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# Gender Mainstreaming the European Union Energy Transition

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**Abstract:** This paper explores gender dimensions of the energy transition in the European Union (EU). The EU has set out its ambitions for an equitable transition to clean secure energy. It has also set out it objectives for gender equality. In this paper, I implement a systematic literature review to explore the intersection of gender issues with the energy transition in the EU. There is little peer reviewed literature in this area. Analysis of academic papers shows most focus on social science rather than technical or engineering problems. A critical review of the grey literature including EU policies and reports shows that there is a disconnect between EU gender equality and clean energy plans and that gender has yet to be mainstreamed into the EU energy transition. This review identifies opportunities to mainstream gender into EU energy policies by linking to EU gender equality objectives, and connecting to gender-energy research themes.

**Keywords:** gender equality; gender mainstreaming; energy transition; energy trilemma

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## 1. Introduction

The Paris accord to keep the global temperature increase to below 1.5° is a reminder of the urgent challenges that require our concerted efforts. There is an urgent need for the energy transition to support climate change mitigation initiatives, and to support sustainable economic and societal objectives. Strategic priorities for gender equality, energy and climate intersect, and challenge us to find innovative ways to address these goals simultaneously. At the core of these challenges is our dependency on energy. Energy is a driver of economic development and requirement for participation in economic activity and daily life. The types of fuels used to serve energy needs is closely connected with climate change. The energy trilemma is the set of connected problems to create a balanced energy system that is secure, clean and equitable. It requires a multidisciplinary whole systems approach to address the trilemma. Gender equality is a cross-cutting priority, the question of gender equality in the energy transition remains open.

Four axes of the Energy Transformation are often highlighted; the four D's of Decarbonisation, Decentralisation, Digitalisation and Democratisation. A fifth D for Deregulation is sometimes considered which aims to facilitate competition and ensure consumers have access to affordable energy options. Each axis of the energy transition contains potential opportunities and challenges for how the energy transition can be achieved. These axes cannot be considered in a univariate fashion. To achieve a secure, clean, and equitable energy system, all intersecting interests must be considered jointly.

Gaps and barriers in regulations, standards and network codes to energy citizen participation in the energy transition are discussed in [1], while prosumer community groups and prosumer relationships are considered in [2]. Both technical innovations and social innovations are necessary for the long-term success of the clean energy transition. However, neither article touch on the role of gender in the clean energy transition.

European Union (EU) energy policies aim to deliver on the EU's Paris Agreement commitments through a Clean Energy Transition which encourages greater efficiency, and the use of low carbon energy sources to replace fossil fuels. The EU clean and fair energy transition aims to create a more secure, competitive and sustainable energy system that supports economic growth and improves the quality of life of its citizens [3]. The clean

energy transition in the EU is sustainability driven, the EU aims to achieve climate neutrality by reducing greenhouse gas (GHG) net emissions by at least 55% by 2030 compared to 1990 and to be the first climate neutral continent by 2050. The EU clean energy transition will transform the EU energy system to one with reduced reliance on fossil fuels, improved energy efficiency and increased use of renewable energy sources (RES) and electric vehicles and other clean-energy transport options [4].

EU Clean energy for all Europeans legislative acts aim to place the citizen at the centre of the energy transition [3]. The EU sets out how it plans to tackle climate and environmental challenges in the European Green Deal [5] , and sets out inter-connected proposals to revise and update EU climate and energy legislation such as the Renewable Energy Directive, and Energy Efficiency Directive in [4]. Each EU member state indicates how it plans to achieve climate and energy targets in its National Energy and Climate Plan (NECP). Sectoral targets specify how each member state plans to decarbonise heat and transport, and increase the use of RES. The participation and engagement of individual and collectives of citizens is seen as key to achieving these targets since changes in how we heat our homes and buildings, how we travel to school and work, and whether households adopt low carbon technologies such as electric vehicles, heatpumps and photovoltaic panels are decisions for citizens supported by their municipal and government policies and available infrastructures.

Gender equality is a core principle of the EU. EU President Ursula von der Leyen has been quoted as saying:

> Using only half of the population, half of the ideas or half of the energy is not good enough.

However, neither the Green Deal, not the Clean Energy documents make any explicit reference to gender or sex, but refer instead to European citizens and to vulnerable European citizens, or vulnerable households. There is no commonly accepted or widely agreed legal definition of vulnerable persons, so there is a risk that actions targeting vulnerable citizens may be ineffective in addressing gender equality. Women, and particularly older women, are at a higher risk of energy poverty than men [6].

The EU has also set out a gender equality strategy for the years 2020–2025 which aims to make concrete progress on gender equality in the EU [7]. It specifies three high level objectives to work with EU countries and foster institutional change to achieve (1) gender equality in scientific careers; (2) gender balance in decision making; and (3) integration of the gender dimension into the content of research and innovation. This paper explores how these gender equality objectives may manifest in the EU energy transition.

Gender has been considered extensively in relation to the global south [8]. However there is a gap, gender may not be explicitly articulated as a component of any of the energy transition axes within EU energy policy documents [9]. A better understanding of gender issues is key to understanding the actors and their agency in the energy transition. The main contribution of this paper is an exploration of gender dimensions of the energy transition in the EU. I implement a systematic literature review to uncover the extent that gender has been incorporated into academic research on the clean energy transition, and link these themes to a critical review of EU gender equality and clean energy policy documents.

This paper aims to answer the following research questions:

1. Which academic papers address gender dimensions of the energy transition in the EU?
2. Which gender dimensions do these paper address?
3. How is gender integrated into EU policies on the clean energy transition?

There is a scarcity of gender-related studies in the clean energy transition in the EU. Gender mainstreaming is the practice of assessing planned laws, policies, or programmes for differential implications for women and men to ensure policies and activities incorporate a gender sensitive perspective. Efforts to promote gender equality are not restricted to specific measures to help women, but leverage all general policies [10]. Mainstreaming helps to achieve gender equality and the empowerment of women [11]. This review shows

that there is a gap in the literature on the intersection of gender equality and clean energy policies in the EU. Much works remains to be done to mainstream gender within the EU clean energy transition.

## 2. Materials and Methods

I use a Systematic Literature Review (SLR) to identify relevant peer reviewed papers and synthesis the analysis of the papers into a taxonomy. This taxonomy helps to understand which topics and research areas have explicitly considered gender, and to suggest gaps where there may be latent gender dimensions that should be considered by those interested in mainstreaming gender in a sustainable energy transition.

SLRs are conducted in three main steps: (1) Planning the Review by defining the research questions and specifying the search protocol; (2) Conducting the Review by retrieving articles that match the search protocol eligibility criteria; and (3) Reporting the Review by analysing and synthesising the selected articles.

The SLR aims to answer research questions 1 and 2 set out in Section 1. The IEEE, Science Direct, and Scopus databases were searched for published journal articles. Terms such as "energy" or "power" were too general and identified papers in the medical and sports literature. The search was restricted to the following string in the title, abstract or keywords fields:

("Gender" OR "SEX") AND
("energy transition" OR "clean energy" OR "renewable energy" OR "renewable electricity") AND
("European Union" OR "Europe" OR "EU")

Next the academic papers are filtered by removing duplicates and those that mention either gender or the EU tangentially but are not the focus of the paper, or were not available in English.

I then perform a critical review of the grey literature using the most recent and relevant EU reports and policy documents on gender equality and the energy transition to answer research question 3 by retrieving official EU documents using the advanced search tool which can be found at https://eur-lex.europa.eu/ accessed on 16 September 2022 .

The retrieved papers and reports are analysed in Section 3.

## 3. Results

Table 1 shows the number of academic papers that were identified in step 1 of the SLR. 35 papers were identified in the Scopus database. Of these 17 were in English and directly relevant to this review, the others being focused on global energy challenges or developing countries that mention the EU in passing. 17 papers were identified in the Science Direct database, of which 15 were duplicates of papers in the Scopus database. One was not relevant, leaving just one additional paper to be reviewed. There were no matches in the IEEE database. Thus, the SLR search protocol yielded 18 papers to be reviewed.

**Table 1.** SLR Academic Paper Results.

| Database | Hits | Relevant | Cumulative |
|---|---|---|---|
| Scopus | 35 | 17 | 17 |
| Science Direct | 17 | 16 | 18 |
| IEEE | 0 | NA | 18 |

### *3.1. Gender Dimensions in the Energy Transition Academic Literature*

Table 2 shows the reviewed papers by year and journal source. We see that the topic is gathering interest in the social science journals. Only two papers were published up to and including 2017, with slow but growing interest since 2018.

**Table 2.** Academic Paper Journal Sources.

| Journal | ≤2017 | 2018 | 2019 | 2020 | 2021 | Total |
|---|---|---|---|---|---|---|
| Amfiteatru Economic | 1 | | | | | 1 |
| Applied Geography | | | | | 1 | 1 |
| Energies | | | | | 1 | 1 |
| Energy | | | | | 1 | 1 |
| Energy Policy | 1 | | | | | 1 |
| Energy Research and Social Science | | | 1 | 2 | 2 | 5 |
| Environment Development and Sustainability | | | | | 1 | 1 |
| Global Transitions | | | 1 | | | 1 |
| International Journal of Management | | | | 1 | | 1 |
| Low Carbon Energy Technologies in Sustainable Energy Systems | | | | | 1 | 1 |
| Sustainability | | 1 | 1 | 1 | | 3 |
| Water | | | 1 | | | 1 |
| Total | 2 | 1 | 4 | 4 | 7 | 18 |

Table 3 shows a taxonomy of the reviewed papers grouped together following a thematic analysis of the topics addressed by the papers. Table 3 also shows the geographic spread of the countries, the data and methods used, and the authors. We see that some papers focus on a specific country while some are pan-European. Both primary sources, such as interviews and surveys, and secondary sources such as national statistics are used. The methods are mixed ranging from qualitative thematic analysis to quantitative techniques such as Exploratory Data Analysis (EDA), Generalised AutoRegressive Conditional Heteroskedasticity (GARCH), Generalised Linear Modelling (GLM), and Multiple Linear Regression (MLR).

**Table 3.** Academic Paper Taxonomy, Methodologies and Geographic Focus.

| Theme | Country | Data and Methods | Authors |
|---|---|---|---|
| Energy Citizen Engagement | Pan-EU | 46 prosumer initiative documents: thematic analysis | Campos and Marín-González (2020) [12] |
| | Finland | Survey of 628 high school students: EDA and MANOVA | Halder et al. (2010) [13] |
| | Pan-EU | Survey of 45 electricity cooperatives: EDA and thematic analysis | Łapniewska (2019) [8] |
| | Germany | Eight case studies: Qualitative review | Mang-Benza (2011) [14] |
| Attitudes and Willingness to pay | Pan-EU | National statistics: logistic regression | Janik (2021) [15] |
| | Pan-EU | 37 academic publications: Literature review | Karasmanaki (2011) [16] |
| | Lithuania | Survey of 1005 householders: GLM | Liobikienė and Dagiliūtė (2021) [17] |
| | Poland | Survey of 960 households: logistic regression and prosumer profiling | Ropuszynska-Surma and Weglarz (2018) [18] |
| | UK | 28 interviews of householders: Theory of domestication | Standal, Talevi, and Westskog (2020) [19] |
| | Pan-EU | Review of funded project | Stratigaki (2019) [20] |
| | Lithuania | Survey of 1002 householders: EDA | Streimikiene (2015) [21] |
| | Poland | Survey of 1001 householders: EDA | Żuk and Pacześniak (2020) [22] |
| Social Justice and Sustainability | Austria, Belgium, and Bulgaria | National statistics: Case studies | Bartiaux (2019) [23] |
| | Pan-EU | National statistics: EDA | Dankevych (2020) [24] |
| | Sweden | 11 interviews of solar energy communities: Thematic analysis | Lazoroska, Palm, and Bergek (2021) [25] |
| | Spain | Review of funded project | Peñalvo-López and Cárcel-Carrasco (2019) [26] |
| Energy Use | Netherlands | National statistics: MLR | Mashhoodi (2021) [27] |
| | Spain | National statistics: GARCH | Zorrilla-Muñoz, Petz, and Agulló-Tomás (2021) [28] |

The main themes that emerge are: energy citizen engagement, attitudes and willingness to pay, social justice and sustainability, and energy use. In the next section I synthesis

the ideas from the papers grouped together under the mains topics identified by thematic analysis.

#### 3.1.1. Energy Citizen Engagement

Finland is a leader in bioenergy with 21% of primary energy consumption coming from bioenergy sources. However, a survey of students in Finland reveals that few students have detailed knowledge about RES, and specifically had little knowledge of and were quite critical about bioenergy [13]. Girls were more knowledgeable than boys in general, with significant urban/rural differences noted. Boys displayed better knowledge of solar technologies than girls. Students from rural areas scored better than urban students where knowledge about RES was likely greater due to the increased visibility of living nearer to RE projects. Bioenergy is a complex topic that extends across many policy areas. It is expected to play a significant role in achieving the EU renewable energy targets but will require public support and public awareness about this form of RES is low. Educating the younger generation is seen as key to enable young citizens, girls and boys, to better participate in the energy transition.

A prosumer is an active energy user who both consumes and produces energy from RES. The authors in [12] focus on prosumerism which they define as collective participation of prosumers in energy projects as a form of energy citizenship, and highlight relationships between prosumerism and issues such as energy justice, energy poverty and gender issues. Casting prosumerism as a social movement allows the socio-political aspects of the impact of prosumerism on future energy systems to be better understood. An analysis of 46 energy citizenship collective initiatives in Europe shows participation in decision-making, solidarity, co-ownership, and transparency were part of all the cooperatives' identities. Mainstreaming gender, empowering women in the energy transition and eco-feminism themes also arose but were not widespread with only two Spanish cooperatives explicitly stating an agenda to promote egalitarian organisation, an eco-feminism look, boosting women empowerment, and gender justice. Other cooperatives mentioned gender balance in relation to energy poverty.

Economic competitiveness correlates strongly with gender equality indicators. Local energy communities or cooperatives (LECs) agree values based on shared community objectives and their values should reflect the perspectives of women and men. The authors in [8] explore a gendered approach to energy issues which they argue could enhance the competitiveness of local electricity cooperatives where women have equal opportunity to participate in decision-making with men due to the "one person-one vote" principle. 45 electricity cooperatives from EU countries were surveyed to find out if they are sensitive to gender equality issues and if they were taken into account when planning activities and strategies. While most did not explicitly incorporate gender into their planning or strategies, most were interested in learning about good practices. The most cited reasons for the lack of participation of women in cooperatives were stereotypical societal roles, the low number of women graduates from science, technology, engineering and mathematics (STEM) fields, and the perception that energy co-ops are technologically complex. The authors identify opportunities to integrate gender perspectives such as gender training, case-studies of best practices from other cooperatives, and active recruitment of women and girls.

Mang-Benza (2020) used the term "gender blindness" to highlight the lack of visibility or explicitly articulated gender dimensions of the energy transition. The author argues that the male dominated energy sector is prone to male biases which do not intentionally exclude women, but rather overlook and do not explicitly aim to include women, their concerns and perspectives. The author explores eight case studies to articulate the role of women across the renewable energy value chain from extraction, through generation and to distribution and consumption, and finds that women are marginal actors with limited decision-making authority. Only one case is in the EU, a LEC in Germany where the gender wealth gap and cultural forces persist in marginalising women. The German example challenges the assumptions of egalitarian energy policies and illusions of a gender-neutral

energy transition in the Global North. The assumption that energy is gender neutral may arise as men in the energy sector often do not see the relevance of gender to their work [14].

#### 3.1.2. Attitudes and Willingness to pay

The factors determining EU citizens' attitudes towards the EU Energy Union priorities are taken up in [15]. Statistical modelling and analysis of a Eurobarometer survey reveals that gender, occupation and the place and country of residence are very important determinants of attitudes. The EU has achieved 2020 greenhouse gas emissions reductions and increased share of renewable energy production targets, but it is unclear if energy efficiency targets have been met. Further actions are required to achieve the 2030 and 2050 targets. EU citizens are more likely to accept energy policies when they are involved in the design and decision-making process, and if they believe the process is fair and their interests are being taken into account. The 2019 Eurobarometer surveyed a representative sample of 6432 EU citizens using face-to-face interviews to discern which objectives respondents felt should be given top priority in a European Energy Union. Developing renewable energy was the highest priority in most countries (17/27), followed jointly by guaranteeing reasonable energy prices for customers (5/27) and protecting the environment (5/27). Gender was found to be a significant predictor of attitudes towards energy policy priorities. Women were more likely to prioritise environmental protection and guaranteeing reasonable energy prices for customers than other EU Energy Union priorities. Country and place (urban/rural) were also significant predictors. Such insights on the predictors of attitudes toward EU policies are important as the policies are implemented through the NECPs of member states who can tailor education and awareness campaigns accordingly.

Attitudes toward energy policies are important, but Karasmanaki (2021) argues that deregulation and market liberalisation mean that diffusion of renewable energy lies in the hands of consumers, and hence their willingness to pay (WTP) for renewable energy is of significant importance [16]. 37 publications from the period 2010–2020 on the topic of WTP in the EU were reviewed, with a mix of significant factors depending on the country of the study. Gender and age did not have significant impact on WTP in a Lithuianian study but income and gender did in a German study. Environmental education programs to promote engagement are advocated for, especially in countries where citizens have expressed low or unwillingness to pay.

A 2017 face-to-face survey of 1005 by [17] uses generalised linear regression to understand Lithuanian citizens' WTP for green energy. Age and income were significant positive influences on WTP, gender was not statistically significant.

A 2015 survey of 960 households in Poland is analysed in [18] to explore their willingness to install RES. Sex, the number of people in a household, floor area, type of building, and energy tariff awareness were statistically significant predictors using a logit model. The main barriers to adoption of RES by Polish households are high costs and long payback periods. Awareness and knowledge about house energy is not high, and only 11 people knew the term "prosumer".

A series of 28 interviews in [19] with men and women from households in Norway and the United Kingdom in 2018 explores how the steps to becoming a prosumer may be gendered. Both countries score well on gender equality indices. The authors explore how different economic, social and cultural capital of women and men influences their choices and decisions on a pathway from consumer to prosumer. Environmental and climate concerns, and economic benefits are important motivations across all ages and genders. Women participants felt that the solar system broke with the aesthetics and practicalities of the house, whereas their partners saw it as a symbol of a modern forward-looking energy-savvy household. Several male participants were motivated by a strong technological interest and had a technology background and skill set. The authors note a need for policies to be designed with inclusivity in mind to appeal to a more diverse group and appeal both to those who are tech-savvy and to those who are not.

A COST action project to promote research, training, networking, collaboration in the wave energy sector is described in [20]. The authors point to a need for research on both the technological challenges and interdisciplinary environmental and social acceptance issues. They highlight the gender imbalance in all engineering sectors, and in particular in wave energy. Women represent almost one third of the participants in the WECANet (Wave Energy Converter Array Network) European COST Action, and 50% of the network participants are early career investigators. 82.9% of participants are from engineering backgrounds but partners from the sciences of economics and business administration, law, policy and environmental assessment, social and gender sciences are also included. The Action aims to leverage gender inclusive practices from industry and academia partners and to encourage female participants to take on leadership roles in funding applications.

A comparatives analysis of indicators of environmentally responsible behaviour in the Baltic States compared to the EU averages in 2014 is described in [21]. A survey of 1002 to identify the main drivers of environmentally responsible behaviour in Lithuania found that Lithuanian consumers are not keen to pay more for electricity produced from renewables.

How gender affects attitudes towards ecology is considered in [22] using a computer assisted survey of 1001 in 2020 to assess the relationship between gender and preferred options for environmental and energy development. Hard coal-fired power plants and combined heat and power plants produced 46.5% of Polish energy in 2019. The survey was conducted during the Covid pandemic at a time when coal mining had been paused and coal became the subject of increased public debate. More men opposed the closing of the mines than women. Polish government documents which favour a centralised energy system using coal and nuclear received higher levels of support from men than women. The authors note challenges in the populist media which portray environmental and ecological concerns as barriers to the country's economic development.

#### 3.1.3. Social Justice and Sustainability

The processes underlying associations between energy transition policies and social inequalities are explored in [23]. A sustainable energy transition requires accountability in the field of energy policies. A capability approach is used as a tool to explore the complex relation between energy and social systems in [23]. The authors explore whether different social groups are provided with the same opportunities to access affordable energy by comparing energy poor and energy richer households in Austria, Belgium, and Bulgaria. An empirical analysis of these three EU countries shows that affordability of energy is crucial to improve equality in the capability to control one's bodily health and material environment, and opportunity to affiliate. The analysis is based on United Nations Economic Commission for Europe Generations and Gender Programme surveys but does not include any specific gender analysis.

Trends in the economic, social, environmental and managerial components of sustainable development are identified in [24]. The study compares progress on the Sustainable Development Goals (SDGs) in the EU and Ukraine. Analysing the Sustainable Development Index they find the SDG 5 on gender equality remains a significant challenge for 20 EU countries and Ukraine. SDG 7 on affordable and clean energy was reached by EU countries (Sweden, Finland, Slovenia, Iceland, Portugal, Bulgaria), with 13 EU countries facing some difficulties, and eight having significant difficulties. I note that the paper was written in 2020 prior to the war and the situation for all Ukrainian citizens in now significantly more difficult.

The use of RES is crucial to achieve clean energy objectives, but the energy technologies themselves are not inclusive by default. The authors in [25] note that RES technologies are controlled by policies and bureaucratic power structures, prevailing gender norms, and in the case of LECs, by the agreed community structures. Participation in energy activities and energy decision-making is influenced by social and economic factors such as gender, economic status and home ownership. LECs tend to be dominated by older men with higher education even though women have more significant environmental concerns. In terms of

volunteering, women tend to dominate in informal and welfare related projects, whereas men take structured role in voluntary sporting groups. The evidence to date shows that men predominate in membership, and in managerial positions in EU LECs, and therefore retain decision control. The authors analyse collective solar ownership models in Sweden using a qualitative study of 11 solar energy communities and one housing association. It is worth noting that all chairpersons were men. They note that lower social standing of women may lead to inequitable workloads, and fewer opportunities to benefit from the LEC resources and assets. They highlight the importance of energy justice principles to recognise women's concerns and perspectives, ensure procedures that formalise roles and allow real influence on decisions by members, and fair distribution of the LEC benefits.

A sustainable transition requires the development of new skills in RES and building technologies. Meeting Energy Professional Skills (MEnS) is an H2020 project to upskill and educate architects, engineers, and building professionals to develop Nearly Zero Energy Buildings (NZEBs) which is described in [26]. Female participation in the building and NZEB industry is low. The project aimed to increase the capabilities of females in the NZEB sector. Semi-structured interviews of 18 women participating in the programme assessed the courses and the women's expectations of employment in the NZEB sector. The unemployment rate of engineers in the Spanish labour market is 7% in the case of males and 29% in the case of females [26]. Themes that arose include: Activities and targeted schemes for the promotion of female engineers and building professionals; identification of new lines of work and knowledge of new technologies in a sector of the future; improved employability; a need for further actions among construction companies to encourage gender equality plans. The authors conclude that the main barrier for women's employability in the construction sector is cultural.

#### 3.1.4. Energy Use

Household gas consumption in the Netherlands is far above the EU average [27]. The Dutch NECP aims to reduce the reliance on gas by 2030. This will require a shift by householders to electricity which is a more expensive source of energy. Energy-poor and low-income households are less likely to be in a position to install solar panels and will be more affected. The author uses geographically weighted regression to model and understand who the most gas-dependent households are, their important socio-economic characteristics and where they live. Household size, income, age, and gender were statistically significant predictors for gas use and gas dependency. The characterisation lends itself to informing gas reduction policy.

The EU Emissions Trading System is explained in [28]. It is an EU scheme that limits the volume of specified GHG pollutants allowed over an area. Companies can trade emission rights within that area. The scheme covers around 45% of the EU's GHG emissions. The authors use a general autoregressive conditional heteroscedasticity (GARCH) model to understand the interaction between emissions, and soil and energy management per capita indicators for Spain. Emissions are related to agricultural management (soil and energy management) and sociodemographic characteristics of agricultural workers such as gender. However, the explanatory value of the models is limited given limited availability of training data.

### *3.2. EU Gender and Energy Transition Reports and Policy Papers*

In this section, I review the grey literature to identify the intersection of gender equality and clean energy transition issues in EU policy documents and reports.

As noted in Section 1, the EU Clean Energy and Green Deal documents do not mention gender. In contrast, the EU gender equality strategy notes that Green Deal policies such as the Building Renovation Wave or the EU Strategy on Climate Adaptation may impact men and women differently [7]. Identifying gender dimensions may unlock the full potential of the clean energy plans.

The EU Gender Equality Strategy aims to end gender-based violence; challenge gender stereotypes; close gender gaps in the labour market; achieve equal participation across different sectors of the economy; address the gender pay and pension gaps; close the gender care gap and achieve gender balance in decision-making and in politics [7]. The three EU gender equality objectives are: (1) gender equality in scientific careers; (2) gender balance in decision making; and (3) integration of the gender dimension into the content of research and innovation.

Next, I explore each of the three high level EU gender equality objectives with respect to the clean energy transition aiming to identify how the gender equality objectives have been, or may be, used to mainstream gender into the EU energy transition.

#### 3.2.1. Gender balance in Scientific Careers

In this section, I review how gender balance in scientific careers connects to the energy transition. It is important to highlight that all general societal gender issues that prevail impact the opportunities to participate in the energy transition.

In the general EU labour force women earned 13.0% on average less per hour than men in 2020. This has only changed minimally since 2010. There are differences per member state, industry sector and employment status. The gender pay gap is partly explained by women working part-time, in lower paid jobs, and not making as much career progression as male counterparts. Women also carry a disproportionate burden of unpaid work which impacts opportunities to engage in paid economic activities [7]. New EU directives on obligatory pay transparency measures are being discussed and if implemented will help to clarify pay rates. Increasing women's participation in the labour market has a strong, positive impact on the economy and allows women to shape their own lives and achieve their full potential. Yet many women still experience barriers to joining and remaining in the labour market, particularly in traditionally male-dominated sectors.

As seen in Section 3.1, gender stereotyping crops up as a barrier to participation in energy activities. Stereotyping by overgeneralising characteristics of groups of people can perpetuate biases about those groups and limit their potential to fully participate and contribute to society. Gender stereotypes about intellectual ability emerge in childhood and influence children's interests [19], and hence their career choices.

Education is required to develop the skills and capabilities of female citizens to participate in the energy transition in scientific careers. Two EU projects, EQUALS-EU and shemakes.eu, aim to challenge stereotypes and to support young women entrepreneurs with digital skills in the ICT and sustainable textile industries. An Austrian initiative, the Austrian STEM-Girls Challenge, aims to spark enthusiasm among girls and young women for STEM and to counteract the shortage of skilled workers in Austria [29].

The gender gap in academia between women and men in the STEM field persists with the proportion of women at higher academic positions showing little improvement since 2015 [30]. This feeds in to fewer role models being available to signpost successful career paths in STEM and the energy transition, and adds pressure on the few senior women to be exemplary.

There is a growing interest in the gender-energy nexus literature and in the potential role of women as agents of change and active energy citizens [31]. A gender transport stereotype toolkit is provided in [32] including resources to identify and question gender stereotypes and discover career opportunities in the transport sector. Currently, only 22% of the people working in the transport sector are women. The toolkits aim to show that the opportunities in the transport sector are not restricted to a particular gender.

The profile of workers in the overall EU energy sector is similar to other STEM sectors. The ASSET study aims to collect gender-disaggregated data on the employment and participation of women and men in the energy sector [33]. Women represent 48.1% of doctoral graduates in the EU, but are over-represented the education, and under-represented in the STEM sectors [30]. One in four boys expect a career in engineering or science compared to one in six girls while only 25% of workers in the transport sector in the EU are women [7].

There are diverse opportunities along the renewables value chain which require different skill sets. Europen women tend not to apply for jobs unless they meet all requirements [11]. All the (PV) installers in [19] were men. Securing a trade apprenticeship is achieved through informal networking in many countries which often acts as a barrier to women's entry. Mentoring and networking are important factors in career success in the U.S. solar energy industry [25]. Networking and mentoring initiatives in the EU are highlighted in [30].

Digitalisation is one of the four D's of the energy transition and is a critical enabler of the Green deal ambitions [34,35]. The EU gender equality strategy stresses the importance of women shaping that digital future [7]. 90% of jobs require basic digital skills but women only represent 17% of ICT students and workers in the EU, and only 36% of STEM graduates. The Digital Education Action Plan and implementation of the commitment on 'Women in Digital' aims to address this gap. The 'Women in Digital' scoreboard will be used more systematically to monitor the progress of the EU GEAP [7].

AI is strategically important in EU policies on digitalisation and the energy transition. There is a risk that AI may intensify gender inequalities. The EU Commission has also proposed legal initiatives that aim to build trustworthy AI. The EU is alert to the dangers of biases such as gender bias in its White paper [36]. The paper also makes recommendations on universal design and accessibility to ensure the AI technology systems are user-centric and so must reflect a gender dimension. Horizon Europe projects will be funded to provide insights and solutions on addressing potential gender biases in AI [7].

#### 3.2.2. Gender balance in EU Decision Making

Clancy and Feenstra (2019) note the potential role of women as agents of change in the energy transition [31]. The EU aims to improve gender balance in EU decision making. This may bring additional gender perspectives and impact how local decisions on energy matters are then made. 14 of the top 20 countries in the world on gender equality are EU Member States [7]. However, only 7.5% of board chairs, 7.7% of CEOs, 22% of AI programmers in the EU, and 39% of Members of the European Parliament are women.

EU Member States (then including the UK) scored 67.4 out of 100 on the EU Gender Equality Index in 2019, compared to 62.0 in 2005. This indicates the slow progress on achieving gender equality. 32.3% of EU government ministers are women. Only 26.8% of EU government ministers with responsibility for policies on environment and climate change are women. This is an improvement up from 19.2% in 2012. There are 58 ministers with transport forming all, or part, of their remit, just nine of these (15.5%) are women [37].

Women still face numerous barriers on the way to the top [38], which limits their opportunity to act as agents of change in the energy transition. Soft law approaches to increase the number of women in managerial positions and on boards in the EU have made little progress to date. Political agreement on a directive to improve the gender balance among non-executive directors of listed companies was reached in June 2022, ten years after it was first proposed. The gap between the high number of female graduates and their under-representation in top-level positions reflects untapped potential of skilled human resources, agency to participate in the energy transition as decision makers.

#### 3.2.3. Gender Dimension in Research and Innovation

Research and innovation in the energy sector could be enhanced through the integration of gender dimensions. A set of resources and practical examples for mainstreaming gender into energy policy are described in [6]. Using sex-disaggregated data and gender statistics is recommended to allow hypotheses to be empirically tested.

Gender mainstreaming was proposed in 2012 in the European Research Area to ensure that gender diversity is fully utilised in research to avoid a "waste of talent". However, just 1.7% of Horizon 2020 projects integrated a gender dimension, and just under 2% of peer previewed publications by Europeans included a gender dimension [30].

Horizon Europe is the EU's current key funding programme for research and innovation which aims to achieve the UN's SDGs to tackle issues such as climate change. Integration of a gender dimiension is a mandatory requirement. Horizon Europe funds partnerships between industry, academia, governmental or civil society organisations organisations in EU Member States, associated countries and other third countries. It sets gender equality as a cross-cutting principle and aims to eliminate gender inequality and intersecting socio-economic inequalities throughout research and innovation systems.

The five EU Missions of the Horizon Europe research and innovation programme for the years 2021–2027 are an approach to make practical progress on the strategic priorities. The missions aim to address the intersection of EU priorities such as the European Green Deal, and a Europe fit for the digital age and include: Adaptation to Climate Change by supporting at least 150 European regions and communities to become climate resilient by 2030; 100 Climate-Neutral and Smart Cities by 2030 [39]. Funding calls are arranged in clusters such as a cluster on Climate, Energy and Mobility.

Implementation of Horizon Europe projects will be monitored with respect to gender equality. Peer reviewed publication is used as a measure to evaluate research funding applicants. Gender gaps persist in the authorship of research publications, particularly in the STEM field, and in inventorships. As authors become more senior, women publish increasingly less than men. Fewer women than men were authors on academic-corporate collaboration teams. Women were less likely to be successful in accessing EU funding than men.funding success rate was higher for men than women by 3.9% [30].

The EU 2021 report on gender equality shows that more women researchers work part-time and under precarious working contracts in the higher education sector than men (11.1% for women and 7.2% for men). Both women and men researchers are more likely to have short term contracts at earlier career stages. In line with the European Commission's approach to foster institutional change through GEAPs, most EU research organisations are developing or have commenced GEAPs [40]. A GEAP is a mandatory requirement for research performing organisation to be eligible for Horizon funding. A survey carried out by the EU Standing Working Group on Gender in Research and Innovation aims to assess the adoption of GEAPs by Member States and Associated Countries and to identify the needs related to the implementation of GEAPs at the national level [41].

At European level for every 10 inventorships held by men, just over one was held by women [30]. The WEgate European online platform offers services such as connecting women entrepreneurs with networks and business organisations, and mentors. The Women Leadership Programme also offers coaching and mentorship, as does the Commission-funded Enterprise Europe Network which also aims to help women attract venture capital [29].

Linking this discussion on gender in research and innovation to the analysis of gender in scientific careers in Section 3.2.1, women are under-represented at the top levels of board members and leaders at European and country level research organisations [30]. Research organisations are still far from meeting the 40% gender balance target on advisory bodies set out in Horizon 2020 despite evidence that gender diversity in research teams enhances knowledge outcomes [42]. Collective problem solving, collaboration, and effective use of expertise can lead to new discoveries and broaden viewpoints.

## 4. Discussion

Paying attention to gender issues is likely to bring more justice and equality in the energy transition [14]. Feminism does not aim to exclude men, but aims to ensure women are included. The themes addressed in the academic literature highlight gaps and opportunities to mainstream gender into EU energy policy. Former U.N. climate envoy Mary Robinson said:

Climate change is a human-made problem and must have a feminist solution.

IEEE publications deal with technologies in electrical engineering, computing, power and energy. As noted in [43], sustainable energy transitions comprise both socio-technical

and social justice dimensions but are treated as distinct phenomena. The same issue is observed in this review. Papers in the social sciences address gender issues, but there is yet little evidence of the mainstreaming of gender into the energy transition technical literature.

Many papers address the role of gender in the Global South. However, gender is not explicitly articulated in EU policies on the clean energy transition. For example, the EU Strategy on Adaptation to Climate Change refers to the Gender Equality (GE) strategy in relation to Africa and less developed countries but not to GE within the EU [44].

The gender blindness noted in [14] is a lack of awareness of gender inequalities, and can further entrench stereotypes and inequalities. There has been a lack of consideration of the role of gender even in egalatarian societies [19]. Gendered differences may be perceived as individual characteristics rather than practices of social differentiation in society. Women still face persistent barriers to entry and advancement but most men working in the energy sector are unaware of those challenges. 75% of women perceive the existence of gender related barriers, while only 40% of men seem aware [11]. Not taking gender explicitly into account can benefit the groups that are already in a more privileged position, such as men, who are already more active in the energy value chain [45].

The COVID-19 pandemic exposed persistent gender inequalities and highlighted society's reliance on women and particularly their care work

Reflecting on the EU GEAP objectives for gender equality in scientific careers, the renewable energy field may exert an appeal on women that the fossil fuel industry has lacked [11]. Achieving the EU GEAP aim on scientific careers and getting women into STEM to participate in the clean energy transition is a significant challenge. Care needs to be taken to maintain the pipeline and ensure if women are attracted in, they receive equal opportunities for career progression and sufficient life balance supports to be able to avail of those opportunities. The ability to stay in a given job and opportunities for professional growth are shaped by a number of factors. Care needs to be taken that addressing the skills gap to implement the transition not be simply portrayed as an opportunity for women to (re)join the labour force as the renewables industry has a vested interest in tapping into this talent pool. GEAPs, gender audits, networking and mentoring programmes and other best practices suggested in [30] can help to improve the situation.

Reflecting on the EU GEAG gender balance in decision making aim, I note that the gender pay gap reduces the opportunity for women for a more active involvement at local level in cooperatives where capital investments are required. A gender dimension is most visible in this review in the concepts of energy citizenship and participation in energy communities or prosumerism. However, if prosuming is socially perceived as a male domain, and the energy transition is portrayed as a purely engineering or technical problem, it may create barriers to an inclusive decarbonised energy future. There is a danger of perceived inclusively. Women who are in the minority in LECs and the energy sector may not have real opportunities to be heard. Policymakers might need to take more direct action and adopt regulations and incentives to make the jointly owned (solar) energy generation accessible to more groups in society [25]. The capability to affiliate [23] affects the opportunity to participate in initiatives such as renewable energy communities and prosumerism [12]. Women may prefer to work in cooperatives, where through collaborative effort, they can overcome challenges, such as lack of technical knowledge [25]. Women are a minority both as members and managers in LECs [25], hence their concerns may not be fully included. The decentralised nature of renewable energy brings energy choices to the household and community level, where women tend to have a greater voice [11].

The EU GEAP aim on research and innovation may be one of the most challenging issues to address. The four themes identified in the SLR of (1) energy citizen engagement, (2) attitudes and willingness to pay, (3) social justice and sustainability, and (4) energy use, suggest future research directions to be explored.

Linkages between EU strategy aims, governance, and EU and national implementation plans need to be monitored. The scarcity of gender-disaggregated data is a major handicap in the effort to enhance awareness of the challenges and to improve the actual

gender balance in renewable energy. Without data, there is no visibility. Furthermore, without visibility, it is difficult to establish policy priorities [11]. Even though residents see their home as gender neutral, certain zones of the house are perceived as more male or female than others [19]. The gendered spaces of the household and the gendered division of household labour may influence how women and men interact with clean energy technologies. Daily household tasks use 24.8% of all the energy produced in the EU [8]. Housework is unevenly distributed between women and men, almost one working woman in two spent one hour a day on caring activities, compared with one out of three working men [31]. Women may be more receptive to energy conservation efforts and willing to change their everyday behaviour to save energy. Care needs to be taken to ensure women are not negatively affected by new energy practices, where energy conservation may lead to heavier workloads [19].

Encouraging female participants to lead funding proposals [20] may lead to novel perspectives of the energy transition being created, while the resources in [6] may help gender unaware researchers to develop a gender dimension in their research.

## 5. Conclusions

The clean energy and digital transitions have yet unarticulated gender dimensions. Gender diversity can bring new perspectives to challenging problems and lead to better outcomes. This review answers the research questions posed in Section 1. This SLR identifies relevant academic articles and provides a taxonomy of the main themes addressed in the EU gender-energy nexus. The critical review of EU reports and policy papers associated with gender dimensions of the energy transition within the EU shows there is a disconnect between EU gender quality and clean energy strategies. The main contribution of this review is to highlight that there is a dearth of research at the intersection of gender dimensions and the technologies that will facilitate the EU clean energy transition.

The discourse in energy research and policy frames energy as gender-neutral, but men and women have different energy needs and concerns [6,9]. Women and men often tackle and solve problems differently. Diverse opinions and approaches can be beneficial in tacking the energy transition. Innovative and creative ideas may be generated by involving more women in design and decision-making in the energy transition.

Men and women have legislative equality within the EU, but gendered pay gaps are evidence that more needs to be done to achieve the EU GEAP ambitions. Much remains to be done to boost women's participation in the clean energy transition and to allow their talents to be fully utilised, and their voices to be heard. The energy sector is missing out on the experiences, skills, and talents of the female half the human population, which severely constrains the sustainable energy transition [46]. Gender dimensions have been largely neglected in EU clean energy policies which may hamper fulfilling European renewable energy targets [19]. The disconnect between EU gender and energy policies may be addressed by ensuring gender dimensions are included in Horizon Europe energy related projects and this may trickle down to national NECPs and research and innovation.

It is too early to draw conclusions on whether EU gender equality and clean energy objectives can be achieved simultaneously. Government actions and policies make tangible differences. They lead the way, send strong signals, and set measurable requirements without which business, economic and societal systems are unlikely to change. Mainstreaming gender into research funding calls sends a strong message to EU member states and associate countries and may be the most effective way to achieve change. The trickle down effect has already begun, with national agencies now requiring gender to be addressed in national research funding applications.

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## Abbreviations

The following abbreviations are used in this manuscript:

| | |
|---|---|
| AI | Artificial Intelligence |
| EDA | Exploratory Data Analysis |
| ETS | Emissions Trading System |
| EU | European Union |
| GARCH | Generalised AutoRegressive Conditional Heteroskedasticity |
| GEAP | Gender Equality Action Plan |
| GHG | Greenhouse Gas |
| GLM | Generalised Linear Model |
| LEC | Local Energy Community |
| MLR | Multiple Linear Regression |
| NECP | National Energy and Climate Plan |
| Nearly Zero Energy Buildings | NZEBs |
| RES | Renewable Energy Source |
| SDG | Sustainable Development Goal |
| SLR | Systematic Literature Review |
| STEM | Science, Technology, Engineering and Mathematics |
| WTP | Willingness To Pay |

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