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D.1.2 – Report on Gendered assessment of the energy systems knowledge community and EU policies for sustainable energy systems

WP1 – Gendered analysis of knowledge creation landscape for energy transition

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GeneSys (Transforming Gendered Interrelations of Power and Inequalities in Transition Pathways to Sustainable Energy Systems) has received funding from the European Union's Horizon Europe - Culture, creativity and inclusive society - under grant agreement no. 101094326.

Report on Gender assessment of the energy systems knowledge community and EU policies for sustainable energy systems

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Report on Gender assessment of the energy systems knowledge community and EU policies for sustainable energy systems

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List of Acronyms

CEDEFOP	*European Centre for Development of Vocational Training*
CINEA	*European Climate, Infrastructure and Environment Executive Agency*
EIGE	*European Institute for Gender Equality*
EC	*European Commission*
EU	*European Commission*
EP FEMM	*European Parliament's Committee on Women's Rights and Gender Equality*
GDP	*Gross Domestic Product*
HAP	*Household Air Pollution*
ICT	*Information Communication Technology*
ILO	*International Labor Organization*
IRENA	*International Renewable Energy Agency*
NECP	*National Energy and Climate Plan*
NGEU	*Non-Governmental Organization*
NRRP	*National Recovery and Resilience Plan*
NRRPs' GEAF	*NRRPs' Gender-Energy Assessment Framework*
NRRPs' GEAI	*NRRPs' Gender-Energy Assessment Index*
RRF	*Recovery and Resiliency Facility*
SLR	*Systematic Literature Review*
STEM	*Science, Technology, Engineering, Mathematics*

1 EXECUTIVE SUMMARY

The deliverable "Report on Gendered assessment of the energy systems knowledge community and EU policies for sustainable energy systems" is the outcome of the tasks T1.3 and T1.4 of the workpackage 1 of the gEneSys project. It includes two parts. The former provides the first-ever comprehensive assessment of gender divide within the energy transition (ET) knowledge community. Employing advanced methods from complexity science and semantic analysis, the study analyses also five ET subcommunities addressing, respectively, the environment, strategy, policy, behaviour, and operation subsystems. The latter aims at presenting a comparative analysis of National Recovery and Resilience Plans (NRRPs) across EU member states, examining their incorporation of 'green deal' provisions, gender equality, and energy transition goals. Special emphasis is placed on assessing how effectively gender equality, diversity, and inclusion are addressed, highlighting areas for targeted gender mainstreaming. As mentioned this represents the first gender-based policy analysis of NRRPs, examining how effectively EU countries uphold equality principles established in national, European, and international gender equality strategies.

Both the studies follow rigorous scientific approaches derived from others existing in the literature and leverage the results previously achieved in the gEneSys project. In details, the report on the gendered assessment of the energy systems knowledge community follows an approach derived from the methodological framework presented in (De Nicola & D'Agostino, 2021) and leverages the Energy System Ontology (gEneSys, 2023), while the comparative analysis of the NRRPs, respectively, a framework derived from the one proposed by (Feenstra & Özerol, 2021) and the systematic literature review of the gender-energy nexus (gEneSys, 2023).

To determine whether there is gender divide in the ET community and its subcommunities, we addressed eight research questions, such as: as a group, are women and men equally successful or, as a group, do women and men study different topics? Our findings indicate a pronounced gender divide within the energy transition sector, with males dominating most subcommunities. The environment subsystem exhibits greater female contribution, while the operation and strategy subsystems show the largest male dominance.

The analysis on EU policies is guided by the hypothesis that the energy transition alone wouldn't automatically address gender inequalities and might even worsen them. It emphasizes the need for gender-sensitive policies to ensure women are included and benefit equally from the transition. One of the key points of our analysis is that the energy transition may not be gender-neutral, potentially reinforcing existing inequalities or even enhancing them. Furthermore, many National Recovery and Resilience Plans lack a gender perspective, neglecting women's needs and roles. Even plans with a gender perspective often do so partially, with some aspects receiving more attention than others. The deliverable proposes research questions for analysing NRRPs' impact and suggests policies for a ''just energy transition'', including funding research on disaggregated gender data; closing the gender gap in STEM fields; and addressing energy poverty and health issues.

The rest of the deliverable is organized as it follows. Section 2 presents the gendered assessment of the Energy Systems Knowledge community and Section 3 entails the EU policies for sustainable energy systems.

2 GENDERED ASSESSMENT OF THE ENERGY SYSTEMS KNOWLEDGE COMMUNITY

2.1 Introduction

Interest in understanding the impact of research and evaluating the performance of researchers has grown in recent years, as evidenced by the existence of specific scientific journals such as Springer's *Scientometrics*[1] and Elsevier's *Journal of Informetrics*[2]. Furthermore, a novel approach based on complexity science and referred to as "*science-of-science*" (Fortunato, et al., 2018) has attracted the interest of researchers that are applying network analysis techniques, semantic methods, and artificial intelligence to cope with the complexity of information available in online scientific repositories, such as SCOPUS and Web Of Science. Despite this context, there is a lack of scientific contributions addressing the energy knowledge communities. To this aim, the part of this deliverable dealing with gender assessment of the energy systems knowledge community proposes an unprecedented study on the energy transition community based on advanced methods leveraging complexity science and semantic analysis to assess gender divide in the community. We define gender divide as any gender difference in the careers of scientists, whether female scientists are disadvantaged or advantaged (De Nicola & D'Agostino, 2021).

While gender is generally recognized as a social construct used to classify a person as a man, woman, or some other identity (LGBTQIA Resource Center), data limitations in this section necessitate a narrower definition. In fact, we are forced to adopt a binary distinction of genders as non-binary genders cannot be inferred from names, nor self-definition of gender identity is available. Therefore, we use the terms 'men/women' and 'males/females' as they are often used interchangeably in current literature (Eagly, Nater, Miller, Kaufmann, & Sczesny, 2020). When gender cannot be determined, we will use the term 'undetermined'. The authors are aware of the huge debate on the former subject and its impact in our life and social organization: present narrative conventions, are not meant to underestimate them, nor they should be intended as lack of sensitivity.

Frequently along this manuscript (especially in the pictures), the pink color is associated to females, while blue to males. It is worth stressing that, that authors do not believe colors having special affinity with genders (e.g. male football teams employ pink in their uniforms): that convention was selected for its broad use, only. Our study is based on the gender divide assessment workflow that is sketchily represented in Figure 1. This consists of five activities: (i) Collect papers on Energy Transition; (ii) Build Energy System Ontology; (iii) Identify community members; (iv) Gender disambiguation; and (v) Gender divide assessment. This chapter mainly covers activities (iii), (iv), and (v), while activities (i) and (ii), even if they were covered

[1] Scientometrics URI: https://link.springer.com/journal/11192
[2] Journal of Informetrics URI: https://www.sciencedirect.com/journal/journal-of-informetrics

comprehensively in the deliverable D1.1 (gEneSys, 2023), are referred to here for the sake of clarity.

Figure 1. The gender divide assessment workflow

In details, we ran a SCOPUS search to select all the papers tagged by either "energy transition" or "energy transformation". Then, we built the Energy System Ontology (ESO) that was presented in (gEneSys, 2023). We used ESO to further filter the sample of papers to, finally, come up with 9097 annotated papers. Afterward, we extracted the semantic social network representing the addressed community. According to (D'Agostino, D'Antonio, De Nicola, & Tucci, 2015), a semantic social network represents the relationships between members, the semantics of the Domain of Interests and the actual interests of the community of members with their weights. Next, we applied the framework for gender divide to measure some indicators to assess the gender divide in the community. Finally, we made some considerations of the achieved results, and we propose some recommendations for the future.

The rest of this chapter is organized as it follows. Section 2.2 briefly describes the Energy System Ontology (gEneSys, 2023) in order to contextualise our study. Section 2.3 describes the construction of the energy transition dataset used for gendered assessment. Section 2.4 presents the methodology for assessing the gender divide based on complexity science and semantic analysis methods (De Nicola & D'Agostino, 2021). Section 2.5 details the software and the methods used for gendered assessment. Section 2.6 lists the research questions we addressed and the results of the gendered assessment of the energy transition community and its subcommunities. Finally, Section 2.7, summarizes the answers to the research questions.

2.2 Energy System Ontology

The Energy System Ontology (ESO)[3] provides a holistic perspective on the energy system, defining the scope of interest across different disciplines. It stems from an extensive analysis of scientific literature. ESO addresses the energy transition and incorporates concepts from various subsystems such as environment, strategy, policy, human behaviour (including energy markets, economics, and consumption attitudes), and energy operations. Built upon the BFO (Basic Formal Ontology) (Arp, Smith, & Spear, 2015) foundational ontology to ensure semantic quality, ESO integrates 18 ontology design patterns, forming its backbone. A multidisciplinary team of researchers from social sciences to engineering, part of the gEneSys consortium,

[3] http://jerico.casaccia.enea.it/genesys/Energy-System-Ontology_v1.0

collaborated on ESO's development, ensuring scientific rigor and a multidisciplinary approach.

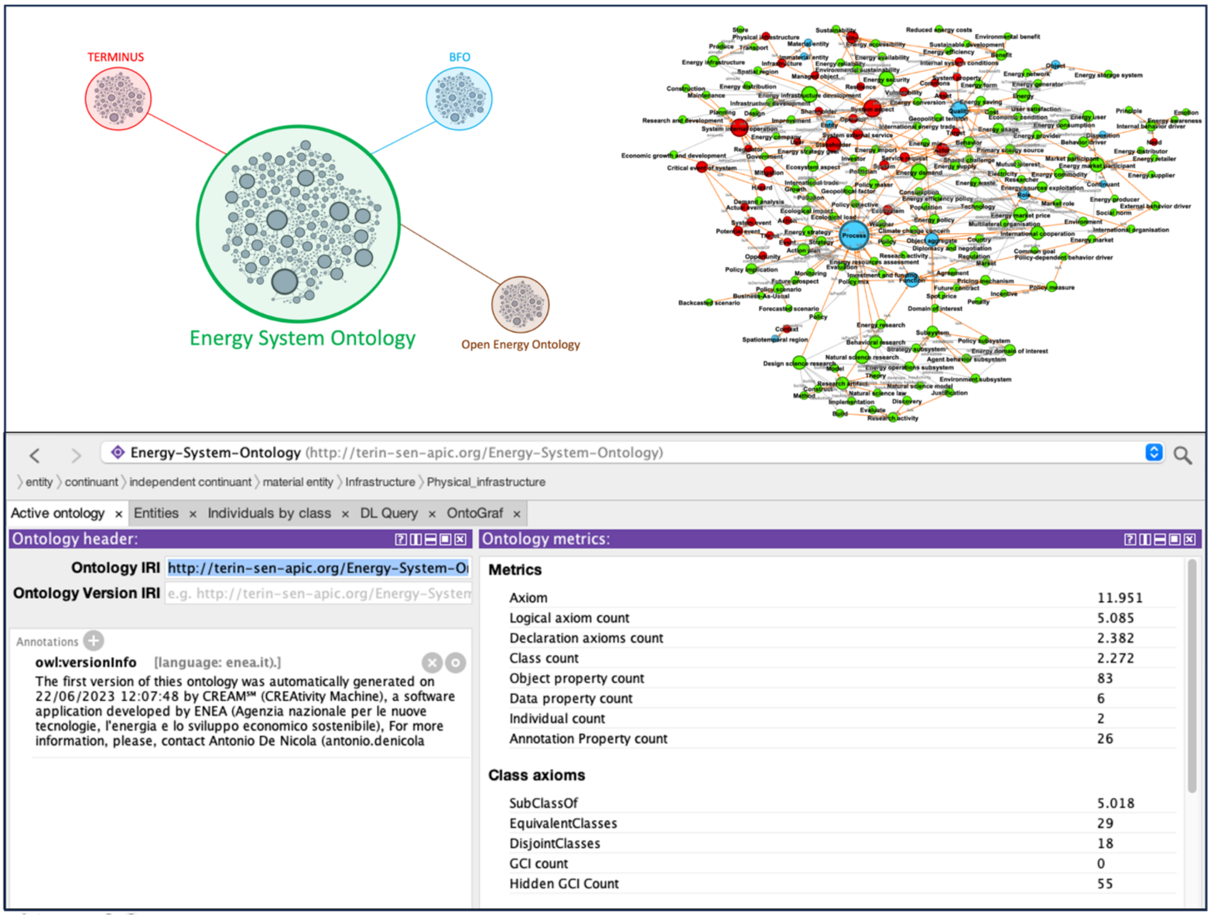


Figure 2. Energy System Ontology (ESO): connection with other ontologies, core ESO ontology, and ontology metrics.

ESO concerns five energy transition subsystems. The environmental subsystem addresses CO_2 emissions, environmental protection, ecosystem risks, with emphasis on global warming, mitigation strategies, resilience, and climate change. Recognizing environmental concerns' influence on energy strategies, ESO encompasses political dimensions such as energy security, international cooperation, and agreements (i.e. the strategy subsystem). The policy subsystem part of ESO covers policy making, frameworks, implementation, acceptance, and governance involvement, including considerations of social justice. The behavioural subsystem focuses on energy consumption, demand, markets, and individual, household, and organizational behaviour. The part of the ontology concerning the operational subsystem explores technological and organizational aspects of energy, including general and specific energy system concepts.

ESO was developed to facilitate communication among gEneSys partners, to identify participants for stakeholder surveys on sustainable energy systems from a gender perspective, and to support gendered assessment of the energy system community by using advanced semantic social network techniques.

The overall ontology gathers 2.272 classes (i.e., concepts), 83 object properties, 6 data properties, and 11951 axioms. ESO has connections with the TERMINUS ontology (Coletti, et al., 2020), Open Energy Ontology, and the mentioned BFO to form a virtual network of ontologies depicted on the top left of Figure 2. The same figure on the top right shows the core concepts of ESO ontology and their relationships and an excerpt from the Protégé Ontology Management System on the bottom.

2.3 Construction of the energy transition dataset used for gendered assessment

The construction of the energy transition dataset has been a long running endeavor that began at the project's outset and also resulted in the creation of the Energy System Ontology. In the following subsections, we present the main steps of this process. In details, they are:

- Collection of papers on energy transition/transformation from SCOPUS;
- Filtering of the selected energy papers through the Energy System Ontology;
- Disambiguation of the gender based on given names;
- Human validation of gender names;
- Partitioning the sample of energy transition (ET) papers into ET subsystems.

2.3.1 SCOPUS papers collection

This first step was already discussed in the Deliverable D1.1 of the gEneSys project (gEneSys, 2023) and it is, here, sketchily represented in Figure 3. We briefly recall here some of the main findings. We employed a bottom-up approach to delineate the scope of the energy transition domain. To achieve this, we executed a query on Scopus on March 17, 2023, to gather bibliometric data pertaining to papers containing the terms "`energy transition`" OR "`energy transformation`". This query yielded information from 17591 papers. Among them, only 15367 papers were indexed by Scopus with keywords. Of these, 12872 papers were published in journals, 2097 in conferences, and 215 in books. Specifically, there were 909 conferences, 3023 journals, and 215 books. Among the most frequently appearing journals for "`energy transition/transformation`" topics, we cite *Energies* (685 papers), *Energy Research and Social Science* (610 papers), *Energy Policy* (516 papers), *Sustainability* (373 papers), and *Renewable and Sustainable Energy Reviews* (253 papers). We report a notable increase in the number of papers on energy transition in recent years.

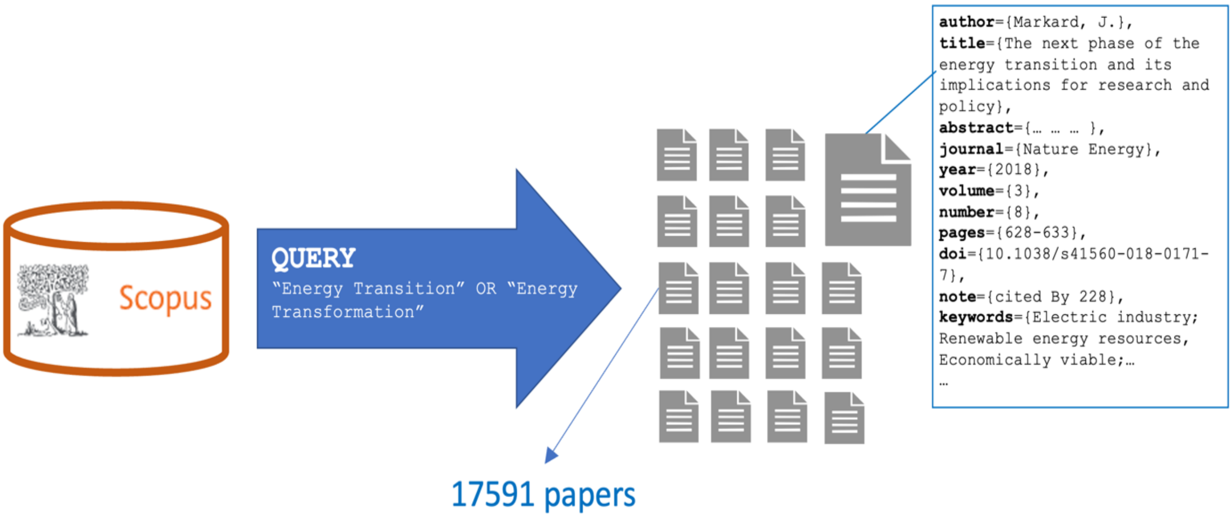


Figure 3. Collection of paper on energy transition/transformation from SCOPUS

2.3.2 ESO filtering

The second step of the process was devoted to further filtering the collection of retrieved papers. To this purpose, we used the Energy System Ontology (ESO) developed during the activities of the task T1.2 of the gEneSys EU project. As shown in Figure 4, the sample of papers was reduced by 42,14%: from 17591 to 10130 papers. The filtering rule we adopted was as follows. Given a paper p_i with $i \in [0,n]$ and a set of tags (t_j) labelling all the concepts of ESO, if p_i is tagged by at least one tag t_j with $j \in [0,K]$ where K is the number of concepts included in ESO then the paper p_i is selected, otherwise it is discharged.

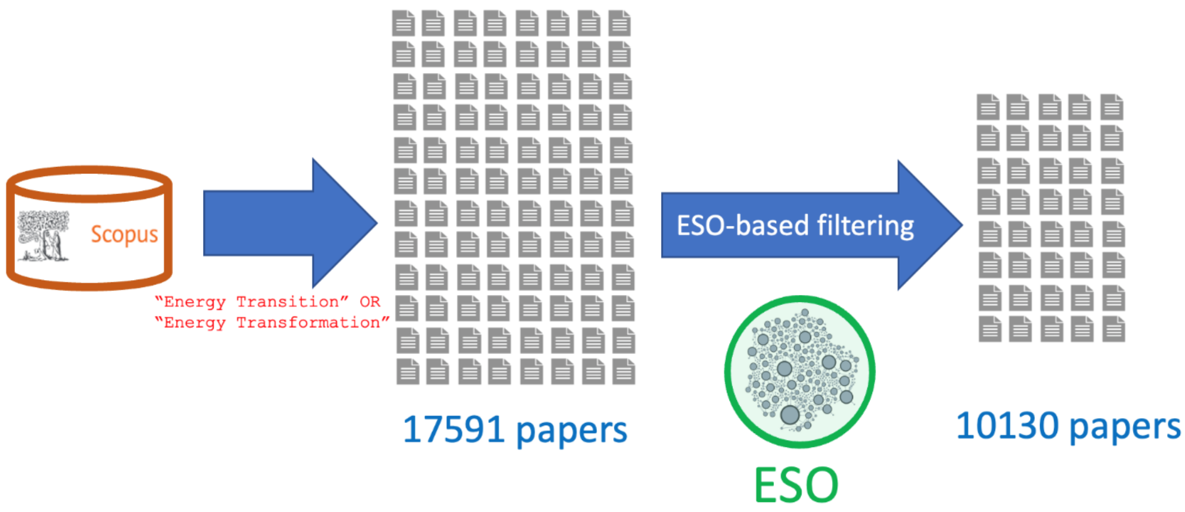


Figure 4. Filtering of the retrieved energy papers through the Energy System Ontology

2.3.3 Gender disambiguation and final dataset selection

The third step of the process aims at disambiguating the gender from the names of the authors. To this purpose, we faced the following challenges:

- Gender of authors is not specified in Scopus.
- To assign the gender to thousands of authors, automatic support is required.
- When bibliometric information of bulk papers are retrieved from Scopus, in most of the cases, only initials are available for the first name of an author (e.g., M. Allen instead of Mark Allen).
- In the information retrieved from Scopus, affiliations are not uniquely associated to authors. Furthermore, often the nationality of an author could be different from that of the university where she/he is based (Deville, et al., 2014).
- In Semantic Scholar[4], i.e., a search engine for scientific literature powered by Artificial Intelligence (AI), first names and surnames are not clearly distinguished, they could be composed by multiple tokens, and affiliation of authors is rarely available.
- Sometimes first names are composed of several tokens that are usually associated to different genders. For instance, if we consider Angelo Maria, we note that Angelo is a masculine name whereas Maria is a feminine name.
- The gender associated with a first name may vary in different countries (e.g., Andrea in Italy is used for males, while in Germany for females).

It is worth mentioning that there are some services that aim to assign a gender to a person with a given name. One of the most popular is Gender API[5]. Unfortunately, the disambiguation algorithms adopted by this service are not fully documented and, therefore, it is not easy to determine the actual level of performance. For this reason, we decided to design and develop a disambiguation software.

Figure 5 outlines how the disambiguation process works. The bibliometric information related to the above mentioned sample of 10130 papers is imported (1) into the disambiguation manager. Here, for each paper, the DOI is used to query the Semantic Scholar search engine (2) and collect information on the authors (3) (i.e., full names and aliases). Next, the disambiguation manager extracts the name from the full name. Then, the previously downloaded HARVARD World Gender Name Dictionary (Raffo, 2021) is used to associate the name (4) with a gender probability (5). The sample of papers was further pruned as Semantic Scholar was unable to provide the full names of the authors of each paper (e.g., some of the articles included in the sample were full conference proceedings). In the end, we considered 9097 papers and the final

[4] Semantic Scholar URL: https://www.semanticscholar.org
[5] Gender API url: https://gender-api.com/it

number of authors related to the Energy Transition community is 27363. For each author, we were able to associate three gender likelihoods: the likelihood that the author is a male, the one that she/he is a female, and the last one that she/he is undetermined.

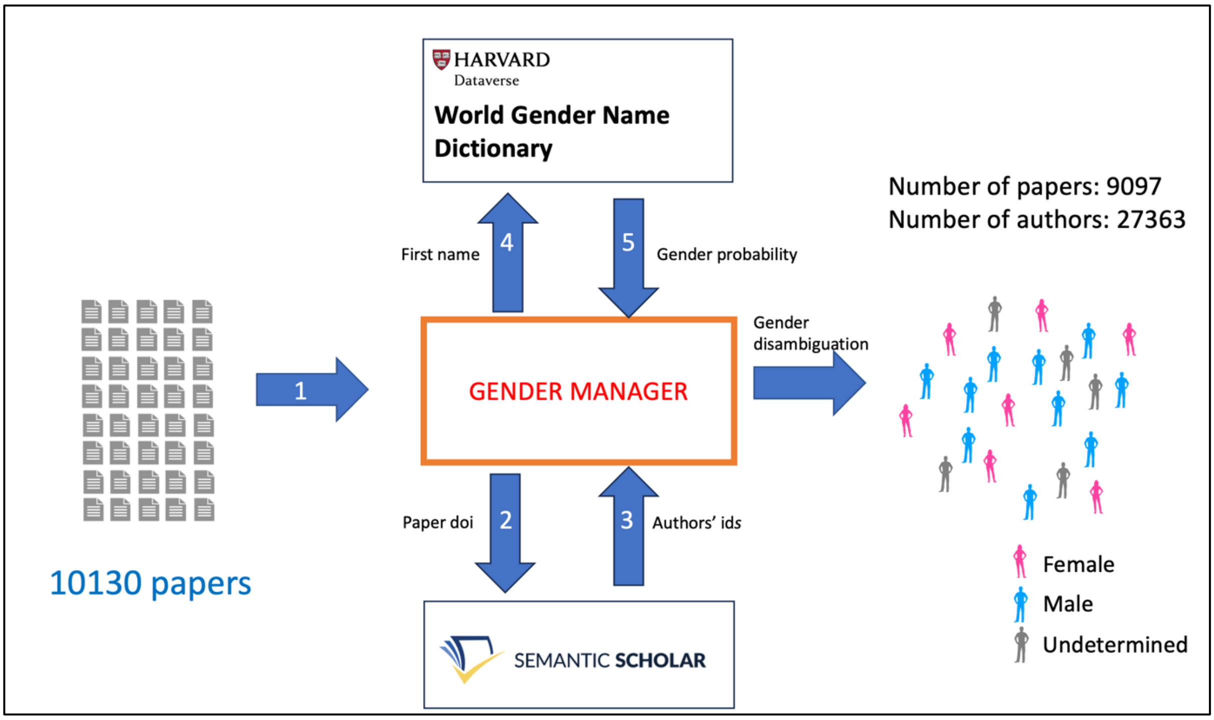


Figure 5. Disambiguation of the gender from the names

2.3.4 Human validation of gender names

The fourth step consists in assessing the actual disambiguation of the gender manager and reducing as much as possible the number of undetermined authors. To this purpose, we set up a task force consisting of three persons that searched the web to find information about the undetermined authors. To ensure replicability of the experiment, we defined and used the human validation workflow shown in Figure 6. First, the author's page of the undetermined author is searched on ResearchGate[6]. If the page exists, the DOI of one of the papers of the candidate author is used as input of a query in Semantic Scholar. If the candidate and the undetermined author are the same, we search for a picture of the scientist. If this exists, we evaluate it to assign the gender. If the page on ResearchGate does not exist or the picture of the author is not available, we search for the author personal or institutional page. If it exists, we check again whether the candidate and the undetermined authors are the same and we search for her/his picture to assign the gender. If we are unable to assign the gender, the latter is considered undetermined.

[6] ResearchGate url: https://www.researchgate.net

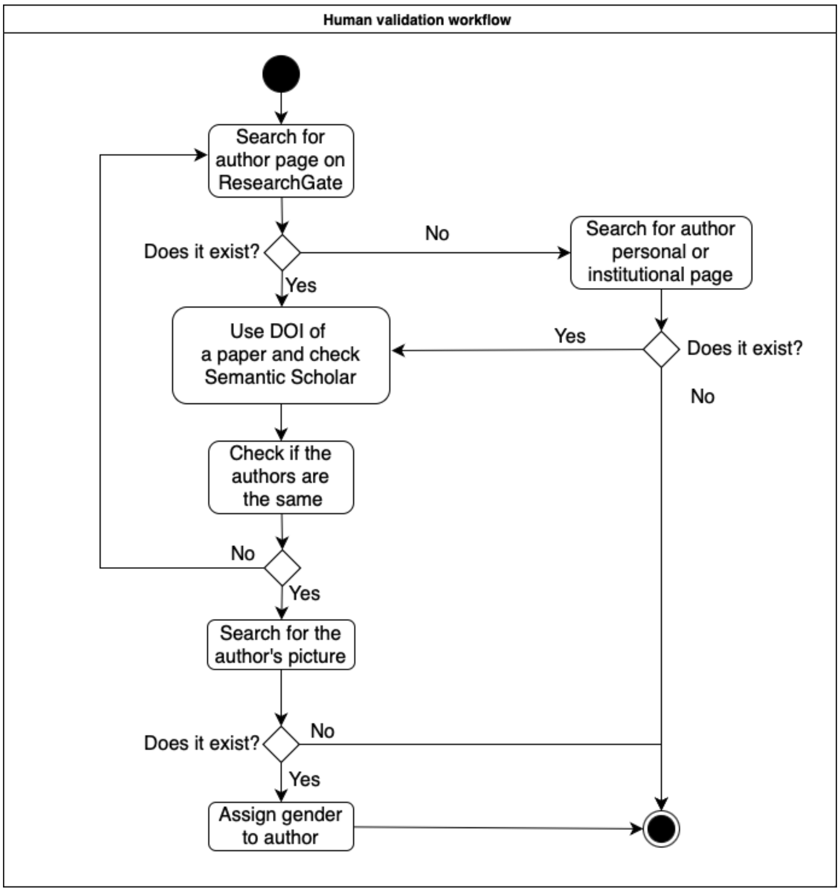


Figure 6. Human validation workflow

At the end of the human validation, we identified **15522** males (56.73 %), **6730** females (24.60 %), and **5111** undetermined (18.67 %). A further discussion on the quality of the results is presented in subsection 2.5.1.1.

2.3.5 Partitioning the sample of energy transition papers into ET subsystems

The last step of the process aims to divide the energy transition papers into the five subsystems presented in the deliverable D1.1 of the gEneSys project (gEneSys, 2023). For this purpose, we defined a formula to compute the relevance of the paper for each thematic area. Then, the paper is assigned to the subsystem in which it achieved the highest level of relevance.

The formula to compute the relevance of the paper is reported in the following.

Given a thematic area a and a paper i annotated by a set of keywords $S_i = \{k_{i,j}\}$, we define the relevance of the paper i with respect to the thematic area a as the product of the impact (I_i) of the paper i on the research community and its pertinence ($P_{a,i}$) with respect to the thematic area a.

Hence:

$$\boldsymbol{R_{a,i}} = \boldsymbol{I_i} \cdot \boldsymbol{P_{a,i}}$$

$$\boldsymbol{I_i} = \left[(1 + \frac{IF_i}{IF_{MAX}}) \cdot (1 + \frac{CIT_i}{CIT(y)_{MAX}})\right]$$

$$\boldsymbol{P_{a,i}} = \left\{\frac{1}{N_i} \cdot \sum_{k_j} \left[\left(\frac{k'_{i,j,a}}{N_a}\right) \cdot w_{e,a,k'_j}\right]\right\}$$

where:

a = {Environment, Strategy, Policy, Behaviour, Operation};

IF_i is the impact factor of the journal where the paper i was published. If the journal has not an impact factor or, alternatively, the paper was published on a book/conference then $IF_i = 0$;

IF_{MAX} is the maximum impact factor of all the journals where the papers of the sample were published (i.e., the *dataset*);

CIT_i is the number of citations of the paper i;

$CIT(y)_{MAX}$ is the maximum number of citations achieved by a paper published in the year y;

N_i is the number of keywords of the paper i (not only those selected by experts);

k_j is the generic keywork j that was used at least once in the whole *dataset*;

$$k'_{i,j,a} = \begin{cases} 1 \; if \;\; k'_{i,j} = k_j | k_j \in K_a \; and \; k'_{i,j} \in S_i \\ 0 \; if \;\; k'_{i,j} = k_j | k_j \notin K_a \;\; or \; k'_{i,j} \notin S_i \end{cases}$$

N_a is the number of keywords belonging to the thematic area a;

$w_{e,a,k'_j} = \frac{n_{e,a,k'_j}}{E}$ is a weight representing the degree of consensus on the thematic pertinence of the keyword reached by a pool of E experts (i.e., number of experts n_{e,a,k'_j} stating that the keyword k'_j concerns the thematic area a / number of involved experts).

After clustering the papers into subsystems, 776 papers were assigned to the environment subsystem, 2970 to the strategy subsystem, 3094 to the policy subsystem, 732 to the behaviour subsystem, and 1525 to the operation subsystem.

This division of papers allowed us to associate the authors with one or more subsystems. It is worth mentioning again that one author could be associated with more subsystems. 3613 authors were assigned to the environment subsystem, 11078 to the strategy subsystem, 10896 to the policy subsystem, 2815 to the behaviour subsystem, and 6640 to the operation subsystem.

2.4 Methodology: a proposed the Framework for Gender Divide Assessment

As mentioned in the introduction, to assess the gender divide in the Energy Transition community, we adopted the methodological framework presented in (De Nicola & D'Agostino, 2021), which addresses gender divide along three dimensions. Each dimension is accompanied by a series of metrics and their corresponding indices, as outlined in Figure 7 and Table 1. The ability to measure these indices may be constrained by data availability. In Figure 7 we used a sunburst representation to depict the hierarchical structure characterizing the framework for gender divide assessment. Indeed, the term "sunburst" suggests a radial visualization, with sections branching outwards from a central point, like the rays of the sun. This representation illustrates various dimensions, metrics, and indicators composing the framework, showing how different factors or indicators contribute to understanding gender divide.

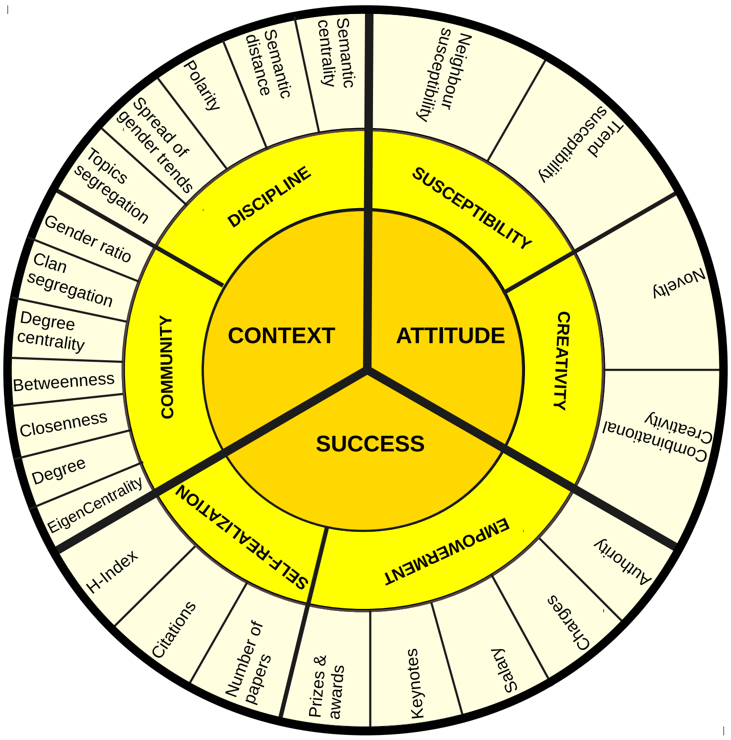


Figure 7. Sunburst representation of the framework for gender divide assessment as presented in (De Nicola & D'Agostino, 2021)

The initial dimension pertains to the *context*, representing the environment in which community members operate. The associated metrics include *discipline* (Nielsen, Bloch, & Schiebinger, 2018), delineating the domain of interest under analysis, and *community*, delineating the characteristics arising from established social relationships and collaborations (Zeng, et al., 2016), along with the female-to-male ratio. The indices considered for the discipline metrics are grounded in semantic analysis, encompassing *topic segregation* (Zeng, et al., 2016), *spread of gender trends*, *polarity*, *semantic distance*, and *semantic centrality*. The underlying concept is that semantics, alongside natural language processing, can enrich quantitative social science (Garg, Schiebinger, Jurafsky, & Zou, 2018). Topic segregation assesses the presence of topic clusters exclusively covered by either females or males. The spread of gender trends evaluates the concentration of interests within each gender. Polarity gauges the discrepancy in attention given by females and males to different topics. A semantic profile comprises the set of interests of a member of the social network, along with corresponding weights. These weights represent both the level of interest in a topic and the likelihood $L_i(c_k, t)$ of member h_i being interested in topic c_k during year t (D'Agostino, D'Antonio, De Nicola, & Tucci, 2015). This likelihood is computed as the relative frequency of publications, indicating interest, authored by h_i in topic c_k. Hence, $L_i(c_k, t) = \frac{v_{h_i}(c_k, t)}{\sum_{c_k} v_{h_i}(c_k, t)}$, where $v_{h_i}(c_k, t)$ denotes the number of papers indexed by topic c_k authored by h_i up to year t. This function ranges from 0 to 1, with 1 indicating total interest and 0 indicating no interest. Semantic distance between genders enables assessment of the diversity in semantic profiles across females and males. Semantic centrality measures the degree to which an author's topics align with mainstream or niche subjects, indicating the importance of their topics within the broader conference discourse. This semantic analysis, as proposed for these metrics, could be instrumental in studying the advantages of increased female involvement in scientific progress, as demonstrated by (Nielsen, Andersen, Schiebinger, & Schneider, 2017). Subsequently, seven indices were considered for the community metrics. *Gender ratio* quantifies the proportion of females to males, while *clan segregation*, *degree centrality*, *betweenness*, *closeness*, *degree*, and *eigen centrality* gauge the topological properties (Boccaletti, Latora, Moreno, Chavez, & Hwang, 2006) of the social network, reflecting the social inclusion of its members. It's noteworthy that each scientific community was treated as a social network, depicted as a graph where nodes represent authors and edges signify co-authorship relationships. Yang et al. (Zeng, et al., 2016) presented evidence suggesting the relevance of network centrality indices in assessing gender disparities, as they can also predict individual success.

The second dimension of the framework pertains to *attitude*, focusing on the psychological inclinations of community members. One potential metric is *susceptibility*, which is further delineated into *neighbour susceptibility* and *trend susceptibility* indices (D'Agostino, D'Antonio, De Nicola, & Tucci, 2015). The former measures the extent to which topics in an author's papers are influenced by those in their co-authors' ones, while the latter gauges the influence of these topics in conference papers as a whole. Another viable metric is *creativity*, defined as "the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)" (Sternberg & Lubart, 1999). This can be evaluated through the *novelty* and *combinational creativity* indices (Gero, 2000). Despite the controversy surrounding the assessment of gender differences in creativity (Abraham, 2016), these two indices offer new perspectives for analysing the creativity of community members.

The final dimension within the framework is *success*, focusing on the attainment of objectives. This dimension is linked to two metrics: *self-realization* and *empowerment*, which respectively gauge the fulfilment of individual potential and the level of power and authority granted to an individual. Empowerment metrics can be evaluated through various means, including the number of *prizes and awards* received, the frequency of *keynote presentations* delivered by a scientist, their *salary*, the roles they hold, and their *authority* (D'Agostino, D'Antonio, De Nicola, & Tucci, 2015). Authority measures the extent to which topics covered in an author's papers influence those in their co-authors' papers. Examples of roles or charges might include positions within an organization (e.g., Full Professor) or within a community. For instance, (Lerback & Hanson, 2017) provided evidence indicating that females are less frequently invited to serve as referees in the peer review process for scholarly publications compared to males. Lastly, self-realization metrics can be assessed by using bibliographic indices such as the *H-index*, *citation count*, and the *number of papers*.

Index	***Description***
Authority	Authority measures to what extent the topics in an author's papers influence the topics in his/her coauthors' papers.
Betweenness	Betweenness (B) (Freeman, 1978) measures how important were a node if all of them would try to communicate along the network by the shortest path. That is, supposing anyone sends a message to anyone, how many of such messages pass through a node.
Charges	Number of positions of responsibility for controlling or caring for something. Examples could be the role of a scientist inside an organization (e.g., Full Professor) or a community.
Citations	Bibliographic index that measures the overall number of times a researcher has been cited by other scientists.
Clan segregation	Clan segregation indicates the presence in a community of prominent clusters of researchers (i.e. clans) consisting of either only males or only females.
Closeness	Closeness measures the average harmonic distance for a member to reach any other member of the community (Bavelas, 1950).
Combinational creativity	Combinational creativity measures the ability of a researcher to combine different topics (Gero, 2000). It is given by the number of times he/she has been the one that combined two topics for the first time.
Degree	Number of coauthors of a member of the community.
Degree centrality	Degree centrality (D_{cen}) for a node is the fraction of nodes it is connected to. It is normalized by dividing by the maximum possible degree in a simple graph (n-1) where n is the number of nodes.
Eigen Centrality	Eigen Centrality (Bonacich, 1987) can be interpreted as the probability of news to reach a node upon spreading on the network.
Gender ratio	Gender ratio allows to measure the female to male ratio.
H-index	H-index is defined as the maximum value of h such that the given researcher has published h papers that have each been cited at least h times (Hirsch, 2005).
Keynotes	Number of *keynotes* held by a researcher.
Neighbour susceptibility	This index measures to what extent the topics in an author's papers are influenced by the topics in his/her coauthors' papers.
Novelty	Novelty measures the ability of a researcher to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)" (Sternberg & Lubart, 1999). It is given by the number of times he/she has been the one that introduced a topic for the first time.
Numbers of papers	Number of papers written by a researcher.
Polarity	Polarity captures the difference of attention paid by females and males to the topics. Polarity of a topic c_k is computed as following: $P(c_k) = P_m(c_k) - P_f(c_k)$, where $P_m(c_k)$ and $P_f(c_k)$ are the average semantic profiles concerning the topic c_k, respectively, of males and of females. Negative values

	of polarity correspond to the topics used mainly by females while positive values to those used mainly by males.
Prizes & awards	Number of prizes and awards won by a member of a community.
Salary	The salary received by a member of a community.
Semantic centrality	Semantic centrality measures to what extent the topics in an author's papers concern the key topics (i.e. the most popular ones) in the whole dataset of papers.
Semantic distance of genders	Semantic distance of genders allows to assess the diversity of semantic profiles relative to females and males.
Spread of gender trends	Spread of gender trends can be used to assess how focused the interests of each gender are.
Topics segregation	Topics segregation measures whether there are clusters of topics covered only by females or only by males.
Trend susceptibility	Trend susceptibility measures to what extent the topics in an author's papers are influenced by the topics in the conference papers as a whole.

Table 1. Summary of the indices as presented in (De Nicola & D'Agostino, 2021)

Due to the availability of new data and the difficulties to finding more of the original configuration, we re-structured the framework for gender divide assessment. In details, we have not considered the following indicators in our analysis: charges, salary, keynotes, and prizes & awards, for the empowerment metric of the success dimension; H-index, for the self-realization metric of the success dimension; topics segregation, spread of gender trends, and semantic distance, for the discipline metric of the context dimension. Conversely, we have considered the following new indicators: *sjr (sum)*, *sjr (average)*, *citations (sum)*, and *citations (average)* for the self-realization metric of the success dimension; and *subsystems*, *keywords (sum)*, and *keywords (average)* for the discipline metric of the context dimension. The descriptions of the new indicators are reported in Table 2, while Figure 8 shows the sunburst representation of the framework for gender divide assessment as used for the analysis of the energy transition community.

Index	***Description***
Citations (average)	Average citations per paper for a community member.
Citations (sum)	Overall citations for the papers written by a community member.
Keywords (average)	Average number of Scopus keywords annotating a paper for a community member.
Keywords (sum)	Overall number of Scopus keywords annotating papers written by a community member.
sjr (average)	Average sjr value for paper of a community member.
sjr(sum)	Overall sjr value for paper of a community member.
Subsystems	Overall number of subsystems covered in the papers of a community member.

Table 2. Summary of the new indices considered for gendered assessment of the Energy Transition community

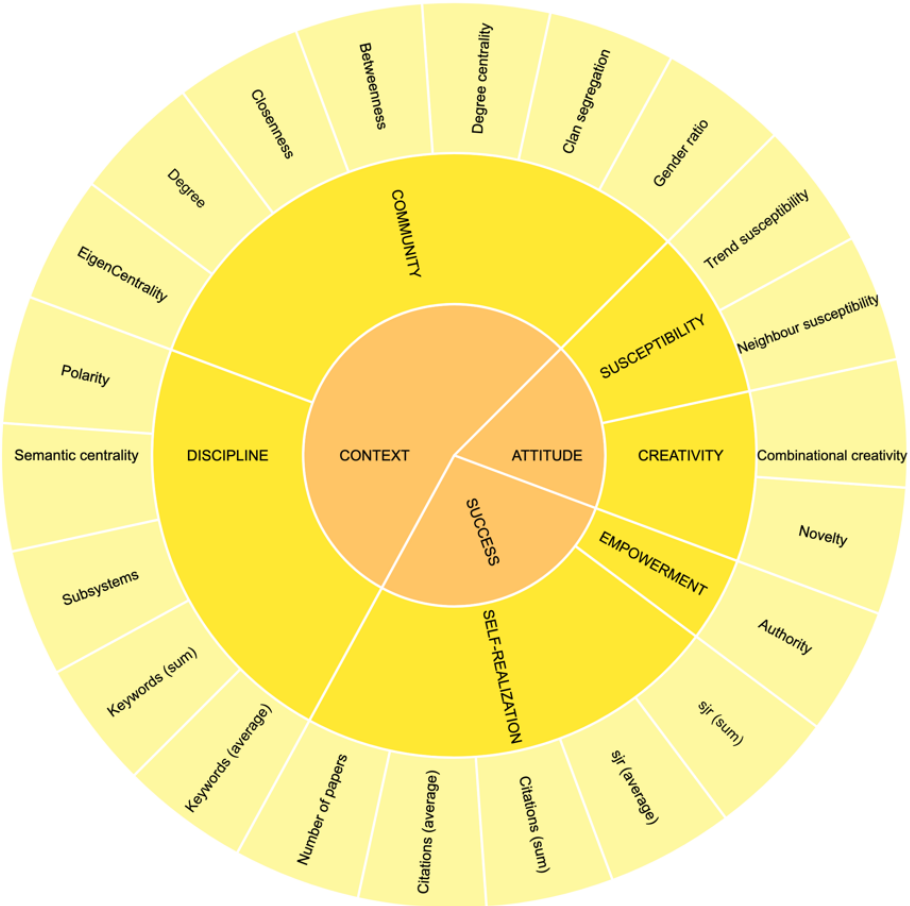


Figure 8. Sunburst representation of the framework for gender divide assessment as used for the analysis of the energy transition community and its subcommunities (i.e., environment, strategy, policy, behaviour, and operation).

2.5 Software and Methods used for Gendered Assessment

2.5.1 Disambiguation Manager

As already mentioned, the system we developed for gender disambiguation of authors is named "*Disambiguation manager*" (Guariglia Migliore, 2024). This was coded with the Python programming language and makes use of several tools. More specifically:

- **Scopus**[7], is the database from which, by means of keywords, the articles on which we carried out the analysis have been drawn.

[7] Scopus URL: https://www.scopus.com

- **Semantic Scholar**[8], is the system on which we performed the queries based on the DOI of the article to retrieve information about authors.

- The **Harvard WDGN dictionary** (Raffo, 2021), is the information source from which we will check the presence of the names and retrieve the gender probability for each one.

The Scopus database was created in 2004 by the publishing house Elsevier and covers approximately 240 disciplines and has more than 1.8 billion citations. It gathers information about more than 17.6 million authors. Its objectives include combating predatory publishing and increasing the impact of research. It also highlights emerging trends, informing users about the release of articles on topics they are interested in or publications by a certain author they follow. The more than 84 million records are updated daily in Scopus. It provides researchers with useful tools to quantify the impact of a scientist's research in a specific field.

Semantic Scholar was founded in 2015 as a project at the Allen Institute for AI, a non-profit research institute founded in 2014. It is a semantic search engine based on an information retrieval algorithm capable of understanding the meaning of natural language. It was created with the aim of complementing existing search engines such as Google Scholar or Pubmed but with one goal: to highlight correlations between articles by studying their underlying semantics. Semantic Scholar provides search tools and open resources for research in the global scientific community. There are more than 200 million indexed academic papers. It provides open-source APIs. Scientific articles and their authors are linked by citations. These relationships can be explored by including data about authors, citations, articles. It is possible to access the data in the dataset via queries that can be made in Python. The aim of Semantic Scholar is to build the Semantic Scholar Academic Graph (S2AG), which is a knowledge graph including information on papers, authors, and citations.

The HARVARD WORLD GENDER NAME DICTIONARY – WGND 2.0[9] is an information resource that provides information about the gender probability of a person given her/his first name. In includes 3 922 294 names and 4 970 295 records. Each record is structured as a 4-uple <`name, country_code, gender, gender_likelihood`>, including the first name, a country code (e.g, IT for Italy and FR for France), the gender, and its probability. For each first name there can be one or more records. The limitation of the Harvard dictionary is that although it is very extensive and complex, it does not include all names, in which case we must assign an undetermined value. From an analysis of the results, we determined that with the help of the Harvard dictionary alone, 15922 of 27363 authors in the Energy Transition domain are managed, which are those for which an exact name match can be found. Whereas for first names with two-string and for the three-string cases we can retrieve 8173 of them using the "*Disambiguation Manager*" that would otherwise be lost, and they represent about 30 % of the sample. It is not possible to manage and, hence, disambiguate the remaining 3268. The reasons for this may be either that those names are not in the dictionary, or that the names reported by Semantic Scholar are, for example, dotted and cannot be treated, or that they are actually ambiguous, consider the case where we have

[8] Semantic Scholar URL: https://www.semanticscholar.org
[9] For the sake of conciseness, we use "Harvard dictionary" in the rest of the deliverable.

the first token making up the first name of the feminine gender and the second token of the masculine gender.

The software architecture of "*Disambiguation Manager*" is shown in Figure 9. It consists of three modules, namely the (i) "*Orchestration module*", (ii) the "*Retrieve first name module*", and (iii) the "*Gender disambiguation module*", briefly presented in the following.

Orchestration module

The "*Orchestration module*" is devoted to orchestrating all the tasks performed by the software aimed at gender disambiguation. First, it allows access to the previously downloaded Scopus dataset and the Harvard Dictionary. Next, it allows communication with Semantic Scholar and, then, provides data to the "*Retrieve first name module*". Finally, it takes the final decision about the gender of an author based on the results of the "*Gender Disambiguation module*".

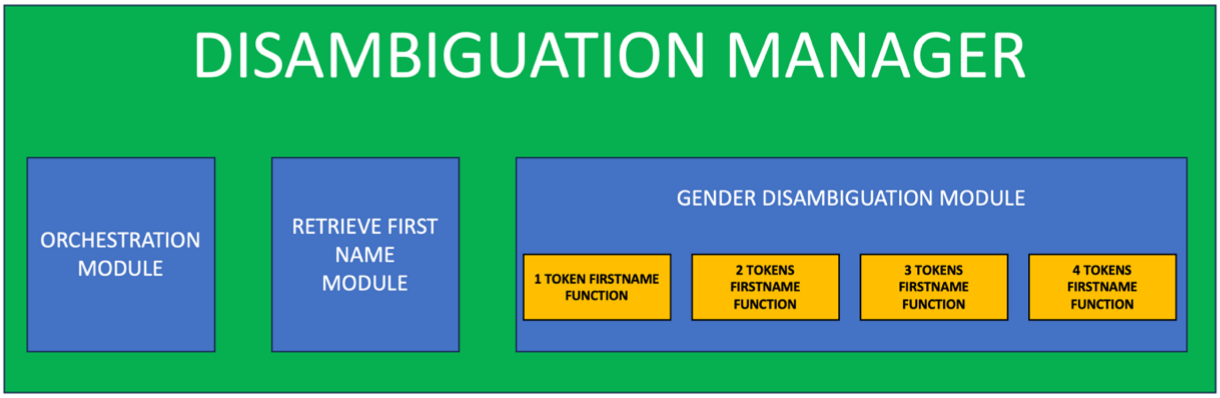


Figure 9. Software architecture of the "Disambiguation Manager"

Retrieve first name module

The "*Retrieve Firstname Module"* identifies the first name on which to perform the disambiguation. Aliases play a key role, because in some cases parts of the name may be dotted or incomplete, instead aliases provide us with several versions of the name and from these the module chooses the longest one thanks to a specific function. The selected portion of the string will then be handled to determine which part is the surname and which is the first name. In the first analysis, the module assumes that the last part of the string is the surname and the remaining part is the first name. Once this is done, we need to determine whether there is anything in the remaining part of the string to exclude, such as dotted parts of the first name that are not useful for analysis purposes, or any prefixes in the surname.

Gender disambiguation module

For each author, the "*Gender Disambiguation Module*" checks with the previously determined first name in which countries the name occurs and performs calculations to estimate a new gender probability based on the gender probabilities of the country.

Let us consider a first name consisting of 1 token. In this case, given a first name, the algorithm sums the probabilities for each gender for the various countries where the name is present and, then, computes the average that returns the probability for each gender (i.e., male, female, and undetermined).

If an exact match of the first name made of multiple tokens is not possible in the Harvard dictionary, the module executes different functions depending on the number of string tokens making up the first name. In this case, the module can handle first names up to 5 tokens.

Let us now consider a first name consisting of 2 tokens. The left part of Figure 10 shows the probability trees representing the possible cases. Given that F stands for female token, M for male token, U for undetermined token and the position in the t-uple (or the index) corresponds to the position of the string token in the first name, the possible cases are as it follows.

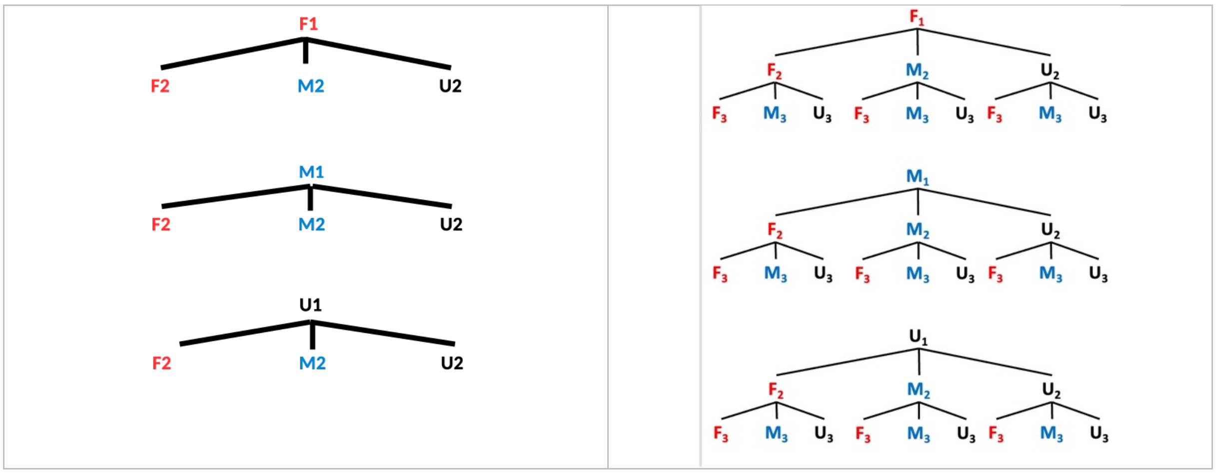


Figure 10. Probability trees for 2-tokens first names (left side) and 3-tokens first names (right sides).

Case of first token associated with female gender: <F1, F2>, < F1, M2>, and <F1, U2>.

- Case of first token associate with male gender: <M1, F2>, < M1, M2>, and <M1, U2>.

- Case of first token associated with undetermined gender: <U1, F2>, <U1, M2>, <U1, U2>.

Similarly, the right part of Figure 10 shows the probability tree representing the possible cases happening with first names made up 3 tokens. These are the following.

- Case of first token associated with female gender: <F1, F2, F3>, <F1, F2, M3>, <F1, F2, U3>, < F1, M2, F3>, < F1, M2, M3>, < F1, M2, U3>, <F1, U2, F3>, <F1, U2, M3>, and <F1, U2, U3>.

- Case of first token associate with male gender: <M1, F2, F3>, < M1, F2, M3>, < M1, F2, U3>, < M1, M2, F3>, < M1, M2, M3>, < M1, M2, U3>, < M1, U2, F3>, < M1, U2, M3>, and < M1, U2, U3>.

- Case of first token associated with undetermined gender: <U1, F2, F3>, < U1, F2, M3>, < U1, F2, U3>, < U1, M2, F3>, < U1, M2, M3>, < U1, M2, U3>, < U1, U2, F3>, < U1, U2, M3>, and < U1, U2, U3>.

The 2-tokens and 3-tokens first name functions calculate the gender probabilities as a compound probability in which the independent events are the genders of the individual tokens.

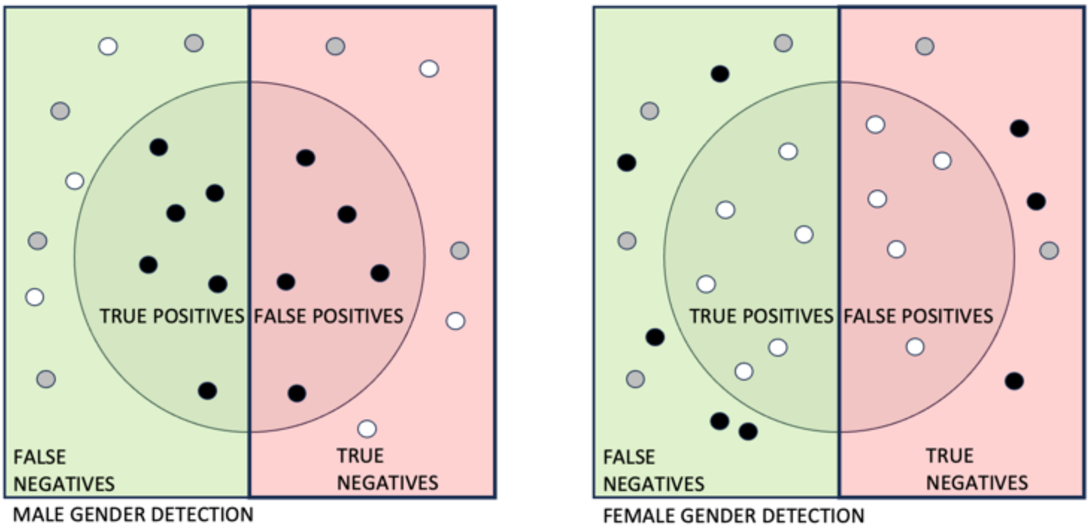
For instance, let's estimate the probability when the first name is Paul Maria. The probability that the gender is male is given by the probability the name Paul is associated with males multiplied by the probability that Maria is also associated with males.

Currently, for first names with more than 3 tokens, the Disambiguation Manager searches for exact matches in the Harvard dictionary. It is worthy to mention that this is a rare event in the Energy Transition dataset.

2.5.1.1 *Evaluation of Disambiguation Manager performance and software fairness*

To assess the quality of the "*Disambiguation Manager*", we computed the precision, the recall, and the F1-score of the actual capability of the software in disambiguating the gender from the first name.

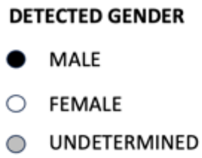
In general terms, precision represents the fraction of relevant occurrences (i.e., true positives) among all retrieved occurrences (i.e., positives). Recall, on the other hand, denotes the fraction of relevant occurrences (i.e., true positives) that were retrieved. F1-score represents the harmonic average of precision and recall and, symmetrically, provides a balanced representation of precision and recall in one metric. Figure 11 shows how precision and recall can be interpreted in the gender disambiguation experiment. We computed precision, recall, and F1-score for both males and females to determine a *threshold probability*, i.e., the probability above which we can confidently identify an author's gender. For benchmarking purposes, we analysed 1000 authors whose gender was validated by the project task force. Ideally, the ratio between male and female indicators should be close to 1, indicating equivalent performance for both genders. We observed this scenario when the threshold probability is 0.65 (see Figure 12). However, due to approximately 40% of authors remaining undetermined at this threshold, we opted for a more conservative choice of 0.5. By using this threshold and conducting additional human validation by the task force to ensure overall quality, we managed to further decrease the number of undetermined authors to 18.68%. This achievement represents a significant improvement compared to previous studies in the field, where the percentage of undetermined cases was around 70% (De Nicola & D'Agostino, 2021).



$$\text{PRECISION}_i = \frac{\text{TRUE POSITIVES}_i}{\text{TRUE POSITIVES}_i + \text{FALSE POSITIVES}_i}$$

i = males, females

$$\text{RECALL}_i = \frac{\text{TRUE POSITIVES}_i}{\text{TRUE POSITIVES}_i + \text{FALSE NEGATIVES}_i}$$



PRECISION AND RECALL

MALES	TRUE POSITIVES: males are correctly detected
	FALSE NEGATIVES: males are wrongly detected (hence, they are detected as females or undetermined)
	FALSE POSITIVES: females are wrongly detected as males
	TRUE NEGATIVES: gender is correctly detected as not male (hence, either female or undetermined)
FEMALES	TRUE POSITIVES: females are correctly detected
	FALSE NEGATIVES: females are wrongly detected (hence, they are detected as males or undetermined)
	FALSE POSITIVES: males are wrongly detected as females
	TRUE NEGATIVES: gender is correctly detected as not female (hence, either males o undetermined)

Figure 11. Precision and recall in the gender disambiguation experiment.

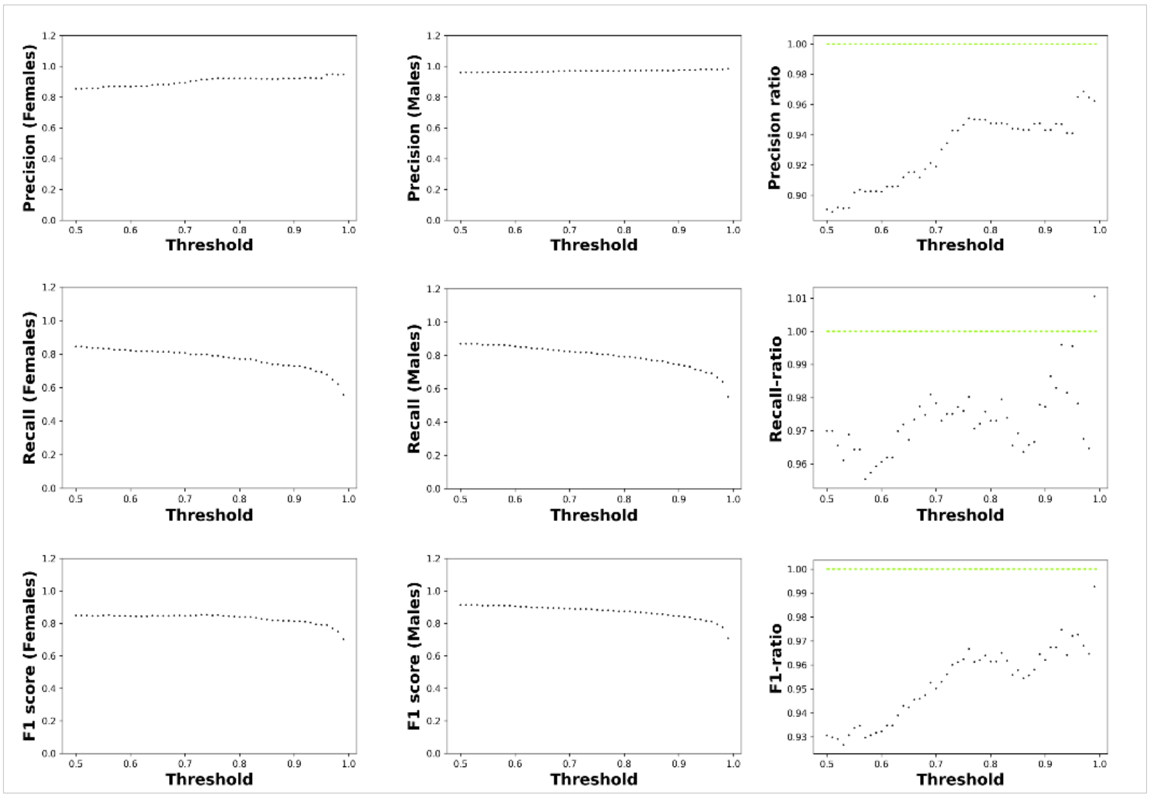


Figure 12. Precision, recall, and F1-score for females, males, and their ratio.

2.5.2 Software for Indicators Assessment

The method for indicators assessment that we follow in this analysis is described in (De Nicola & D'Agostino, 2021) and comprises the following key steps. Firstly, a domain ontology is extracted from a repository of raw data to delineate the research topics within the discipline. The second step involves identifying members by their names and determining the gender of each participant (see Section 2.3.3). Subsequently, expressions of interest of the members in various topics are inferred from their publications. The third step facilitates associating a dynamic semantic profile to each member of the social network for each year. Moving forward, a topological analysis of the social network is conducted using complexity science methods and techniques. Following this, susceptibility to trends, neighbours, and authority are estimated. However, this analysis is restricted to a subset of community members termed semantically treatable. Notably, only authors who have published in at least two different years and have exhibited a change in their interests over time are eligible for this analysis. For this purpose, we employed a software application called the "*attitude manager*", which is built upon the interest propagation model and related dynamics equations presented by (D'Agostino, D'Antonio, De Nicola, & Tucci, 2015). This model assumes that each member tends to maintain their beliefs, is partly influenced by one-to-one interactions with others, and is partly influenced by trends. The sixth step involves identifying creative members of the social network by detecting those who have introduced new topics or novel combinations of them. Lastly, the final step entails measuring success indices dependent on data availability, such as the number of papers and citations.

The method described above is facilitated by a suite of tools developed specifically for this purpose. These tools take natural language texts from conference papers as input and conduct an analysis of the semantic social network. Figure 13 provides a schematic overview of the architecture of the tool suite, which comprises five modules outlined as follows.

The software is primarily developed using Java and Python programming languages. While most of the modules were built from scratch, we also utilized various existing libraries. These include Apache Lucene, Colt, CommonsMath, and rdf4j for Java, and NetworkX and matplotlib for Python.

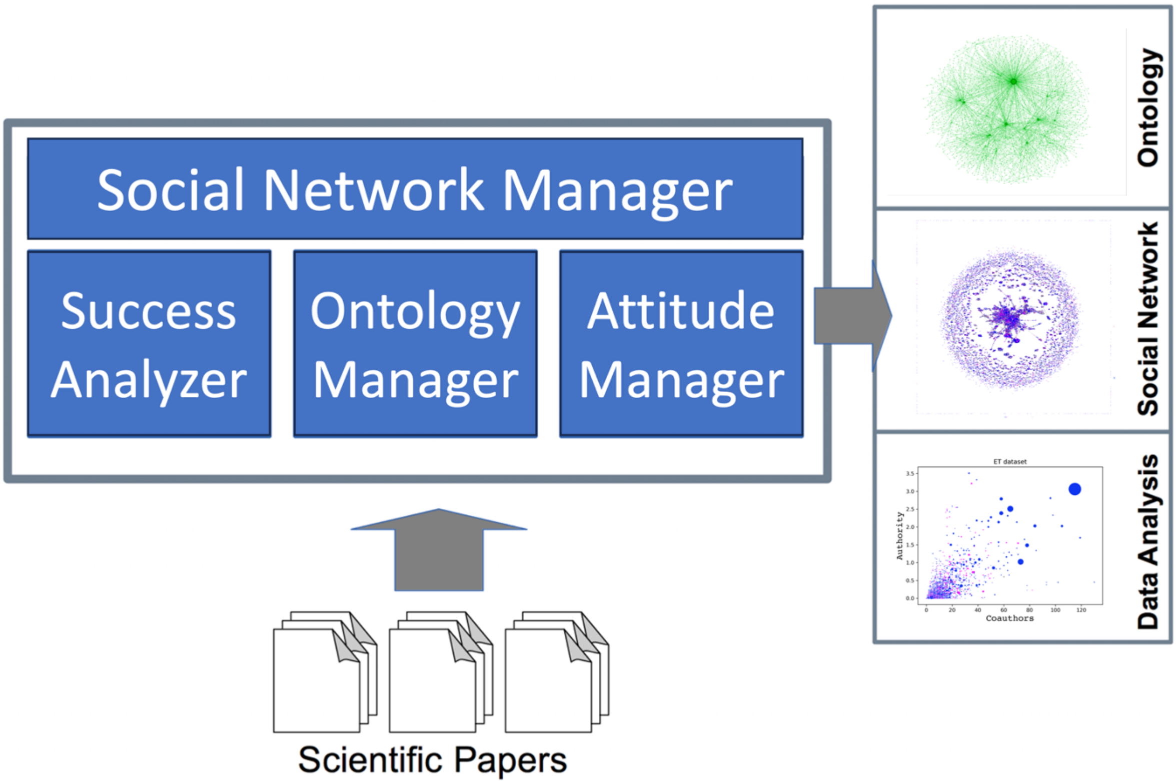


Figure 13. Architecture of the software for gendered assessment of scientific communities.

The "*ontology manager*" operates by taking the available paper titles as input. We opted to focus our analysis on titles because they typically encapsulate the main topics addressed in the papers. While other options exist for semantic analysis, such as utilizing keywords, it's important to acknowledge that authors' keywords may not always accurately reflect the paper's specific content. At times, they may encompass broader aspects of the field, potentially including topics unrelated to the paper's primary subject matter.

The ontology manager automatically extracts a collection of topics and, employing the incremental ontology engineering methodology UPON lite (De Nicola & Missikoff, 2016), establishes specialization and generic relationships between them. This module follows a defined workflow to generate an approximation of the set of fundamental topics that is described in (D'Agostino, D'Antonio, De Nicola, & Tucci, 2015).

The new ontology[10] was automatically saved in RDF (Resource Description Framework) and GML (Graph Modeling Language) for visualization purposes. Then, together with the gender manager, this module allowed to perform the gender-based assessment of the semantics of the field.

The "*social network manager*" derives the social network by examining the authors of the publications and constructs a graph accordingly. Whenever two scientists collaborate as co-authors on at least one paper, the social network manager establishes a connection within the graph. Next, the social network manager calculates various topological characteristics of the network, including closeness, betweenness, eigen centrality, and degree.

The "*attitude manager*" computes the susceptibility indices of treatable members within the social network using an algorithm based on information diffusion (D'Agostino, D'Antonio, De Nicola, & Tucci, 2015). Subsequently, it identifies community members who have introduced new topics or novel combinations thereof for each year within the considered time interval.

The "*success analyser*" conducts an evaluation of success, specifically estimating authority values for treatable members in the social network. Authority values are inferred from the susceptibility values of treatable members connected to them.

2.5.3 Methods for Statistical Analysis

This section outlines the statistical analysis conducted to determine the presence of a gender divide associated with a specific indicator. The statistical analysis can be viewed as examining the hypothesis of an actual gender divide in contrast to the "null hypothesis," which suggests no gender disparity exists. In certain instances, the analysis presents evidence supporting a gender divide, whereas in others, the distribution of females resembles that of a randomly selected sample.

For each indicator, we created a figure displaying the distributions of the average values obtained from random samples of equal size to the female group. For example, Figure 14 illustrates the distributions of sample averages of the *average citations* index for the energy transition community. This enables an estimation of the level of confidence regarding whether the observed deviations in the female group are statistically significant. Additionally, we present the average values of the same index for females, males, and undetermined. We generated 100 000 samples by randomly

[10] It is worth mentioning that this new ontology is different from the Energy System Ontology (ESO) and it was developed only to the purpose of internal operations aimed at gendered assessment.

selecting authors from each available community population. Typically, the vertical pink line, labelled with an F, depicts the average value of the indicator for females. The blue line, indicated by an M, signifies the average value for males; the grey line, denoted by U, signifies the average value for authors with undetermined gender; and lastly, the black line, labelled with an R, signifies the average value for the aforementioned random samples.

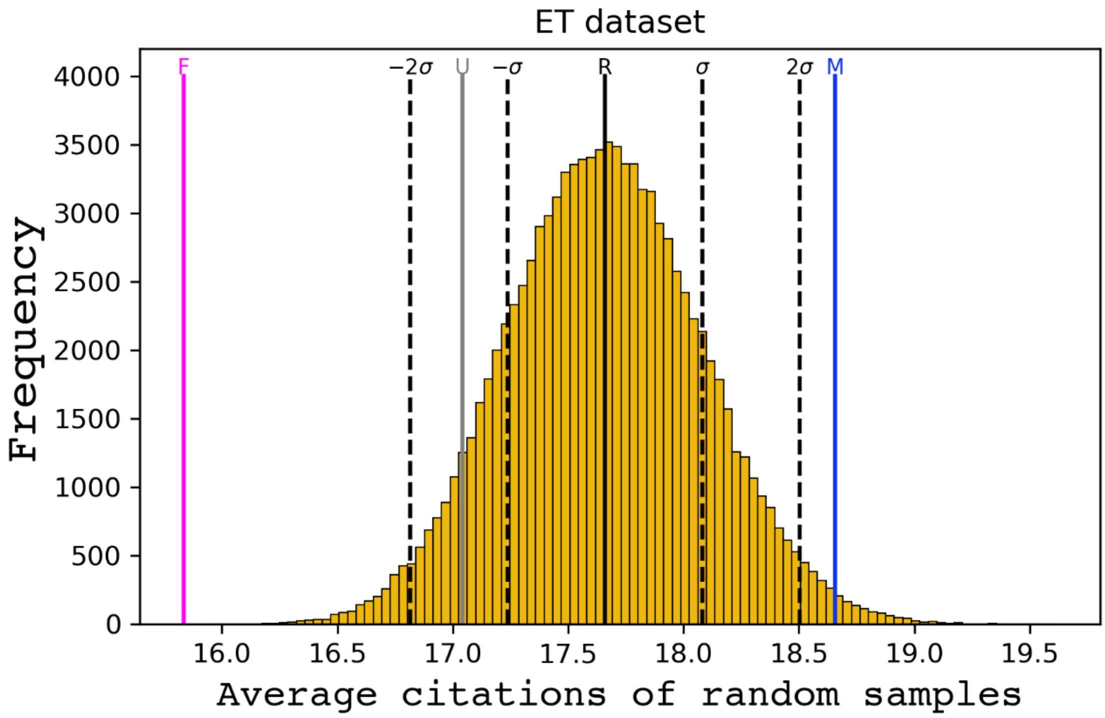


Figure 14. Distribution of sample averages of the average citations index.

To enhance clarity, dashed black lines corresponding to multiples of the standard deviation σ of the distributions are depicted in the figures and documented in the tables.

Subsequently, for each indicator, the Z-scores (z_F) (Stuart & J.K., 1987) of the female groups across different communities are provided. These scores represent the normalized deviations relative to the distribution of the random samples. It is worth noting that the Z-score serves as the effect size, where the mean of the experimental group corresponds to the average of values for members belonging to the female group, and the mean of the control group represents the average value (for that indicator) derived from 100,000 randomly generated samples of the same size as the female group. Specifically, we computed the average of values for each sample, resulting in the mean of the control group being the average of all 100,000 average values, and the standard deviation σ being the standard deviation of the sample distribution.

The *p-value* (i.e., the complementary cumulative distribution function) signifies the probability of having either a higher average indicator value if $\overline{ind_F} > \overline{ind_R}$ or a lower one if $\overline{ind_F} < \overline{ind_R}$. Thus, it quantifies the significance of the observed average indicator value for the female groups. Lower *p*-values indicate more significant deviations.

In this study, the hypothesis of a gender divide for an indicator was generally affirmed against the null hypothesis when the effect size exceeded σ/2.

However, this hypothesis was deemed highly significant if the effect size surpassed 5/2σ, significant if it fell between 3/2 σ and 5/2σ, and weakly significant if it ranged from σ/2 to 3/2σ. Conversely, it was rejected if the effect size was below σ/2.

2.6 Gendered Assessment of the Energy Transition Community

In this Section, we present the analysis conducted to assess whether there is gender divide in the Energy Transition (ET) community and in the subcommunities. To this purpose, we address several research questions outlined in the framework for gender divide assessment (De Nicola & D'Agostino, 2021) adapted here for the specific case of the energy transition community. The rest of this Section is organized as it follows. First, we introduce the mentioned research questions. Then, we show how the indicators of the framework for gender divide assessment may be used to answer them. Subsequently, we present the results of the assessment for each dimension of the framework. Finally, we discuss our findings and provide answers to the research questions in the subsection 2.7.

2.6.1 Research questions

This deliverable addresses the following research questions.

RQ1. As a group, are women and men equally successful?

RQ2. As a group, are women and men equally creative?

RQ3. As a group, are women and men equally key to the larger community?

RQ4. As a group, are women and men equally important in determining the future direction of energy transition research?

RQ5. As a group, do women and men study different topics?

RQ6. As a group, do women and men work with each other?

RQ7. As a group, do women and men have different sources of inspiration?

RQ8. Does the gender divide depend on energy transition subsystem?

Table 3 outlines the application of the gender divide assessment framework indicators to address the first seven research questions. However, answering the eighth question necessitates a comprehensive analysis of all indicators alongside a comparative evaluation of the results obtained for the five energy transition subcommunities.

	CONTEXT										ATTITUDE				SUCCESS					
	COMMUNITY						CONTEXT				SUSC.		CREAT.		EMP.	SELF.-REAL				
	EigenCentrality	Degree	Closeness	Betweenness	Degree centrality	Gender ratio	Keywords (average)	Keywords (sum)	Subsystems	Semantic centrality	Trend susceptibility	Neighbour susceptibility	Novelty	Combinational creativity	Authority	sjr (sum)	sjr (average)	Citations (sum)	Citations (average)	Number of papers
RQ1. As a group, are women and men equally successful?															■	■	■	■	■	■
RQ2. As a group, are women and men equally creative?													■	■						
RQ3. As a group, are women and men equally key to the larger community?	■	■	■	■	■	■				■										
RQ4. As a group, are women and men equally important in determining the future direction of Energy Transition research?	■	■	■	■	■								■	■	■					
RQ5. As a group, do women and men study different topics?							■	■	■	■										
RQ6. As a group, do women and men work with each other?												■			■					
RQ7. As a group, do women and men have different sources of inspiration?											■	■								

Table 3. Relationships between the research questions and the indicators of the framework for gender divide assessment

2.6.2 Results

Within this subsection, we present the findings pertaining to each dimension of the established framework, encompassing context, attitude, and success. For the sake of concision, the acronym "ET" will be employed throughout to denote the complete Energy Transition community, with further sub-divisions designated as "ET_env" for the environment subcommunity, "ET_str" for strategy, "ET_pol" for policy, "ET_beh" for behaviour, and "ET_ope" for operations. Please, refer to Table 4 for a comprehensive explanation of addressed communities and corresponding acronyms.

Community	Acronym
Energy Transition (whole)	ET
Energy Transition – environment	ET_env
Energy Transition – strategy	ET_str
Energy Transition – policy	ET_pol
Energy Transition – behaviour	ET_beh
Energy Transition - operation	ET_ope

Table 4. Communities addressed in the analysis and related acronyms

Table 5 shows the main data characterizing the Energy Transition community and its subcommunities. As mentioned in the previous sections, the whole dataset on energy transition includes 9097 papers and the time range spans from 2000 to 2023. The overall number of authors is 27363. 15522 are males and 6730 are females. Even if there are 5111 undetermined authors, the methods designed for statistical analysis in our study are still valid as they have been conceived to deal with such uncertainty in the data (see subsection 2.5.3). Automated ontology-based classification (see subsection 2.3.5) assigned each paper to one or more of the five established Energy Transition (ET) subsystems. Policy (3094) and strategy (2970) were the most frequently addressed subsystems, followed by operations (1525). Environment (776) and behaviour (732) received the least attention.

Community	Pap.	Period	Mal.	Fem.	Und.	Total	Ratio
Energy Transition (whole)	9097	2000-2023	15522 (56.73%)	6730 (24.60%)	5111 (18.68%)	27363	2.31
Energy Transition – environment	776	2000 -2023	1920 (53.14%)	857 (23.72%)	836 (23.14%)	3613	2.24
Energy Transition – strategy	2970	2001 -2023	6921 (62.48%)	2873 (25.93%)	1284 (11.59%)	11078	2.41
Energy Transition – policy	3094	2000 -2023	6571 (60.31%)	2919 (26.79%)	1406 (12.90%)	10896	2.25
Energy Transition – behaviour	732	2002 -2023	1627 (57.80%)	752 (26.71%)	436 (15.49%)	2815	2.16
Energy Transition - operation	1525	2000 -2023	3880 (58.43%)	1326 (19.97%)	1434 (21.60%)	6640	2.93

Table 5. Main data characterizing the Energy Transition community and its subcommunities. (Pap.: Papers; Mal.: Males; Fem: Females; Und.: Undetermined; Total: Number of overall authors; Ratio: Number of Males / Number of Females.)

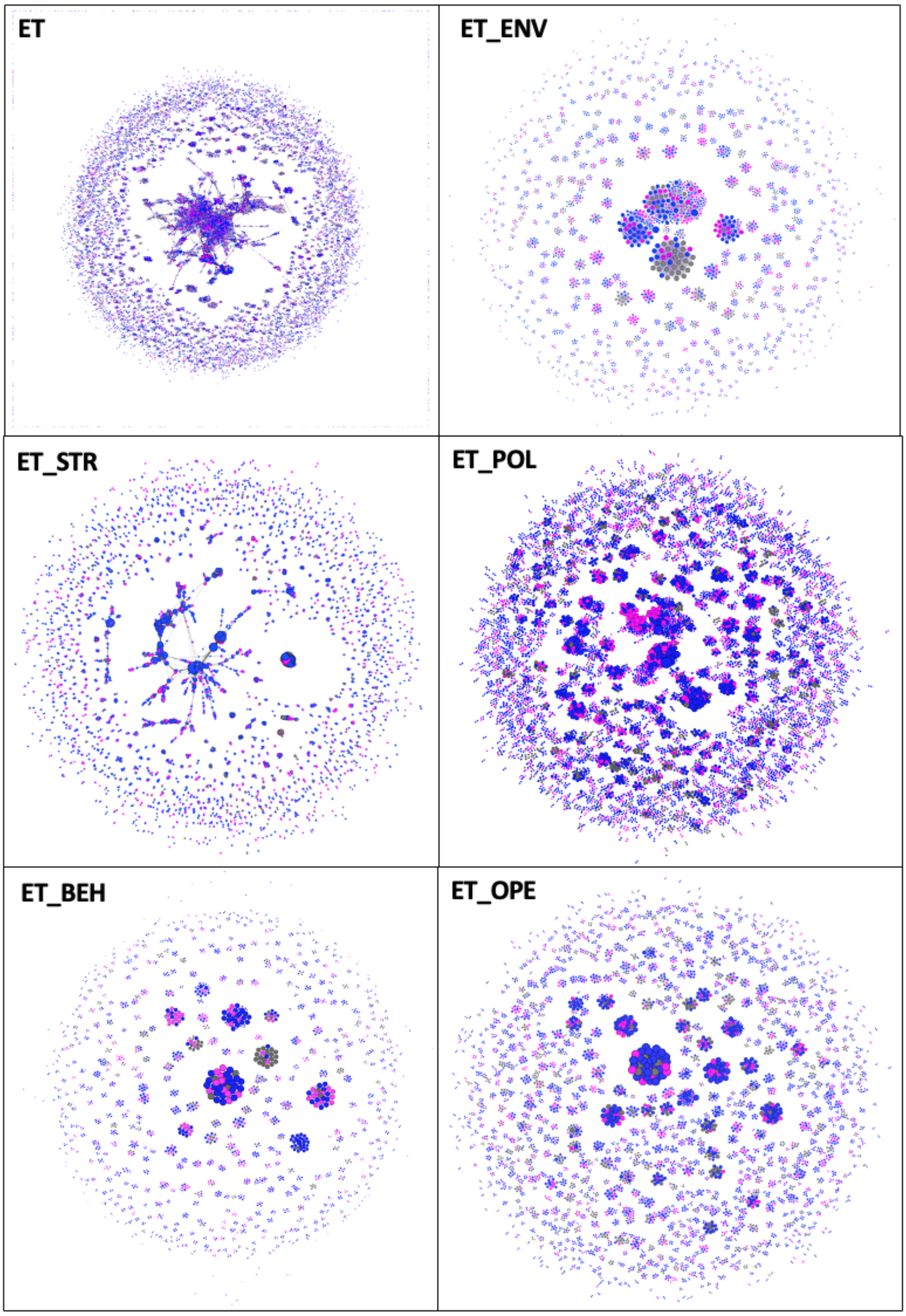


Figure 15. Network visualization of the Energy Transition (ET) community and its subcommunities: environment, strategy, policy, behaviour, and operations.

2.6.2.1 Results for the Context Dimension

The context dimension is associated with the discipline and the community metrics, which are presented in the following.

Discipline

To the purpose of discipline assessment, we considered four indices: polarity, semantic centrality, keywords (sum), and keywords (average).

This analysis employs topic **polarity** to unveil potential gender bias within communities. It explores whether specific topics resonate more with one gender than the other. We recall that a semantic profile is the set of interests of a member of the social network together with the corresponding weights (De Nicola & D'Agostino, 2021). For each topic c_k, we calculate its polarity as

$$P(c_k) = P_m(c_k) - P_f(c_k)$$

where $P_m(c_k)$ is the average semantic profile of topic c_k associated with males and $P_f(c_k)$ is the average semantic profile of topic c_k associated with females. To better interpret this indicator, it is worth to mention that negative values correspond to topics primarily used by females; positive values to topics primarily used by males; and values near 0 to topics used equally by both genders.

Figure 16 depicts the topic polarity across the Energy Transition community and its five subcommunities. Topics appearing in yellow rectangles indicate their neutral usage by both genders. Blue and purple rectangles represent topics primarily used by males or females, respectively.

We observe by evidence that in all the communities the fraction of topics treated only by males is larger than that treated only by females or both genders. Hence, our study reveals that there is a polarity issue in all the communities.

This analysis uses also **semantic centrality** to explore where authors concentrate their research within a field. This metric reveals whether an author leans towards mainstream topics or delves into more niche areas. For author h_i, her/his semantic centraility $\mathcal{SC}_{\hbar_i}$ is calculated as

$$\mathcal{SC}_{\hbar_i} = \sum_{c_k} L_{h_i}(c_k) \cdot L_s(c_k)$$

where $L_{h_i}(c_k)$ is the author's interest in topic c_k and $L_s(c_k)$ is the likelihood of finding information about topic c_k (De Nicola & D'Agostino, 2021). This score ranges from 0 (fully niche) to 1 (fully mainstream).

As shown in Figure 17, males address more mainstream topics by females. This is mainly due to the operation subsystems where there is clear-cut evidence that females treat fully niche topics (see Table 6). Conversely, it is interesting to observe that females treat more mainstream topics.

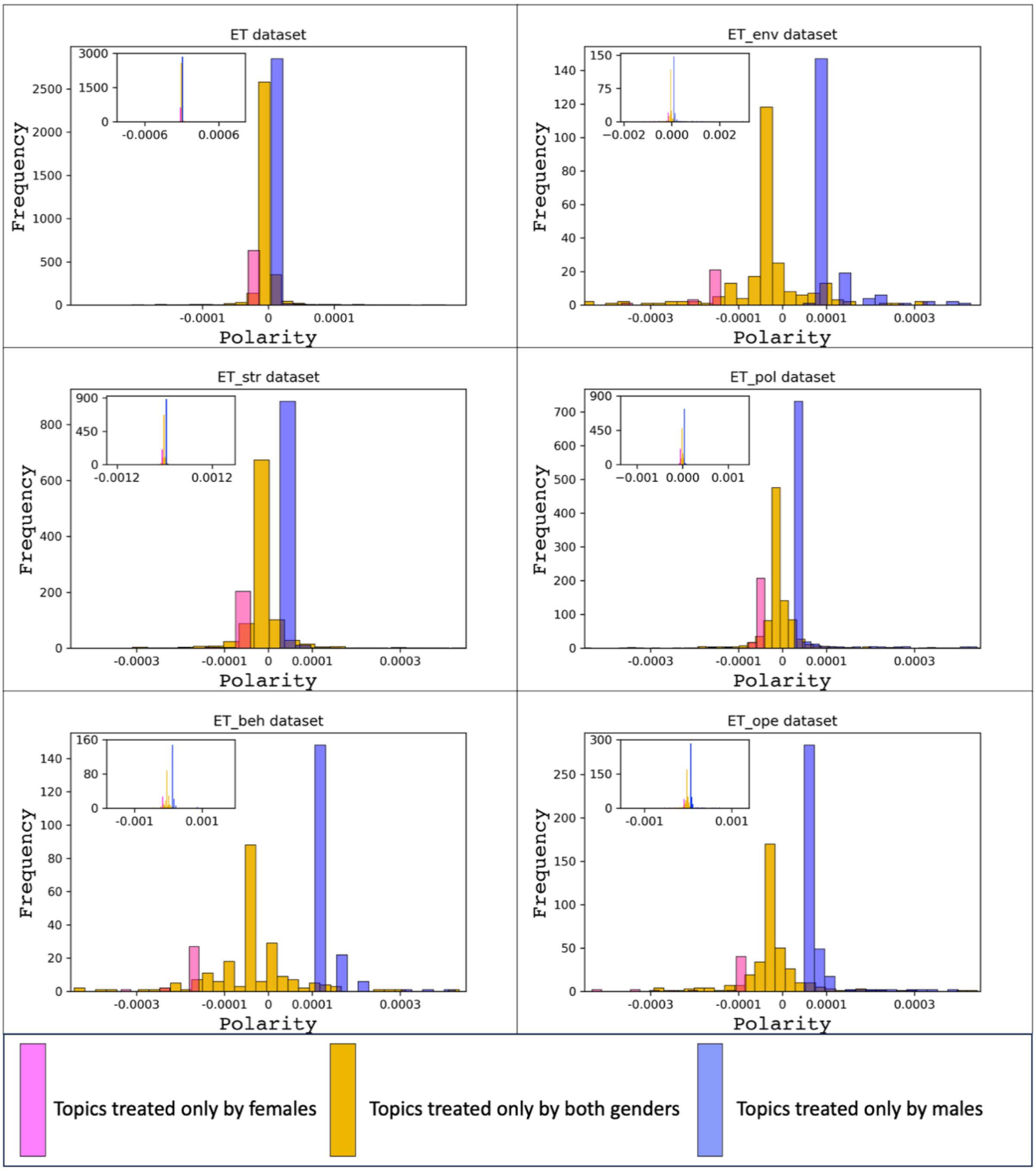


Figure 16. Polarity distribution of topics for the Energy Transition (ET) community and its subcommunities (environment; ET_env; strategy: ET_str; policy: ET_pol; behaviour: ET_beh; and operation: ET_ope).

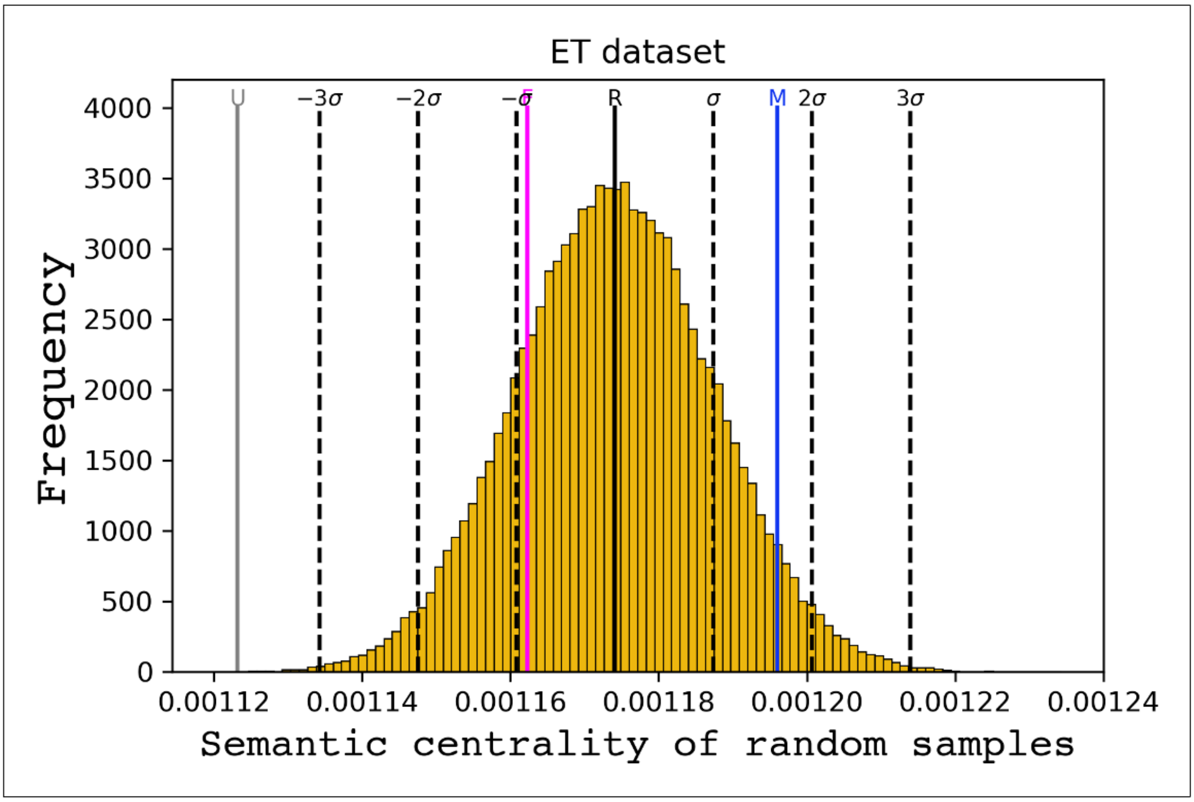


Figure 17. Distributions of sample averages of the semantic centrality index for the Energy Transition (ET) community.

Com.	Subsyst.	$\overline{SC_F}$	$\overline{SC_M}$	$\overline{SC_U}$	$\overline{SC_R}$	σ	z_F	p-value
ET	All	0.00117	0.00120	0.00113	0.00117	$1.4*10^{-5}$	-0.66	18.71 %
ET	Env.	0.00063	0.00060	0.00081	0.00065	$2.2*10^{-5}$	-0.59	28.00 %
ET	Str.	0.00102	0.00098	0.00062	0.00092	$2.1*10^{-5}$	4.56	100.00 %
ET	Pol.	0.00099	0.00094	0.00068	0.00090	$2.2*10^{-5}$	3.83	99.99 %
ET	Beh.	0.00074	0.00069	0.00059	0.00068	$2.8*10^{-5}$	1.91	97.14 %
ET	Ope.	0.00078	0.00094	0.00115	0.00094	$2.3*10^{-5}$	-7.01	0 %

Table 6. For each scientific community: $\overline{SC_F}$ is the average semantic centrality index value for females; $\overline{SC_M}$ is the average semantic centrality index value for males; $\overline{SC_U}$ is the average semantic centrality index value for undetermined authors; $\overline{SC_R}$ is the semantic centrality index value for the random samples; σ is the standard deviation of the different averages of the random samples; z_F is the Z-score of the standard normal distribution corresponding to the average semantic centrality index values for each female group; the p-value is the likelihood given by the complementary cumulative distribution function.

Table 7 presents two indexes related to keyword usage by gender: the **average number of keywords per paper** ($\overline{K_a}$) and the **average number of overall keywords** ($\overline{K_s}$). The former reflects the typical number of keywords an author uses in a single paper. The latter shows the overall number of keywords an author uses across all her/his papers.

Concerning $\overline{K_a}$, statistically significant differences between males and females were observed only for three subcommunities: environment, where the value for females is higher, and strategy and policies, where the value for females is lower. No significant differences in keyword usage were found for the other subcommunities or the overall energy transition community.

Concerning $\overline{K_s}$, statistically significant differences between males and females were observed only for the strategy and policy subcommunities and for the overall energy transition community. It is not statistically significant for the other subcommunities. In all these cases, the gender gap is in favour of males.

Com.	Subsyst.	Gender	$\overline{K_a}$	$\overline{K_s}$
ET	All	Females	2.76	3.44
		Males	2.77	3.57
		Undetermined	2.76	2.90
ET	Env.	Females	3.33	3.51
		Males	3.26	3.48
		Undetermined	3.09	3.14
ET	Str.	Females	3.57	4.09
		Males	3.73	4.48
		Undetermined	3.92	4.03
ET	Pol.	Females	2.26	2.54
		Males	2.33	2.66
		Undetermined	2.39	2.47
ET	Beh.	Females	3.27	3.43
		Males	3.33	3.51
		Undetermined	3.24	3.27
ET	Ope.	Females	1.86	1.93
		Males	1.84	1.95
		Undetermined	1.82	1.86

Table 7. Comparison of the average values of the keywords (average) and keywords (sum) indices

Community

The first index that we considered to the purpose of community assessment is gender ratio (see Table 5). As mentioned in the previous sections, we recognized the gender from the first names only of a limited number of authors. The overall energy transition community consists of 27 363 authors. In this community, the ratio between males and females is 2.31. The environment subcommunity encompasses 3 613 authors, followed by the strategy subcommunity with 11 078 authors, the policy subcommunity with 10896 authors, the behaviour subcommunity with 2 815 authors, and the operations subcommunity with 6 640 authors. It is worthy to note that an author could belong to one or more community. Among the energy transition subcommunities, "behaviour" has the lowest male-to-female ratio (2.16), aligning with its smaller gender gap. In contrast, "operations" has the highest ratio (2.93). Strategy, policy, and environment show ratios of 2.41, 2.25, and 2.24, respectively.

An analysis of the Energy Transition community and its subsystems reveals a disparity in female representation. This prompts investigation into whether the impact of female contributors is commensurate with that of their male counterparts.

Another crucial aspect of a community is its connectivity, or how closely its members collaborate. Within the Energy Transition (ET) community, we identified 4 782 clusters, which we aptly nicknamed "clans." Think of a clan as a group of authors who have all co-authored at least one publication together.

Among these clans, 50 stand out with particularly large sizes (over 19 members). These "prominent clans" act as bridges, connecting numerous researchers within the community. On the other hand, numerous smaller clans exist, bringing together smaller groups of authors who may have published fewer papers or primarily collaborated with a limited circle of colleagues. While prominent clans showcase the well-connected individuals within the community, smaller clans might represent researchers with more focused collaborations or those newer to the field.

Com.	Subsyst.	Persons	Clans	Clans (cs>19)	cs_{MAX}	$\overline{cs}$	σ_{cs}	$\widehat{H_c}$	$\widehat{H_{cF}}$	$\widehat{H_{cM}}$	$\widehat{H_{cU}}$
ET	All	27363	4782	50	6409	5.72	92.72	0.67	0.69	0.68	0.79
ET	Env.	3421	676	4	244	5.06	9.86	0.75	0.83	0.80	0.80
ET	Str.	9099	1833	24	1208	4.96	28.88	0.72	0.80	0.74	0.83
ET	Pol.	9290	2040	28	646	4.55	15.12	0.77	0.82	0.80	0.86
ET	Beh.	2666	643	6	35	4.15	3.36	0.79	0.87	0.83	0.84
ET	Ope.	6283	1339	11	47	4.69	3.73	0.80	0.90	0.83	0.85

Table 8. Summary of data concerning clans for each scientific community: community, overall number of persons (Persons), number of clans (Clans), number of clans with clan size (cs) higher than 19, maximum clan size, average clan size $\overline{cs}$, standard deviation σ_{cs} of clan size, normalized community entropy considering all genders ($\widehat{H_c}$), only females ($\widehat{H_{cF}}$), only males ($\widehat{H_{cM}}$), and only undetermined ($\widehat{H_{cU}}$).

Table 8 presents key statistics about the identified clans within each community. These statistics provide insights into the overall collaboration patterns and connectivity within each group. Here's a breakdown of the table columns:

- *Persons*: Total number of researchers in the community.
- *Clans*: Total number of identified clans within the community.
- *Clans (cs > 19)*: Number of clans with more than 19 members, considered "prominent clans" due to their larger size.
- cs_{MAX}: Size of the largest clan in the community.
- $\overline{cs}$: Average size of all clans within the community.
- σ_{cs}: Standard deviation of clan sizes, reflecting the spread of clan sizes within the community.
- $\widehat{H_c}$: Normalized community entropy, measuring the diversity of clan sizes within the community. We define $\widehat{H_c}$ as $\widehat{H_c} = \frac{H_c}{H_{c,max}}$ where $H_c = -\sum_i (p_{cl_i} \cdot \ln p_{cl_i})$ is the *community entropy*; p_{cl_i} is the probability of a researcher to belong to the clan *i*; and $H_{c,max}$ is the maximum entropy of the community. The latter is the entropy of a completely disconnected community where every clan consists of only

one researcher. The normalized community entropy spans the [0,1] range and measures the “state of disorder” of the community: 0 if all the researchers belong to only one clan and 1 if all the researchers belong to different clans (De Nicola & D'Agostino, 2021).

$\widehat{H_c}$ in Table reveals that operation subcommunity is the “less ordered" community. The strategy and policy subcommunities have the largest clans. Then, analysis of $\widehat{H_{cF}}$ and $\widehat{H_{cM}}$ values reveal comparable distributions for males and females across all clans within the energy transition community and its subcommunities. This finding supports the hypothesis of no significant **clan segregation** within these networks.

To analyze the other community assessment indices, i.e., betweenness, degree centrality, closeness, degree, and eigenvector centrality, we treated each scientific community as a network. Within this network, authors represent nodes, and co-authorship relationships form the edges (see Figure 5).

Com.	Subsyst.	Gender	$\bar{B}$	$\overline{D_{cen}}$	$\overline{Cl}$	$\overline{D_{all}}$	$\bar{E}$
ET	All	Females	$1.27*10^{-5}$	0.00020	0.008	5.72	0.0002
		Males	$2.14*10^{-5}$	0.00022	0.007	6.01	0.0004
		Undetermined	$0.13*10^{-5}$	0.00020	0.004	5.52	0.0003
ET	Env.	Females	$5.10*10^{-6}$	0.0019	0.0030	6.62	0.0010
		Males	$6.96*10^{-6}$	0.0018	0.0027	6.08	0.0008
		Undetermined	$0.6.2*10^{-6}$	0.0021	0.0028	7.13	0.0049
ET	Str.	Females	$0.60*10^{-5}$	0.00056	0.0034	5.10	0.0004
		Males	$1.65*10^{-5}$	0.00064	0.0036	5.85	0.0011
		Undetermined	$0.03*10^{-5}$	0.00060	0.0020	5.46	0.0012
ET	Pol.	Females	$3.68*10^{-6}$	0.00052	0.0015	4.87	0.00078
		Males	$3.46*10^{-6}$	0.00054	0.0013	4.97	0.00082
		Undetermined	$0.004*10^{-6}$	0.00050	0.0007	4.63	0.00004
ET	Beh.	Females	$1*10^{-7}$	0.00189	0.00198	5.02	0.0024
		Males	$2*10^{-7}$	0.00180	0.00193	4.80	0.0023
		Undetermined	$0.3*10^{-7}$	0.00200	0.00211	5.34	0.0016
ET	Ope.	Females	$2*10^{-8}$	0.00085	0.00092	5.35	0.00097
		Males	$6*10^{-8}$	0.00087	0.00094	5.45	0.00127
		Undetermined	$0.9*10^{-8}$	0.00082	0.00087	5.18	0.00055

Table 9. Comparison of the average values of the main centrality indices.

Betweenness (*B*) acts like a traffic controller in the research network. It measures how many "shortest paths" between researchers pass through a particular person. If someone sends a message to someone else, imagine all the possible routes it could take. Betweenness tells us how often a specific person's connections are on those fastest routes.

Males’ betweenness values are higher than those of females in the overall energy transition community and in the strategy, policy, behaviour, and operation subcommunities. This means that gender influences who plays a central role in connecting researchers in these networks. Conversely, we did not observe statistically significant betweenness differences in the environment subcommunity.

Degree centrality (D_{cen}) for a node is the fraction of nodes it is connected to. It is normalized by dividing by the maximum possible degree in a simple graph (n-1) where n is the number of nodes.

Degree centrality showa a gap in favour of males in the overall energy transition community and in the policy and strategy subcommunities. Differences of the average values of this indicator are not statistically significant for the behaviour and operation subcommunities. Conversely, we observed statistically significant degree centrality in favour of females in the environment subcommunity.

Closeness (*Cl*) is the average harmonic distance for a member to reach any other member of the community. Closeness is in favour of females in the overall energy transition community and in the environment and policy subcommunity. The differences are not statistically significant in the behaviour subcommunity. Conversely, we observed statistically significant closeness in favour of males in the strategy and operation subcommunities.

Degree (D_{all}) represents the number of co-authors of an author. When it is in favour of one group, it means that the members tend to publish with more co-authors.

Degree exhibits a gap in favour of males in the overall energy transition and in the strategy and policy subcommunity. Conversely, it is in favour of females in the environment subcommunity. Differences are not statistically significant in the operation and behaviour subcommunities.

Eigen centrality (*E*) can be interpreted as the probability of news to reach a node upon spreading on the network.

Eigen centrality shows a gap in favour of males in the overall energy transition community and in the strategy subcommunity. Differences are not statistically significant in the other subcommunities.

2.6.2.2 Results for the Attitude Dimension

Our analysis of the "attitude" dimension explored several individual characteristics of community members, including their susceptibility to the ideas of their peers and current trends, as well as their general creativity.

Susceptibility

The analysis of susceptibility examines individual characteristics within the community, focusing on how members interact with ideas and trends. We utilize susceptibility indices, which explore how an author's research interests evolve over time compared to their collaborators and the broader community. These indices rely on the idea that an author's topic choices can reflect their underlying "attitude." By treating the community as a semantic social network, we track the flow of research interests between individuals. Two distinct susceptibilities are measured:

Neighbour Susceptibility (x_i) gauges how much an author's interests align with their co-authors' shifting focus. Changes in their semantic profile (topics explored) are compared to changes in their collaborators' profiles, revealing the influence of direct interactions.

Trend Susceptibility (x_{is}) measures how an author's interests align with the broader community trends. Changes in their profile are compared to the average changes in all the papers of the considered community, indicating their receptiveness to prevailing currents.

The specific formulas for calculating these indices are detailed in (De Nicola & D'Agostino, 2021). However, it's important to note that we only apply them to authors who have published at least two papers across different years, i.e., semantically treatable authors, ensuring sufficient data for meaningful analysis.

Table 10 shows the average values of the susceptibility indices for semantically treatable values while Figure 18 and Figure 19 depict, respectively, the histograms of neighbour and trend susceptibility concerning the overall energy transition community and its subcommunities. Figure 20 shows the relationships between trend susceptibility, neighbour susceptibility, and authority (ball size) for authors having authority greater than average for the Energy Transition (ET) community and its subcommunity.

The difference between the average susceptibility to neighbours ($\bar{x}$) for males and that for females is not significant neither in the overall energy transition community nor in its subcommunities.

Conversely, the trend susceptibility of females is higher in three subcommunities: operation, behaviour, and policy. Hence, the general tendency for the authors of these communities is to be more influenced by trends than by co-authors. In the other subcommunities and in the overall energy transition community, the differences between males and females are not statistically significant.

Com.	Subsyst.	Gender	$\bar{x}$	$\overline{x_s}$	$\bar{a}$
ET	All	Females Males Undetermined	0.113 0.106 0.076	0.175 0.174 0.158	0.212 0.207 0.122
ET	Env.	Females Males Undetermined	0.064 0.099 0.145	0.160 0.159 0.175	0.214 0.124 0.171
ET	Str.	Females Males Undetermined	0.114 0.116 0.130	0.185 0.191 0.175	0.177 0.210 0.292
ET	Pol.	Females Males Undetermined	0.076 0.088 0.053	0.177 0.166 0.176	0.152 0.150 0.037
ET	Beh.	Females Males Undetermined	0.002 0.009 0.141	0.199 0.196 0.075	0.012 0.009 0.001
ET	Ope.	Females Males Undetermined	0.033 0.034 0.058	0.114 0.093 0.080	0.019 0.055 0.041

Table 10. Comparison of the average values of the susceptibility indices and authority for semantically treatable values. Average susceptibility to neighbours: $\bar{x}$; average susceptibility to trends: ($\overline{x_s}$); average authority: ($\bar{a}$).

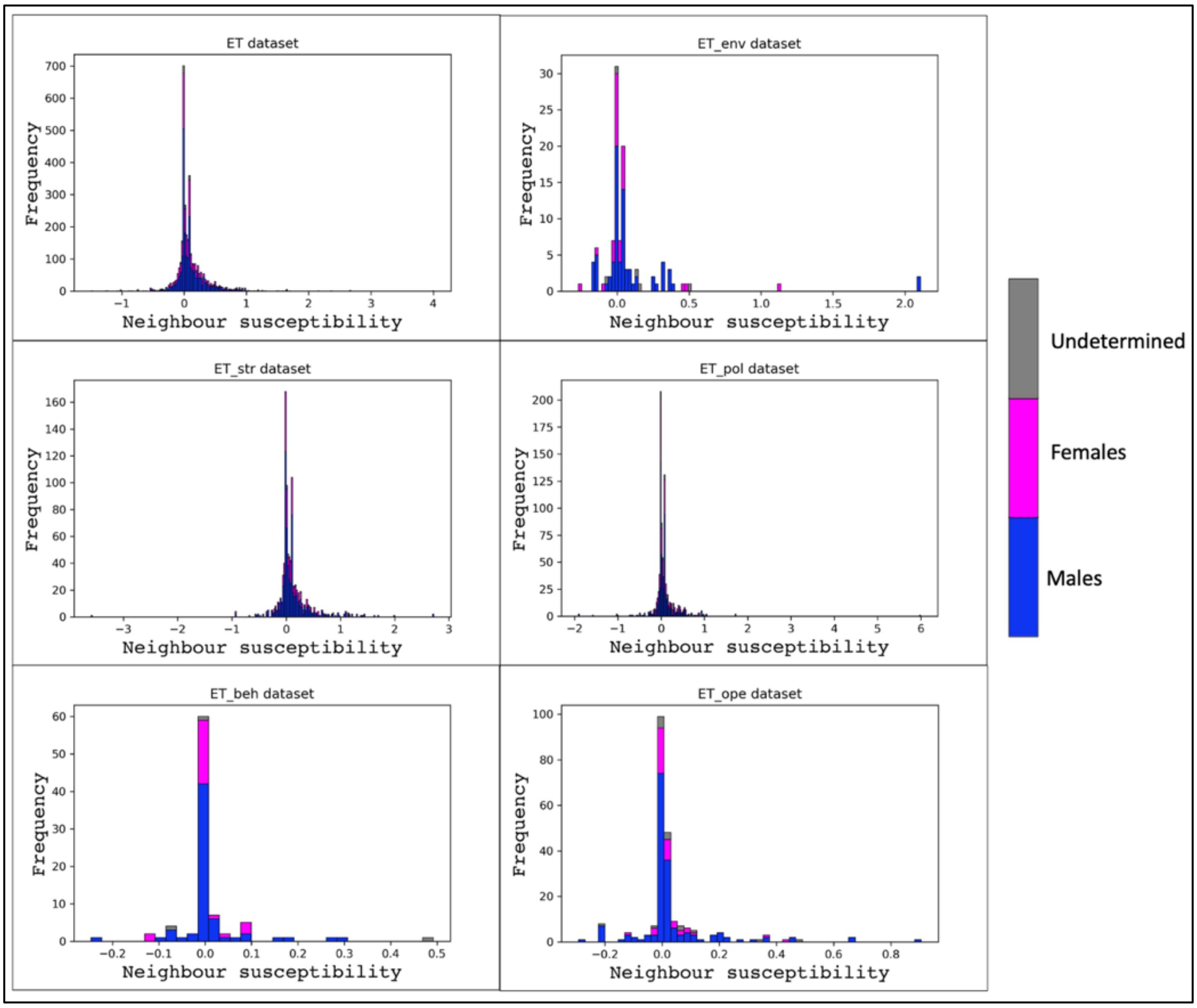


Figure 18. Histograms of neighbour susceptibility for the Energy Transition (ET) community and its subcommunities (environment; ET_env; strategy: ET_str; policy: ET_pol; behaviour: ET_beh; and operation: ET_ope).

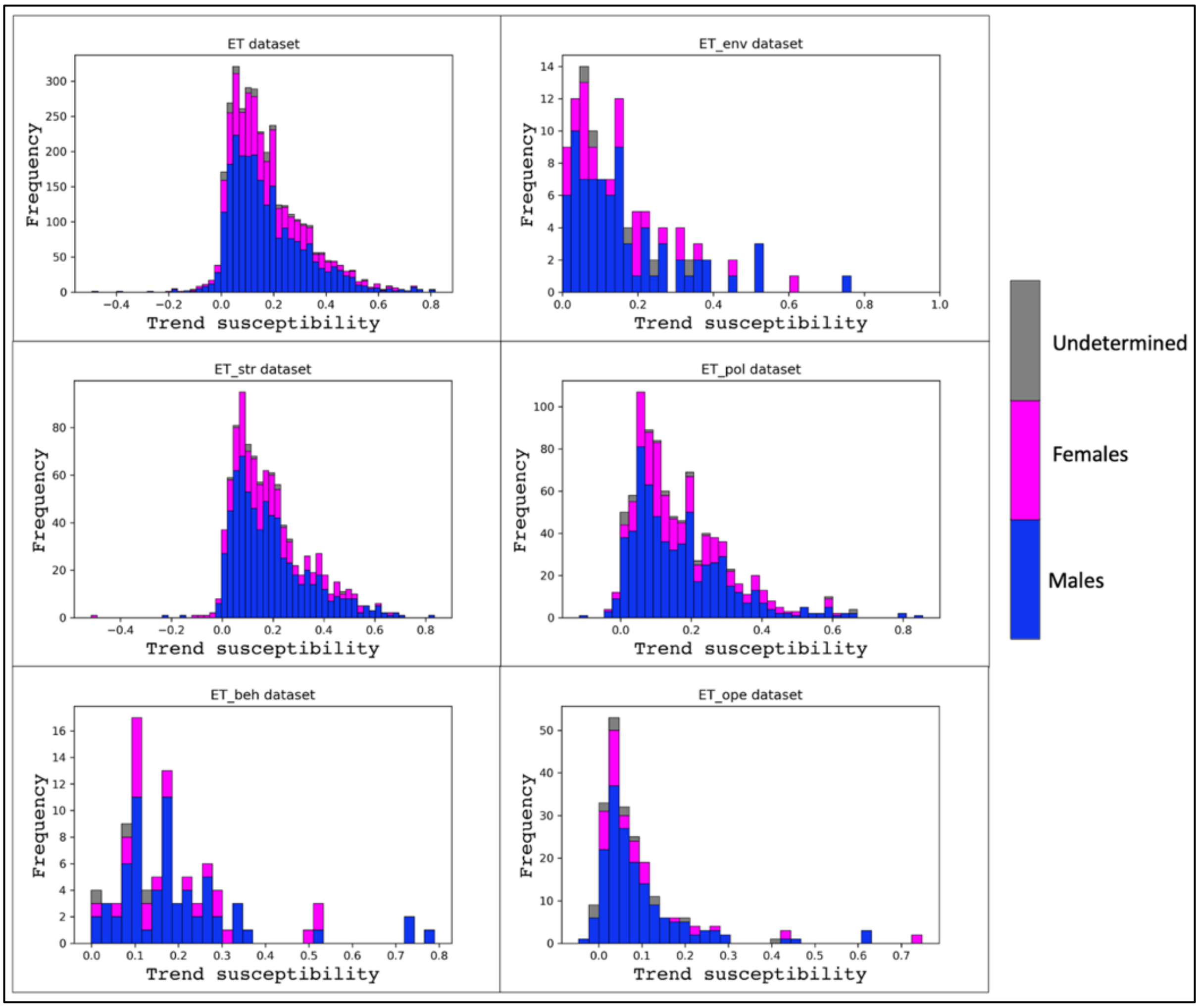


Figure 19. Histogram of trend susceptibility for the Energy Transition (ET) community and its subcommunities.

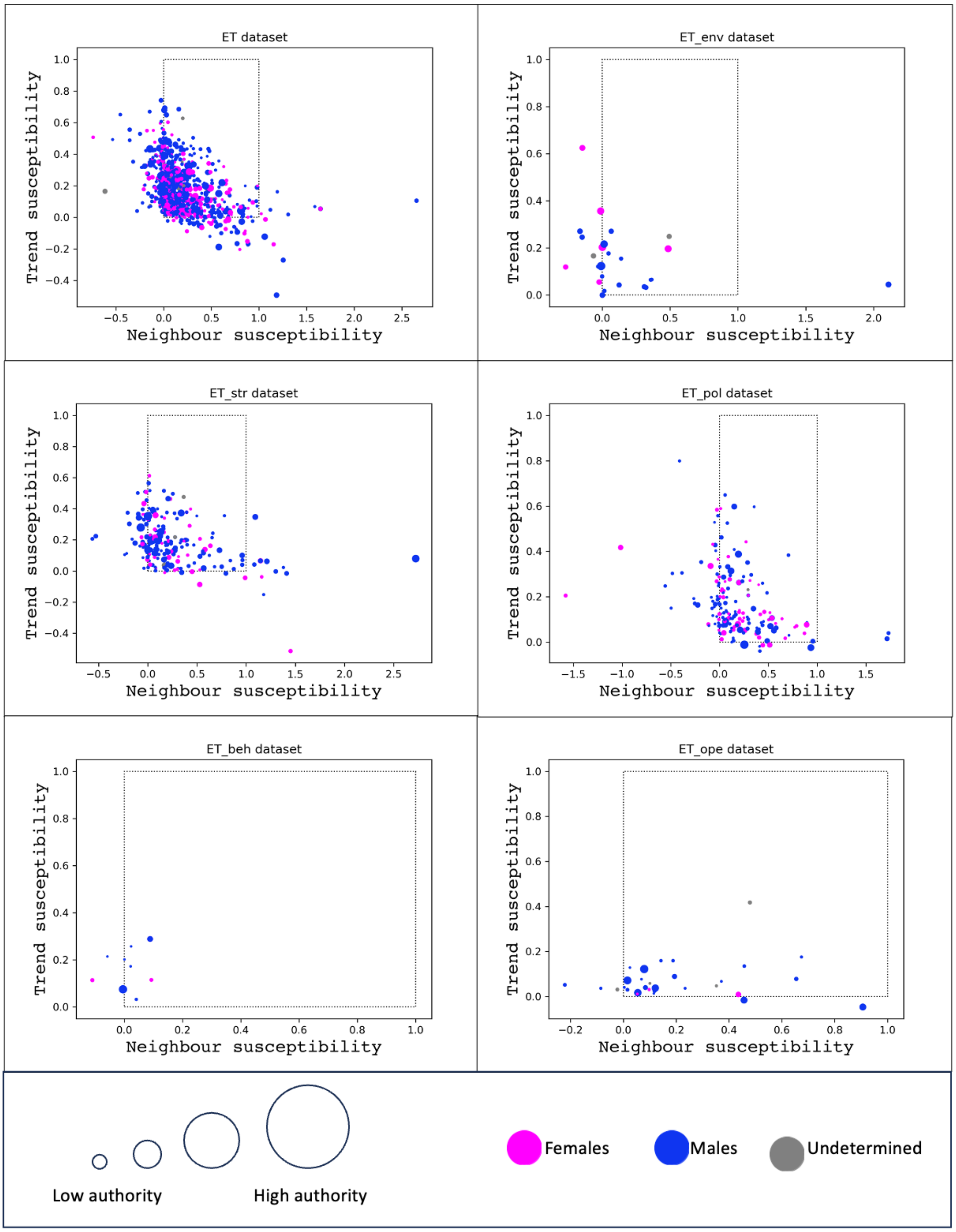


Figure 20. Relationships between trend susceptibility, neighbour susceptibility, and authority (ball size) for authors having authority greater than average for the Energy Transition (ET) community and its subcommunities (environment; ET_env; strategy: ET_str; policy: ET_pol; behaviour: ET_beh; and operation: ET_ope).

Creativity

Innovation and disruption in science require not only ground-breaking ideas but also the creativity to bring them to life. This analysis focuses on individual creativity by introducing two new metrics: **novelty** and **combinational creativity**. These go beyond traditional measures by capturing the originality of a scientist's work, even if its significance takes time to be recognized.

As a first step, we identified the "pioneers" in each year of the study period - the authors who were the first to introduce a new topic within the community. This paves the way for investigating combinational creativity, which delves into the ability to combine existing topics in unique and insightful ways. Along this line, we identified the authors that combined different existing topics first. Then, we compared the ratios of creative authors by gender with the general gender distribution of authors.

Table 11 displays the findings of our creativity analysis. Interestingly, females exhibit higher novelty-based creativity compared to males in the policy and strategy subcommunities, but lower in other subcommunities and the overall energy transition community. On the other hand, combinational creativity analysis reveals higher scores for females across all subcommunities and the overall community compared to males.

Com.	Subsyst.	Gender	Ratio (%)	$\mathcal{N}$ authors (%)	$\mathcal{C}$ authors (%)	$\overline{\mathcal{N}}$	$\overline{\mathcal{C}}$	$\overline{p}$
ET	All	Females	30.24 %	30.13 %	30.40 %	$3.65*10^{-5}$	$3.93*10^{-5}$	1.297
		Males	69.76 %	69.87 %	69.60 %	$4.04*10^{-5}$	$3.86*10^{-5}$	1.348
ET	Env.	Females	30.86 %	29.68 %	31.91 %	$3.25*10^{-5}$	$3.47*10^{-5}$	1.057
		Males	69.14 %	70.32 %	68.09 %	$3.70*10^{-5}$	$3.41*10^{-5}$	1.074
ET	Str.	Females	29.33 %	29.72 %	30.90 %	$3.68*10^{-5}$	$3.86*10^{-5}$	1.189
		Males	70.67 %	70.73 %	69.10 %	$4.22*10^{-5}$	$3.94*10^{-5}$	1.272
ET	Pol.	Females	30.76 %	31.33 %	31.64 %	$3.82*10^{-5}$	$4.38*10^{-5}$	1.178
		Males	69.24 %	68.67 %	68.36 %	$4.11*10^{-5}$	$3.86*10^{-5}$	1.205
ET	Beh.	Females	31.61 %	28.80 %	31.44 %	$3.31*10^{-5}$	$3.96*10^{-5}$	1.065
		Males	68.39 %	71.20 %	68.56 %	$4.13*10^{-5}$	$3.65*10^{-5}$	1.065
ET	Ope.	Females	25.47 %	23.69 %	25.80 %	$2.53*10^{-5}$	$2.94*10^{-5}$	1.047
		Males	74.53 %	76.31 %	74.20 %	$4.05*10^{-5}$	$3.85*10^{-5}$	1.072

Table 11. Results of the creativity analysis and average number of papers for the Energy Transition (ET) community and its subcommunities. $\mathcal{N}$ authors are the authors introducing novel topics. $\mathcal{C}$ authors are the authors introducing novel combinations of topics. $\overline{\mathcal{N}}$ is the average novelty index. $\overline{\mathcal{C}}$ is the average combinational creativity index. $\overline{p}$ is the average number of papers.

However, as such deviations are small and counting the number of creative authors does not consider to what an extent an author is creative, we defined two new indices as it follows.

The novelty index $\mathcal{N}$ measures to what extent an author contributes to the formation of the discipline by introducing novel topics. The novelty index of the author h_i is defined as

$\mathcal{N}_{\hbar_i} = \frac{1}{N_{c_k}} \cdot \sum_{c_k} \frac{\delta_{k,i}}{n_{c_k}}$ where $\delta_{k,i} = 1$ if the author h_i was one of the first authors to propose the topic c_k; $\delta_{k,i} = 0$ if the author h_i was not one of the first authors to propose the topic c_k; n_{c_k} is the number of the authors that first proposed the topic c_k; and N_{c_k} is the overall number of topics. This index spans the [0,1] range.

Similarly, the combinational creativity index $\mathcal{C}$ measures to what extent an author contributes to the formation of the discipline by introducing novel combinations of topics. The combinational creativity index of the author h_i is defined as

$$\mathcal{C}_{\hbar_i} = \frac{1}{N_{p_{kl}}} \cdot \sum_{p_{kl}} \frac{\delta_{p_{kl},i}}{n_{p_{kl}}}$$

where p_{kl} is the pair of topics (c_k, c_l); $\delta_{p_{kl},i} = 1$ if the author h_i was one of the first authors to propose p_{kl}; $\delta_{p_{kl},i} = 0$ if the author h_i was not one of the first authors to propose p_{kl}; $n_{p_{kl}}$ is the number of the authors that first proposed p_{kl}; and $N_{p_{kl}}$is the overall number of detected pairs of topics. Also, this index spans the [0,1] range.

According to the $\bar{\mathcal{N}}$ index, females are more creative in the overall energy transition community and in all the subcommunities. The $\bar{\mathcal{C}}$ index is in favour of males only in the operation subcommunity while it is in favour of females in the behaviour and policy subcommunities. The differences are not statistically significant in the other subcommunities and in the overall energy transition community.

Figure 21 depicts the scatter plots, concerning the overall energy transition community and its subcommunities, with the relationship between the novelty and the combinational creativity values.

2.6.2.3 Results for the Success Dimension

To understand how well scientists achieve their goals, we analysed the success dimension.

Empowerment

Following (D'Agostino, D'Antonio, De Nicola, & Tucci, 2015), we estimated the **authority** of semantically treatable authors (h_i) in the four communities by adding the neighbour susceptibility values (x_i) of their neighbours (i.e. coauthors) h_j: $a_i = \sum_{h_j \in N_{h_i}} x_j$, where N_{h_i} is the overall set of the co-authors of the author h_i. Table 10 presents the average values ($\bar{a}$) for females and males.

Authority is in favour of females in the environment subcommunity, while it is favour of males in the strategy and operation subcommunities. Differences are not statistically significant in the policy and behaviour subcommunities and in the overall energy transition community.

Figure 22 shows the histograms of authority distributions concerning the overall energy transition communities and its 5 subcommunities. Blue rectangles represent males, while purple ones represent females. The figure depicts that, within the environment subcommunity alone, female authority values exhibit a more uniform distribution across the whole range.

Figure 23 shows how author's authority relates to the number of papers published. The size of each circle indicates how many co-authors (degree) they have. Blue circles represent males, while purple ones represent females. The scatter plots in the figure tell us that while there's no obvious connection between author's authority and either the number of papers published or the number of co-authors (degree), it seems like degree has a stronger influence on authority than the number of papers. This is especially true in the environment subcommunity. So, one way to improve female authority might be to increase their network of collaborators rather than focusing solely on publishing more papers.

Figure 20 plots the relationship between two specific indicators, "trend susceptibility" and "neighbour susceptibility," for authors whose authority is higher than average. Again, the circle size represents authority. Here, we don't see any clear connection between authority and either of these susceptibility measures.

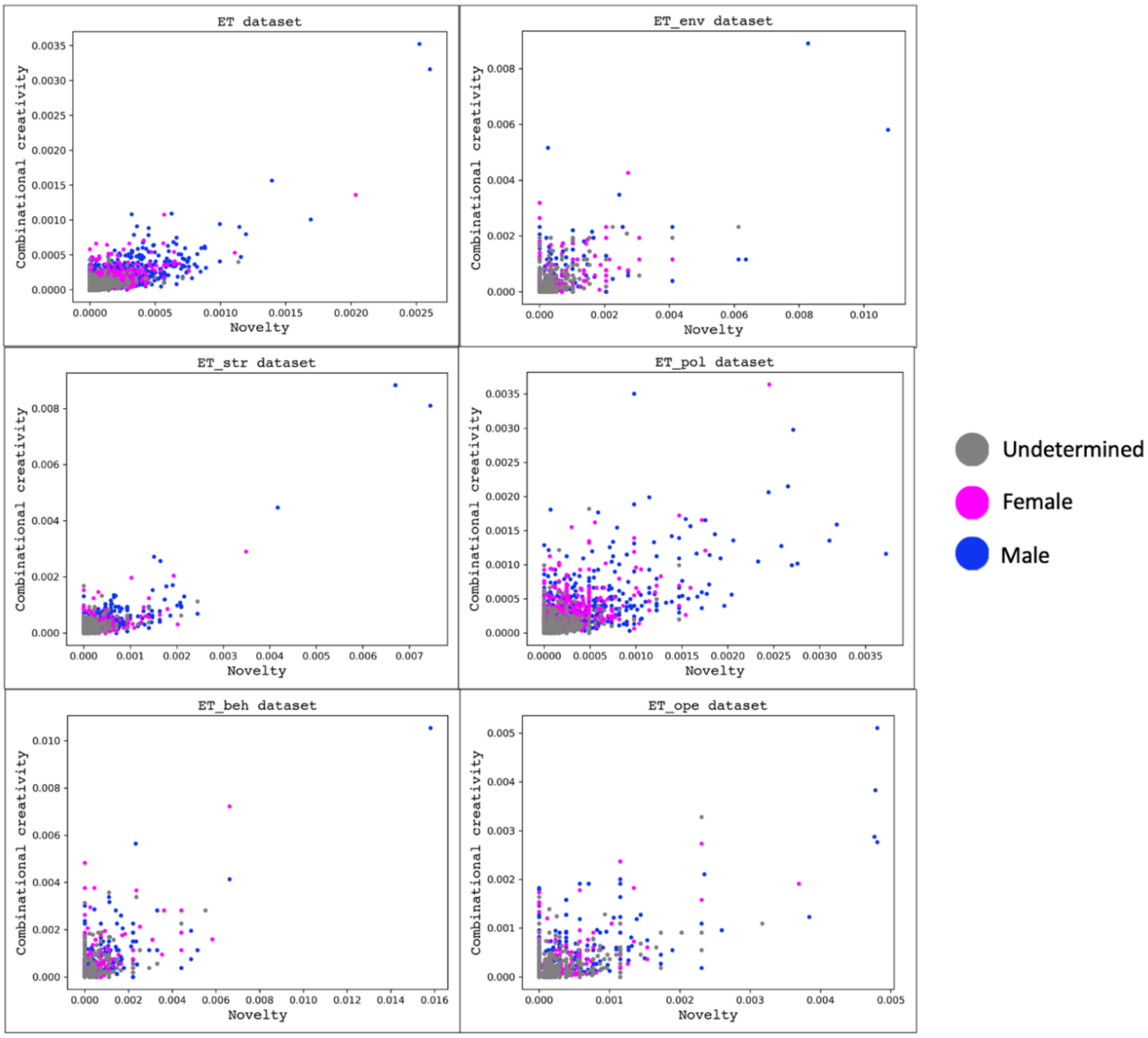


Figure 21. Relationship between novelty and combinational creativity for the Energy Transition (ET) community and its subcommunities.

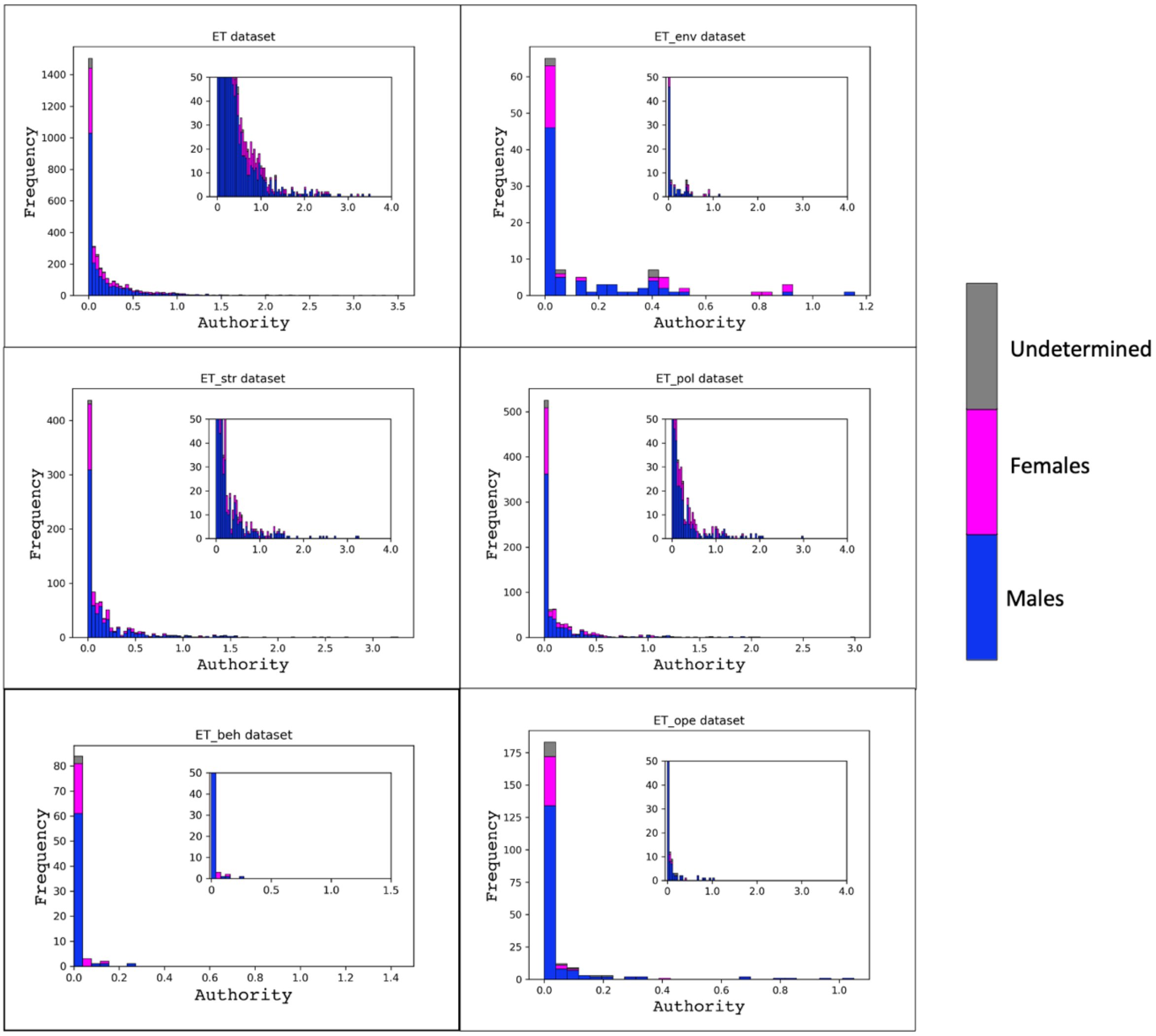


Figure 22. Histograms of authority for the Energy Transition (ET) community and its subcommunities.

Self Realization

The **number of papers** index (Table 11) concerns the number of papers written by an author. It is in favour of males in the overall energy transition community and in the environment, operation, strategy, and policy subcommunities. The differences are not statistically significant for the behaviour subcommunity.

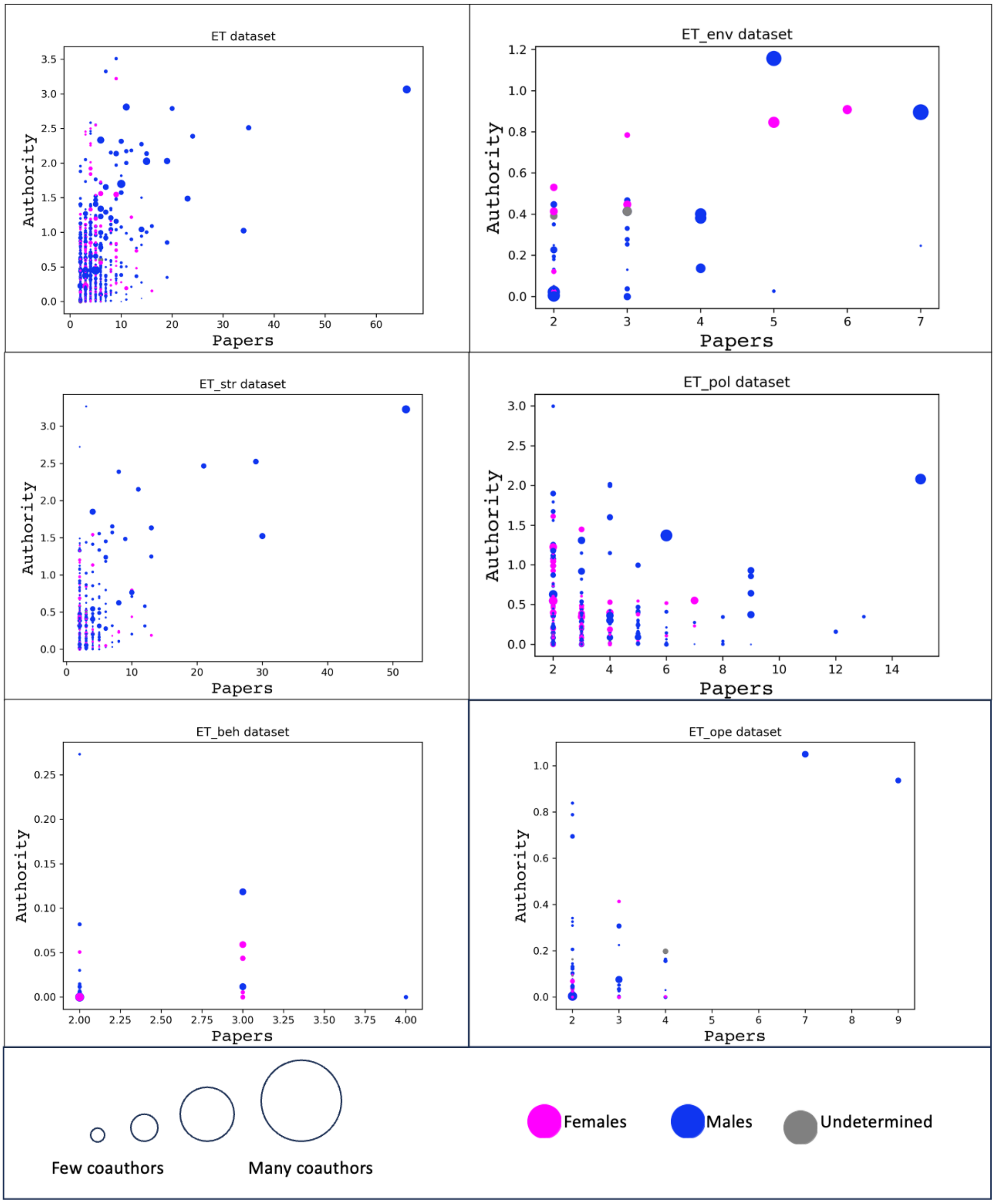


Figure 23. Relationships between authority, number of published papers, and coauthors (circle size) for the Energy Transition (ET) community and its subcommunities (environment; ET_env; strategy: ET_str; policy: ET_pol; behaviour: ET_beh; and operation: ET_ope).

Both the **average citations** ($c\mathcal{T}_a$) and the **overall citations** ($c\mathcal{T}_s$) indices (Table 12) are always in favour of males for the overall energy community and its subcommunities.

This means that papers written by males have more impact than those written by females.

Com.	Subsyst.	Gender	CT_a	CT_s
ET	All	Females Males Undetermined	15.83 18.66 17.04	21.97 28.09 18.10
ET	Env.	Females Males Undetermined	24.15 28.77 22.31	26.09 31.57 22.91
ET	Str.	Females Males Undetermined	16.13 19.57 15.25	20.12 27.84 15.68
ET	Pol.	Females Males Undetermined	13.65 15.45 15.36	17.08 20.92 15.94
ET	Beh.	Females Males Undetermined	14.45 17.60 15.49	15.93 18.90 15.65
ET	Ope.	Females Males Undetermined	18.05 21.77 18.08	19.29 23.53 18.45

Table 12. Average citations (CT_a) and overall citations (CT_s) for the Energy Transition (ET) community and its subcommunities (environment; ET_env; strategy: ET_str; policy: ET_pol; behaviour: ET_beh; and operation: ET_ope).

The **average sjr** (Table 13) is in favour of females in the overall energy transition community as well as in the environment, operation, and policy subcommunities. This means that females of these communities select and can publish in more selective journals. It is in favour of males in the strategy subcommunity. Differences in the behaviour subcommunity are not statistically significant.

The **overall sjr** (Table 13) is in favour of females in the environment and policy subcommunity, while in the strategy subcommunity this index is in favour of males. Differences in the overall community and in the behaviour and operation subcommunities are not statistically significant.

Com.	Subsyst.	Gender	s_a	s_s
ET	All	Females Males Undetermined	0.0261 0.0252 0.0246	0.0353 0.0358 0.0259
ET	Env.	Females Males Undetermined	0.0381 0.0358 0.0329	0.0414 0.0394 0.0336
ET	Str.	Females Males Undetermined	0.0262 0.0272 0.0252	0.0316 0.0360 0.0259
ET	Pol.	Females Males Undetermined	0.0243 0.0222 0.0182	0.0297 0.0279 0.0190
ET	Beh.	Females Males Undetermined	0.0247 0.0250 0.0258	0.0270 0.0269 0.0261
ET	Ope.	Females Males Undetermined	0.0265 0.0251 0.0250	0.0273 0.0267 0.0254

Table 13. Average srj and overall srj for the Energy Transition (ET) community and its subcommunities (environment; ET_env; strategy: ET_str; policy: ET_pol; behaviour: ET_beh; and operation: ET_ope).

2.6.2.4 Overall results

Table 14 and Table 15 summarize, respectively, the *p-values* for key indicators of gender diversity for females and a summary of gender divide direction ($GD_{\nearrow}$) for the other indicators where it was not possible to compute the *p-value*, across the entire energy transition community and its subcommunities.

ind$_i$	Description	*p-value ET (%)*	*p-value ET_env (%)*	*p-value ET_str (%)*	*p-value ET_pol (%)*	*p-value ET_beh (%)*	*p-value ET_ope (%)*
$\overline{\mathcal{SC}}$	Semantic centrality	18.71 %	28.00 %	100.00 %	99.99 %	97.14 %	0 %
$\overline{\mathcal{B}}$	Betweenness	3.97 %	55.59 %	0.4 %	55.71 %	25.60 %	8.66 %
$\overline{D_{cen}}$	Degree Centrality	3.45 %	79.40 %	0 %	39.35 %	66.57 %	46.06 %
$\overline{\mathcal{C}l}$	Closeness	100.00 %	93.08 %	57.30 %	100.00 %	53.45 %	43.74 %
$\bar{E}$	EigenCentrality	8.33 %	5.18 %	0.19 %	69.80 %	68.34 %	45.04 %
$\bar{\mathcal{N}}$	Novelty	45.89 %	4.55 %	58.81 %	87.61 %	10.03 %	0
$\bar{\mathcal{C}}$	Comb Creativity	100.00 %	18.33 %	93.07 %	100.00 %	90.83 %	0
$\overline{p_{all}}$	Number of papers	92.49 %	51.21 %	3.58 %	66.97 %	84.09 %	8.41 %
$\overline{D_{all}}$	Degree	3.54 %	79.54 %	0	39.44 %	0.26 %	45.88 %
$\bar{x}$	Neigh. susc.	79.01 %	35.83 %	46.32 %	34.20 %	28.83 %	47.79 %
$\bar{x}_s$	Trend susc.	64.11 %	51.40 %	31.65 %	84.00 %	61.11 %	85.31 %
$\bar{a}$	Authority	74.95 %	94.21 %	10.42 %	61.15 %	65.56 %	6.71 %
$\mathcal{CT}_a$	Citations (average)	0	11.46 %	0.47 %	2.16 %	2.38 %	0.83 %
$\mathcal{CT}_s$	Citations (sum)	0	12.00 %	0.02 %	1.00 %	6.64 %	0.95 %
K_a	Keywords (average)	42.71 %	94.02 %	0	0.72 %	31.96 %	68.29 %
K_s	Keywords (sum)	82.77 %	93.41 %	0	2.93 %	39.14 %	50.97 %
$\mathcal{s}_a$	sjr (average)	99.35 %	95.04 %	17.31 %	100.00 %	29.42 %	90.94 %
$\mathcal{s}_s$	sjr (sum)	99.26 %	95.67 %	1.38 %	100.00 %	56.92	80.25 %

Table 14. p-values for key indicators of gender diversity for females.

ind$_i$	*Description*	*GD↗ ET*	*GD↗ ET_env*	*GD↗ ET_str*	*GD↗ ET_pol*	*GD↗ ET_beh*	*GD↗ ET_ope*
$\mathcal{CS}$	Clan segregation	**F**	**F**	**M**	**F**	**F**	**F**
$\mathcal{B}$	Gender ratio	**M**	**M**	**M**	**M**	**M**	**M**
$\mathcal{P}$	Polarity	**M**	**M**	**M**	**M**	**M**	**M**

Table 15. Summary table of gender divide direction ($GD_{\nearrow}$) for polarity, topics segregation, and gender ratio. M represents the case there is gender divide and the indicator value is higher for males; EQ represents the case of gender equity.

Figure 24 and Figure 25 present a pictorial depiction of the assessment framework. Shaded areas in yellow signify gender equity, denoting statistically insignificant differences between men and women on an indicator. Conversely, shades of blue and pink highlight statistically significant gender gap, with blue representing areas where men have an advantage and pink representing areas where women hold the edge. To assess whether an indicator is in favour of a specific gender, we considered both the average values achieved by females and males. However, in some cases, high and statistically significant *p-values* existed for both genders due to the presence of authors with undetermined genders. In such instances, we chose to classify the indicator as representing gender equity, indicating no significant advantage for both genders.

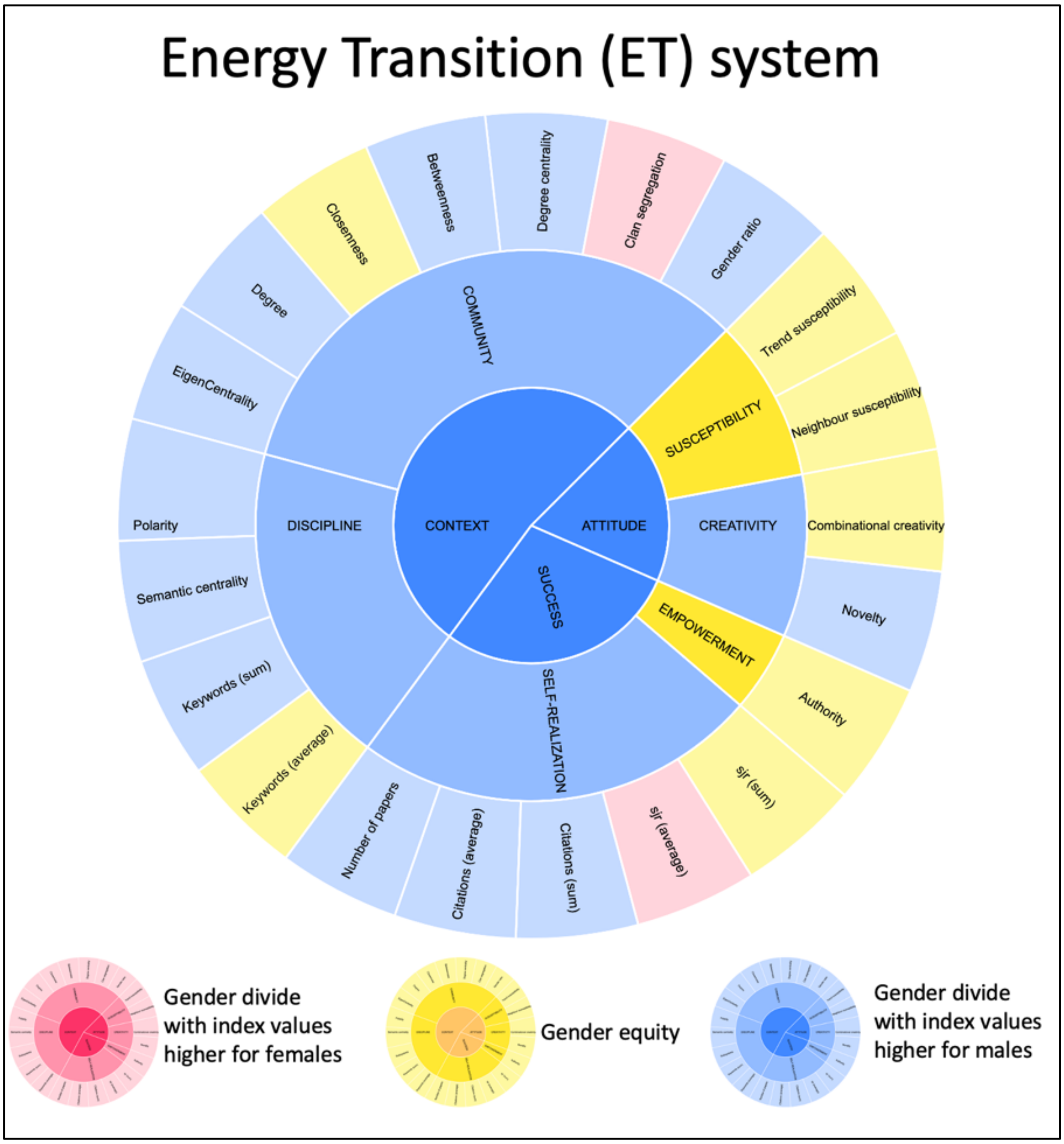


Figure 24. Results of the assessment of the overall Energy Transition (ET) community

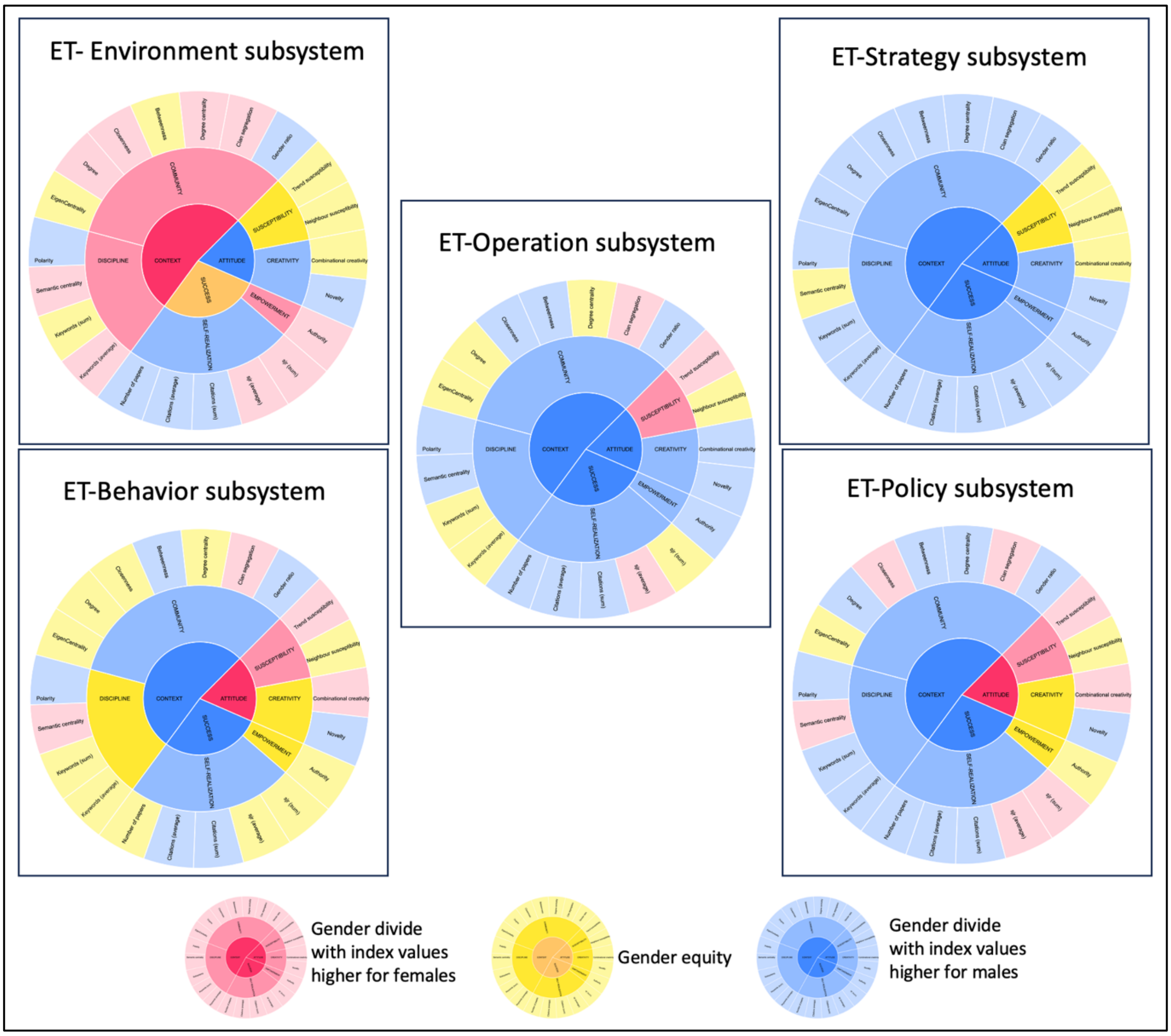


Figure 25. Results of the assessment of the Energy Transition (ET) subcommunities

2.7 Discussion

This section addresses the research questions using the results from our semantic network analysis. We will do this by:

- Summarizing the key findings for each research question in a concise comment;
- Highlighting the main topics that emerged from the analysis;
- Comparing our findings to similar studies (particularly in STEM fields) to provide context;
- Examining the differences between subsystems to identify potential variations;
- Suggesting areas for further investigation in future research.

RQ1: As a group, are women and men equally successful?

The sjr average registers a better result for women: they have a higher scientific influence in relation to men considering the higher level of the academic journals where they publish. On the contrary, in terms of citations of papers and number of papers realized, men register better results. The authority index is balanced, as well as the sjr sum.

In general terms it is possible to state that women are more successful on the quality, due to the scientific journals where they publish, while men are more successful on the quantity dimension (number of papers and citations).

This result is in line with similar studies, especially in the technical fields of research. According to (Meho, 2021), for example, if men record better performance for "average number of articles per year" and for "citations per article", women performances are more positive for the presence of their articles in the "top 25% journals per CiteScore" and in the "top 10% journals per CiteScore". Same results emerge in the study of (Lavelle, 2023), who focus on how men publish more than women and receive 30% more citations than women.

The quantitative analysis does not allow us to identify the reasons for this result. In the next steps of research, it would be useful to explore the following elements:

- the co-authorship of the papers where at least one woman is present: are also men present?
- the heterogeneity of "scientific relevance" of men: being men more than women, they also may have a certain heterogeneity in terms of scientific relevance (so in different stages of their academic career, and so they publish on different journals).
- the gap to enter in the community: is there an obstacle to be part of the community? So, can only women with a higher scientific relevance enter?

If we conduct an in-depth analysis for subsystems, we can observe that there are many differences with the sector of energy transition considered as a whole. The women influence on the co-authors is higher in the environment subsystem, but the influence of men is higher in the operation subsystem. Moreover, in terms of scientific journals, women are more successful in the environment, operation and policy subsystems, while men are more successful in strategy. Finally, in terms of citations, men register the best results in all the subsystems.

So, compared with the entire energy transition system, if men continue to have more success in terms of citations in all the subsystems, women are more influential in the environment subsystem, considering the possibility they have in influencing their co-authors.

RQ2: As a group, are women and men equally creative?

Men display higher creativity in introducing new topics within this research field. However, when it comes to combining existing topics, both genders exhibit equal levels of creativity. This suggests that women play a valuable role in ensuring research doesn't get siloed within diverse streams, by forging connections between different areas.

This means that men are more horizontally-oriented in terms of creativity, since they contribute to the introduction of new terms and it is possible to affirm that they set the agenda of the topics of interest. On the other side, women are more vertically-oriented: they have the ability to go more in-depth with (one or more) topic(s), not only giving a more complete vision, but also contributing at identifying unexplored fields of research. In this sense, they are multi-and interdisciplinary.

This result is in line with similar studies.

(Trapido, 2022), for example, affirms that research has shown that audiences penalize novelty in women's work (with different degrees), particularly in the production of technological and scientific knowledge. The author also emphasizes how, when authors possess status characteristics that are more task-relevant than gender (prestigious graduate degrees and prestigious mentors), this penalty erodes. Yang et al. (2022) on the other side, focus on how gender-diverse teams produce more novelty articles in terms of the re-combination of knowledge in new ways.

It would be useful to explore the following elements:

- The authority of men: what are their dimensions?
- The link between novelty and combinational creativity: is the novelty based on a previous combinational creativity activity?
- Resources of combinational creativity: what are their components? What are the contacts of women with other disciplines, are they influenced by other disciplines?
- Is combinational creativity "encouraged" by gender discrimination? (e.g. women are allowed to talk about already introduced topics)

Concerning the analysis of the subsystems, the environment and strategy register the same results of the energy transition system. Better results for women in terms of combinational creativity are registered for the behaviour and policy subsystem; on the contrary, men register better results for this indicator in the operation. The novelty indicator registers more positive results for men in all the subsystems.

So, in general terms, also from the analysis of the specific subsystems, it emerges that men contribute more than women in the definition of new topics, but in terms of topic recombination women are more creative, especially in specific sectors.

RQ3: As a group, are women and men equally key to the larger community?

The number of men is higher than the number of women. This also justifies the fact that they have more interactions in the network (and, also, more co-authors) and that they are more important than women to create the short paths among researchers in the network. This means that, if anyone sends a message or news to anyone, it is highly probable that they pass through a man. Moreover, men also cover the key topics of the field we are investigating. However, the difference between women and men in terms of closeness to the other nodes than men is not so high. This means that women tend to have central positions in the network, so they are in more crucial positions.

In general terms, we can affirm that the presence of men creates a distributed network model (with a similar importance of the different nodes of the network), while women tend to create a more decentralized network model (because some nodes – precisely represented by women – tend to be more important than others).

These results are aligned with previous research. For example, (Hajibabaei, Schiffauerova, & Ebadi, 2023) affirm that (in the AI domain) there is a women's under-representation in influential academic/scientific network positions. However, the same research emphasizes how, regardless of gender, performance metrics (number of publications, citation counts, journal impact factor), being involved in more diverse research areas, and having a higher degree of internationalization play crucial roles in acquiring network positions with a high degree of centrality. These positions with a lot of direct connections may help researchers to access new opportunities. Moreover, there is a stronger impact of centrality among female social researchers, suggesting that they might gain more from their direct and distinct collaborators than male social researchers. This is complementary to prior research that found more weak ties in female scientists' collaboration networks compared to their male counterparts who tend to have more long-lasting and strong ties. The same study also emphasizes subtle differences between female and male researchers when influential researchers are defined based on their number of close collaborators and the degree of reachability (higher closeness centrality).

To go deeper with this analysis, the specific topics covered by men and women should be investigated in more details (if, for example, there are some specific topics on which women are more key than men and if women create community around specific topics). The analysis of the subsystems plays an important role to answer these questions. In general terms, the subsystem more representative of the entire energy transition sector is the strategy subsector, where the men are key for the community in all the sectors. The subsystem where women are more key than men is the environment, where their situation for all the indicators improved compared to the energy transition system as a whole. Good results for women are also registered for the behaviour subsystem, where women and men are balanced in almost all the indicators, followed by the operation subsystem. Two elements need to be underlined:

- The gender ratio indicator is unbalanced in favour of men in all the subsystems;
- Even if in the policy subsystem men are generally more key than women, women are more key than men for two indicators, that is to say closeness and semantic centrality, so that they are closer than men to the other members of the community and more central in terms of treated topics.

RQ4: As a group, are women and men equally important in determining the future direction of energy transition research?

As already emphasized, in the investigated research field, men introduce new topics, are more present in the network and can contribute to spread messages through the network. Women and men are equally present in key positions in the network, and are equally useful to creatively recombine topics through a direct and qualitative interaction with researchers. Moreover, both men and women influence their co-authors in the same way.

In general terms, in the future direction of research, according to the results men and women would play different roles. The process would be: (1) men can set the "agenda" of the research topics; (2) women can play a more central role to identify the connections of the new topics with existing ones; (3) men spread the obtained results (and the related key messages) throughout the network; (4) women contribute to go more in depth by discussing results in specific internal and external communities. Of course, this process should not be linear as described.

The results are in line with previous studies. For example, in the work of (Santos, Horta, & Amancio, 2021) states that the research agenda preferences of women are less risky and less focused on fields likely to lead to scientific discovery, but are organized in a more collaborative way than those of men.

Additional issues to be addressed in future research:

- "The agenda of the research topics": how is it set? How are new topics introduced? Are they connected with a "recombination" of research topics?
- Is the recombination of research topics connected with external communities and disciplines? How recombination is possible?
- How the research results and messages can be spread throughout the network and with specific communities? Do women and men use different channels?

From the analysis of the specific subsystems, it seems that women are better positioned than men for the environment subcommunity in terms of their centrality, but the topics are still dictated by men. In the behaviour sector, women have good results in terms of being central for the network and contribute more than men in terms of topics (especially in relation to the combinational creativity indicator). The operation subsystem is the more male-oriented one in terms of topics men can spread. The strategy subsystem is the one which reflects more the orientations of the entire energy transition system. A particular attention needs to be paid to the policy subsystem. Indeed, if on the one side it is more male-oriented, there are two indicators in which women results are more positive: closeness and combinational creativity, so they give a higher contribution to orientate the topics, maybe due to their centrality in the related network.

RQ5: As a group, do women and men study different topics?

According to the analysis, men cover more topics of research, while women deal with more popular ones. The data analysis does not allow to identify if there is an overlap between the topics. However, we can imagine that part of these topics are the same.

In any case, the data collected in our study are coherent with similar studies. For example, a study of (Philipps, Weymann, & Kahmann, 2022) focuses the attention on how usually male applicants contribute to all research topics, while females are considered forerunners in a relatively narrow spectrum of research topics.

Additional elements that need to be investigated:

- real overlap between the different research topics;
- the reasons why women follow trend topics: is this connected with a lower authority than men?

From the analysis of the subsystems it emerges that women and men study different topics. If women are more oriented to the environment and behaviour, men are more oriented to operations and strategy. The policy subsystem registers balanced results.

RQ6: As a group, do women and men work with each other?

From the analysis it emerges that women and men equally influence and are influenced by their co-authors. The specific level of influence and how men are influenced by women and vice versa are not investigated.

(Holman & Morandin, 2019) affirm that researchers co-publish with colleagues of the same gender more often than expected by chance and show that this "gender homophily" is slightly stronger today than it was 10 years ago. Moreover, there is no evidence that homophily is driven mostly by senior academics, and that it is stronger in fields where women are in the minority. Journals with a high impact factor for their discipline tended to have comparatively low homophily, as predicted if mixed-gender teams produce better research.

In similar work it emerges that women and men collaboration is positive. For example, (Yang, Tian, Woodruff, Jones, & Uzzi, 2022) affirm that, even if gender-diverse teams are underrepresented in science, science teams made up of men and women are more novel and highly cited than those of all-men or all-women teams. These performance advantages increase the greater the team's gender balance and appear nearly universal.

Specific elements that need to be investigated in our research:

- Level of influence of co-authors;
- The specific influence of men on women and vice versa;
- The impact of gender diverse teams in research quality.

From the analysis of the subsystems it emerges that men and women equally influence and are influenced by their co-authors in the behaviour, the strategy and the policy subsystems, while in the environment subsystem women influence and are influenced by their co-authors more than men, and men influence and are influenced by their co-authors more than women in the operation subsystem.

RQ7: As a group, do women and men have different sources of inspiration?

From our research, it emerges that women and men are equally influenced by trend topics and by the topics of their co-authors. The way and level of influence by trend topics and co-authors are not explicitly investigated.

In the academic debate, there are no references to the different sources of inspiration between women and men. Maybe this topic is not crucial in the academic literature on gender divide in research; this is probably an expression of the fact that there are no substantial differences worthy of note.

Specific elements that need to be investigated in our research:

- Level of influence of co-authors;
- Level of influence of trend topics;
- The channels by which they are inspired;
- Is the concept of inspiration gender-based?

Same balanced results are registered in specific subsystems, which are: environment and strategy. Women are more influenced than men by trend topics in the behaviour, operation and policy subcommunities.

RQ8: Does the gender divide depend on the energy transition subsystem?

Gender divide definitely depends on the subsystem, as mentioned in the previous research questions.

The environment sector is the one where women register the best results. In particular, they excel in their presence in this specific domain, in the relations they have and in their empowerment and authority. However, here, the fulfillment of the individual possibilities as well as the ability to produce a work which is both novel and appropriate is still under male domain.

Women are influenced by their co-authors and by the trend topics in the behaviour subsystem. They also register good results in terms of the creativity in preparing novel and appropriate works.

Operation subsystem is a male domain in the energy transition. Here, men have a more favorable general context, influence others (including women) and are more successful.

Also, strategy is a male-oriented subsystem, as policy one. However, in the latter, women are particularly creative.

From the analysis it seems that the two more affected fields (environment and behaviour) are the ones that can be considered more interdisciplinary and also more connected with social sciences. In general terms, it seems that the fields of research traditionally addressed to women or men (that is to say that women are traditionally more oriented to humanities and social sciences while men more oriented to technical fields) have their representation in the energy transition field. However, women are achieving important results in the energy transition also in other subfields (for example, the policy one).

As defined, the topics related to our research questions need to be better explored. More in details, the analysis will be organized in the following steps:

- In depth analysis of the similar studies: literature review on the results emerged from the research questions;
- Definition of research hypothesis: exploring motivations under the results;
- Definition of new research questions and of the related methods (not only social network analysis, but also quantitative and qualitative social research methods – e.g.: focus groups, interviews, surveys, etc.- involving key informants and researchers).

2.8 Conclusion

This section of the deliverable presents the results of the gendered assessment of the energy systems knowledge community, which leverages complexity science and semantic analysis methods.

To ensure scientific replicability, we detailed our data sources, methods, and limitations stemming from data uncertainty. We structured our analysis around eight research questions for clarity, providing an intuitive snapshot of gender divide in our results through sunburst visualizations.

The analysis was repeated six times to have an overall picture concerning the energy transition knowledge community and its related subcommunities addressing the environment, the strategy, the policy, the behaviour, and the operation subsystems.

Unfortunately, the results of our study highlights that there is a strong gender divide in favour of males in most of the subcommunities and in the overall one. The subcommunity addressing the environment subsystem is the one more in favour of females, while those more in favour of males address the operation and strategy subsystems.

According to (University of Auckland), gender dynamics encompass the relationships and interactions between and among people, based on gender. The present analysis aims to provide an overview of the current status of these relationships between genders with no intention to reinforce them. We firmly believe that these relationships and interactions have the potential to evolve in near future. Indeed, in the coming years, we plan to repeat this assessment again to see whether the gender dynamics in knowledge creation and dissemination have changed positively. In such an event, we will see less blue, and more pink/yellow in the sunbursts, reflecting a positive and fairer progression in our society.

3 EU POLICIES FOR SUSTAINABLE ENERGY SYSTEMS

3.1 Introduction

In the last years, the topic of the relationship between gender and energy has received growing interest from both the academic world and policymakers. However, a research gap still exists in the empirical analysis of energy policy through a gender lens (Carroll, Singh, & Mangina, 2022). This is true especially for the Global North, where gender lenses for studying energy-related social dynamics were applied later compared to contexts of the Global South (Clancy & Roehr, 2003). The gender-energy nexus has been overlooked and there appears to be a paucity of literature from the Global North (Johnson, et al., 2020).

In this perspective the gEneSys project is contributing to produce new knowledge on the gender and energy nexus. In particular this deliverable is devoted to analysing the EU policies focusing on National Recovery and Resilience Plans (NRRPs), a key policy instrument that supported, among others, the green transition in EU member states.

In this report we present the results of a comparative policy analysis of the National Recovery and Resilience Plans (NRRPs) elaborated by all the EU member states to map out and compare how the different countries have incorporated provisions concerning the 'green deal', gender equality, and the mission to achieve the energy transition. The comparison has paid special attention to whether and to what extent gender equality, diversity, and inclusion have been accounted for, highlighting the dimensions in which gender mainstreaming needs to be strengthened. The Next Generation EU (NGEU[11]) and the new multiannual financial framework 2021-2027 are the largest and most ambitious tools to restart a greener, digital, and sustainable Europe after the Covid-19 pandemic. The Next Generation EU does not only aim to stem the damage caused by the pandemic but envisages real change for member states. Indeed, it is a huge step forward for the integration process, as it is not only a way to reduce the effects of the crisis, but a common long-term development plan. It is an unprecedented effort and an innovative approach, promoting convergence, resilience, and transformation in the European Union. The concern at stake covers two different needs of the EU: on the one hand, the need to repair the damages of the pandemic situation, on the other hand, to improve the future of the next generations and to make Europe greener, digital, and more resilient.

To benefit from the funds allocated by the EU institutions, each member state had to formulate a National Recovery and Resilience Plan, setting out a coherent package of projects and reforms for a greener, more digital, and resilient Europe. The Commission has offered several guidelines and criteria for the member states to shape their NRRP (European Parliament, 2021).

The main priorities settled were the digital transformation and the green transition. Regarding the first one, at least 20% of investments ought to finance the digital transition. The policy reform actions on energy transition contained in the NRRPs are a strategic priority of the European Union. Every NRRP should include no less than 37% of

[11] See: https://next-generation-eu.europa.eu/index_it.

spending on green in line with the ambitious goal of zero emission until 2050. In line with the European Green Deal, the Paris Climate Agreements, and the Fit for 55 commitments, the energy transition measures must focus on three main areas of intervention: energy efficiency, renewable energy, and decarbonization of the industrial sector.

The EU aims to reduce energy consumption by 32.5% in the timeframe 2007-2030, and to achieve a 32% share of renewable energy in gross final energy consumption by 2030 (European Parliament, 2023). To achieve this goal, policies have been introduced such as the obligation for member states to reach certain national targets on renewable energy, the promotion of renewable energy through market mechanisms, and support for research and development in this sector.

Several areas of intervention were defined by the Commission as priorities such as:

- Employment and smart, sustainable, and inclusive growth: this pillar refers to economic cohesion, inclusive job market, development and innovation, and sustainable firms. A special focus is on employment policy which has to be redefined according to the green and digital transformation.
- Social and territorial cohesion: the NRRP must consider local, regional, and national disparities in terms of infrastructure and demography.
- Health and resilience: as mentioned above, resilience means the capacity to address and be prepared for future crises. Health is related to the Covid-19 crisis, in which we faced all the vulnerabilities of our system in a pandemic framework.
- Policies for the next generation: among other things, such as education and skills, include gender equality. It is worth highlighting that this last area represents a horizontal priority, meaning that it shall be considered in the program assessment and evaluation.

The energy transition was a priority of the National Recovery and Resilience Plans, which must include a series of provisions regarding equality. As pointed out by the European Gender Equality Strategy (2020: 15) "The core challenges affecting the EU today – including the green and digital transitions and demographic change – all have a gender dimension". The inclusion of a gender perspective in all EU policies and processes is essential to reach the goal of gender equality. We want to understand to what extent this has been acknowledged by EU member states in designing the strategic policy plan defined in NRRPs.

EU member states must promote gender equality and equal opportunities for all, in line with principles 2 and 3 of the European Pillar of Social Rights (EPSR), UN SDG 5, and, where relevant, with the national gender equality strategy (EIGE, 2023). Notwithstanding, the report by EIGE (EIGE, 2023) highlights how Member States did not systematically adopt a gender perspective in measures on green transition funded by the Recovery and Resilience Fund.

With this endeavor, we aim to offer empirical support for the assertion and help bridge the gap in gender analysis concerning the green policies of EU member states, particularly those pertaining to energy transition, with a specific focus on NRRPs. This undertaking marks the inaugural attempt to conduct a policy analysis on NRRPs from a gender perspective, intending to gauge the extent to which EU countries adhere to the equality principles articulated in national, European, and international gender equality strategies.

The Deliverable is designed as follows. The report will first present an overview of the literature regarding the gender dimensions in EU energy policies. Secondly, it will present the NRRPS' Gender-Energy Assessment Framework (NRRPs GEAF) specifically designed for this task. Thirdly, it will describe the data collection process and the methodology employed in the analysis. Fourthly, we describe the results of the analysis. In the last section, we discuss the results and provide some conclusive remarks.

3.2 An overview of the Literature on the Gender Dimension in European Energy Policies

The nexus between gender and energy in the context of the energy transition is gaining attention and an increasing corpus of knowledge has been produced in the last decade. Also at policy level, the recent study published by the Joint Research Centre (Murauskaite-Bull, et al., 2024) reports that a shift toward implementing energy transition measures according to gender equity principles is underway at different levels. At the international and European levels, the increasing number of policy initiatives and directives demonstrates that there is a political commitment to a just energy transition (Murauskaite-Bull, et al., 2024).

From the review of the literature on energy policies, we identified several areas covered: energy poverty, women labour force and the just energy transition concept promoted in the EU.

Concerns about the need for engendering energy policy, however, are not new. More than 25 years ago, Skutsch (Skutsch, 1998) noted that the expectations and roles of women and men concerning energy need to be carefully considered. Feenstra (Feenstra M. H., 2002) proposed the formulation of a gender-aware energy policy by defining its main characteristics and analysing under which conditions such a policy can be realized, with a particular focus on South Africa and Uganda.

In recent years, coincidental with the emergence of green, climate, and energy policies and agreements, studies have deepened the link between gender and energy, especially in the form of policy analyses. In 2017, a study commissioned by the European Parliament Policy Department for Citizens' Rights and Constitutional Affairs presented an overview of EU legislation and policy to address energy poverty together with an analysis of the interpretation and implementation of EU legislation at the national level (Clancy, Daskalova, Feenstra, & Franceschelli, 2017). This study found that in the European context, there was little data available on the nexus between gender and energy and a lack of awareness amongst politicians, advisors, and researchers about the gendered aspects of energy poverty. Indeed, despite the recommendation of the Inter-Agency and Expert Group on Sustainable Development Goals indicators and EP FEMM Committee, this study highlighted the surprising lack of systematic collection of sex-disaggregated data on energy poverty (Clancy, Daskalova, Feenstra, & Franceschelli, 2017).

Two years later, the same EU Parliament Department commissioned a study reviewing the evidence on the role of women in the energy transition in the European Union and assessing the extent to which gender equality was embedded in the process, particularly in relation to the renewable energy sector (Clancy & Feenstra, 2019). The study identified gender inequalities preventing women from the involvement in the energy transition and career advancement in this domain and assessed how the transfer to the sustainable energy model is likely to affect gender equality and the role of women as actors of change (Clancy & Feenstra, 2019). The gender inequalities identified by this study concern the access to energy, the energy sector workforce and the energy decision-making process (Clancy & Feenstra, 2019).

The claim made by these studies is that to reduce the existing gender inequalities in the energy sector, as well as to allow both men and women to reap the benefits of the energy transition, and to avoid reproducing or even worsening such inequalities, policies considering the gender issues within the energy sector are needed. However, there is still a consistent research gap in the empirical analysis of macro-level energy policy through a gender lens (Carroll, Singh, & Mangina, 2022), especially in the Global North where the attention to the gender dimension has been mainly posed on understanding how gender is related to energy poverty and how to increase women participation in the energy sector workforce (Carroll, Singh, & Mangina, 2022).

One of the most relevant and comprehensive analytical efforts to bridge the gap of knowledge is carried out by Feenstra and Özerol (Feenstra & Özerol, 2021). The authors develop and apply a gender-just energy policy framework that allows for the systemic analysis and comparison of national energy transition policies. The gender-just energy policy framework encompasses provisions for engendering the energy policy (women empowerment, gender mainstreaming, social inclusion) and for including in its energy justice principles (recognitional, distributional, procedural).

Some analyses have been recently performed on European energy and climate policies and their implementation by EU member states. In particular, the National Energy and Climate Plans (NECPs) have been the most investigated. Feenstra and Özerol (Feenstra & Özerol, 2021) analysis of five national case studies concerning energy justice (Bulgaria, France, the Netherlands, Spain, and Sweden) concluded that these countries' NECPs mostly do not use gender-disaggregated data nor a gender mainstreaming approach, but they employ a general social inclusion approach. This approach, however, does not allow to address gender-specific needs and challenges.

Another recent gender assessment of the Fit for 55 package (the EU's target of reducing net greenhouse gas emissions by at least 55% by 2030), found that there has been some attempt to include a gender dimension, however, there is limited recognition of gender and other social categories in terms of the potential impacts of the initiatives contained in the package, as well as the roles that different groups of citizens can play in making the energy transition work (Clancy, Kustova, Elkerbout, & Michael, 2022).

EIGE (EIGE, 2023) also reached similar conclusions with its recent report, Gender Equality Index 2023. Towards a green transition in transport and energy. The thematic focus of this report is precisely on the green transition linked to energy systems and transport. The report shows a picture in which current European policies have not truly integrated the gender perspective as promised, risking an EU-funded gender-blind green transition.

The European Green Deal seems not to have comprehensively recognized the connection between its policy areas and gender equality. The commitment of the Commission to mainstream gender into all its major initiatives is represented by the European Gender Equality Strategy (European Commission, 2020) as well as flagship project funded under the Technical Support Instrument (TSI). Notwithstanding such commitment, EU member states' energy strategies takes a weak stand on gender equality (EIGE, 2023).

European energy policies are dominated by men even quantitatively: although 43% of senior ministers with responsibilities for energy in EU member states are women (EIGE's data from November 2022), the representation of women in national parliamentary committees working on energy was only 29% in September 2022 (EIGE, 2023). Furthermore, the report states that Member States did not systematically adopt a gender perspective in measures on green transition funded by the Recovery and Resilience Fund (EIGE, 2023), and this seems to contradict EU policy to mainstream gender into all aspects of the budget.

With this work, we propose to provide evidence to support this statement and contribute to filling the gap in gender analysis of European green policies, especially those focused on energy transition.

3.3 NRRPs' gender-energy assessment framework

In this section, we present the analytical framework developed to analyze the NRRPs. Our framework is built upon the framework proposed by Feenstra and Özerol (Feenstra & Özerol, 2021) for the analysis of NECPs. Taking from there, we added the clusters identified in the systematic literature review of the gender-energy nexus carried out in Task 1.1 of the gEneSys project (gEneSys, 2023).These clusters included: Transition to modern energy, Behaviours, Knowledge, Employment, Health, and Empowerment (for a complete explanation of the clusters, see (gEneSys, 2023)).

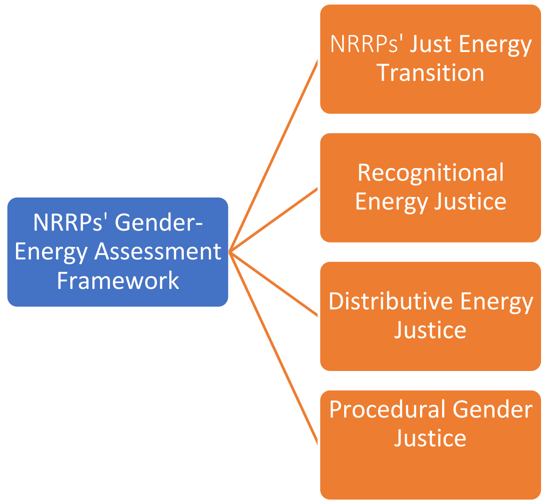


Figure 26. NRRP's Gender- Energy Assessment Framework and its dimensions

The NRRPs' GEAF consists of 4 dimensions Figure 26, each of which is composed of different sub-dimensions (6 in total) and indicators (12 in total). Each indicator can be broken down into one or more questions (19 questions in total). The dimensions are: 1) Just Energy Transition; 2) Recognitional Energy Justice; 3) Distributive Energy Justice; 4) Procedural Gender Justice Figure 26. Below we describe each dimension, sub-dimension, and related indicators and research questions.

3.3.1 NRRP's Just Energy Transition

The first dimension, NRRPs' Just Energy Transition Figure 27, refers to the general structure of the energy transition targets and main beneficiaries. The term "Just" refers to the social equity that the energy transition must aim for, in addition to the objectives of environmental and climate sustainability. The International Labour Organization define a Just Transition as greening the economy in a way that is as fair and inclusive as possible for everyone concerned, creating decent work opportunities and leaving no one behind (ILO, 2024). The meaning of Just Transition of the EU commission operationalized by the Just Transition Mechanism (JTM) and its first pillar, the Just Transition Fund (JTF), is broad, referring to the concept of justice between territories differently impacted by the transition towards climate neutrality (European Commission, 2024). A just transition, according to the EU Commission, can reduce regional disparities (European Commission, 2024).

The energy sector has so far been characterized by processes of social and gender exclusion. A recent study funded by the European Climate, Infrastructure and Environment Executive Agency (Gareis, 2023), confirms how women are still underrepresented in the energy sector workforce within EU countries. The persistent gender inequalities in the energy sector have been summarised as: gender gaps in energy access; gender gaps in the energy labour market; gender gaps in energy-related education; and gender gaps in decision-making (EIGE, 2016). "A just and inclusive transition should enable and even encourage stronger engagement of women in the energy workforce by promoting and supporting women's roles as engineers, policymakers, and entrepreneurs" (United Nations, 2021).

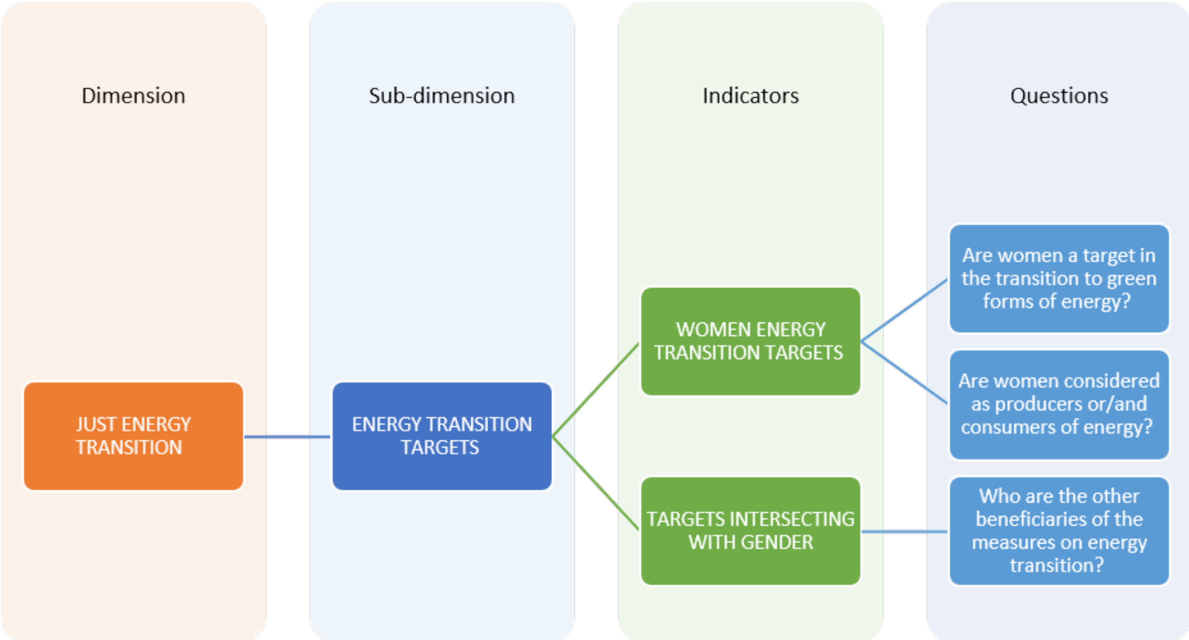


Figure 27. NRRPs' Just Energy Transition dimension of the analytical framework

Energy Transition Targets

The Energy Transition Target indicator defines the beneficiaries of the measures financed by the plans. First, with a gender lens, this indicator allows us to recognize in which NRRPs women are acknowledged as a specific target group.

<u>Women as energy transition targets</u>

Here, we focus on the roles implicitly assigned to women within each plan in the context of the energy transition. More specifically, we examine whether women are mostly depicted as beneficiaries of initiatives and innovations (energy consumers) or as agents of the ongoing transformation efforts (energy producers). To identify women as energy consumers, we have taken into consideration the presence in the plan of measures concerning access to energy (e.g., subsidies) or measures to support energy consumers (e.g., energy bonus for energy efficiency) specifically aimed at women. To identify women as energy producers, we have considered two strongly connected aspects: measures to increase the number of women trained in STEM subjects and measures aimed directly at encouraging the presence of women in the energy labour market. The extent to which each indicator is covered in the plans is analysed in a disaggregated form in the section relating to Distributive Energy Justice (see below, sub-section 3.5.5).

<u>Targets intersecting with gender</u>

By adopting an intersectional lens, we evaluate whether gender intersects with other inequality axes (e.g., disability, class, ethnicity, race, age, nationality, etc.). The questions that guided the data extraction on this aspect are therefore the following: (i) Are women mentioned as a target in the energy transition? (ii) Are women considered as producers or/and consumers of energy? Are women considered with other intersectional axes? If women are not mentioned, who are the stated beneficiaries of the measures on energy transition?

3.3.2 Recognitional Energy Justice

The second dimension of the framework, Recognitional Energy Justice Figure 28, focuses on the extent to which the plans recognize the gender-differentiated needs and behaviours of energy consumers and highlights the gendered aspects of energy poverty. The challenge is to go beyond the level of the household understood as a monolith, to be able to recognize the needs and behaviors at an individual level, and thus discern gender inequalities - together with other axes of inequality - inherent in energy poverty. Addressing inequalities at this level is critical for a gender-just energy transition (Feenstra & Özerol, 2021).

The sub-dimensions that compose Recognitional Energy Justice are: 1) energy users, whose indicators are energy users' needs and energy behaviours, and 2) energy poverty, whose indicators are energy poverty recognition and energy poverty measures.

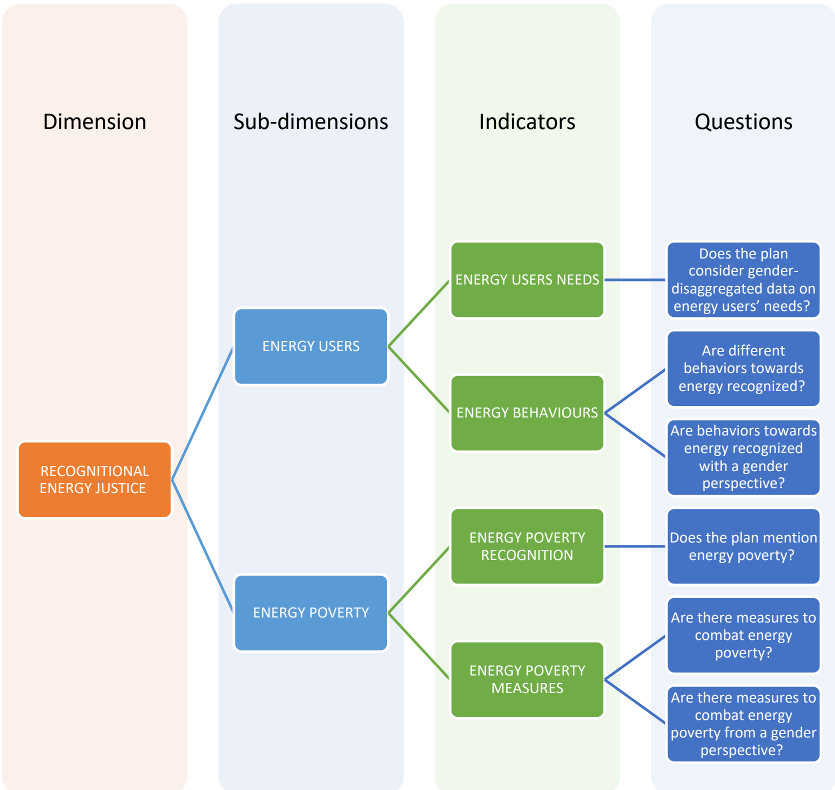


Figure 28. Recognitional Energy Justice dimension of the analytical framework

Energy Users

The central idea driving this sub-dimension is that energy consumption is not gender-neutral and it is determined by social norms that in turn regulate behaviour and influence the needs of individuals. As several studies show, gender roles come into play in energy consumption, e.g., women spend more time than men on domestic work related to energy consumption, while men have more decision-making power regarding the technologies in the household. The fact that gender differences have a differentiated impact on energy consumption implies that the costs and benefits of the energy transition will also be distributed differently among genders.

At a policy level, therefore, Recognitional Energy Justice requires that energy users are recognized as subjects with different needs and behaviours concerning energy (for more on the relevant literature, see (Feenstra & Özerol, 2021)).

Energy users' needs

The energy users' needs indicator is aimed at detecting whether gender-disaggregated data on needs related to energy consumption are used to draft the plans (data on energy consumption rates by gender). For an energy policy to be gender equitable, there needs to be a recognition that women and men have different energy needs in their daily lives (Clancy & Feenstra, 2019).

This indicator allows us to probe the following question: Do the NRRPs include gender-disaggregated data on energy users' needs?

Energy behaviours

The energy behaviour indicator assesses whether the differences between women and men regarding behaviours related to energy are recognized in the NRRPs. This indicator allows us to explore the following: Are different behaviours towards energy recognized?

Energy Poverty

Energy poverty is a complex, multidimensional concept, which has been defined differently by authors from countries with different energy contexts; therefore, even the indicators for measuring it and the discussion of its causes are not homogeneous in the literature. In the effort to combine the different definitions and embrace the different meanings of energy poverty, we consider energy poverty as the inability of a household to secure a socially and materially required level of energy services in the home (Bouzarovski & Petrova, 2015). Energy poverty has been largely explored in the context of the Global South where barriers to energy access are linked to poor infrastructure and low incomes, but it has been scarcely studied in Europe. As a result, there is only limited data available on gender and energy poverty in Europe (Clancy, Daskalova, Feenstra, & Franceschelli, 2017).

However, the data that is available shows that energy poverty exists in all countries in the EU; although the highest levels of energy poverty are recorded in the countries of Eastern and Southern Europe (Clancy, Daskalova, Feenstra, & Franceschelli, 2017). A recent review of the literature shows that the distribution of energy poverty is linked to social and geographical dimensions of inequality. For example, energy poverty is prevalent among women -particularly in Mediterranean and Eastern EU countries- elderly people, disadvantaged social classes and low-income people, and among those living in certain territories of Europe mainly Mediterranean, Eastern European countries, and certain areas of Greece (Ballesteros-Arjona, et al., 2022).

Energy poverty recognition

Energy poverty became part of the vocabulary of the EU institutions in 2009 with the formulation of the Third Energy Package (Bouzarovski et al., 2012). Electricity Directive (2019/944) is the earlier legislation referring to the concept of energy poverty (Clancy, Daskalova, Feenstra, & Franceschelli, 2017) (Widuto, 2023). This directive obliged the Commission to guide the definition and calculation of the number of households in energy poverty (Article 29). Also, the Natural Gas Directive (2009/73/EC) refers in similar terms to energy poverty and vulnerable consumers. These EU Directives generally mention vulnerable consumers, but these are not clearly defined and identified in gender terms (Clancy, Daskalova, Feenstra, & Franceschelli, 2017). Energy poverty is also mentioned in the Clean Energy for all Europeans package proposed (2016); as well as in the Regulation on the Governance of the Energy Union and Climate Action (the Governance Regulation, 2018/1999) (Widuto, 2023). The NRRPs fit into this growing recognition of energy poverty as a problem to be addressed at a community and national level. Based on the above, we focus our analysis on understanding the following: does the plan mention energy poverty? Does the plan mention energy poverty with a gender perspective?

Energy poverty measures

The corollary of the recognition of energy poverty is the formulation of measures to reverse it. The Energy Efficiency Directive and Energy Efficiency of Buildings Directive require measures to alleviate energy poverty. The 'renovation wave' initiative under the European Green Deal aims to boost structural renovation in private and public buildings, while the Social Climate Fund includes households in energy poverty among its main beneficiaries (Widuto, 2023). Measures to alleviate energy poverty are also present in the NRRPs, but here we are interested in investigating whether these are formulated from a gender-sensitive perspective. We therefore investigate the following question: Are there measures to combat energy poverty with a gender perspective?

3.3.3 Distributive Energy Justice

The third dimension of the framework, Distributive Energy Justice, is central as this is where the presence - or conversely the absence - of gender-sensitive energy measures in the NRRPs is concentrated. Distributive justice identifies where the injustices in the energy system are located in terms of the access to energy services, in the labor markets; and in the multi-level governance (Jenkins, McCauley, Heffron, Stephan, & Rehner, 2016). By Distributive Energy Justice we mean investigating how the resources, incentives, and opportunities linked to energy transition are distributed among the different participants in energy transition.

Womens' role in energy transition has been defined as agents of change. There are three roles they could have as change agents: energy consumers, energy professionals, and energy decision-makers (Clancy & Feenstra, 2019). In this framework, we focus on the first two, which emerge from the analysis of two indicators: energy consumption and energy production.

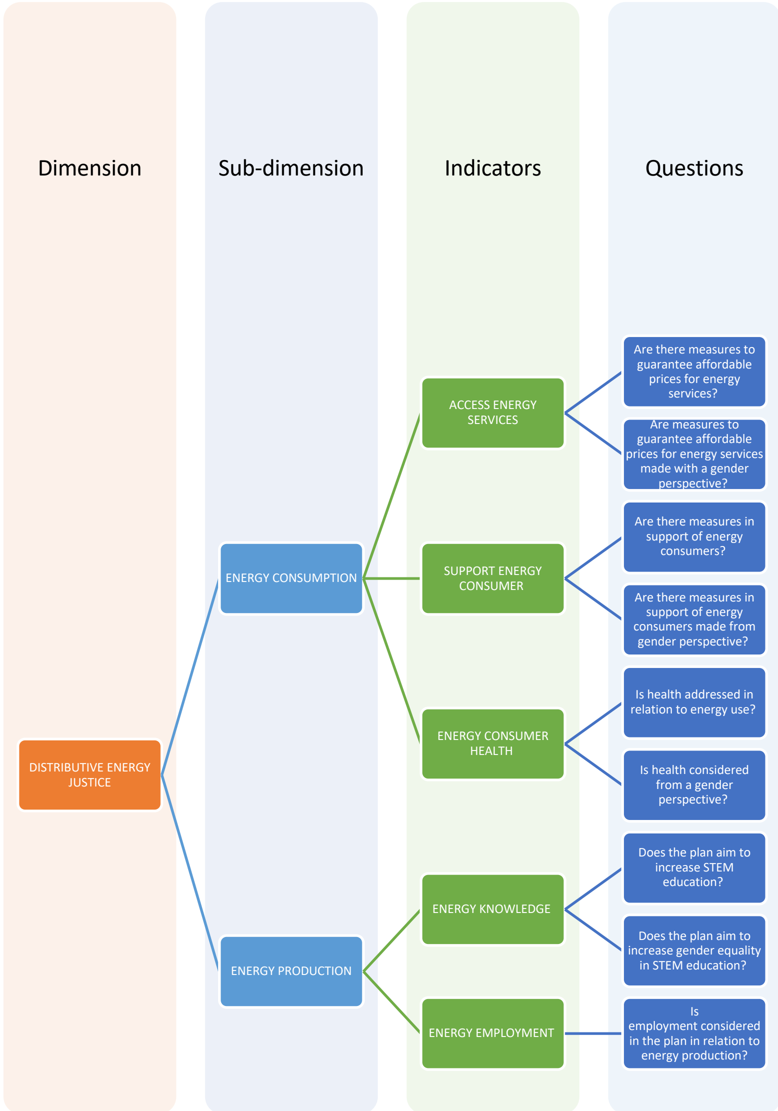


Figure 29. Distributive Energy Justice dimension of the analytical framework

Energy Consumption

The energy consumption indicator helps to inform the framework on the dimension of Distributive Energy Justice through a gender lens as it allows to identify unequal energy access of women and men (Feenstra & Özerol, 2021). From this perspective it is possible to recognize whether the issue of unequal access to energy based on gender is addressed in the NRRPs.

<u>Access to Energy Services</u>

The energy consumption that we are interested in analysing, as suggested by (Feenstra & Özerol, 2021), is that relating to the micro-level of the private sphere of individuals and households. The indicator named "Access to Energy Services" is intended to measure the presence of measures (e.g. subsidies) in the NRRPs that guarantee affordable prices for energy services from a gender perspective. The related research questions are the following: Are there measures to guarantee affordable prices for energy services? Are these measures formulated taking gender differences into account?

In addition to distributive justice in access to energy for consumers, there is also the aspect of consumer support, for example in terms of energy efficiency bonuses, housing renovation/reconstruction loans, grants, incentives, and all measures that promote energy savings for consumers. Therefore, another analysis indicator of energy consumption is “support energy consumer” and the associated question is: Are there in the NRRPs measures in support for energy consumers made with gender perspective?

Energy Consumer Health

Gender differences in energy consumption intersect with the dimension of energy poverty. One of the impacts of energy poverty on energy consumption can be found in health. This brings us to the indicator "Energy Consumer Health". Worldwide, women and children accounted for over 60% of all premature deaths from household air pollution (HAP) related to the combustion of fuel for cooking in 2012 (World Health Organization, 2016). For women in Low- and Middle-Income Countries, HAP is the single leading cause of noncommunicable diseases like stroke, chronic obstructive pulmonary disease, lung cancer, and heart disease (World Health Organization, 2016). In the Global South, many households rely on wood and other forms of biomass which is strongly associated with health issues for women (Clancy, Daskalova, Feenstra, & Franceschelli, 2017).

A scoping review recently carried out on the state of knowledge on the energy poverty-health nexus, shows the negative effect of energy poverty on physical and mental health and its association with higher odds of being exposed to health risks such as indoor inadequate temperatures, allergens, increased risk of mouldy and damp conditions, or food insecurity (Ballesteros-Arjona, et al., 2022). This review also shows that the distribution of energy poverty and its effects on health are linked to dimensions of inequality. Higher energy poverty prevalence is found among women - particularly in Mediterranean and Eastern EU countries-, elderly people, disadvantaged social classes and low-income people, and those in certain territories of Europe -mainly Mediterranean, Eastern countries, and certain areas of Greece (Ballesteros-Arjona, et al., 2022).

Energy Production

The other aspect of Distributive Energy Justice concerns energy production, which includes knowledge of technological innovation on the one hand, and employment opportunities in the sector on the other. In terms of employment, the energy sector is one of the most gender-imbalanced sectors in the economy globally and within the European Union (Clancy & Feenstra, 2019). At the same time, it is one of the sectors where strong growth is expected in the near future. It is estimated that globally the number of jobs in renewables will increase from 10.3 million in 2017 to nearly 29 million in 2050 (IRENA, 2019).

Energy knowledge

In addition to the gap in the employment sphere, it is also essential to address the root of the problem, which lies in the gender gap in energy-related education, with the small number of women with an educational background appropriate for a technical career in the energy sector (Clancy & Feenstra, 2019). The need to include women in education careers related to the energy sector is also confirmed by the CEDEFOP (CEDEFOP, 2024). Skill forecast and projections on the future trends in employment, which indicates that such competences will be increasingly required in the next future.

We therefore considered it necessary to explore to what extent the plans are aimed at increasing and strengthening STEM education and doing so according to gender equality criteria. The “Energy Knowledge” indicators and the related questions (“Does the plan aim to increase STEM education?” and “Does the plan aim to increase gender equality in STEM education?”) are used here to collect data on the presence of measures aimed at reducing the gender gap in science, technology, engineering and mathematics education.

Energy employment

With the "Energy Employment" indicator and the related question "Does the plan aim to explicitly increase the presence of women in the energy labour market?'', we try to shed light on the degree to which the NRRPs have taken into account the gender gap in the energy labour market.

3.3.4 Procedural Gender Justice

The last dimension of the analytical framework is Procedural Gender Justice which relates to the decision-making process that led to the development of the plans. We referred to Jenkins et al. (Jenkins, McCauley, Heffron, Stephan, & Rehner, 2016) interpretation of procedural justice understood as a fair policy process in which all groups and stakeholders can equally participate in decision making. The three mechanisms of inclusion identified to achieve procedural justice are local knowledge mobilization, greater information disclosure, and better institutional representation (Jenkins, McCauley, Heffron, Stephan, & Rehner, 2016).

In the framework built by Feenstra and Özerol (Feenstra & Özerol, 2021), this dimension is defined as Procedural Energy Justice, but in this work, it has been redefined as Procedural Gender Justice. Indeed, it was not possible to infer the participation of groups and organizations focusing on gender equity specifically in the design of energy-related measures. We have therefore considered the participation of these groups in the formulation of the overall plan, as reported in the Consultation Process section of the document.

Women participation

The sub-dimension of Procedural Gender Justice included in this framework is women's participation, that is the involvement of institutions/groups on gender equity in decision-making processes related to the formulation of the NRRPs.

<u>Women empowerment</u>

To ensure that women become active contributors to energy transition efforts, they must participate in policy decision-making processes. Thus, this indicator aims to detect the aspect of female empowerment and to explore the question: Is there any reference to the participation of institutions/groups on gender equity in the process of the plan's design?

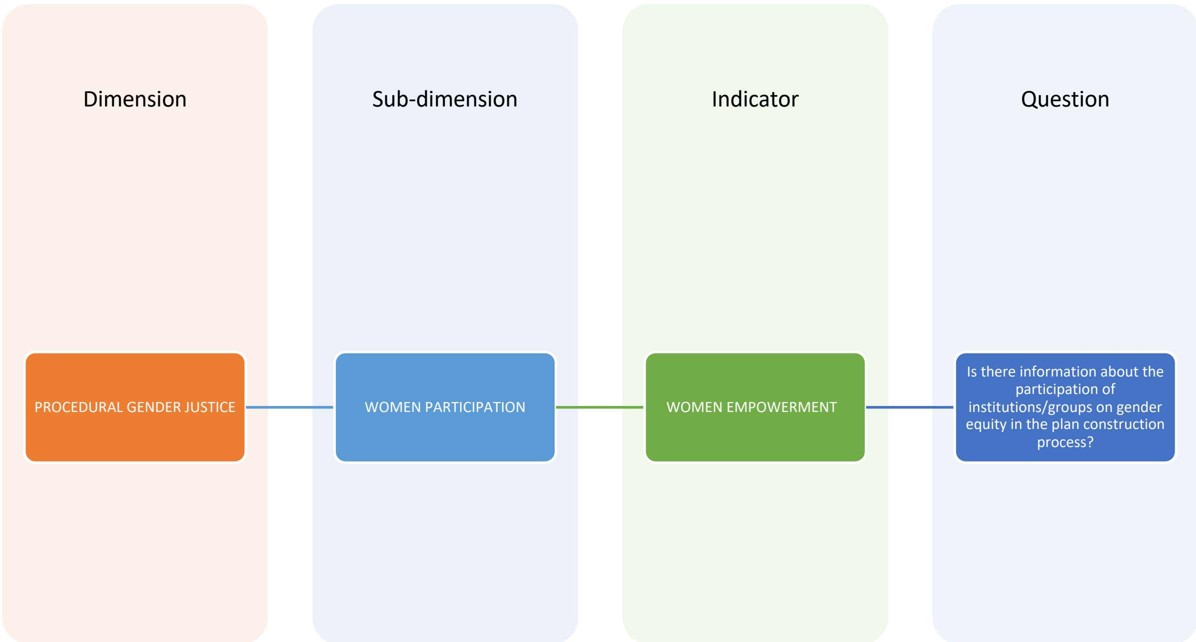


Figure 30. Procedural Gender Dimension of the analytical framework

3.4 Methodology

We conducted a comparative policy analysis of all European countries' NRRPs on the energy transition and gender equality nexus. To this end, we decided to analyse the original version of the NRRPs12 rather than the revised ones in order to capture the countries' positions before the revision by the EU Commission.

We retrieved the original version of the NRRPs from the EU-dedicated website13. Since most of the plans retrieved from the EU website were in the countries' official language and due to time and budget constraints, we opted to translate all plans to English using automatic translation services, in particular Google Translator. To code and

[12] The original version of the plans was found from the official website: https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/country-pages_en

[13] https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/country-pages_en

analyse the information, we purposively created an NRRPs GEAF that built on the Gender just energy policy framework elaborated by Feenstra and Özerol, (Feenstra & Özerol, 2021) and integrated the clusters identified in Deliverable 1.1. of the gEneSys Project (gEneSys, 2023).

Once the framework has been finalized, we proceeded to the collection of the information from the NRRPs. Due to their qualitative nature, data have been manually collected, by the means of an Excel matrix, by the CNR team members. Operatively, it has been created with each row representing a country and each column representing a dimension identified in the framework, with each dimension containing one or more indicators. A set of NRPPs was first randomly assigned to each CNR team member for scrutinization and then re-assigned to another team member for cross-validation.

Qualitative data collected from the NRRPs have been combined with some quantitative data retrieved from different sources. In particular, the 2023 EIGE gender equality index has been retrieved from the EIGE website14. The EU Recovery and Resiliency Scoreboard15 was used to gather data on the total grants allocated to each country, the ratio between funds allocated and countries' GDP, the share of the plan's estimated expenditure contributing to green transition, and the share of NRRPs' measures with a focus on gender equality 16.

Data have been analysed with a mix of qualitative and quantitative methods. From a qualitative perspective, we performed a content analysis of the plans against the dimensions, subdimension, and indicators identified in the framework. It is worth highlighting that, when mentioning parts off the plans, the citations are English translations of the original documents and therefore they should not be considered as textual quotations.

On the other hand, from a quantitative perspective, we calculated the frequencies of occurrence of the dimensions and indicators identified in the framework and created an index that assessed the extent to which NRRPs incorporated the gender dimension as part of their energy transition measures.

The index has been created by assigning equal weight to each of the twelve gender-related indicators of the analytical framework and normalizing the values to a base of 100 according to this formula:

$$Framework\ Index = \left(\frac{100}{12}\right) * X$$

where X is the number of framework dimensions incorporating a gender perspective within each NRRP. The index, therefore, can vary from a minimum score of 0 to a maximum score of 100.

[14] https://eige.europa.eu/gender-equality-index/2023

[15] https://ec.europa.eu/economy_finance/recovery-and-resilience-scoreboard/index.html?lang=en

[16] https://ec.europa.eu/economy_finance/recovery-and-resilience-scoreboard/index.html?lang=en

Also, we correlated our index with the EIGE index to verify whether the countries that performed well on the latter matched with the ones that exhibit better performances on the former.

3.5 Analysis

In this section, we present the results of the analysis. The data is presented against the structure of the analytical framework elaborated. Therefore, the section will delve into the following topics: Fund allocation, General Data, NPRRs Just Energy Transition, Recognitional Energy Justice, Distributive Energy Justice, and Procedural Gender Justice.

3.5.1 Funds Allocation

Before moving to the analysis of the plans we report available data concerning the economic dimensions of the plans. This provides a picture of the amount of funds requested by each country and how the different countries decided to allocate them based on their priorities.

The NRRPs allocate huge resources precisely for the shift to renewable energy, energy efficiency and for the decarbonization of industries; in fact, at least 37% of total resources of each NRRP had to be allocated to finance measures for the green transition (Article 3 of the RRF Regulation). In particular, the plan envisages measure related to, for example, the creation of new renewable energy installations, the modernization of electricity networks, and the support of R&D in this sector in addition to investments to improve the energy efficiency of buildings, transport, and industries; incentives for the purchase of electric vehicles.

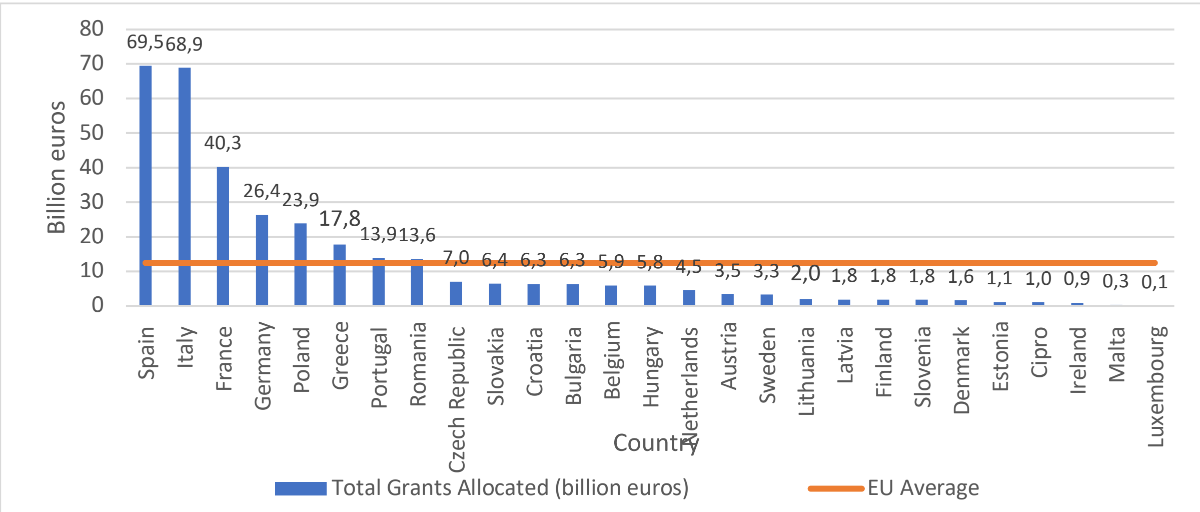


Figure 31. Total Grants Allocated in the NRRPs (billion euros)

Figure 31 shows the total funds allocated for each NRRP in billion euros. Data illustrate how the amount of funds granted to each country varies considerably from 0.1 billion to Luxembourg to 69.5 billion to Spain, with an average EU allocation of 12.4. Eight countries out of twenty-seven received a total amount of funds higher than the average, with Spain, Italy, France Germany, and Poland receiving twice or more than the average value.

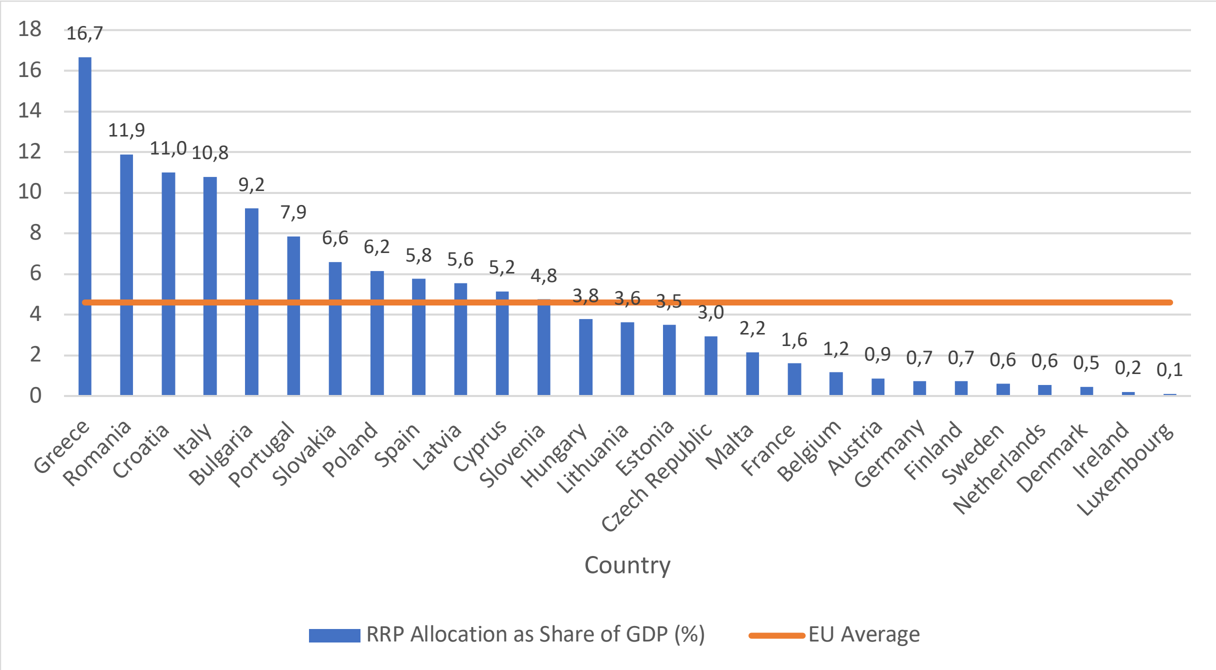


Figure 32. NRRPs' Allocation as Share of GDP (%)

Looking at the NRRPs allocation in terms of countries' GDP, Figure 32 shows how the average share of GDP allocated is 4.6 varying from 0.1 for Luxembourg to 16.7 for Greece. The allocation of funds, therefore, seen through the lens of the share of countries' GDP seems to be less skewed and more equilibrated.

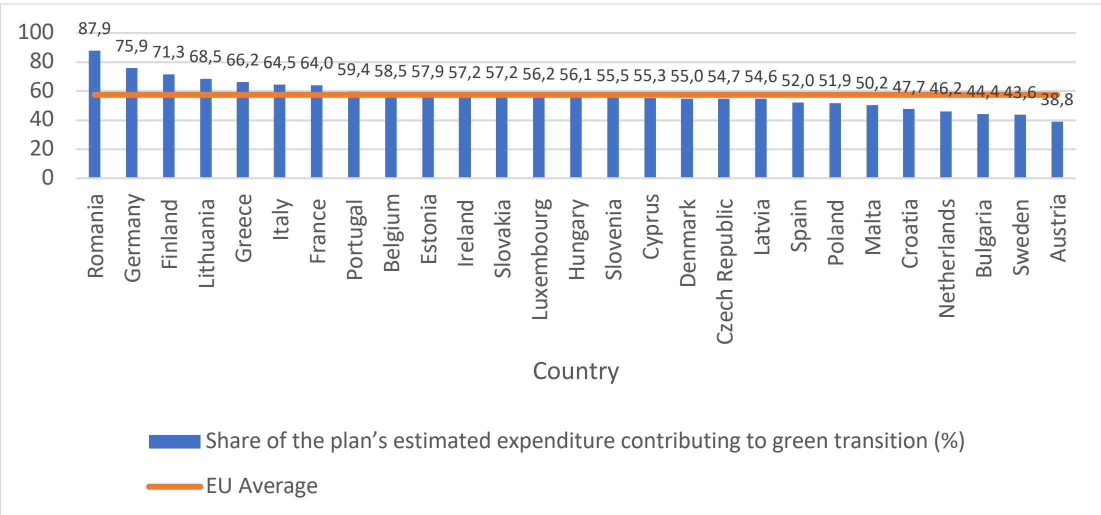


Figure 33.Share of NRRPs estimated expenditure contributing to green transition (%)

Figure 33 reports the data on the share of the plans' estimated expenditures devoted to the measures for the green transition. In light of the fact that each country had to compulsorily allocate at least the 37% of total resources to measures for the green transition, it is interesting to note that some countries such as Austria, Sweden, and Bulgaria devoted a share of the total funds close to the required minimum (respectively 38.8%, 43.6% and 44.4%) while others such as Romania and Germany went well beyond doubling the required budget (respectively 87.9% and 75.9%). Overall, the share of the total budget allocated for the green transition has been relatively high across all the EU countries with an average of 57.43%.

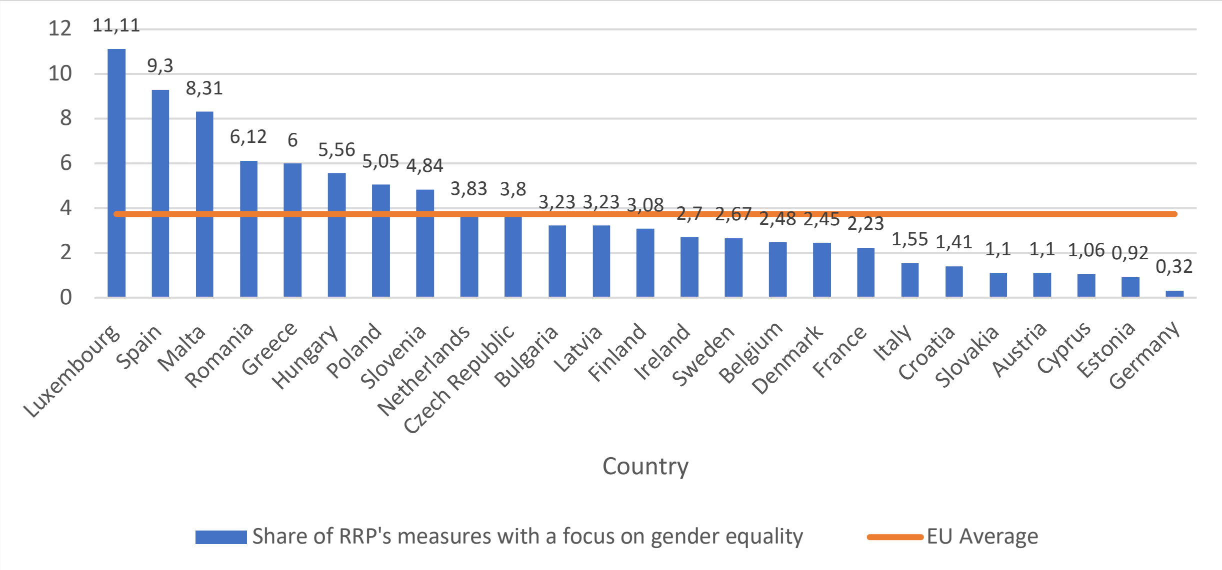


Figure 34. Share of NRRPs measures with a focus on gender equality

Figure 34 reports the data on the share of NRRPs' total funds allocated to implement measures aimed at increasing gender equality. It is important to stress that these data refer to all the measures foreseen in the NRRPs and not only those concerning the energy transition. However, the Figure shows how the percentage of resources within the RPPs dedicated to increasing gender equality considerably varies among EU countries from 0.32% of Germany to 11.11% of Luxembourg, with an average of 3.73%.

3.5.2 General Data

To assess to what extent the gender dimension was considered within the NRRPs, for each country we calculated the number of entries that appeared in the documents for the terms "gender", "woman", "women", "female" and "sex". Given the different lengths of the NRRPs we normalized the values for the number of words of each NRRP and we multiplied it by one thousand for the sake of better visualization. Data are reported in Figure 35.

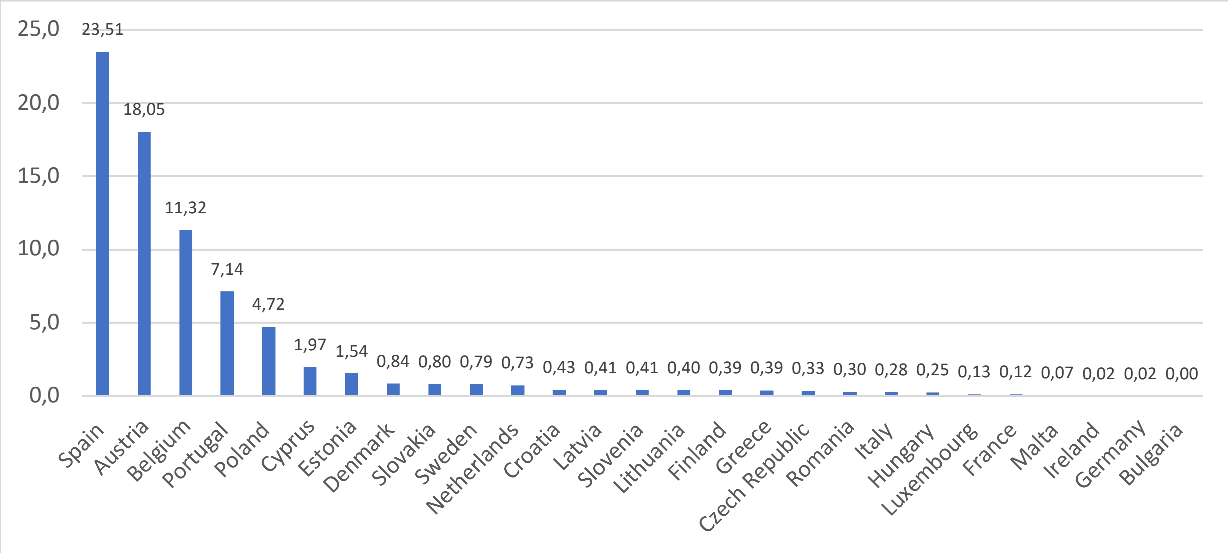


Figure 35. Number of entries for the terms ''gender'', ''women'', ''female'' and ''sex'' by countries' NRRPs

Concerning the terms considered, the analysis shows that their usage varies from 0 per thousand of the Bulgarian RRP to 23.51 per thousand of the Spanish RRP. Five countries (Spain, Austria, Belgium, Portugal and Poland) employed the considered terms more than 4 times per thousand while four countries (Bulgaria, Germany, Ireland and Malta) employed it equal to or less than 0.1 times per thousand. It is worth stressing that the number of the terms "gender", "woman", "women", "female" and "sex" employed are referred to the entire NRRPs and not only to the parts devoted to the energy transition.

3.5.3 NRRPs' Just energy transition

As mentioned in the introduction, the components of the NRRPs referring to the energy transition are framed in the European macro-objectives such as the net zero target by 2050. Therefore, all the plans, even though with different degrees of details contain measures related to the just transition inscribed in the European mandate of climate neutrality, low carbon economy, and energy efficiency. The main forms of energy mentioned in the plans are green hydrogen, solar, wind, biomass, and geothermal.

In the NRRPs, gender equality is treated as an issue that cuts across all the plan's components. Despite this, our analysis revealed that gender appeared more frequently in the plan in relation to macro-themes such as social care, employment, disability, and health. Unsurprisingly, these are also the themes traditionally more linked to social vulnerability. Conversely, innovation and sustainability themes, of which the energy transition is a concrete example, are less gender sensitive.

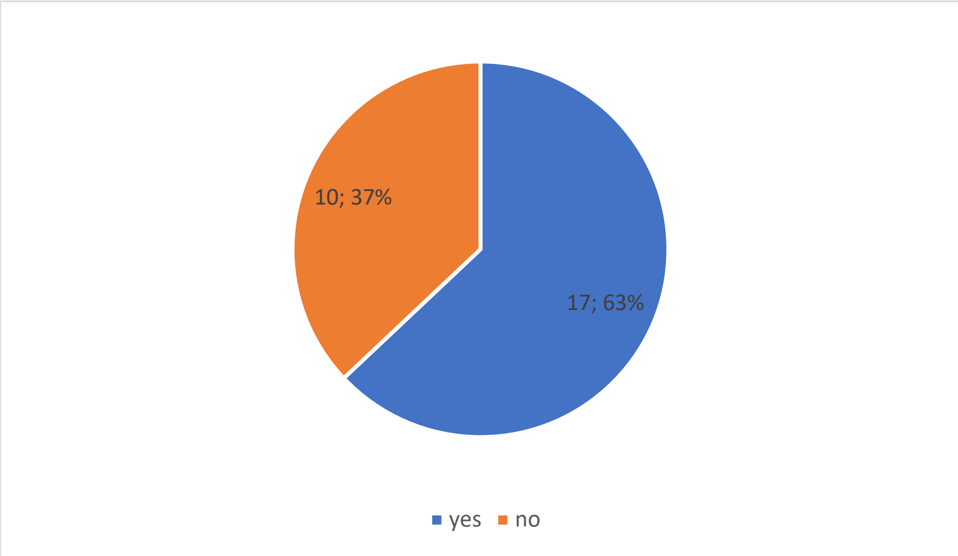


Figure 36. NRRPs in which women appear as beneficiaries of the measures for the energy transition

As shown in Figure 36, women are mentioned as beneficiaries of measures linked to the different dimensions of the energy transition in just over half of the NRRPs (17 countries, 63%). 10 countries (Bulgaria, Finland, France, Germany, Greece, Hungary, Lithuania, Luxembourg, Malta, Poland, and Romania) which account for the 37% of the total do not highlight gender and gender equity as a relevant aspect of the energy transition.

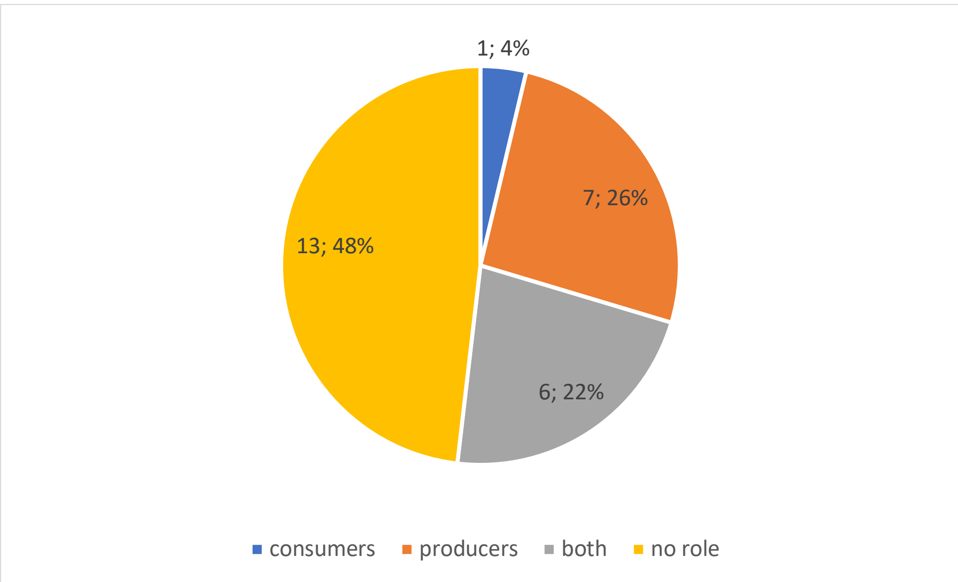


Figure 37. Role of women in energy transition according to the NRRPs

Another important consideration that came out from our analysis pertains to the representation of women in the energy transition. As reported in Figure 37, the NRRPs analysis shows a picture of the European energy transition in which women are not considered either as consumers or producers (13 NRRPs, 48%). Notwithstanding, in other countries women are depicted either as energy producers (7 NRRPs, 26%), consumers (1 NRRP, 4%), or as both energy consumers and producers (6 countries, 22%). It is interesting to note that, among the NRRPs accounting for the role of women in energy transition, with the exception of Netherlands, women are depicted not only as consumers but also as agents of change, with an active role in the energy production and the technology development sectors.

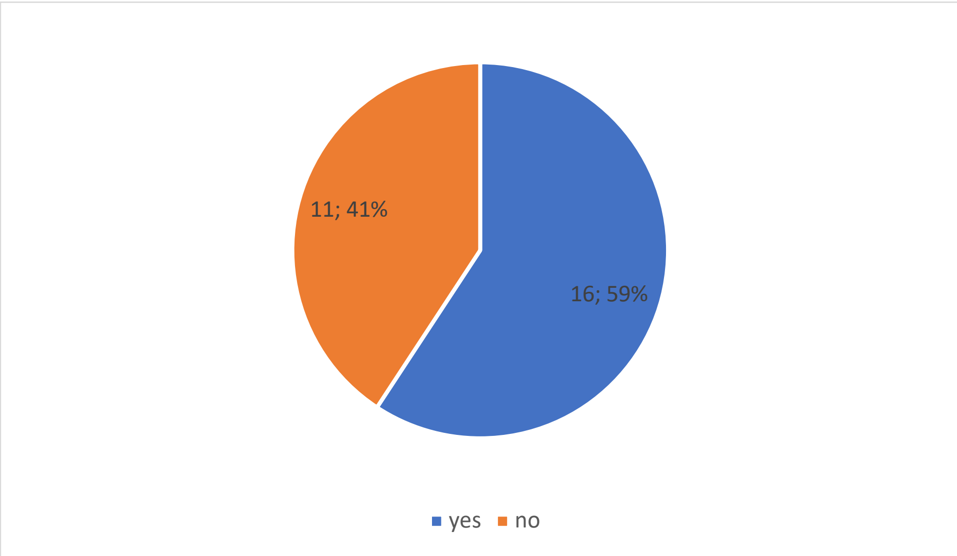


Figure 38. Targets intersecting with gender in energy transition NRRP's measures

In 16 NRRPs (59%), gender inequalities are considered, through an intersectionality lens, alongside several other axes of inequality. The most mentioned are the following: being a single parent, having a disability, economic status, ethnicity, migrants, age, youth, nationality, and regional divide (Figure 38).

The Estonian Plan, for instance, recognizes the need for intersecting gender with several other characteristics. The plan claims that to create equal opportunities for people of different gender, nationality, age, racial or ethnic origin, religion or belief, special needs or sexual orientation to participate in activities and to share in the results, the needs of the participants, which arise from their membership in different social groups, are analysed and taken into account, and barriers are reduced, that prevent underrepresented groups from participating in activities or benefiting from benefits deriving from the energy transition (Estonian RRP, p. 218).

Similarly, the Spanish Plan accounts for the necessity of using an intersectional approach, describing how the intersectional gender perspective will be incorporated to include, beyond women as victims of gender violence, other groups. Of especially vulnerable women such as women with disabilities, long-term unemployed, mothers raising their sons and daughters alone, older women in single-person households, immigrants, including seasonal workers, refugees and those belonging to minorities (Spanish RRP, pp. 108-109)

Another example is represented by the Irish Plan, which declares that Ireland is strongly committed to the advancement of gender equality and equal opportunities for all, including in the context of the National Recovery and Resilience Plan. Equality is promoted through a range of cross-Governmental equality strategies which aim to address the particular needs of specific groups, including women and girls, those with disabilities, Traveller and Roma inclusion, LGBTI+ inclusion and migrant integration (Irish RRP, p. 14).

The analysis, therefore, shows how most NRRPs do consider the gender issue with an intersectional approach, indeed, targeting different vulnerable groups according to each diverse national context.

3.5.4 Recognitional Energy Justice

"Understanding, recognizing, and targeting the needs of energy users is at the core of recognitional justice" (Feenstra & Özerol, 2021). For this reason, it is compelling to rely on gender-disaggregated data on the differential needs of energy consumers. Despite that, only two plans out of 27 (Belgium and Spain) contain gender-disaggregated data on energy user's needs. The Spanish plan mentions the existence of disaggregated data regarding a greater energy expenditure of single mothers, elderly women, and dependents of people with disabilities, but the source of the data is not cited. The Spanish plan recognizes that it is necessary to keep in mind that energy poverty affects women to a greater extent. The data are clear: single-parent mother households, those in which at least one person with a disability lives, and especially households of older women who live alone, have energy expenditure on electricity and heating higher than the national average and present indicators higher than average risk of energy poverty (Spanish RRP, p. 310). The Belgian plan in turn recognizes that single-parent households and people aged over 65 are particularly affected by energy poverty. Women are over-represented in these two categories (with 75% and 56% respectively) (Belgian RRP, p. 24, French version).

Different behaviours towards energy are recognized in 8 out of 27 countries (30%); of these, only half (15%) incorporates a gender lens. Some of the gender-differentiated energy-related behaviours relate to mobility: for example, in the Austrian plan, it is mentioned that women use public transport in a higher proportion than men. The Austrian Mobility Master Plan 2030 anchored in the recovery and resilience plan aims to increase the proportion of walking and cycling, public transport, and shared mobility through different innovations and improvements in the mobility system: the introduction of the 123 climate ticket, investments in zero-emission buses, the construction of new railway lines and the electrification of regional trains, the use of public transport will become easier. This creates mobility options for women who travel an above-average number of journeys without a car and people with low incomes in urban areas (Austrian RRP, p. 46).

Croatia's RRP, however, recognizes differentiated needs that could be better satisfied thanks to energy efficiency. The plan says that bearing in mind the division of household responsibilities in the family and the fact that women stay at home to a greater extent, using different energy sources for food preparation, heating, and lighting, investments to strengthen energy efficiency in the heating sector contribute to increasing their quality of life (Croatian RRP, p. 451). In the Croatia's plan, it is also recognized that in the workplaces linked to services' sector, whose staff is predominantly female, energy efficiency could benefit precisely this group of workers, as stated: enhanced energy efficiency measures in service industries, it opens up the possibility of higher incomes for employees among whom the majority of the workforce is female (Croatian RRP, p. 451).

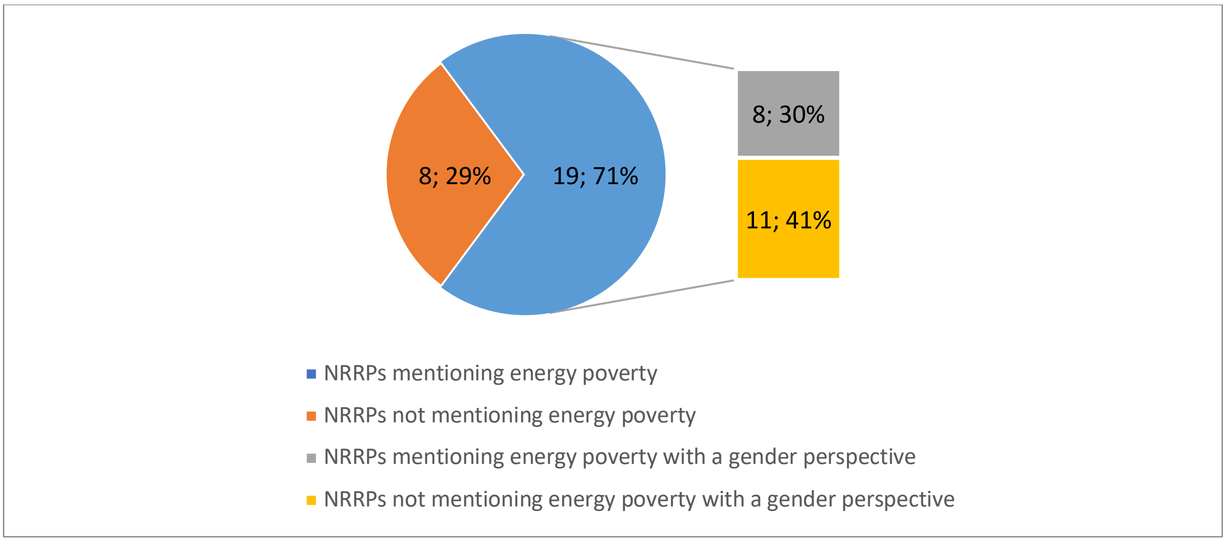


Figure 39. Energy poverty recognition in the NRRPs

71% of the plans mention energy poverty (19 out of 27), of these, however, only 8 (30% of the total) highlight the connections between energy poverty and gender inequality (Figure 39).

3.5.5 Distributive Energy Justice

Distributive justice refers to how the resources, incentives, and opportunities linked to energy transition are distributed between men and women. In our framework, distributive energy justice has been articulated in terms of energy production and consumption.

Concerning energy consumption, we addressed energy access and support to energy consumers, and health aspects related to energy consumption. Firstly, we consider whether NRRPs incorporate measures to guarantee energy access through affordable prices for energy services, such as subsidies to reduce energy costs. In this respect, 15 out of 27 NRRPs do mention such kind of measures. However, even if these measures are often directed to firms or generally to families and households, none of them incorporate a gender perspective.

Secondly, we assessed whether the Plans mention any measures aimed at financially supporting energy consumers, such as energy efficiency bonuses, housing renovation/reconstruction loans, grants, and incentives. As reported in Figure 15, 21 out of 27 NRRPs contain such measures. Among these 21 NRRPs, only 6 (Austria, Belgium, Croatia, Italy, Slovenia, and Spain) incorporate a gender perspective.

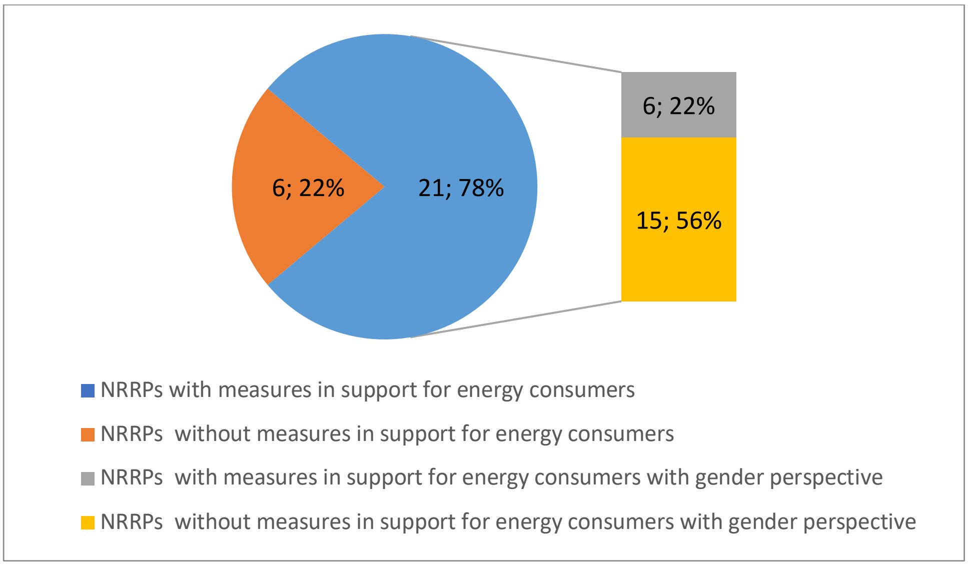


Figure 40. Measures in support of energy consumers in the NRRPs

In general terms, to support energy consumers, the different plans provide similar measures focused on the improvement of energy efficiency through the offering of wide-ranging incentives for the renovation of private buildings. In light of the over-representation of women in energy-poor households, especially in those single-parented, as well as the gender-segregation in family and household activities, these measures have relevant gendered implications. Some differences can be noted concerning the different intersectional approaches used by the NRRPs. The Austrian Plan targets older women and low-income households. The Belgian and the Spanish Plans focus on gendered energy poverty. The Italian Plan focuses on single-parent families, poverty, and housing shortage.

Thirdly, we investigate whether the Plans incorporated measures related to the energy-health nexus. Out of 27 NRRPs, only 4 account for a relation between energy and health: Cyprus, Denmark, Lithuania, and Slovakia. However, none of the Plans incorporate a gender perspective within these measures.

Regarding energy production, we analysed the commitment of the NRRPs to promote and improve equal access to knowledge on technological innovations in order to guarantee equal employment opportunities for women in the energy sector.

In this respect, we first consider whether the NRRPs foresaw measures to increase participation in STEM disciplines. As shown in Figure 41, out of the 27 plans analysed, 18 do mention some measures to increase access to STEM disciplines. Among these, 13 NRRPs formulate measures with a gender perspective: Austria, Belgium, Croatia, Cyprus, Denmark, Estonia, Italy, Latvia, Portugal, Slovakia, Slovenia, Spain, and Sweden.

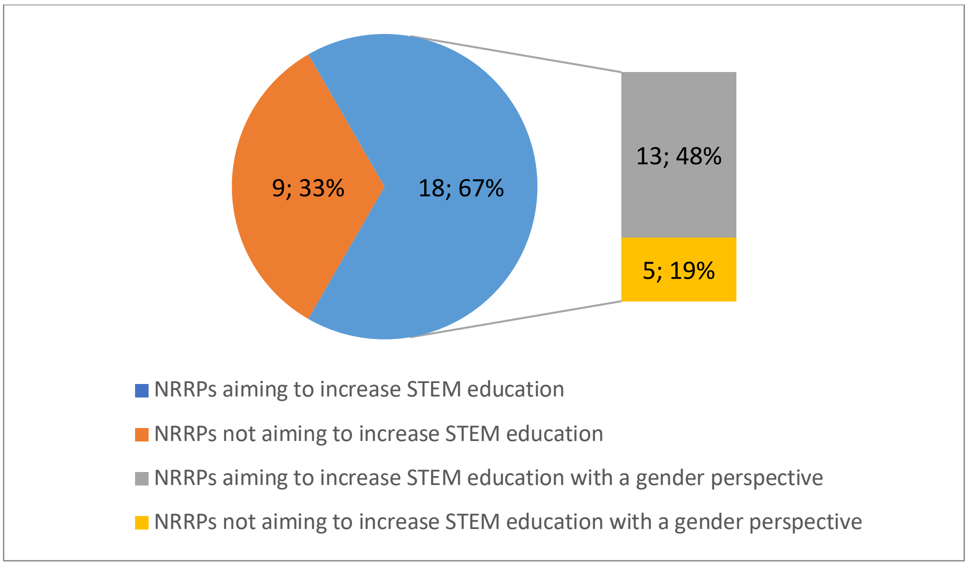


Figure 41. Measures in support of increasing women in STEM education in the NRRPs

The measures considered here are predominantly directed at combatting gender stereotypes, mitigating the risk of increasing inequalities due to the increase of jobs requiring knowledge and skills linked to STEM disciplines, and in general increasing women's participation in all those subjects connected with the energy transition.

For instance, the Belgian Plan reports that the orientation of public investments in the Plan could potentially create a significant demand for labour in predominantly male sectors (construction, energy, STEM/ICT, green jobs, circular economy, etc.). To mitigate this risk, additional attention will be paid to the integration of the gender dimension in the planned education and training measures, in order to combat stereotypes and promote the presence of girls and women in the economic sectors of the future. In addition, the gender dimension will be taken into account in monitoring the plan to ensure that the implementation of the plan is aligned to promote gender equality (Belgian RRP, p. 28).

Similarly, the Austrian plan claims that the RTI Strategy 2030 (3.A.1) and the measures based on it not only ensure a successful research, technology, and innovation policy for Austria but also aim to increase the proportion of women among graduates in technical subjects by 5 to increase percentage points (Austrian RRP, p. 49).

The Portuguese Plan mentions removing limitations to integrated use of technological and digital equipment and eliminating the lack of specialized equipment for developing digital skills. It also mentions encouraging continuation of STEM careers, promoting equal participation of girls and boys, creating conditions for integrated use of different technological equipment in teaching-learning - face-to-face, mixed and distance learning - and for the participation of male and female students in specific projects promoting development of digital skills (Portuguese RRP, p. 200).

Secondly, we assessed whether the NRRPs envisaged measures to increase women's participation in job markets related to energy transition. As shown in Figure 42, out of the 27 plans analyzed, 9 mention some measures to increase women's participation.

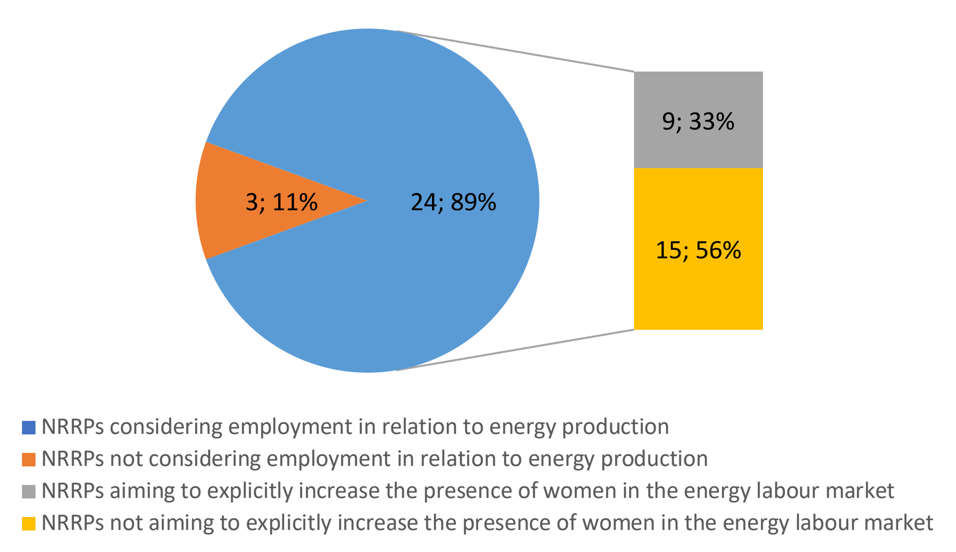


Figure 42. Measures considering employment concerning energy production in the NRRPs

In general, on the one hand, these measures are aimed at fostering women's entrepreneurship in the context of the energy transition, while, on the other hand, at increasing the share of women working in the green energy labor market to reduce the gender gap affecting the sector.

For instance, the Cypriot RRP includes financial schemes promoting women entrepreneurship, education, and training programs for women on ITC. The measures aim to enhance productivity, effectiveness, and efficiency (e.g., by accelerating the digital transformation, improving the recruitment and promotion procedures, and reforming the performance appraisal system), increase participation of women in paid work and representation in decision-making positions, as well as reduce gender segregation in certain occupations and improve working conditions (Cypriot RRP, p. 37).

3.5.6 Procedural Energy Justice

Procedural justice is usually described as the sense of justice in the processes that distribute advantages and disadvantages. In the context of the energy transition, it encompasses the process with which decisions about energy issues are made and to what extent the procedures used by decision-makers are considered just (Jenkins, McCauley, Heffron, Stephan, & Rehner, 2016).

To assess to what extent NRRPs have been approved following a procedural just process, we looked whether their drafting has been carried out by including stakeholders' participation and consultations. Stakeholders' consultations are essential to allow policymakers to gain an understanding of, and possibly account for, the different needs of diverse groups of citizens, making the policy process more just.

In the present analysis, procedural justice was assessed by verifying if the NRRPs have been drafted based on stakeholder consultation. Taking a gender perspective, we gauged whether, among the stakeholders included in the consultation process, there were institutions or groups with a focus on women.

Overall, 22 out of 27 NRRPs mentioned some sort of stakeholder consultation process used during the drafting process. Within all EU countries, only Bulgaria, Hungary, Latvia, Luxembourg, and Malta do not mention any stakeholder consultation.

However, applying our gender lens, we found that only 7 NRRPs (Cyprus, Czech Republic, Estonia, Ireland, Lithuania, Netherlands, and Portugal) explicitly mention the inclusion of stakeholders that have a specific focus on gender issues. For instance, the Cypriot Plan included the National Mechanism for Women's Rights to design the RRP measures related to gender equality (Cypriot RRP, p. 35); while the Czech Plan was discussed at the round table of the Government Council for Sustainable Development. The plan was then also submitted to the Government Council for Gender Equality (Czech RRP, p. 8).

3.5.7 NRRPs' Gender-Energy Assessment Index

In order to assess and visualise to what extent EU countries' NRRPs incorporate a gender dimension within the measures concerning the energy transition, as described in the methodology in Section 3.4, we created an index based on the results of the analysis of the framework presented in Section 3.3. The index also allows us to compare the considered countries and to look at to what extent the countries that perform better on gender mainstreaming according to the EIGE index match with the countries that incorporate a gender perspective into the NRRPs to a greater extent. Table 16 reports an overview of the number of NRRPs assessing the gender-related questions as formulated in our theoretical framework. Figure 43 visualizes on a map the framework index countries' score calculated on the basis of the gender-related questions.

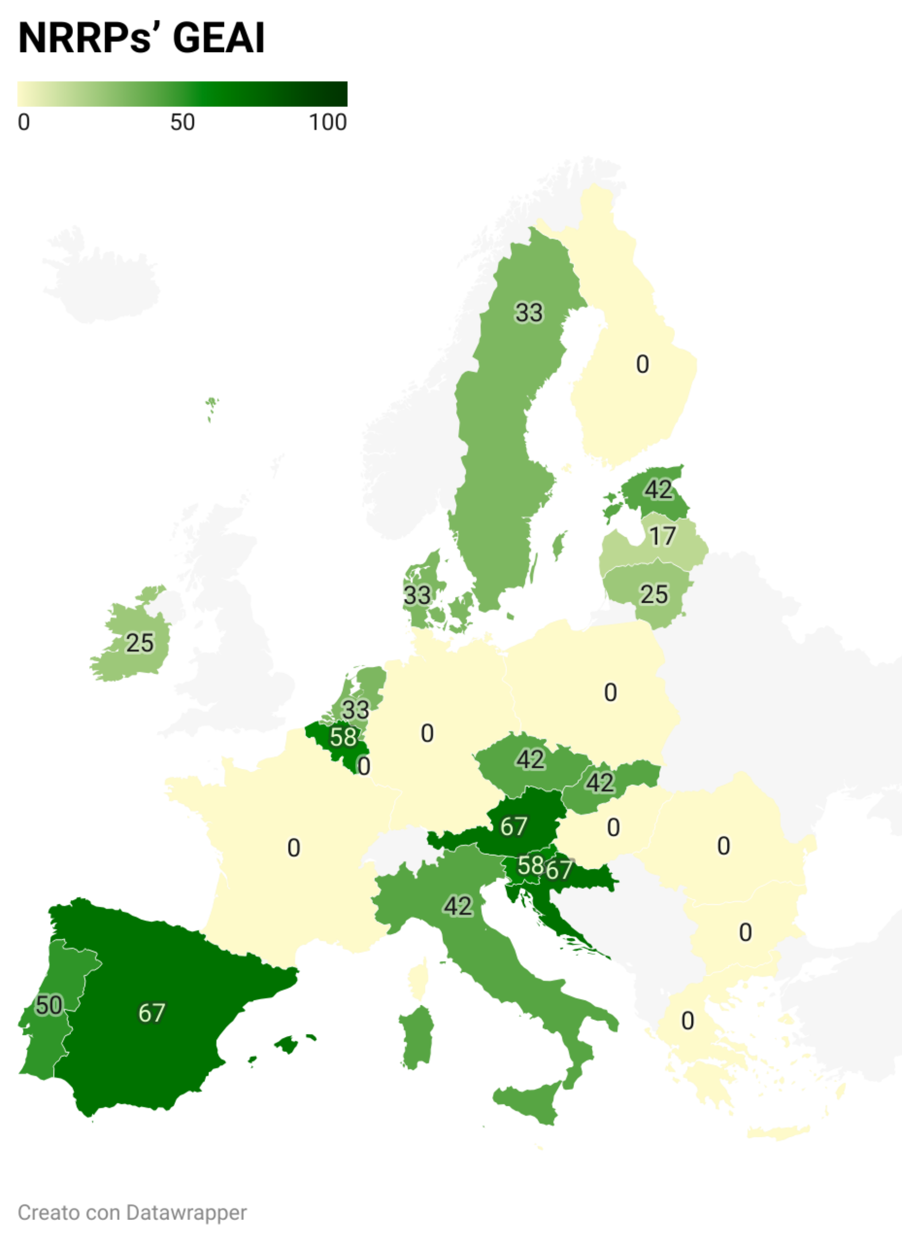
Dimension	***Sub-dimension***	***Indicator***		***# NRRPs***
JUST ENERGY TRANSITION	Energy Transition Targets	Women as energy transition targets	Are women a target in the energy transition?	17
		Targets intersecting with gender	Are women considered with other intersectional axes?	16
RECOGNITIONAL ENERGY JUSTICE	Energy Users	Energy users' needs	Does the plan consider gender-disaggregated data on energy user's needs?	2

		Energy behaviour	Are behaviors towards energy recognized with a gender perspective?	4
	Energy Poverty	Energy poverty recognition	Does the plan mention energy poverty with a gender perspective?	8
		Energy poverty measures	Are there measures to combat energy poverty from a gender perspective?	7
DISTRIBUTIVE ENERGY JUSTICE	Energy Consumption	Access energy services	Are measures to guarantee affordable prices for energy services made with a gender perspective?	0
		Support energy consumers	Are there measures in support of energy consumers made with a gender perspective?	6
		Energy consumers health	Is health considered from a gender perspective within the energy context?	0
	Energy Production	Energy knowledge	Does the plan aim to increase gender equality in STEM education?	13
		Energy employment	Does the plan aim to explicitly increase the presence of women in the energy labor market?	9
PROCEDURAL ENERGY JUSTICE	Women Participation	Women Empowerment	Is there information about the participation of institutions/groups on gender equity in the plan construction process?	7

Table 16. Number of NRRPs assessing the different indicators of the theoretical framework elaborated

The table shows that, the EU level, except for the questions related to the dimension of Just Energy Transition, which has been assessed by most of the NRPPs, the questions considered in the framework have been largely overlooked. Some questions have been addressed by none of the NRRPs such as the one related to the measures to guarantee affordable prices for energy service, and that referring to the health issues as related to energy. On the contrary, the question on the increase of women in STEM education, and the one on the energy labor market are the ones that have been more frequently addressed by more countries, (respectively by 13 and 9 countries).

The index within the countries considered varies from a minimum of 0 to a maximum of 67. While none of the countries considered scored the maximum possible, 10 countries (Bulgaria, Finland, France, Germany, Greece, Hungary, Luxembourg, Malta, Poland, and Romania) scored 0. On the other side of the spectrum, with an index of 67, the best-performing countries have been Austria, Croatia, and Spain.



Country	Index
Austria	67
Croatia	67
Spain	67
Belgium	58
Slovenia	58
Portugal	50
Cyprus	42
Czech Republic	42
Estonia	42
Italy	42
Slovakia	42
Denmark	33
Netherlands	33
Sweden	33
Ireland	25
Lithuania	25
Latvia	17
Bulgaria	0
Finland	0
France	0
Germany	0
Greece	0
Hungary	0
Luxembourg	0
Malta	0
Poland	0
Romania	0

Figure 43. NRRPs' Gender-Energy Assessment Index (NRRPs' GEAI)

It is interesting to note that the elaborated NRRPs' GEAI and the EIGE index present a positive but very low correlation, as reported in Figure 44.

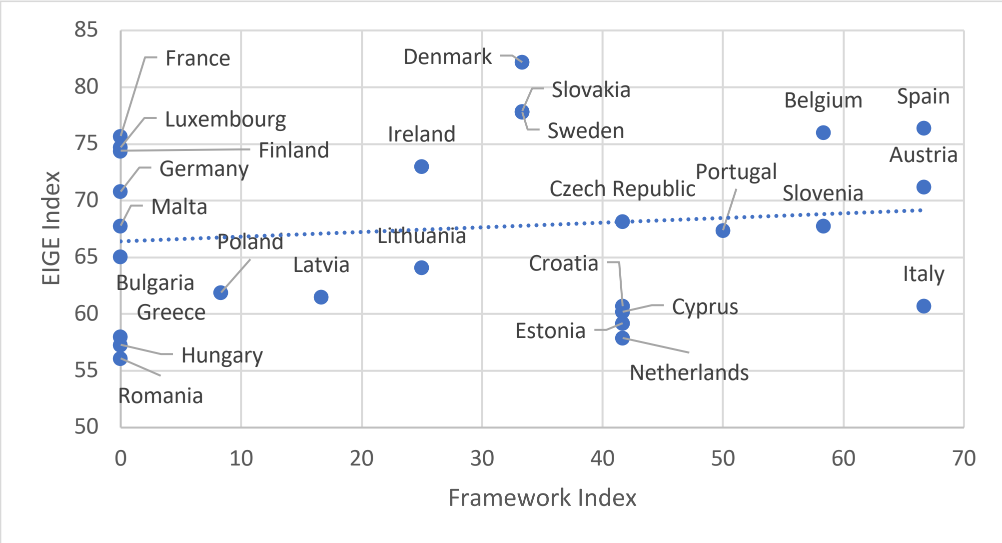


Figure 44. Correlation between the NRRPs' GEAI and the EIGE Index

The positive correlation means that increasing the score of the Framework Index is associated with an increase in the EIGE Index, however, the correlation coefficient is only 0.14. The results, however, are not surprising. The positive correlation could be explained by the fact that both indices assess how the gender dimension is considered within a national framework. The very low correlation, on the other hand, could be explained by the fact that our index has a very specific focus on the presence or absence of a gender perspective within the energy transition in the NRRPs. Another possible explanation is that some of the countries scoring low on our index are those that are already more advanced in terms of gender mainstreaming (with higher EIGE Index values) and therefore have not feel the urgency to incorporate specific gender measures within the energy related policies in their NRRPs, for instance Germany and Finland.

3.6 Discussion and conclusion

In this section, we discuss the results of the policy analysis of the first approved version of the NRRPs with the intent to compare to what extent the EU member states incorporated provisions concerning gender equality in the context of the energy transition. This work represents a first attempt to analyse the energy transition measures and dimensions in the NRRPs from a gender perspective.

To do so, we developed an analytical framework that, based on the framework proposed by Feenstra et al. (Feenstra & Özerol, 2021) for the analysis of NECPs, was tailored to the specificities of NRRPs and expanded with the clusters identified in the systematic literature review carried out in the task 1.1. of the gEneSys project (gEneSys, 2023).

Such a framework, referred to as the NRRPs GEAF, thoroughly described in Section 3, is made of 4 dimensions, each of which composed by different sub-dimensions and indicators. Each indicator, in turn, is broken down into one or more questions that allowed us to collect and systematize the qualitative data employed in the present analysis. The methodology employed is detailed in Section 3.4. Except for some quantitative data related to the amount of funds allocated to the NRRPs that we retrieved from the EC databases, the framework guided all the collection of the information from the NRRPs.

Concerning the funds allocated to NRRPs, the analysis shows a high degree of variability both in terms of absolute values and shares of countries' GDP. It is interesting to note that out of a total of 335.5 billion budgeted for all the EU countries, 274.1 billion (81.7%) was allocated to only eight countries (Spain, Italy, France, Germany, Poland, Greece, Portugal, and Romania). As mandatorily required by the EC, data also showed that all the countries allocated more than 37% of the funds to measures contributing to the green transition. However, while countries such as Austria and Sweden allocated a share of funds very close to the mandatory requirement (respectively, 38.8% and 43.6%), other countries such as Romania, Germany and Finland decided to dedicate more than twice the requirement (respectively 87.9% and 75.9%). Lastly, considering not only the energy transition but all the themes included in the plans, data on the funds allocated shows that countries dedicated varying shares of the total funds to measures focusing on gender equality, with an EU average of 3.37%.

Just energy transition

Moving to the results of the analysis carried out through the lens of the NRRPs GEAF, we observed that, with the notable exception of Bulgaria, all the NRRPs made some references to measures directed towards women, in particular in the contexts of social care, employment, disability, and health, but only 17 (63%) countries out of 27 explicitly adopt a gender perspective within the measures concerning the energy transition. In the attempt to explain the lack of provisions concerning the gender-energy nexus we can formulate at least two hypotheses. On the one hand, most EU countries may not recognize the importance of designing gendered policies on energy transition. On the other hand, the NRRPs could be reproducing the pattern of gender segregation of societal sectors whereby some sectors (e.g., those related to care and employment) are traditionally regarded as gender-sensitive and others (e.g., those related to infrastructures) as gender-neutral. This may be a legacy of the way energy policies have been conceived in the countries of the Global North, where energy has long been considered a sector of technical expertise, divorced from social policies.

Furthermore, the results highlighted that NRPPs differently represent women in the energy transition. In fact, out of the 17 NRRPs that explicitly mention a gender perspective within the measures concerning the energy transition, 7 NRRPs consider women as producers of energy, and 6 consider them as both producers and consumers. It is interesting to note that among the 11 NRRPs that recognize a role of women in the energy transition, just one of them consider women only in the role of consumers. This seems a positive sign of the increasingly recognised active role of women as energy producers.

Recognitional energy justice

Even in the dimension of Recognitional Energy Justice (i.e. the recognition of gender-specific needs and behaviors among energy consumers), our analysis reveals that the Plans are still far from achieving it. Among the 27 NRRPs, only two include gender-disaggregated data regarding energy user's needs, 8 of them recognize different behaviors towards energy, among which only 4 incorporate a gender lens. This deficiency stems from the widespread absence of gender-disaggregated data on these aspects.

This lack of data is constantly reported in the scientific literature and policy documents on the gender-energy nexus. Numerous publications of grey and scientific literature highlight the challenge of implementing gender-responsive policies due to the lack of data (see (gEneSys, 2023)). Data can be defined as a driver to unlock policymaking (GWEC, 2021). According to the grey literature on the gender-energy nexus, sex-disaggregated and gender-relevant data are essential for visualizing skills and workforce equality gaps, identifying women's needs to enhance energy access, evaluating the gendered impacts of energy infrastructure projects, and measuring gender inequalities and energy poverty. Recognized as a crucial driver for policymaking, gender-disaggregated data and indicators should undergo continuous monitoring and regular publication, including in annual national gender reports (gEneSys, 2023).

The lack of data and lack of analysis of available data reinforce the invisibility of women's energy poverty (Hagenmaier, 2023). One major issue with current data collection methods on energy poverty in Europe is that they predominantly gather information at the household level rather than individual level (Hagenmaier, 2023). This approach assumes income distribution is uniform among all adult household members, disregarding that, in some contexts, women do not have power over the decisions regarding household's expenditures. Additionally, it assumes that gender relations within mixed-sex households are symmetrical, overlooking the financial disparities and decision-making dynamics that often exist between men and women within households (Hagenmaier, 2023).

Regarding the recognition of energy poverty through a gender lens in the NRRPs, we found that although 71% of plans mention energy poverty, only 30% highlight the connections between energy poverty and gender inequality. This seems to confirm that, as noted by Murauskaite-Bull (Murauskaite-Bull, et al., 2024), energy policies often overlook the identity of energy consumers, resulting in a failure to address gender-specific needs. Without disaggregated data, it is challenging to understand the complexity of the issue beyond income poverty, gauge its extent, and devise appropriate interventions in both scope and implementation methods (Clancy, Kustova, Elkerbout, & Michael, 2022). Precise definitions and data are needed because using terms like 'vulnerable households' allows for broad interpretation and risks ineffective actions towards gender equality (Carroll P. , 2022). Without clearer definitions and data, interventions targeting vulnerable citizens may miss the mark addressing gender equality (Carroll P. , 2022).

Distributive energy justice

The analysis of the dimension of distributive energy justice showed that despite that more than half of the NRRPs include measures to guarantee energy access such as subsidies to reduce energy's costs, none of them incorporates a gender perspective. On the contrary, 6 out of 27 NRRPs (Austria, Belgium, Croatia, Italy, Slovenia, and Spain) mention measures supporting energy consumers that incorporate a gender perspective, such as energy efficiency incentive for buildings' renovation. The plans, however, mostly encompass measures directed to the improvement of buildings' energy efficiency. This is indeed a good starting point, since as illustrated by previous analysis (Ballesteros-Arjona, et al., 2022), (Murauskaite-Bull, et al., 2024) women are over-represented in low-income poor households, especially in single-parents ones, thus being more affected by energy poverty.

Distributive energy justice also assessed the extent to which NRRPs incorporated measures focusing on the nexus between energy and health. In this respect, it is interesting to note that EU countries were blind to such a nexus. In fact, only 4 NRRPs (Cyprus, Denmark, Lithuania, and Slovakia) do account for a relation between energy and health. Surprisingly, none of them included a gender perspective. Most EU countries, apparently, do not recognize the role of energy in health issues, and the few that acknowledge this nexus, do not adopt a gender lens. This result, however, could also be linked to the scarcity of gendered data on these themes in the EU.

Lastly, distributive energy justice included dimensions concerning the commitment to promote and improve equal access to knowledge on technological innovations, and to guarantee equal employment opportunities for women in the energy sector. From this perspective the analysis shows, compared with the other dimensions considered, a more positive picture. Indeed, 13 out of 27 NRRPs do mention some measure aimed at increasing women's access to STEM disciplines. In general terms, NRRPs recognize as a challenge the low participation rate of women in STEM disciplines. As a matter of fact, most NRRPs provide measures aimed at increasing their presence, often also in the perspective of increasing their participation in energy sector-related jobs. Nevertheless, we found that only 9 (33%) Plans mention measures to increase women's participation in the energy job market. In most of the cases, these measures are aimed at, on the one hand, fostering women's entrepreneurship in the context of the energy transition, and, on the other hand, increasing the share of women in the workforce to reduce gender imbalances in the sector. Overall, therefore, the plans seem not to guarantee what we have defined as distributive energy justice creating the risk of increasing gender inequalities due to gender-blind measures.

Procedural energy justice

The last dimension considered by our framework concerns procedural energy justice, defined as the process by which decisions about energy issues are made and measured in relation to what extent the procedures used by decision-makers are considered just (Jenkins, McCauley, Heffron, Stephan, & Rehner, 2016). To assess it through our gender lens, we considered whether NRRPs have been drafted in tandem with institutions or groups whose mission focused on the promotion of women's empowerment. The results that show only 7 NRRPs (Cyprus, Czech Republic, Estonia, Ireland, Lithuania, Netherlands, and Portugal) have consulted these groups. This may prove particularly problematic since, when designing policies, it is of outmost importance to include the viewpoints of all the stakeholders that might be potentially affected by such policies.

NRRPs' Gender-Energy Assessment Index

Overall, the results show that most of the EU countries' NRRPs consider women as a subject of the energy transition, but with quite different degrees of involvement. The elaboration of the index based on the theoretical framework (Figure 43) graphically displays such variegated picture. The index, ranging from 0 to 100, namely from not considering gender in any indicator to considering gender in all the indicators, illustrates that, while none of the countries scored the highest possible value, 10 countries scored 0. The rest of the considered countries' scores varies from 17 for Latvia to 67 of Austria, Cyprus, and Spain. We can therefore highlight how, overall, even in the cases NRPPs take a partial stand on gender equality when it comes to energy transition.

Concluding remarks

This analysis provides a glimpse into how and to what extent countries have planned for the transition towards sustainable and socially just energy systems. In line with the literature, our analysis was guided by the hypothesis that we cannot assume that the energy transition will spontaneously bring along more gender equality. The benefits and the negative impacts of the transition will not be distributed equally between genders; on the contrary they may reinforce existing inequalities. Women's empowerment in the energy sector must be bolstered through policy instruments specifically designed for or, at least embedding, gender equality principles and objectives. Only a policy-oriented energy transition designed in a gender-sensitive manner will be able to truly reduce the gender imbalances in the sector.

In the framework of the NRRPs, the present analysis demonstrates how this has been done only partially. On the one side, many countries did not include any gender perspective in the provisions concerning the energy transition, not explicitly recognizing the different energy needs that women and men have and the roles that women can play to actively participate in the transition. On the other side, many of the countries that included to some extent a gender perspective in the provisions concerning the energy transition have done so partially, incorporating only some of the dimensions of the NRRPs GEAF.

This result could depend on the fact that policymakers have a little awareness of the gendered dimensions of the energy transition and therefore do not deem it necessary to include gender-specific measures. Consistently with the "no data, no problem, no policy (or sometimes "no action")" principle, this lack of recognition could be reinforced by the dearth of gender-disaggregated that can substantiate the need for gender-sensitive policies. This seems somehow confirmed by the fact that the dimensions of the energy transition in which the gender dimension have been most recognized, such as education and employment, are also those in which most gendered data are available. However, we cannot draw any conclusive remarks on this aspect, and future research is needed to verify it.

Lastly, the little inclusion of a gender perspective into many NRRPs could also be attributed to the peculiar nature of NRRPs that are simultaneously a policy instrument and a programmatic document. On the one hand, they set up a normative framework guiding the subject matters included in the document, while on the other hand, they enucleate a series of principles that underpin the allocation of the funds. This consideration, together with the Commission's requirement of considering the gender dimension as transversal through the plan, opens up the possibility that EU member states will decide to include the gender dimension as a criterion for the selection of the projects that will be funded under NRRPs, rather than just mentioning it in all the dimensions of the energy transition included in the NRRPs.

Due to the lack of open data on NRRP's funded projects in each country, however, we were not able to assess the extent to which the mandate for gender mainstreaming was clearly stated as a criterion for the projects to be funded. This limitation of the analysis opens a venue for further research on the implementation of the NRRPs through gender-sensitive analytical lens. For future monitoring and evaluations and of the impact of the plans we propose the following research questions: has the inclusion of the gender dimension been required for the project to be funded under the NRRPs and, if so, to what extent? Are there specific NRRPs' funded projects assessing the gender dimensions of the energy transition? What are the most successful projects financed by the NRRPs and the good practices to be replicated for a just transition from a gender perspective?

If not accompanied by the systematic collection of disaggregated data and addressed through gender-specific measures, the gender mainstreaming runs the risk of becoming a buzzword useful for fulfilling the EU's mandatory requirements, but not sufficient to redress gender power inequalities. Furthermore, as we have observed, the gender perspective is not transversal homogeneously along all the components of the plans. On the contrary, some components are highly gendered, while others are barely touched by the gender perspective. The dimensions identified in the analytical framework regarding the energy transition are among the least gendered ones.

Policy recommendations

The national recovery and resilience plans are policy documents developed in the wake of the covid-19 pandemic, which added to the adverse effects of the ongoing climate change, the energy crisis, political instability and social inequalities. These are therefore one-of-a-kind documents through which member countries were granted access the largest funding programme ever financed by the EU. These documents represented the opportunity to reframe development in a sustainable and just manner; yet, as demonstrated in this study, there are still many gaps that need to be filled. Below we highlight some suggestions for the development of gendered policies in the context of the energy transition.

Seemingly, data reveal a pattern between the availability of data and the inclusion of certain dimensions in sector-specific policies. In fact, most of the dimensions of NRRPs GEAF addressed in the PNRRs are also those for which more data is available. On the contrary, the less studied topics, therefore less known, are those less addressed by the Plans. As suggested by several authors, policies addressing a just energy transition should include the financing of research to generate of gender-disaggregated data, especially on aspects considered less, such as women's health, gendered energy needs and energy poverty (European Court of Auditors, 2021). Further research is needed on the energy practices and lived experiences of vulnerable energy users as data could shed light on existing injustices and inequalities in energy access (Murauskaite-Bull, et al., 2024).

Since the term STEM encompasses various disciplines, but not all of them present gender imbalances in terms of representation of men and women. In some disciplines women are more represented than in others. For instance, biomedical science reports higher shares of women compared to technology, mathematics and engineering (European Commission, 2021). To increase career opportunities for women in the field of energy innovation and technologies, there is a need to support their presence in the respective STEM disciplines. We therefore suggest designing specific policy measures to reduce the gender gap in higher education and in initial professional career's choices (for instance through tailored intervention in primary and lower secondary schools) to make energy transition jobs more inclusive and gender balanced.

Some dimensions of the energy-gender nexus are not recognized and addressed in the Plans, namely the energy consumers' health, the inequalities in access to energy services and the energy user's needs. We suggest that these issues are addressed as an integral part of the just energy transition if we are to realize an energy transition that is fair and avoid producing disparities between 'winners' and "losers".

Finally, in the context of climate change and air pollution, the link between energy and health is becoming increasingly more evident. It is therefore necessary to study and address in public policies the relationship between energy poverty and vulnerability to increasingly extreme temperatures, such as heat islands in urban contexts, as well as the link between energy poverty and indoor air pollution linked to the use of wood as fuel in rural Europe.

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