imbalance reproduces a hierarchical order between male-dominated and female-dominated disciplines. Feminist perspectives have challenged the notion of science as neutral ("malestream"), arguing that it is deeply influenced by cultural values, social constructs, and power dynamics (Allegrini, 2015). Gender affects knowledge production at multiple levels, including scientific theories, research methodologies, scientific language, and academic institutions. From this perspective, the feminist question in science goes beyond the goal of increasing women's representation in STEM, aiming to overcome the gender biases embedded within the scientific system and to propose theoretical and practical alternatives to dismantle the polarization between masculine and feminine sciences.

One of the concepts developed by feminist theory that has been applied to explain gender differentiation in both educational choices and professional paths related to engineering is *doing gender* (West & Zimmerman, 1987). *Doing gender* is a complex set of prescribed and socially guided practices that allows individuals to conform to social expectations regarding masculinity and femininity (Buquet & Moreno, 2021). These reflections align with gender identity theories, which conceptualize gender not as a fixed essence but as a cultural and performative construct (Holmegaard et al., 2015). Identity plays a central role in educational and career choices, shaping perceptions of which disciplines are socially acceptable for men and women. The gendered representations of science –historically linked to the idea that rationality and objectivity are male attributes (Keller, 1985) – further reinforce this divide.

Allegrini (2015) proposes a dual strategy to achieve greater gender balance in science. On the one hand, efforts should not only focus on increasing women's participation in STEM but also on encouraging men's participation in feminized sciences. On the other hand, addressing the gender-science nexus requires approaches rooted in diversity and plural knowledge systems, which can contribute to a systematic rethinking of the nature of knowledge and science. Rather than solely striving for equality in science, such approaches acknowledge and incorporate diverse epistemologies and ways of knowing.

Educational choices in STEM fields are influenced by implicit and unconscious biases, often perpetuated by teachers, family members, and employers. These biases reinforce gender barriers, shaping individuals' orientation toward educational and professional pathways (Dunlap & Barth, 2023; Hayes et al., 2018; García-Holgado et al., 2018; Masters & Barth, 2022). Gender stereotypes manifest both as implicit beliefs, ingrained from early childhood, and as explicit beliefs, shaped by more recent experiences (Dunlap & Barth, 2023). Dunlap and Barth highlighted the implicit associations between gender and STEM careers and their impact on university choices. Furthermore, they demonstrated that early support for STEM interests and exposure to specific activities can influence these implicit associations as well as the educational choices.

The "goal congruity perspective" in tertiary education

The "goal congruity perspective" suggests that STEM careers are often perceived as less likely to fulfil communal goals (e.g., working with or helping others, making a positive societal impact) compared to careers in other fields (Boucher et al., 2017; Dunlap & Barth 2019; Dunlap & Barth, 2023). Such perceptions may disproportionately influence women's career choices, as women due to socialization tend to place more value on communal goals than men (Diekmann et al., 2010; Diekmann et al. 2011; Diekmann et al. 2017). Kilgore et al. (2006) have investigated this issue by examining how male and female students perceive engineering studies and practices. They found that women often approach engineering with a broader perspective, valuing collaboration, teamwork, and social impact. In contrast, male students tend to focus more on individual technical challenges and achievements (Kilgore et al., 2006). However, a more recent study shows that being perceived as an uncommunal discipline has a deterrent effect not only on women, but also on communally-oriented men (Boucher et al., 2017).

Our study contributes to this discourse by offering a unique perspective on the energy transition sector within higher education, an area that potentially aligns with communal goals related to sustainability, climate change, and societal challenges.

Engineering, like other STEM disciplines, offers the opportunity not only for technical problem-solving but also for driving meaningful global change. These differing perspectives suggest that traditional engineering education, which often emphasizes isolated problem-solving, may not resonate with many women who are drawn to the field's broader societal contributions. By rethinking engineering education to place greater emphasis on teamwork, interdisciplinary applications, and societal impact, higher education institutions could potentially attract and retain more women in academic and technological research. International agendas and debates on sustainable development have encouraged the creation of a new meta-discipline in sustainability science and engineering (Mihelcic et al., 2003), with the aim of integrating technological progress with a systematic focus on the interconnections between environmental, economic and social dimensions. This reorganization of knowledge

around the principles of sustainability, coupled with the acquisition of technical and soft skills, facilitates the design of more sustainable energy products and systems that are in line with societal values and real needs. It also increases the attractiveness of educational curricula by promoting communal goals (Mihelcic et al., 2003). Given that the gender imbalance in engineering fields can be partly attributed to the poor link between the hard sciences and social concerns, strengthening this link could increase the social relevance of these disciplines and promote more equitable participation, thereby fostering greater women in science.

Another relevant perspective is the deterrent effect identified by Saliklis et al. (2009) regarding the structure of STEM education. Specifically, they highlight how undergraduate engineering curricula often focus on lower levels of Bloom's taxonomy (primarily knowledge acquisition) rather than higher levels, such as synthesis and evaluation. This approach can result in curricula that avoid making value judgments about the social relevance of technologies (Synthesis) or to address complex problems by breaking them down into smaller, more manageable components (Analysis) (Bloom, 1965). This issue may complement the goal congruity perspective and further explain the reduced appeal of certain STEM educational pathways especially for female students.

Genderizing Teaching

The issue of gender gap in STEM fields cannot be reduced to a mere numerical imbalance; it also encompasses teaching methodologies and classroom dynamics. Gender-blind curricula have the potential to exacerbate existing societal disparities by skewing subject matter toward a particular gender, creating unequal opportunities for success, or even reinforcing role stereotypes. Gender-blindness in science education often reflect and reinforce the long-standing belief that science is inherently neutral and meritocratic, evaluated through objective standards alone (Harding, 1991; Longino, 1990). However, this assumption obscures how systemic biases and institutional structures shape who participates in science and whose contributions are recognized. By omitting gendered perspectives and social contexts, such curricula ignore the barriers—both visible and invisible—that disproportionately hinder women and other underrepresented groups (Subramaniam, 2009). The rhetoric of neutrality, rather than levelling the playing field, can act as a mechanism for sustaining existing power hierarchies in scientific institutions (Schiebinger, 1999). As such, challenging the myth of neutrality is essential to reimagining a more inclusive and reflexive scientific practice that acknowledges the sociocultural dimensions of knowledge production (Haraway, 1988). In highly theoretical and technological disciplines, the integration of a gender perspective has traditionally been overlooked based on the assumption that scientific concepts, theories, and methods are inherently neutral (Pascual et al., 2021). Furthermore, just as implicit biases influence students' educational choices, they can also profoundly shape the way professors assess their students (Lavy & Sand, 2015; Pascual et al., 2021).

Organizational climate in academic and workplace

STEM and engineering education has traditionally been a male-dominated sector. One of the key aspects impacting this lack of gender and intersectional diversity has been identified by literature in persistent inequality in the workplace culture. Research overwhelmingly demonstrates the academic climate for women in STEM is chilly (Casad et al., 2019; Cheryan et al., 2009; Gunter & Stambach, 2005; Miner et al., 2019; Riffle et al., 2013; Settles et al., 2006; Willemsen & van Vianen, 2014). Chilly, unwelcoming, and threatening academic environments discourage women from entering the field and predict women leaving academia (Riffle et al., 2013). Women and underrepresented groups faculty in STEM experience greater ostracism and microaggression compared to male faculty in STEM (Miner et al., 2019, Lester et al., 2017, Ong et al., 2018).

Women in STEM often contend with stereotyped perceptions that influence hiring decisions and limit opportunities for career advancement (McKinnon & O'Connell, 2020; Casad et al., 2021). These stereotypes contribute to an unwelcoming academic climate, where female students frequently report experiencing hostility, discrimination, and lack of recognition. Furthermore, female students often face a lack of supportive social networks, which can be crucial for academic and professional success. In professional careers female engineers, for example, often encounter gender-based filtering, devaluation of their skills, and exclusion from key professional networks. This disparity exacerbates gender inequality, limiting the professional growth of women within academia and industry (Casad et al., 2021). Faulkner (2009) has theorized how engineering workplace cultures create both a gender In/Authenticity and the In/Visibility Paradox. Faulkner argues that engineering is culturally coded as a masculine profession, making it difficult for women to be seen as "authentic" engineers. Women often feel pressured to either conform to masculine workplace norms or risk being seen as outsiders. But if they adopt behaviors traditionally associated with femininity, their competence as engineers may be questioned.

Women in engineering also face a contradictory experience of being hyper-visible and invisible at the same time. They are highly visible as women often standing out as one of the few female engineers in a male-dominated environment. This visibility subjects them to extra scrutiny and stereotypes. However, they are also "invisible as engineers"—their contributions may be overlooked, and they may struggle to gain recognition for their technical expertise. These dynamics create barriers to inclusion and career advancement for women in engineering. The in/authenticity dilemma forces women to constantly navigate gender expectations, while the in/visibility paradox makes it harder for them to establish professional authority. Addressing these issues requires structural and cultural changes in engineering workplaces, such as diversifying leadership, challenging gender biases, and fostering more inclusive professional norms.

Methodology

This study qualitatively analyzes the mechanisms of gender-based exclusion in the educational trajectories and professional pathways of men and women in sectors related to the energy transition. To address this objective, the research draws on qualitative data from focus group interviews (FGIs) involving faculty and students, engaged in or preparing for careers in the energy sector.

With a gender lens, the study seeks to uncover the structural, socio-cultural, and individual factors influencing educational and professional pathways within the energy transition sectors. Furthermore, the study explores the extent to which gender-based analysis is embedded into pedagogical and research practices within higher education institutions (HEIs), assessing its role in promoting women's participation and representation in energy-related disciplines.

FGIs were conducted between 2024 and 2025 within the context of the EU funded project *gEneSys* in Germany, Italy, and the United Kingdom (UK). A purposive sampling strategy was adopted to capture a range of perspectives from students, academic staff, and professionals involved in gender equality (e.g., Gender Equality Officers, career service providers).

A total of nine FGIs were conducted (three in each country): three with faculty and non-academic staff, and six with students. Each session lasting 90–120 minutes, was recorded, transcribed, and thematically analyzed. Interviews were coded by country, participant type (lecturer/student), disciplinary field (STEM/SSH/Interdisciplinary), interviewed number, and gender (e.g., LEC/STU_M/B_SS/ST/IN+n+gender).

Recruitment strategies varied across countries and included collaboration with participants from previous projects, professional networks, and snowball sampling. FGI formats with faculty members and professionals varied across countries to maximize accessibility for participants: online in Germany and the UK, hybrid in Italy. Lecturers were drawn from STEM disciplines directly related to energy, as well as social sciences and interdisciplinary programs addressing energy transition and sustainability issues (see Table 1).

Country	Date	Number of participants	Disciplines
Germany	25.09.24	9 participants (4 women, 5 men)	Geotechnology; Traffic and Machine Systems; Energy Systems and Energy Technology; Energy Technology (Energy Industry); Sustainable Mobile Drive Systems; Power Engineering; Energy Technology; Energy Process Engineering

Italy	5.11.24	7 participants (5 men and 2 women)	Department of Astronautical, Electrical and Energy Engineering (DIAEE), Department of Communication and Social Science, Department of Technology, Department of Political and Social Sciences.
United Kingdom	16.01.25	5 participants (3 men, 2 women)	Energy Institute, Centre for Agroecology, Water and Resilience, Faculty of Engineering and Physical Sciences and Faculty, Chemical Engineering Department

Table 1. Sampling for FGIs with faculty members and professionals

Further, two student FGIs were conducted in each country (see Table 2). In Germany and the UK, they occurred in person; in Italy, six of eight students participated in person, two remotely. To accommodate the varying structure of energy-related programs, a flexible approach was adopted in determining whether to include undergraduate (Bachelor's) or postgraduate (Master's) students. German participants were mainly from Bachelor's programs, while UK and Italian participants were from Master's programs. Within each country, students from STEM and SSH backgrounds were selected from the same academic level to ensure consistency.

Country	Date	Number of participants	Study level	Field of study	Program
Germany	15.10.24	17 participants (8 women, 9 men)	Bachelor's program, I year	Inter-disciplinary	Technical communication
	15.10.24	20 participants (11 women, 9 men)	Bachelor's program, I year	Inter-disciplinary	Technical communication
					Strategic management,

Italy	10.12.24	8 participants (5 women, 3 men)	Master's level	SSH	innovation sustainability; social design for sustainability, gender innovation/inclusion
	10.02.25	5 participants (3 women, 2 men) ⁹	Master's level (4), Bachelor's level (1)	STEM	Mechanical Engineering and Green Industrial Engineering for Sustainable Development
United Kingdom	18.11.24	5 participants (3 women, 2 men)	Master's level	STEM	Sustainable Energy Futures
	20.11.24	6 participants (4 women, 2 men)	Master's level	Inter-disciplinary	Interdisciplinary Program Environmental Technology

Table 2. Sampling for FGIs with students

All FGIs followed a common research protocol. Discussions focused on the factors influencing students' educational choices and career aspirations, as well as the barriers and enablers they faced in career progression.

Among faculty members and professionals, the discussions explored the factors influencing women's interest in the energy sector, the organizational culture, and the integration of gender perspectives in teaching and research. Further topics included promising practices, persistent challenges, and policy recommendations to enhance gender diversity in the field.

While the framework remained consistent across all countries, the qualitative design of the study enabled adaptability to national and institutional contexts. This flexibility allowed the emergence of context-specific themes and priorities, ensuring the study captured the diverse challenges and opportunities shaping women's participation in the energy transition.

Results

Drawing on qualitative data from Italy, Germany, and the UK, we identify two key mechanisms that shape educational and professional trajectories: (1) the 'unmet aspiration', stemming from inadequate program design and communication in the educational curriculum; (2) the repelling effect, encompassing cultural stereotypes and institutional biases that effectively discourage, particularly women—but not exclusively—from entering and remaining in the sector.

Across contexts, both STEM and SSH students—particularly women—seek meaningful, interdisciplinary paths aligned with sustainability values, yet structural barriers remain. Curricula often lack integration of gender and social dimensions, and women’s contributions continue to face diminished recognition. These patterns extend into the workplace, where gendered expectations and unequal support structures constrain opportunities and advancement. The sections below explore these dynamics in detail.

Unmet aspiration in higher education pathways related to the energy transition

The first exclusion mechanism—unmet aspiration—consists in the mismatch between the potential of STEM education to contribute to major socio-technical changes, such as the energy transition, and how this potential is communicated and perceived.

Academic content is often framed as isolated technical knowledge, largely decoupled from real-life applications and broader socio-political contexts (Hill et al., 2010; Mei et al., 2023; Mansour, 2025). In general, programs perceived as strictly technical and disciplinary—offering a compartmentalized education lacking elements to understand and address complex problems—tend to be less attractive than interdisciplinary programs and those in the social sciences focusing on sustainability issues. Lectures in Italy brought the example of electrical engineering frequently associated with technical skills, while broader aspects like managing complex electrical systems and strategic planning are often overlooked (IT_LEC_ST2M; IT_LEC_ST3M). Students also raised this issue, stating that engineering—unlike other subjects such as biology—is not perceived as a tool for addressing socio-environmental issues. As a result, this common perception may discourage female high school students, but also male students, interested in sustainability issues from enrolling (IT_LEC_ST4M). Engineering fields are considered by Italian and German lectures more attractive to men due to their association with activities historically associated with a stereotyped masculine identity -e.g. Formula 1, automotive, and space exploration- (IT_LEC_ST2M; IT_LEC_ST4M). In particular, the energy sector is perceived as a male-coded field (GE_STU2_IN3F; UK_STU_ST3W).

One of the discussed reasons for this problem is the lack of effective communication regarding the potential of engineering education in different job fields related to the energy and green transition. According to STEM lectures in Italy, university departments often fail to effectively communicate the scope and potential of their engineering programs, reinforcing reductive and stereotypical perceptions on the discipline. In this vein, STEM students in Italy agree that engineering programs are not always well-publicized, resulting in very few enrollees (IT_STU_ST3W). A different picture emerges from the focus group conducted in UK with students with a STEM background enrolled in the MSc Sustainable Energy Futures, run by the Mechanical Engineering Department at Imperial College. This program, aimed at graduates in engineering or physical sciences, offers a broad, comprehensive, prestigious, and internationally recognized engineering education, thereby also expanding the perceived range of potential applications of the discipline (add references).

Several students with STEM backgrounds of both genders chose the master's program because of their interdisciplinarity, focus on sustainability and broader societal relevance (IT_STU_ST1M; IT_STU_ST2W; IT_STU_ST3W; IT_STU_ST04W; IT_STU_ST5M; UK_STU_ST3W; UK_STU_ST4W; UK_STU_IN1W, UK_STU_ST5M). Some female participants mentioned that they also wanted to play a role in climate change (UK_STU_ST4W UK_FGAS4_W) and help address energy challenges (UK_STU_IN1W UK_FGBS1_W). Energy fields are considered one of the most direct ways to address climate change, resource scarcity, and other global challenges. This aspect is also considered relevant for several male students, such as the exemplary testimonies reported below. *"I have an Engineering background, and I realised that there are so many aspects, while deciding: the policy, the social aspect, the environmental aspect, the legal aspect. This program will teach all the multidisciplinary aspect"* (UK_STU_ST5M). *"I am Interested in energy development [...] I want to learn broader aspects of sustainability, not only technical, [such as] design policy and planning to achieve Net Zero [with a focus on] energy power"* (UK_STU_ST1M).

"I liked the idea of doing something socially useful, something that can really make a difference" (IT_STU_ST2W). One of the female participants from Italy with background in Aerospace Engineering reports her choice to enroll in a master's degree that combine management, governance, and technical aspects related to sustainability and energy. *"I think it's vital to combine ethical motivation with engineering tools. [...] I have an ethical drive linked to sustainability. I feel a duty to listen to that drive"* (IT_STU_ST3W).

A similar tension is detected in the group of students with SSH and interdisciplinary background from Italy, Germany and UK. Some students expressed a preference for interdisciplinary roles that combine their social science background with aspects of sustainability and/or energy issues. They recognize that their expertise in social studies could contribute meaningfully to energy policy discussions and the public understanding of energy-related topics. However, there is a general concern that social studies background may not provide the technical expertise typically required in energy-related roles. This perceived gap in technical knowledge has led to hesitancy in pursuing careers directly within the energy sector, as they may feel underqualified compared to individuals with engineering or other technical degrees (IT_STU_SS5W, GE_STU_IN5W).

Similarly to students, the lecturers from UK, Germany and Italy agree that the desire to do meaningful work contributing to society and having positive impact on the world is a driver in career decision, especially for women. The interdisciplinary and sustainability approach fulfills this desire of purpose and can therefore be considered a key element to reducing the gender gap in energy-related fields. A lecturer from the Institute NOWUM-Energy and the Institute for Data-based Technologies stated that in Germany many women are motivated in their educational choices by this driver (GE_LEC_ST7M). A lecturer at the Energy Institute, University College London also declared that *"often the interdisciplinary courses attract more women"* (UK_LEC_ST2W); whilst an Assistant Professor at the Centre for Agroecology,

Water and Resilience, Coventry University stated that “*once they feel that there is a sustainability aspect, then interest seems to grow*” (UK_LEC_S1M).

Unmet aspiration: the gender blindness in teaching contents

Related to the unmet aspiration mechanism, we found that the integration of the gender approach in the teaching contents can play a role in attracting more students, especially women, in higher education curricula.

According to the literature, educational curricula – particularly within STEM disciplines – tend to incorporate gender perspectives, only to a limited extent. Findings from focus group interviews with lecturers and students across STEM, SSH, and interdisciplinary programs show that gender analysis is absent from energy-related curricula, with engineering courses especially characterized by a narrow focus on technical domains such as mathematics, design, and thermodynamics.

From lecturers’ perspectives in Germany, the United Kingdom, and Italy, the absence of gender stems from the technical nature of the subjects (UK_LEC_ST1M, IT_LEC_ST3M), as well as from deliberate choices made by lecturers to exclude such topics (GE_LEC_ST8M). Some justify the absence of references to gender-related content by asserting that students can interpret the masculine generic form as inclusive of all genders (GE_LEC_ST3M). Even when gender issues are addressed, integration tends to be limited to marginal initiatives, such as promoting networking opportunities for women (GE_LEC_ST4M, GE_LEC_ST7M), informal discussions among faculty members and doctoral students about the underrepresentation of women in the energy sector (IT_LEC_ST4M, IT_LEC_ST3M, IT_LEC_ST5M), or adopting gender-neutral language (GE_LEC_ST6W). These efforts, though limited in scope, are more commonly observed among female lecturers, who demonstrate heightened awareness of their pedagogical responsibilities and a more proactive approach to integrating gender and diversity considerations into their teaching practices (GE_LEC_ST2W; IT_LEC_SS1W).

Students’ responses further affirm the limited integration of social and gender issues into course content and materials (UK_STU_ST3W, IT_STU_SS3W). STEM students criticized the depersonalized transmission of technical knowledge, which remains largely disconnected from its social applications and implications (IT_STU_ST1M). As argued by an engineering student:

"When you talk about technological development, man, woman, humanity is not addressed at all. Engineering is like neutral [...] I mean in content, it is generally absent... but the being human is not really addressed, which is the problem in engineering. Or the human is treated as an object with mass M , at most, or with some other counting category" (IT_STU_ST1M).

When gender analysis is addressed, it is often treated loosely (UK_STU_IN4M), and the use of non-inclusive language persists in teaching (IT_STU_SS6W), reflecting varying levels of

lecturers' awareness, especially men (IT_STU_SS6W, IT_STU_SS5W, IT_STU_SS1W). In some cases, gender issues are narrowly addressed – for instance, by restricting the discussion to domestic energy access, such as cooking (UK_STU_IN6W) - or treated separately within SSH courses, without being fully integrated into an intersectional framework relating to the broader social domains, including the sustainable energy transition (IT_STU_SS3W, IT_STU_SS2W).

Overall, the perspectives of both students and lecturers underscore that the lack of gender-sensitive frameworks and the insufficient contextualization of technical knowledge significantly hampers the capacity of students to critically engage with the broader societal implications within the energy sector. The absence of a gender perspective can also constitute a factor of non-attractiveness, particularly for female students. As shown by a study, in fact, female engineering students have a significantly more positive perception of the integration of a gender perspective into the academic programs of the discipline compared to their male peers (Pascual et al., 2021).

The repelling effect: How disciplines specific attitudes and practices create exclusion

A second exclusion mechanism has been identified as repelling effect, encompassing all attitudes and practices that effectively discourage, particularly women—but not exclusively—from entering and remaining in the sector.

SSH lectures and both SSH and STEM students acknowledge that educational choices are deeply intertwined with the persistent cultural norms that associate specific disciplines/fields with stereotyped gender roles. These norms are shaped by family, social contexts, and broader societal influences (IT_LEC_SS1W; IT_LEC_ST5M; IT_LEC_SS2M). This issue is particularly evident in certain STEM fields (e.g. engineering), where female enrolment is still low. However, these considerations are largely absent among most STEM faculty, who report gender-blind perceptions regarding the imbalances in educational choices made by male and female students. We found a trend among engineering professors, especially in Italy, to deny the existence of gender issue in energy-related curricula, arguing that the underrepresentation of women results from independent decisions unaffected by societal expectations on gender roles (IT_LEC_ST3M). From this perspective, the energy-related engineering field is neutral—“essentially asexual” (IT_LEC_ST4M)—and free from gender bias.

In contrast, the STEM students' experience in Italy reveals a very different picture, where the supposed neutrality of the field is replaced by an environment filled with sexist stereotypes and misogynistic behaviors. Some also reported that women are often perceived as less suited for careers in STEM fields (IT_LEC_ST5M). Misogynistic attitudes of lecturers have also been reported which hinders equal experience of engineering education. IT_STU_ST4W recalled professors making sexist and inappropriate examples on fluid dynamics that implicitly assumed a male audience, such as: “*We had an example in class of crossing a river faster if there's a*

pretty girl waiting on the other side. It just assumed everyone was a man interested in women” (IT_STU_ST4W). From Italian STEM students focus group emerged that sexist attitudes were more frequently attributed to lecturers than to peers (IT_STU_ST2W, IT_STU_ST3W, IT_STU_ST4W).

It should be noted, however, that in some cases, the repelling effect triggers a response that produces the opposite outcome—namely, it increases the motivation of some women to pursue careers in male-dominated fields. In Italy and in the UK, we found that the fact that STEM fields are male-dominated motivated some female students to choose this path to demonstrate that women can succeed in these fields. A female student in Green Industrial Engineering for Sustainable Development master's degree affirms that in her educational choice *“there was some influence related to gender, honestly, because the STEM field often seems like a glass ceiling for women, especially when I had to choose my undergraduate degree a few years ago. So, I liked the idea—having also studied at a science-oriented high school—of entering a field that is traditionally male-dominated. That’s why I was also drawn to STEM subjects”* (IT_STU_ST4W). A female student in the master program Sustainable Energy Future in the UK says she chose this program *“to prove that a woman can contribute [...] to prove the stereotype wrong”* (UK_STU_ST2W).

The strong motivation of female students is also acknowledged by some STEM lecturers; however, it is not perceived in connection with gender disparities. This perception both genderizes and naturalizes the motivation, effectively detaching it from the structural mechanisms that require women to exert greater effort to achieve the same outcomes. Within this view, strong motivation is seen as a self-correcting factor.

As emerged from the various focus groups, the repelling effect does not manifest only at the university level but has its roots much earlier within the socialization process during the childhood, both in the school experience and in the family context. Participants from Italy and Germany highlighted differential treatment of children based on gender at the school level (IT_FGI03_I04) and gender stereotypes influencing peer dynamics, which could lead to bullying or discriminatory practices (IT_STU_ST3W, IT_STU_ST5M). Additionally, there is a tendency to associate STEM subjects with practical skills traditionally deemed more suited to men (IT_STU_ST1M). As expressed by an Italian lecturer, this issue is particularly evident *“in Southern Europe, including Italy, especially in the southern regions, where, until recently, a woman engineer was seen as an alien”* (IT_LEC_ST5M). Traditional mindsets assign women roles more consistent with family care responsibilities (IT_LEC_ST5M), implicitly limiting their professional aspirations.

The repelling effect: how professional practices create careers barriers and exclusion

In the near future, the renewable energy sector may represent a real opportunity to promote greater gender inclusivity than traditional energy sectors, which have historically been male

dominated (Baruah & Gaudet, 2022; Lazoroska et al., 2024). Nevertheless, evidence suggests that despite the increase in female presence in renewable energy sectors, women remain underrepresented, with participation largely concentrated in administrative roles and significantly limited in technical and decision-making roles (IRENA, 2019).

To explore the dynamics underlying the gender imbalance in the energy sector beyond a mere quantitative perspective (Allegrini, 2015), this study examined the enabling and hindering factors that influence women's career trajectories through the involvement of lecturers and students. The latter group were asked to reflect on the opportunities and systemic forms of disadvantage that women may encounter in their career pathways.

Two central themes emerged from the lecturers' reflections. The first concerns the inadequacy of current measures to promote gender equity and achieve real balance in the energy sector. In this regard, the principle of meritocracy was often advocated, particularly in relation to public competitions for access to scientific careers in energy research. With regard to the Italian public sector, it emerged that, in order to avoid discrimination, the constitution does not allow for criteria based on gender—as well as religion or ethnicity—to be used in public competitions. As a result, instruments such as gender quotas cannot be implemented (IT_LEC_ST1W). Instead, as regards the private sector, illegal practices have been reported that disadvantage women in the sector. In some contexts, such as the offshore energy industry, recruiters tend to select only male candidates, who are considered more “employable”: *«if we put forward women to work in the offshore industry, they will be turned down, because they're women... we don't get our fee, if we put forward people who aren't employable, so we would only ever put forward men»* (UK_LECST3M).

The second issue relates to the persistence of both explicit and implicit gender stereotypes. Several lecturers noted that by internalizing social norms and cultural expectations, women themselves often appear more hesitant to take up professional opportunities, contributing to forms of self-exclusion. Some interviewees reported that *women often may be more hesitant to put themselves forward*, (UK_LEC_ST4M), *tend to be quite risk-averse* (UK_LEC_ST5W), and often doubt their abilities and skills, even when proven to be superior to their male counterparts: *«frequently, you have female students who know more than a male student...and yet, they tend to doubt themselves»* (UK_LEC_ST1M). However, more commonly, women face gender-based filters that hinder career progression (Casad et al., 2021). Lecturers shared concrete instances that challenge the legitimacy of women's expertise, such as comments about physical power: *«I need three strong men to lift this»* (GE_LEC_ST9M), or insinuations about gender quotas that devalue individual merit, like it was for a female student worker: *«during a high-level meeting with some new potential clients in my company, my manager introduced me as a 'gender quota.' This calls into question my competence, as if I was only there to satisfy a number, not my abilities»* (IT_STU_ST3W).

An analysis of enabling and hindering factors, conducted among students from all three countries, revealed a cross-cutting issue: limited awareness of career opportunities in the

renewable energy sector, feeding uncertainty in career choices. The lack of clear references to communal goals in career education and guidance pathways contributes to this uncertainty (Boucher et al., 2017), with different effects depending on students' disciplinary backgrounds. Specifically, some students from SSH and interdisciplinary curricula reported a lack of recognition of how their skills can contribute to the energy transition (IT_STU_SS2W; IT_STU_SS5W; IT_STU_SS3W; GE_STU1_IN1W; GE_STU1_IN1M). While many acknowledge the relevance of their skills – especially in critical analysis, communication, and mediation – for shaping energy policy and fostering broader public understanding of energy-related challenges, they nonetheless express a perceived inadequacy compare to the technical-scientific profiles typically associated with the energy sector (GE_STU2_IN1W; GE_STU2_IN6W). The perceived lack of specialized technical expertise – often considered as a prerequisite for entering in the energy job market – contributes to a latent sense of exclusion, which in turn discourages students from actively pursuing roles associated with the energy transition.

In addition, career choices appear to be shaped by gender-differentiated motivations: while male students are often driven by economic goals, female students tend to favor ethical and environmental values, perceiving the renewables sector as more dynamic and inclusive (IT_STU_ST5M, IT_FGI03_I02; UK_FGIBI).

«A boy, when offered the opportunity to work for an oil company where he can earn much more compared to pursuing a socially driven energy transition path, is – in my opinion – more easily convinced than girls, who are generally more focused on social and socio-environmental aspects» (IT_STU_ST5M).

Among the enabling factors, students identified the pivotal role of mentors who can counteract gender stereotypes and support women's careers in male-dominated fields (IT_FGI02_I05), along with leadership skills that enhance individual skills. This requires the promotion of more informed and inclusive decision-making *styles* that are sensitive to gender equity (IT_STU_SS8M; IT_STU_ST4W). Special emphasis is also placed on promoting women's self-determination in professional advancement and economic empowerment (IT_STU_ST3W).

On the other hand, several barriers to women's careers have been identified. First, it is the persistence of stereotypes and misogynistic attitudes among employers. Such attitudes manifest especially during the transition to the labour market, leading to gender pay gap and discriminatory treatment based on looks rather than competence (IT_STU_ST5M, IT_STU_ST4W). Other students pointed out that physically demanding jobs in remote locations are perceived as less accessible or attractive to women, due to both cultural representations (UK_STU_ST3W, UK_STU_ST4W; GE_LEC_ST9M) and concerns about safety in male-dominated workplaces: *«safe work environment... because it is dangerous... it's too many men there»* (UK_STU_IN6W). In addition, lack of access to formal and informal

networks hinders women's participation in decision-making processes and professional development opportunities, while strengthening male-exclusive niches (UK_STU_ST4W).

A wide corpus of studies has also highlighted the challenges women face in balancing work with caregiving responsibilities (Raukar & Mishkin, 2020; Pace & Sciotto, 2022; Tabassum & Nayak, 2025), particularly acute in the energy sector (Baruah & Biskupski-Mujanovic, 2021; Henriques et al., 2024), due to work intensity and frequent travel (Bhattacharya et al., 2024). Consistent with these findings, students identified motherhood and care responsibilities as critical factors limiting career progression (IT_FGI03_I05, IT_FGI03_I04, IT_FGI03_I03; UK_STU_ST4W).

«Pregnancy is a very, very big obstacle in a woman's career. [...] You either must decide to have a family or a career, and it's very difficult to combine the two» (GE_STU2_IN1W).

«The woman simply must cut back. I can't have a child now. [...] Of course you must make sacrifices» (GE_STU2_IN4M).

Across the three national contexts analyzed, maternity leave is perceived as a potential obstacle to professional advancement, leading to downgraded responsibilities or career stagnation: *«once they come back to the office, they might never catch up...it's going a big job to compete»* (UK_STU_IN5W).

These reflections underscore the longstanding nature of organizational and cultural structures that perpetuate systemic gender inequalities, thereby preventing the full recognition of women's potential in the energy sector. Consequently, there is an urgent need for systemic interventions aimed at overcoming the institutional, cultural, and social barriers that still limit women's equitable access and advancement in professions related to the ecological transition.

The repelling effect: how work environment and organizational culture create exclusion

Faculty generally perceive academic evaluation processes as meritocratic and gender-neutral process. The concept of meritocracy is not questioned, as it is perceived as objective. The interviews did not highlight any merit-related factors that could have an advantage or disadvantage for either gender. However, the general gender gap in the energy transition is referred mainly to the initial gender imbalance in applicant pools. Yet, informal cultural factors persist, as another faculty member observed, *"A range of practices persist that are not favourable for women, who still bear disproportionate family workloads compared to men"* (IT_LEC_SS1W). Similarly, GE_LEC_ST6W indicated a lack of awareness regarding supportive measures for women at her workplace indicating that the issue of workplace climate in scientific organizations has not been recognized as a topic worthy of attention. Interviews with lecturers reveal a tension often present in institutional approaches to gender equality: while the issue is widely recognized as important, its operationalization can become entangled in administrative complexity. As GE_LEC_ST7M notes, the proliferation of initiatives can

generate substantial bureaucratic workload, making implementation uneven and heavily dependent on individual study programs. This suggests that, despite good intentions, gender equality measures may be perceived yet another layer of administrative responsibility rather than as integral to institutional culture. Similarly, GE_LEC_ST2W's concerns about ineffective implementation due to insufficient expertise point to a broader challenge: without proper resources and skilled personnel, even well-designed policies risk becoming symbolic rather than transformative. Together, these accounts highlight how the relevance of gender equality can paradoxically contribute to a sense of institutional fatigue when not matched by effective support structures.

From the students' perspectives gender biases persist, influencing classroom interactions and professional environments. As illustrated by a student's experience: *"Lab coats are only available in M-L sizes, while shoes exist only in large sizes. Since I am only 1.60 meters tall, my lab coat drags on the floor"* (IT_STU_ST3W). Other student testimonies point to a deeper, systemic issue within organizational cultures—namely, the persistence of appearance-based bias in the evaluation of women's professional worth. In Italy and UK student's FG reveals how physical appearance can overshadow skills and intelligence in recruitment and promotion processes. UK_STU_ST4W observation that some people *"don't pay for intelligence"* but instead *"value women from their physical appearance"* underscores a troubling norm: women's professional trajectories may be shaped not by merit, but by superficial judgments rooted in gender stereotypes. This dynamic not only distorts fair evaluation but reinforces outdated roles—evident in the comment comparing women to a *"type of joke, like for a secretary"* (UK_STU_ST4W). Such views diminish women's credibility and contribute to a workplace culture where competence is undervalued.

Discussion and Conclusions

The global energy transition represents not only a technical challenge but a societal transformation. At its core lies the question of who participates in shaping, guiding, and benefiting from this transformation. Our study, grounded in qualitative data from Italy, Germany, and the UK, highlights the deep-rooted gender asymmetries that continue to structure education and careers in the energy sector. Our findings point to a systemic misalignment between students' values and institutional configurations—particularly within STEM disciplines—where gendered exclusions persist in both explicit and implicit forms.

A critical insight emerging from the focus group interviews is that students across disciplines are increasingly motivated by a desire to contribute to socially meaningful work, especially in areas related to sustainability and justice. Women, in particular, express a strong commitment to addressing global challenges such as climate change and resource equity. Yet, their aspirations often clash with educational structures that continue to valorize narrow technical expertise and masculinized professional cultures. This discord—between institutional supply and student demand—results in what we define as “unmet inclination,” where students are

deterred from certain educational pathways not due to a lack of interest or ability, but due to the sector's failure to signal relevance, inclusivity, and societal purpose.

Addressing this gap requires a fundamental rethinking of curricular design. Energy education must move beyond compartmentalized knowledge to foster integrative learning experiences that link technical skills with societal application. Interdisciplinary programs that bridge STEM and SSH are particularly promising in this regard, as they reflect the complexity of real-world energy challenges. Such programs also resonate more with students who seek careers aligned with ethical, environmental, and communal goals—goals which our data show are more strongly articulated by female students. Designing for this inclination does not mean feminizing curricula; rather, it requires reclaiming education as a *site* for democratic engagement with science and its social implications.

In this context, pedagogy emerges as a key site of intervention. The current absence of gender-sensitive and socially embedded teaching approaches in many STEM programs reinforces exclusionary dynamics. Participants frequently reported that engineering and related fields are taught in ways that ignore the social, ethical, and systemic dimensions of technology. This absence is not neutral—it shapes who feels welcome, who sees themselves as competent, and ultimately, who stays. Implementing feminist, critical, and intersectional pedagogies can help educators unearth implicit biases, include marginalized perspectives, and create classrooms that value a plurality of knowledges. Peer learning and co-teaching across disciplines are not ancillary to education quality—they are foundational to building epistemic diversity.

Beyond education, our study reveals that the transition to the energy workforce is similarly shaped by structural and cultural barriers. Female students reported facing skepticism, diminished expectations, and overt sexism during internships, job applications, and professional training. These challenges are compounded by a persistent myth of meritocracy that dominates both academic and industry discourses. While meritocratic ideals suggest fairness, they often obscure the invisible labor and structural disadvantages women navigate. Importantly, some institutions recognize the need for gender equity but implement solutions through bureaucratic checklists rather than through transformative, resourced commitments. As a result, well-intentioned initiatives risk becoming symbolic rather than effective.

The consequences of these dynamics are twofold. On the one hand, women who enter the energy sector often do so with a strong sense of purpose and a desire to disrupt gender norms. Their testimonies highlight resilience and ambition—but also the cost of constantly having to “prove” one’s worth in male-coded environments. On the other hand, many potential contributors are dissuaded altogether. The loss is not only individual but collective: the energy transition suffers when diverse talents, perspectives, and knowledges are excluded or marginalized.

This exclusion becomes even more acute at the intersection of career and care responsibilities. Across all three countries, participants identified motherhood, caregiving, and family expectations as major obstacles to career progression. These constraints are intensified by the

demanding nature of many energy sector jobs—long hours, travel, physical labour, and male-dominated environments. Moreover, prevailing organizational cultures continue to valorize presenteeism, linear career paths, and hierarchical authority, which disproportionately disadvantage women and others with non-normative professional trajectories. Creating truly inclusive workplaces will require not only gender-sensitive hiring and promotion practices, but also a redefinition of what leadership, competence, and commitment look like.

Institutional culture, then, is not a neutral backdrop—it actively shapes participation, performance, and belonging. Our study finds that even where formal equality measures exist, informal norms, language, and microaggressions continue to hinder women's full participation. The normalization of jokes, stereotyped assumptions, and appearance-based judgments corrodes workplace dignity and reinforces hierarchies of value. These dynamics not only harm individual careers, but signal to students and early-career professionals that the energy sector is not a space where they can thrive.

Finally, our study calls for a reframing of the energy transition itself—not merely as a technological shift, but as an epistemic and institutional transformation. Who we educate, how we educate, and what values are encoded in professional cultures will determine not only who leads the energy transition, but also what kind of future it enables. A gender-just energy transition is not only about balancing participation—it is about reimagining science and innovation as spaces of shared responsibility, social relevance, and collective flourishing.

Competing interests

The authors declare no competing interests.

Ethical statements

The Commissione per l'Etica e l'Integrità nella Ricerca - Consiglio Nazionale delle Ricerche has granted an ethical clearance for the research activities described in the paper. All research was performed in accordance with relevant guidelines/regulations applicable when human participants are involved. In particular, the research complies with all relevant and current international and EU legislations and conventions: Ethics in Social Science and Humanities; Ethics and data protection; United Nations Universal Declaration of Human Rights; European Convention on Human Rights; Convention for the Protection of Human Rights and Fundamental Freedoms; Charter of Fundamental Rights of the European Union; European Charter & Code for Researchers; European Conduct for Research Integrity (All European Academies [ALLEA]); Global Code of Conduct for Research in Resource-Poor Settings; Horizon Europe Regulation 2021/695, Eligible actions and ethical principles (Article 18), Ethics (Article 19); General Data Protection Regulation (GDPR).

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Scope of approval: The ethical clearance was submitted and obtained for all the research activities involving human beings within the Horizon Europe funded gEneSys Project.

Any other supporting information: The research activities of the gEneSys Project, involving human beings, including those research activities from which the data presented here was collected, also undergone for an ethical check performed by an Ethic expert appointed by the European Commission. After two rounds of reviews, on 2/09/2024, all requirements were considered to be fulfilled by the Third Ethics Check - Report (reference number Ares(2024)6467440)

In addition to the mentioned clearance the Research Ethics Committee at the Faculty of Philosophy, Jagiellonian University, approved on 20 March2024 the project Transforming Gender Interrelations of Power and Inequalities in Transition Pathways to Sustainable Energy Systems (gEneSys) and confirms that the project does not violate ethical standards of scientific research.

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