

Review

Complete but Fragmented: Research on Energy in Central and Eastern Europe

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Abstract: This paper examines 16 years (2004–2019) of research on energy in eleven Central and Eastern European countries. The findings are based on an analysis of 3534 academic articles indexed in the Web of Knowledge database. The paper presents a systematic overview of the authorship, journal of publication, countries covered, and article content. The main conclusion is that the discussion is fragmented, because most of the journals (800 were identified) published only one paper on energy in the region. About one-fourth of the research was published in a handful of major journals. Male researchers dominated our dataset and there has been a visible increase in the average number of authors per article. The country most often covered by the research was Poland and energy efficiency was the most-discussed issue and renewables the most-frequently researched energy source. Surprisingly, nuclear energy and energy security, considered to be the dominant features of the CEE region energy picture, were studied only minimally.

Keywords: Central and Eastern Europe; energy; literature review; academic journals



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1. Introduction

Although energy security has attained a dominant position within the European Union's energy policy following the Russian invasion of Ukraine [1,2], decarbonization and energy transition (which are closely linked) remain the EU's ultimate goals [3]. The 2022 energy crisis is seen as an opportunity to speed up decarbonization efforts to decrease both the EU's dependency on Russian energy supplies and greenhouse gases emissions. The increasing importance of the energy transition within the current decarbonization discourse has been mirrored in the academic literature [4–6]. There is interest in moving beyond the current system of burning fossil fuels and this requires a large amount of research into new technologies, on how they will link into the existing energy infrastructure, and their deployment in individual countries [7–9]. This brings new technical, economical, and societal challenges [10,11]. Researchers react to these by studying energy systems and how they change from different perspectives [12]. Scientific research examines the potential of renewables sources, energy efficiency, and storage technologies, while engineering research leads to the development of new compounds. Energy, a key indicator of economic growth [13,14], is an important part of the economic research on energy markets and trade. Social science research examines the political and social processes driving the energy transition and the social acceptance of and barriers to change [15–17].

Consequently, a vast amount of knowledge has often been gathered separately within different (sub)disciplines. An effort has been made to provide overviews of the existing literature to obtain a more complex picture about what we actually know and what research gaps there are. These analyses examine the existing literature on, for example, renewable energy in general [18] and solar energy in particular [19,20], carbon capture and storage technology [21,22], energy security [23,24], justice [25], democracy [26], or energy efficiency [27]. This type of overview provides an incomplete picture, which, although it can

tell us a lot about the issue, is but one small piece of the decarbonization puzzle. Another approach is to study the literature from a regional perspective, although this approach is often combined with the previous one [28,29], resulting in a very narrow perspective. As a result, both types of review tend to analyze a very small number of articles—for example, 99 [28], 92 [26], or 52 [29] (but see [25] or [30] for a different approach). This provides some qualitative depth but, given the small number of articles analyzed, the quantitative data cannot provide a more complex picture.

The present paper examines all the research (i.e., population, not a sample) on the energy sector in Central and Eastern Europe (CEE), defined here as Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia, conducted between 2004 and 2019. Contrary to the above-mentioned review papers, we were interested in the general characteristics and directions of the research and therefore adopted a holistic approach to the data collection and analysis. The main goal of our research was to study the existing knowledge about energy in CEE. Our main research question asks: What do we know about the energy sector in the region? Moreover, we were interested in identifying topics that have been part of the public discourse that have only partially been covered by the existing academic literature. For example, although energy security is firmly embedded in the energy policy discourse within CEE, especially after the 2009 gas crisis [31], the results of our analysis show that this is not reflected in academic outputs. This study identified research gaps and new questions that stem from them, and we propose avenues for future research that can investigate the challenges outlined by this research in more depth and with the use of different methods. Our unique dataset thus presents a springboard for future research on energy in CEE.

Our dataset consists of 3534 papers on the CEE energy sector published in journals indexed in the Web of Knowledge (which is a key database for this type of research; [27,32]). The region was part of the communist bloc that subsequently embarked on a difficult economic transition in the 1990s followed by an energy transition in the 2000s [33]. Although the economic transition was, to some degree, associated with the EU, the energy transition is very closely linked to the CEE countries' EU membership [34]. Therefore, our research is temporally linked to EU membership—from EU accession in 2004 to the introduction of the European Green Deal, EU's major green initiative from 2019 [35].

The aim of this review paper is to map and analyze articles published on the CEE energy sector so as to obtain systematic insights into the existing research. The Section 2 provides information on the paper's methodology, including case selection, data collection, and coding. The Section 3 presents the results of our analysis in four subsections: the journals in which the research was published, authorship, country coverage, and article content. The conclusion summarizes the main findings of the paper and suggests avenues for future research.

2. Materials and Methods

2.1. Case Selection

This paper examines the literature on Central and Eastern European countries: the 11 post-communist countries that joined the EU during the so-called Eastern enlargement [36]. In the communist period, energy supplies to Europe served not only as a source of income for the Soviet Union (as was the case with supplies to Western countries), but also as a political means of controlling the Soviet satellite countries in Central and Eastern Europe [37]. CEE energy systems were heavily centralized and, similarly to other sectors, lay exclusively in state hands. Relatively cheap natural gas, in addition to other energy sources such as oil or coal, from the Soviet Union formed the backbone of their energy sectors. One of the legacies of this is the poor energy efficiency in many CEE countries [38]. During the 1990s, several CEE countries improved household access to natural gas (often subsidized), prompting greater consumption and the need for stable supplies, especially during the heating season. Dependency on Russian energy supplies varies among the CEE countries; the Czech Republic, Estonia, Poland and Romania have important domestic

fossil fuel sources and are therefore much less dependent than other countries from the region. However, this also means that the energy decarbonization associated with the EU's ambitious climate and energy goals therefore present a particular challenge for some CEE countries, for example, Poland [33].

As Poland is often implicitly or explicitly considered to be representative of the region as a whole, rejection of the EU's ambitious climate goals is often thought to apply across the region [39]. However, this is not the case [40], as CEE countries' approaches towards decarbonization vary. For example, Lithuania decided to pursue ambitious policies supporting a 100% renewable electricity target by 2050 without relying on nuclear power [41]. In contrast, Slovakia, together with the Czech Republic, Hungary, and Poland, belongs to a group of countries that consider nuclear energy crucial to meeting their climate goals and therefore take it into account in future plans [42]. Nuclear energy was also an important issue during the EU accession negotiations, especially for Bulgaria, Lithuania, and Slovakia, as they agreed to shut down their nuclear reactors due to safety concerns (Kozloduy units 1 to 4, Ignalina units 1 and 2, and Jaslovské Bohunice V1 units 1 and 2). Other countries in the region had a much smoother ride when concluding the energy chapter of their negotiations.

At the political level, energy has gained particular attention within the CEE region since the 2009 gas crisis [31]. As a result of the conflict between Ukraine and the Russian Federation over transit fees and the price of natural gas, no gas flowed to the EU via Ukraine (through the Brotherhood pipeline) for almost two weeks at the beginning of 2009 during the peak heating season [43]. Not all countries in the region were affected to the same degree. Some of them (the Czech Republic, Poland) either had no problems as they used different supply routes such as Yamal, had domestic sources, or used other suppliers. However, for some (most notably Bulgaria and Slovakia), the crisis had severe consequences as these countries had no alternative supplies ready and thus had no natural gas supplies for most of the duration of the crisis [44]. This event served as a wakeup call for the region that—in spite of all the changes that have occurred since the fall of the communist regimes in 1989—has not exerted much stress on developing the energy sector and diversifying energy supplies (the Czech Republic being an exception). Although generalizations about the region have their limits [40], in most cases before the 2009 gas crisis the CEE countries had not taken the time to revise their communist-era energy policies and infrastructure. The crisis caused many CEE countries to change their position on energy in general and energy security in particular [45]. However, despite the implementation of numerous diversification projects, especially within the so-called Visegrad Group countries [46,47], the Russian invasion of Ukraine in February 2022 fully uncovered the problems connected to continued dependence on Russian supplies, most notably in the natural gas and oil sectors. The Czech Republic, Hungary, and Slovakia (together with Germany) have been especially reluctant to impose strict sanctions against Russia in the aforementioned sectors, searching instead for opt-outs from the EU agreement [48].

Moreover, the CEE came to attention when EU leaders tried to reach agreement on climate neutrality by 2050. At the European Council in June 2019, four countries (the Czech Republic, Hungary, Estonia, and Poland) opposed climate neutrality within the EU, perceiving the goal to be too ambitious, potentially damaging to their economies, and hard to implement without financial assistance [33]. At the next summit in December 2019, the European Council was able to conclude the final agreement on climate neutrality by 2050. Poland remained the only EU country that did not commit to implementing the goal, although it was not named directly in the meeting's conclusions [49]. Regarding the importance of the deployment of renewables in decarbonization efforts, there are remarkable differences between CEE countries concerning mid-term 2030 commitments as set by Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action. While Croatia, Estonia, and Lithuania overreached, and Bulgaria and Latvia followed the recommended renewables target set by the European Commission, the remaining six countries did not commit to the more ambitious goals, remaining below the Commission's recommendations [50]. Nonetheless, CEE countries are often considered to be a homoge-

nous group with similar preferences at the EU level that reject ambitious decarbonization goals.

Thus far, efforts to aggregate the existing research and determine what knowledge has been gained about the CEE energy sector, and what has yet to be explored, have been limited. This paper's main goal is to provide an overview of the contemporary scholarship on the CEE energy sector and contribute to the general knowledge about the region and its energy challenges, notably decarbonization, energy efficiency, and energy security.

2.2. Data Selection

In the first step, we created a dataset containing all the papers that met our criteria. Contrary to similar research, we did not look at just one journal [51] or select journals ([52] usually referred to as the “leading” or “main” journals) but opted to collect all articles relating to the region. We searched the Web of Knowledge (WoK) database with the help of two sets of keywords and did not focus on particular journals or disciplines. This approach allowed us to focus on the energy sector more broadly, to collect all the research papers, and to go beyond the more traditional (and much less time-consuming) approach of choosing a limited number of journals for coding. Altogether, we collected articles that were published in (exactly) 800 different journals (see Figure 1). We used the WoK database as our source of articles, an approach commonly utilized by scholars examining existing research [32] (see [27] for an example of the use of different databases or [53] for combining WoK and other databases).

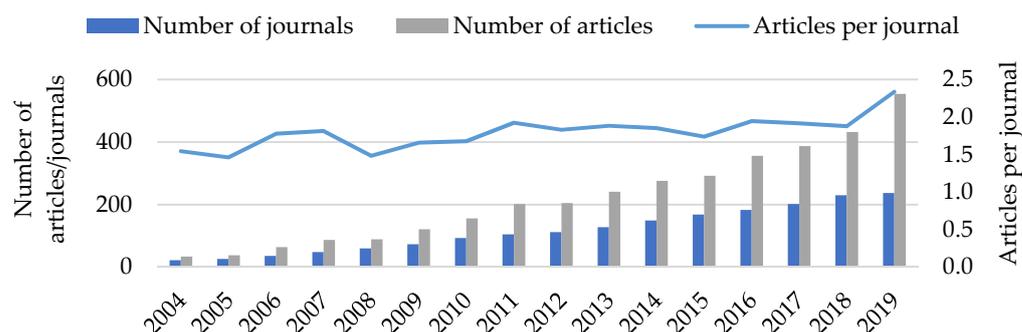


Figure 1. Number of articles and journals. Source: Authors; N = 3534.

We collected all articles that had a combination of the following two sets of keywords in the title, abstract, or keywords. The first keyword was always ‘energy’ and the second one was country specific: name of country (‘Bulgaria’, ‘Croatia’, etc.) or adjective (‘Bulgarian’, ‘Croatian’, etc.). Since our research concerned the whole region, the second keyword related also to terms identifying the region or subregion (‘Baltic’, ‘Baltics’, ‘CEE’, ‘CEEC’, ‘Central Europe’, ‘Visegrad’, ‘V4’). We excluded articles not related to energy as a market commodity—those that focused on kinetic energy or nutrition value, for instance. We also excluded articles that did not specifically deal with at least one of the 11 CEE countries. For example, some articles found with the keyword ‘Central Europe’ dealt with Germany, or even just Northern Italy.

We collected journal articles only and excluded other types of publication such as books, chapters, and conference proceedings, in addition to other types of journal content such as book reviews or editorials. This decision was made based on the dominance of journal articles over other types of academic publications because this dominance provides them with their scope, author overlap, and a manageable dataset [52]. Our dataset contained papers in English only as we acknowledge that English is a lingua franca that enables worldwide conversations among scholars from different countries.

We searched for articles published between 2004 and 2019 as this period captured the beginning of the three waves of the EU’s Eastern enlargement—in 2004, eight CEE countries joined the Union (the Czech Republic, Estonia, Hungary, Latvia, Lithuania,

Poland, Slovakia, and Slovenia); in 2007, Bulgaria and Romania became members; and, in 2013, Croatia joined the Union, and is still the youngest member state today. The end of the period marks the introduction in 2019 of the European Green Deal by the European Commission [54]. Although not all the papers relate directly to the EU, the timeframe was selected so the results can be discussed within the framework of EU membership as this has had a significant impact on the CEE energy sector [33]. Our final dataset consists of 3534 articles published over 16 years.

2.3. Coding

In the second step, the articles were coded. This was undertaken manually by two researchers with the help of a codebook. We coded the following: first author gender, number of co-authors (and gender), name of journal, year of publication, disciplines, countries covered, level of governance, research area, and energy source. The first author was considered to be the main author (although a last author policy is currently being adopted in many research communities), so we coded the author's full name and gender. We also coded the co-authors' gender as we wanted our data to contribute to the ongoing discussion about gender biases in research (see, for example, Refs. [55,56]). Year of publication was included so trends could be observed over time, while journal name was selected so we could monitor the frequency with which the CEE region is discussed in individual journals.

We differentiated between four main disciplines—science, the social sciences, economics, and interdisciplinary research. Articles coded as 'interdisciplinary' are a combination of at least two of the above-mentioned categories with 'the focus on integration of knowledge as an essential factor distinguishing interdisciplinary research' [57]. Interdisciplinarity was thus measured based on a detailed analysis of the individual articles, as suggested by Barthel and Seidl [58]. Since several journals required manuscripts to discuss policy implication, the presence of this section alone was not a sufficient reason to code an article as interdisciplinary.

We also looked at the countries studied in the articles. A further coding category was level of governance, i.e., the unit studied. This varied from international (covering several states) to category of location, which included buildings or even smaller units (walls, windows, etc.). All other codes are self-explanatory, except company, which covers issues such as green management in a particular firm or the trade strategies of energy majors. We coded the research area according to the five Energy Union dimensions—energy security, internal energy market, energy efficiency, decarbonization, and research and innovation [59]. The last coded category was the energy source considered in the article: specific (biofuel, biogas, biomass, geothermal, hydro energy, solar, wind, coal, natural gas, oil, nuclear, hydrogen, and waste) and general (fossil fuels, renewables, and electricity). If no specific energy source was mentioned, the article was coded as research on a general energy source.

3. Results

In this section we present the results of our analysis using four main categories. We discuss (A) journals publishing research on CEE countries in 2004–2019, changes in the number of articles on the topic, and the research discipline (science, social sciences, etc.); (B) authors of the papers, including gender and collaboration pattern; (C) number of articles covering individual CEE countries and non-CEE (and non-EU) countries in our dataset; and (D) research content focusing on different energy sources (various renewable sources, fossil fuels, etc.), research area (energy security, market, etc.), and level of governance (local, national, regional, etc.).

3.1. Journals Containing Articles on CEE Energy

In the period studied (2004–2019) 3534 scholarly articles from various disciplines were published in (precisely) 800 academic journals listed in WoK. The large variety of journals in our dataset indicates that a wide range of journals, not just those focusing on energy

related issues, are interested in research on the CEE energy sector. For example, the Journal Citation Report lists 144 journals in the Energy and Fuels category, 274 in Environmental Sciences, and 377 in Economics. Moreover, the number of journals (and articles) publishing research on energy in the CEE region has risen (Figure 1, left axis).

Although only 34 papers on the CEE energy sector were published in 22 different journals in 2004, in 2019 that number increased to 554 articles published in 237 different journals. The increase has been steady and there is not one year over the 16 years when fewer articles were published in fewer journals than in the previous year. This demonstrates both an increase in scholarly interest in the CEE energy sector and in editors wishing to publish such research in a wider spectrum of journals.

The right axis of Figure 1 shows the average number of articles per journal, which increased in the last year (2019), when it reached almost 2.5. In 2004 the average number of articles per journal was slightly over 1.5 and in 2011–2018 it remained under 2 articles per journal. Thus, although the average number of articles per journal stayed very similar for most of the period, in 2019 we can observe an increase in the discussion in the journals as more articles were published on the CEE energy sector.

This picture, albeit a very general one, is indicative of a positive direction in the scholarship on the CEE energy sector. Figure 2 shows the distribution of the articles across the journals. Although most of the discourse is limited to just a few journals (28% of articles were published in 11 journals), many other journals (368) published a number of articles on the subject (between 2 and 49). In addition, just under one-third (32%) of the articles (1116) were published in journals containing fewer than 10 articles on the CEE energy sector. The top 11 journals published 995 articles in total, with each publishing more than 50 papers in the timeframe (the pie chart in Figure 2). The greatest number of articles was published in *Energy Policy* (143 articles), followed by *Energy* and *Renewable and Sustainable Energy Reviews* with 141 articles in each. Most of the journals (421) published only one paper on the subject. However, this accounts for only 12% of all the articles in our dataset (421 out of 3534).

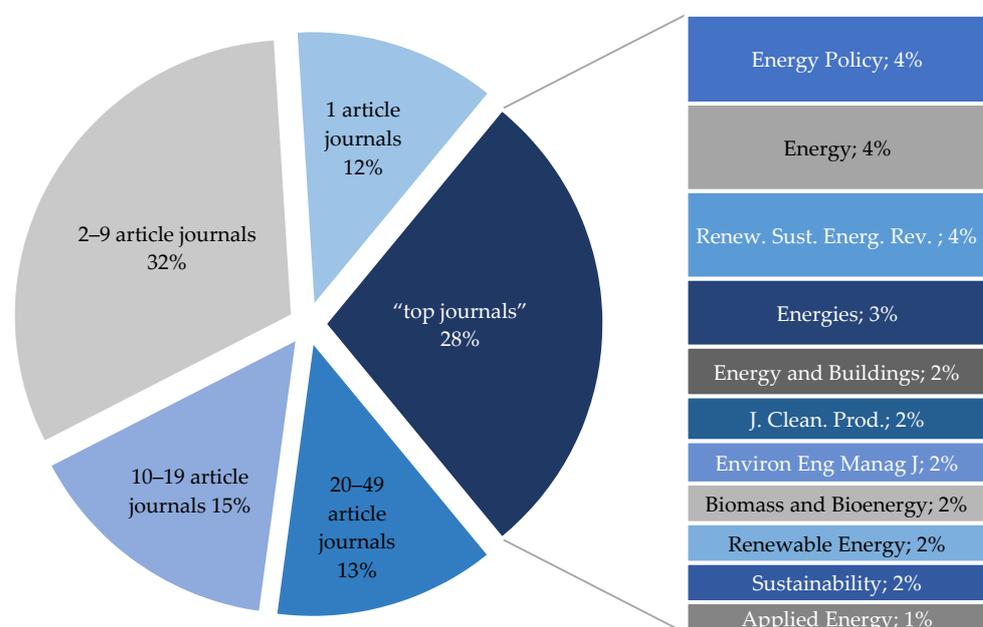


Figure 2. Article distribution across the journals. Source: Authors; N = 3534.

The variety of journals shown in the figures above is indicative of the range of disciplines within which the research was conducted. To investigate this, we looked at the four main families of academic disciplines. Figure 3 shows the number of articles and the number of journals in the four disciplines: economics, science, social sciences, and interdisciplinary (see Section 2 for more details on the coding). The right axis shows the number of different journals in which articles belonging to these four main disciplines were

published, and the left axis shows the number of articles published each year. We coded the articles, rather than the journals, as the journals are often interdisciplinary and thus publish papers belonging to several main disciplines.

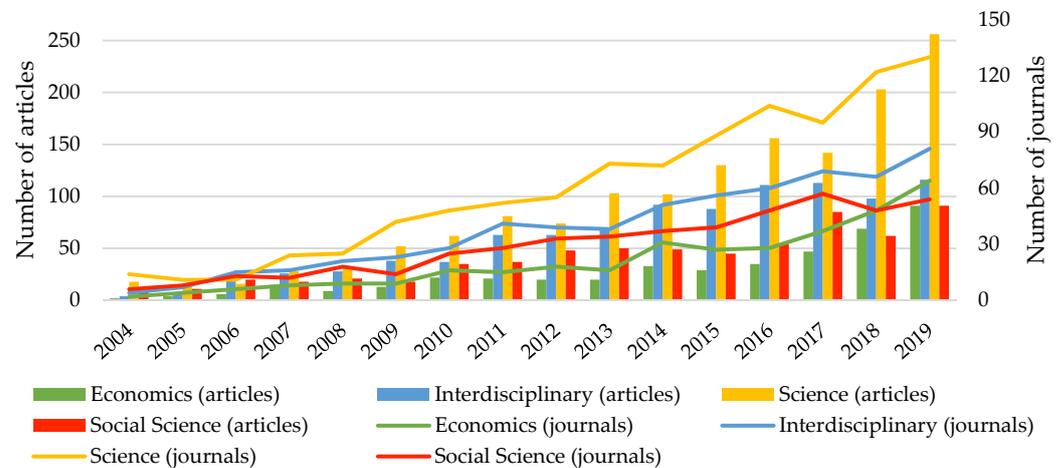


Figure 3. Number of articles by main discipline. Source: Authors; N = 3534.

3.2. Authors of Papers on CEE Energy Sector

We then looked at the authors of papers published on CEE energy between 2004 and 2019 from two main perspectives: gender and collaboration. Figure 4 shows the number of male and female authors (left axis) compared to the average number of authors per article (right axis). Some authors occur in the data multiple times. Altogether we identified 3658 female authors (almost 32% of all authors) and 7886 male authors (slightly over 68%). Male authors dominated our dataset each year, both as first authors and as authors in general. The lowest share of female authors occurred in 2004 (above 20%) and the highest in 2018 (almost 36%). Overall, a male researcher was the first author of 2300 articles (more than 65%) and women were the first authors of 1234 (almost 35%). There were 431 articles (about 12%) by female authors; of these, 189 were written by a single author and 242 in collaboration with other female authors. Papers authored by men amounted to 1405 articles (almost 40%); of these, only 348 were written by a single author and the remaining 1057 were collaborative efforts with other male authors.

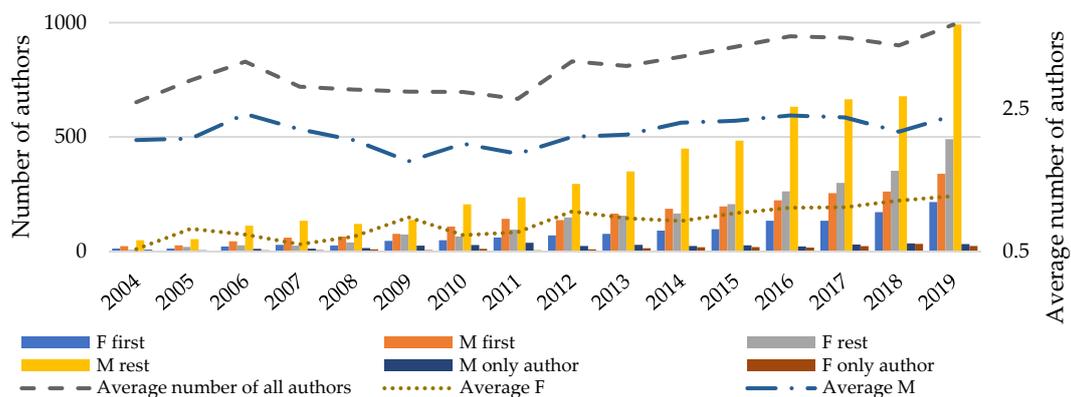


Figure 4. Gender distribution and collaborative patterns. Source: Authors; N = 11,544. Note: M/F rest—all authors male/female except the first author.

Figure 4 also shows other aspects of collaboration. Most articles (2997 or 85%) were written by two or more authors. The remaining 537 articles (15%) were written by one author. The number of single-author articles written by female researchers peaked in 2018 at 32 articles, while most of the single-author articles by male researchers were written in 2011. Although the number of single-author articles has not risen over time, the number of

articles written in collaboration has increased remarkably. Moreover, there has been a rise in the average number of authors per article: from 2.5 to 3.7 authors per article between 2004 and 2019. This increase is mainly due to the increased involvement of female researchers in publishing—the average number grew from 0.5 in 2004 to almost 1.3 in 2019.

3.3. Countries Examined in the Literature

In the next step, we looked at the countries analyzed in our dataset. In total, 119 countries were studied, including 11 CEE countries, which were the primary focus of the research. Figure 5 shows the EU and non-EU countries covered in the articles in our dataset more than 50 times (with the exception of the USA, which was mentioned 58 times).

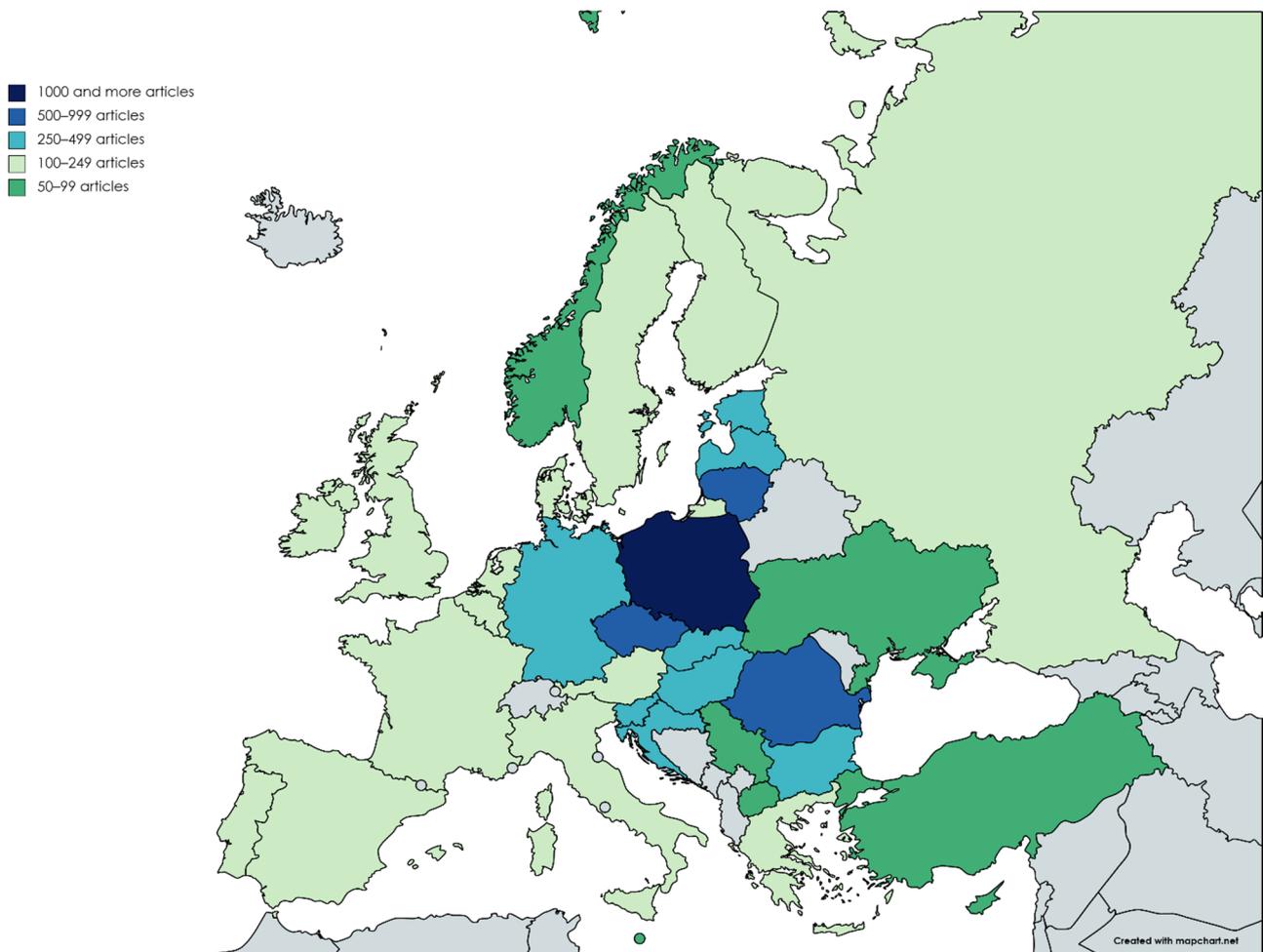


Figure 5. Number of articles (above 50) examining select countries. Source: Authors; N = 3534; made with Mapchart.net (accessed on 20 July 2022).

The most frequently investigated non-CEE country was Germany, at 284 articles. Sweden was second, featuring in 203 articles, followed by Finland (192 articles), Denmark (185 articles), and France (182 articles). The Russian Federation was mentioned in 138 papers and ranked twelfth among non-CEE countries. This is quite surprising given the position of Russia in the energy discourse in the European Union [60]. For the same reason [61], the rather small number of articles including Ukraine in their analysis (78) was unexpected. Not all countries are shown on the map; in many cases the comparative articles on the CEE energy sector included other non-European countries. Besides the USA, China featured in 42 articles and Canada in 30.

We also wanted to find out which countries were dealt with as case studies and how many articles utilized a comparative approach. We coded the country names in articles

focusing on a particular country (i.e., the country was the level of analysis), and those on a specific part of a country; for example, if a paper looked at a municipality in Poland, we coded the paper as being linked to Poland. The results are shown in Figure 6. Only one-third of the articles (893) utilized a comparative design, whereas most of the papers (2641) analyzed an issue connected to one country. Regarding the share of comparative studies by year, the highest proportion was in 2004, of over 40%, whereas in 2011, only 19% of papers published were comparative analyses, which highlights the domination of single-country papers.

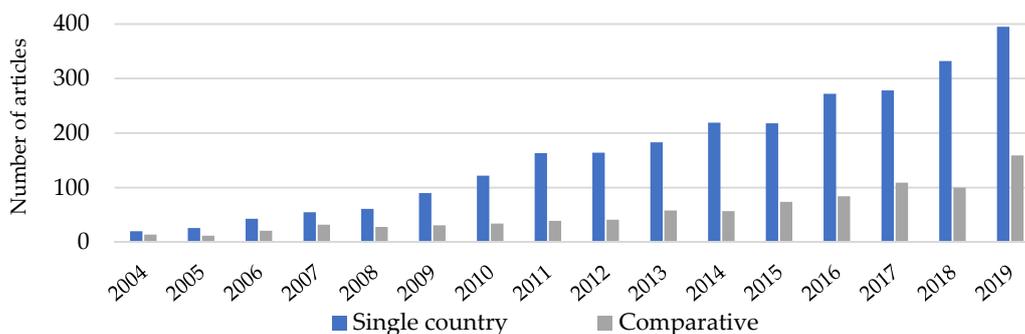


Figure 6. Share of single country and comparative studies. Source: Authors; N = 3534.

Within the CEE region Poland was the most commonly studied country, with 1303 articles researching energy issues in Poland between 2004 and 2019. There was a significant increase in interest in Poland—from 14 articles in 2004 to 262 in 2019 (see Figure 7). No other country received as much academic attention. Romania was ranked second and was the country of interest in 668 articles, followed by the Czech Republic on 554, and Lithuania on 552. Bulgaria was ranked last, with 312 papers covering this country. However, Bulgaria often featured in comparative studies—76% of the papers (238 out of 312) on Bulgaria looked at a minimum of one other country (see Figure 8). This may be indicative of a lack of expertise on Bulgaria and its distinctiveness within the CEE region. By contrast, only 35% of articles examined Poland and Romania with a comparative research design.

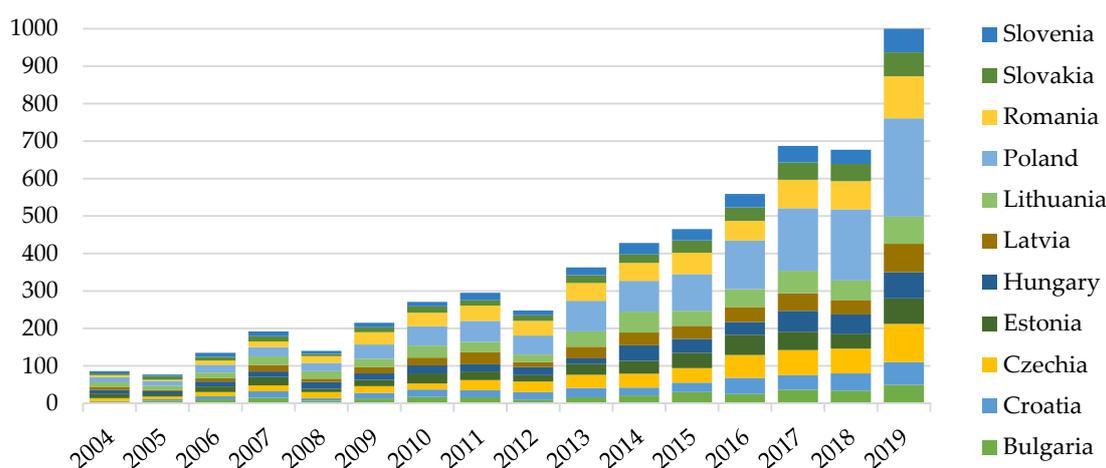


Figure 7. Number of articles covering CEE countries in our dataset. Source: Authors; N = 5838.

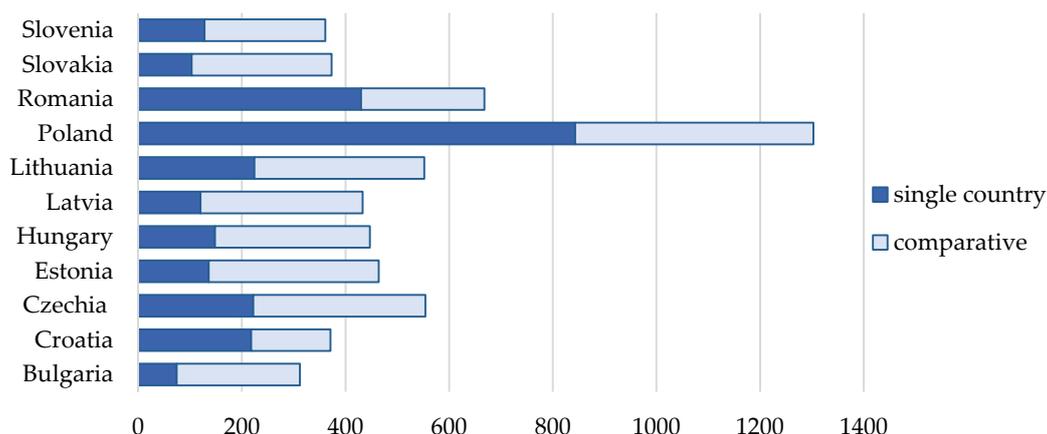


Figure 8. Share of single country and comparative studies among the 11 CEE countries. Source: Authors; N = 5838.

3.4. Content of the Dataset

The current section is concerned with the content of the articles in our dataset. Figure 9 provides information on the level of governance and shows that most of the articles adopt a whole-country perspective when considering energy issues. The number of articles is broken down by six categories of level of governance (location, company, municipality, region, country, and international). The greatest increase in the number of articles was seen at the country level (up from 16 in 2004 to 257 in 2019), followed by papers on a single location; for example, energy efficiency experiments on a single building or biomass cultivation in a specific field (from 12 to 166). It is interesting that the number of company-level and municipality-level analyses remained very low—the highest number of articles researching a company was 27 in 2019 and for municipalities the highest number was 36 articles in 2018. Further research on both these levels is required, as cities and companies will be a crucial aspect of energy efficiency measures as part of climate change mitigation.

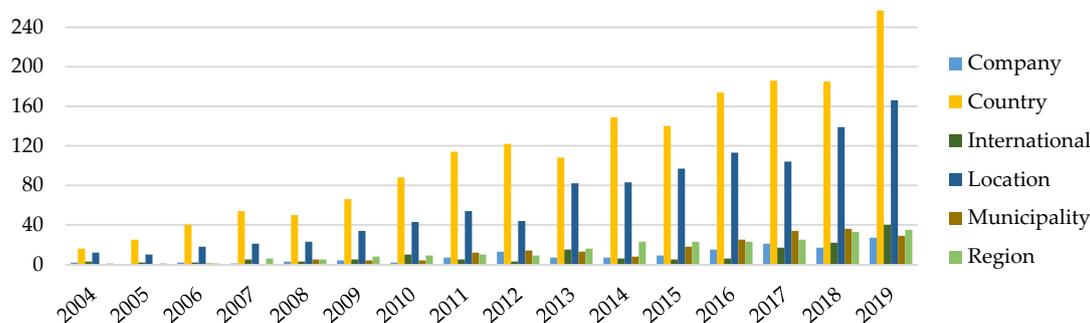


Figure 9. Level of governance. Source: Authors; N = 3534.

We then looked at the Energy Union dimensions (Figure 10). The European Commission's Energy Union initiative proposed five main categories for EU energy policy—decarbonization, energy efficiency, energy security, internal energy market, and research and innovation [59]. We coded our dataset accordingly to find out which categories have been researched most and which require further analysis. We can observe a clear trend in the rise of papers on decarbonization and energy efficiency, especially since 2017. In 2004, only five papers were published in each of the two categories and, in 2017, this rose to 56 and 81 respectively; by 2019 there were 121 articles on decarbonization and 187 on energy efficiency in CEE countries. The trend in research and innovation is less clear-cut, with 2018 seeing a rather sharp decrease, despite it having previously dominated the research. Research on the internal energy market recorded some increase, but this was only minimal. The least-covered area was energy security, despite this having changed considerably in the

CEE region after the 2009 gas crisis [44]. Some increase was recorded in the years following the 2009 crisis and the 2014 dispute between the Russian Federation and Ukraine, but overall interest remained low, peaking in 2017 with 19 articles.

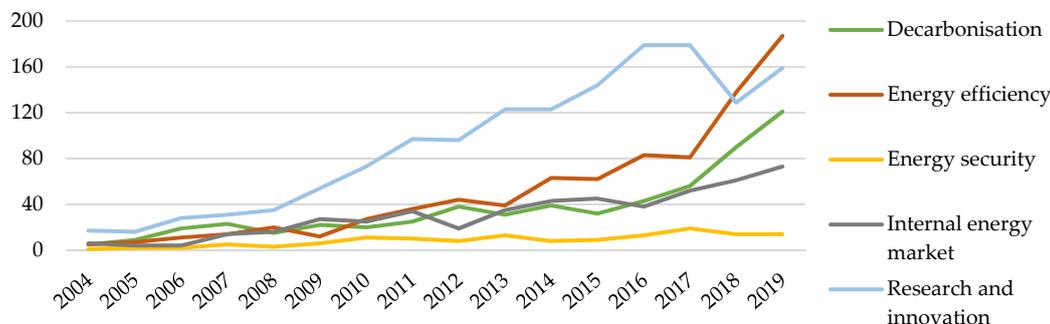


Figure 10. Number of articles featuring the Energy Union dimensions. Source: Authors; N = 3534.

We then looked more closely at the relation between the five Energy Union dimensions and the various scholarly disciplines (Figure 11). Economic papers tended to focus on the internal energy market (213 articles) and energy efficiency (137 articles); interdisciplinary research was mostly concerned with research and innovation (310) and energy efficiency (279); and decarbonization research was ranked third (236 articles). Science was clearly dominated by research and innovation (1073 articles). There were no articles coded under energy security or the internal market dimension. The social sciences focused mostly on decarbonization (233 articles) and the internal energy market (162 articles), in addition to the other three Energy Union dimensions. The social sciences—unlike all the other disciplines—also paid attention to the energy security of the CEE region (97 articles).

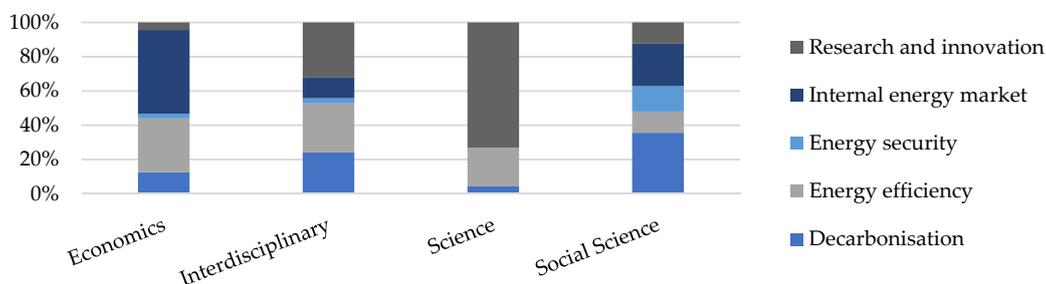


Figure 11. Relation between disciplines and the Energy Union dimensions. Source: Authors; N = 3534.

Finally, looking at the type of source in the articles, research on renewable energy sources (RESs) dominated, with 1803 articles or 51% of all the research in our database (Figure 12). Within this category, most research was on biomass (542 articles), solar energy (337 articles), wind energy (269 articles), hydro energy (154 articles), geothermal (140 articles), biogas (119 articles), and biofuel (67 articles). RESs in general (with no indication of RES type) featured in 175 articles. The second-largest category was general energy sources (no particular energy source was mentioned in these articles) and was covered primarily in articles analyzing the energy efficiency of buildings. Fossil fuels were discussed in 734 articles, especially coal (315 articles), then natural gas (234 articles) and oil (182 articles). Three articles dealt with fossil fuels in general. The number of articles on natural gas was very small given that the region experienced two gas crises in 2006 and 2009 (and at least one other tense period between the Russian Federation and Ukraine, the main actors in the two crises). Research on electricity was covered in 252 articles, nuclear in 184 articles, and waste in 153 articles, whereas the research on hydrogen is in a nascent phase, having 37 articles. This is despite the first paper on hydrogen in the CEE region being published in 2006 [62].

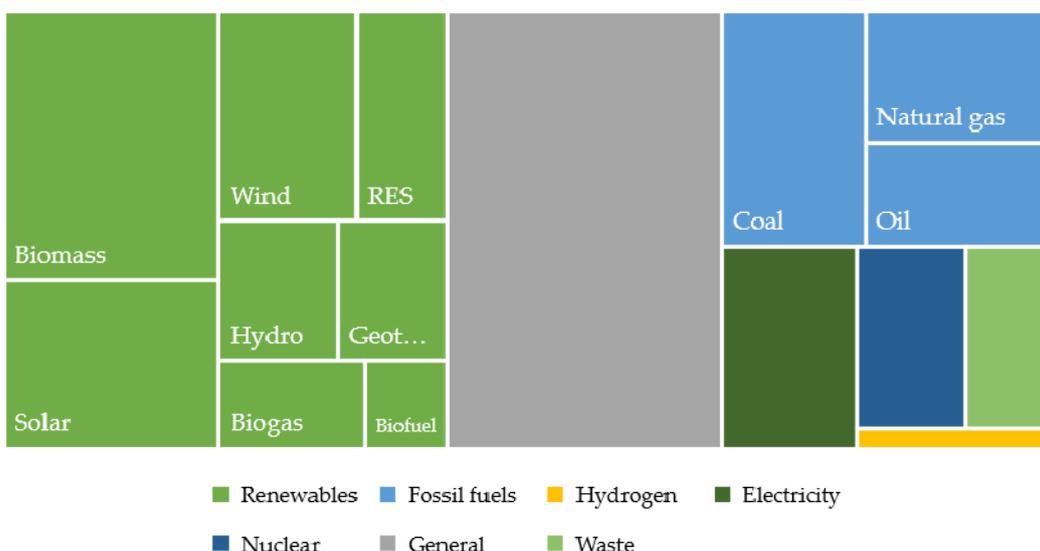


Figure 12. Type of source. Source: Authors; N = 4284. Note: Individual energy sources were coded separately, so N is larger than the size of the dataset.

The greatest share of articles on RESs, excluding papers not mentioning a particular energy source, looked at Croatia (76%) and Latvia (73%) (Figure 13). However, in absolute numbers, the greatest number of articles on RESs featured Poland (594) and Romania (340). Fossil fuels were mainly investigated in relation to the Czech Republic, Estonia, and Poland, which is not surprising as these countries have large reserves (oil sands and coal).

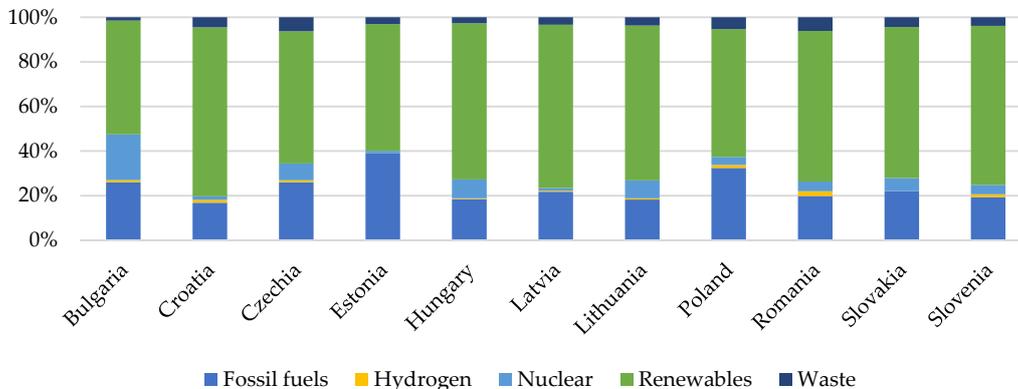


Figure 13. Type of source by country. Source: Authors; N = 4111. Note: This figure shows research on different energy sources in the 11 CEE countries and therefore the number of cases differs; for example, a comparative study on three countries’ utilization of coal was coded separately for each country.

Nuclear energy was mostly considered in connection to Bulgaria (41 articles), whereas other countries that have been expanding nuclear energy attracted little academic attention compared to other sources. This is unexpected given the fact that nuclear requires considerable public investment. For example, there were 111 articles on fossil fuels in the Czech Republic, but only 32 on nuclear. Interestingly, the only energy source that was not researched at all in connection to two CEE countries (Estonia and Slovakia) was hydrogen.

4. Discussion and Conclusions

This paper analyzed the academic literature on the Central and Eastern European energy sector in 2004–2019 by looking at 3534 scholarly articles published in journals indexed in the Web of Knowledge database. We did not focus on a particular set of journals

but constructed our dataset with the help of a set of keywords related to our research. This enabled us to develop a dataset that contained (we hope) all the articles written on the subject. This approach proved successful, as a large majority of the articles (72%) were found in journals that published fewer than 50 articles on the CEE energy sector within the timeframe. Indeed, more than half (421) of all the journals (800) published only one article on the topic. We therefore argue that focusing on the ‘main’ journals when searching for the research on this topic (and probably any other) will fail to reveal the extent of the literature.

Our research confirmed the dominance of male authors in academia [63], in relation to both first and general authorship. However, our data indicate that the overall increase in the number of co-authors is mainly due to the growth in female authors, with the average number rising over the period. Our research also showed that CEE countries very often feature in comparative studies together with other countries, both EU and non-EU. In total, we identified 119 countries in articles dealing with the CEE region. The country studied most often was Poland, whereas Bulgaria was studied the least, and featured most often in comparative studies.

We identified energy efficiency and decarbonization as the categories that attracted the greatest academic interest, which is also in line with the biggest challenges faced by CEE countries due to the rather slow penetration of renewables (with the exception of Croatia and the Baltic States) and inefficient energy systems inherited from the communist period. Rather surprisingly, the research on energy security was limited. Since the 2009 gas crises, it has become one of the more prominent topics at the political level, receiving a significant push during 2022, but this has not been reflected in the research. Relatively little research was undertaken on nuclear energy and hydrogen. In the case of nuclear, this is rather surprising, as many CEE countries have experience with constructing, operating, and decommissioning nuclear power plants [64–66]. Moreover, several of them are strong supporters of this technology at the EU level, viewing it as solution to both security and climate issues [67]. Most research was on different renewable energy sources, which dominated the research on all the CEE countries, even those with governments supporting domestic fossil fuel industries, such as the Czech Republic, Estonia, or Poland, but lacking the ambition for their deployment.

The main limitation of this research is its descriptive nature, which did not allow us to go deeper into the individual findings. However, this was not the main goal of this paper, which was to study existing knowledge about energy in Central and Eastern Europe. Our results can then be used as a basis for future research on specific energy-related issues that require different approaches. For example, future research can look into research within a single discipline; for example, social science research on decarbonization or economic research on energy efficiency. Similarly, there is a gap in the research at the company level. Given the importance of industry in CEE countries and the need to make it more energy efficient and decarbonized, this is an area worth future investigation.

Another limitation stems from examining only research published in the English language. We are aware of the pitfalls of this approach as many articles written on the CEE region have been published in other languages; nonetheless, we chose English as the universal language of science that enables the dissemination of results and academic discussion. Concerning the increased number of publications on energy in CEE, we can only speculate at this point whether this can be linked to the increasing internationalization of CEE researchers [68] or the overall increase in academic output noted in the last period [69]. Future research should shed light on this issue by examining authorship in more detail.

The dominance of male scholars in the field can also be examined. Future research can look at whether the quantitative dominance of male scholars identified in this research somehow translates into qualitative research characteristics (such as publishing in journals with a higher impact factor). Moreover, there is a need for further research at the local level (e.g., cities) so we can obtain a better understanding of the various sorts of energy transitions. Future research should also look more closely at the role of renewables in the

CEE countries. Indeed, this research has presented many findings that can form the basis of future research on energy in the CEE region.

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