e-ISSN 2786-8958
ISSN-L 2616-7107

UDC 621.31:504.5
JEL A13, Q54, K32, P48

A CROSS-SECTIONAL REVIEW OF ENERGY TRANSITION, SECURITY AND CLIMATE CHANGE POLICIES

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Received: 03/02/2025
Revised: 31/03/2025
Accepted: 12/05/2025

DOI: 10.61954/2616-7107/2025.9.2-2

Introduction. Energy, security, and climate change are essential concerns for policymakers and economic agendas, prioritising data monitoring, national resources, resilience, and informed planning. The analysis of these topics is relevant for achieving sustainability objectives and targets, especially for understanding and analysing societal, technological, environmental, and economic developments, aiming to guarantee a fair and inclusive transition.

Aim and tasks. This study presents a legal and policy nexus linking energy transition, security, and climate change by completing a complex analytical and conceptual analysis of key terms and policies developed from 1985 to 2022. Furthermore, it reviews the evolution of climate change, security, and energy transition concepts and analyses European and international policy and judicial options to reach a consensus on addressing climate change.

Results. The findings are intended to provide insights into the nexus of energy-security-climate change by reflecting the terminology and associated concepts in digitalised academic literature from 1985 to 2022 using the Google Ngram Viewer platform. The modelling analysis displayed various interrelated graphical representations that support future green energy and climate change policy settings, linking Ngram monitoring, result analysis, and data interpretation. The cross-sectional analysis examines the dynamic conceptual processes of specific terms and emerging research streams on security and climate change over four decades. The findings show linkages between climate change, sustainability, renewable energy, energy security and new conceptual associations that influence diverse academic research. Pearson correlation for statistical analysis results showed strong dependencies between variables, consistent with the values represented using the Google Ngram Viewer platform.

Conclusions. This study provides an overview of the circulation of concepts in the energy and climate change sectors within digitalised academic literature, mapping emergent conceptual trends over the selected period. The visualisation of the modelling analysis correlates with the temporal frequencies, as classified by the research sections. It organises data using graphical representations of energy resources and climate change concerning sustainable development and security.

Keywords: energy transition, climate change, security, policies, Ngram Viewer.

1. Introduction.

The energy transition and the operationalisation of an interrelated nexus with security mechanisms and policy objectives in the context of climate change implement different visions shaped by the inputs of the government agenda and the outputs of development strategies in specific sectors of the economy, such as energy, transport, industry and public health. In this context, the central objective of development strategies focuses on green and inclusive transitions, climate change impacts and resilient economic growth.

The interconnection and design of policies based on sustainable development and sustainability require configuring and integrating adaptation components to reduce greenhouse gas emissions and improve energy efficiency (Kim & Park, 2023). These ambitious objectives encourage key actions and initiatives to identify opportunities in renewable energy sources and climate change mitigation initiatives and measures (Cergibozan, 2022).

An analysis of the scenario of key actions and proactive measures primarily highlights the increased attention to the energy conversion sector but also the need to expand the analytical scope and assimilate innovative comparative analyses regarding the potential of integrated concepts using the terminological sphere of energy transition and the potential of assimilated concepts from the field of biodiversity and energy resources, as well as reduced carbon emissions (Khan et al., 2021).

The research approach of the terminological spectrum, both from the perspective of reviewing and analysing relevant academic literature, but also from a methodological perspective focusing on the flow of use in the digitised scientific literature from the last four decades of inner concepts, contributes to the expansion of the analysis and prospective options of good practice and collaborative management (Chu et al., 2023).

In the first stage, this study aims to appeal to the expertise of the relevant academic (scientific) literature by proposing an in-depth research agenda based on the analytical understanding of the energy-security-climate change nexus.

In this stage, the modelling of ngams frequencies and the patterns in which societies and languages have responded to the emerging terminology in the field of energy transition will be developed, and a detailed analysis of the concepts and lexico-semantic relations in the lexical field of the energy-security-climate change nexus will be undertaken.

Considering the complex semantic values of this nexus, this study presents a theoretical and applicative analysis outlining the interactions between the conceptual focus, lexical terms, and temporal framework, limited to the period from 1985 to 2022. Through this dual interpretation, this study proposes a descriptive and prescriptive approach that focuses on the changing landscape of the energy sector and climate policy at a global level.

2. Literature Review.

For the last two decades, specialised literature has redefined the knowledge potential and terminological and conceptual analysis of the three defining concepts of the present study: “energy transition”, “security”, and “climate change”.

The first assessment reshapes the holistic panorama and maps two structural changes in the regulatory framework and structural changes in global politics (Kaspar & Kunsch, 2022), as well as the links between the energy industry, security, investment policies, and technologies (Koval & Mikhno, 2020).

The analytical development of specialised literature remodelled the relations between states and changes in the energy sector and the factors in energy transition, energy production costs, and environmental impact (Sribna et al., 2023). A significant part of the literature in the early 2010s focused on the structure and dynamics of economic and energy models, emphasising the role of international and regional policies (Bazilian et al., 2020).

The role of the analysis launched in 2020 employs four analysis sequences that pursue critical assessment and economic and geopolitical consequences:

1) The first sequence integratively evaluates climate change from the perspective of a multilateral approach.

2) The second sequence focuses on the role of states and the terms of the agenda of interest at the national level.

3) The third sequence associates technological developments and the role of energy interests at the regional level.

4) The fourth sequence dimensions the consequences of the energy transition and outlines the implications for the geopolitics of the energy transition.

Further studies explore the impact of climate change on renewable energy by correlating three dynamic roles: renewable innovation, green financial development, and energy risks (Tiwari et al., 2024); the benefits of decarbonisation; and the role of technological progress through the expansion of technology and the framework of the sustainable economy and development (Todorov et al., 2023).

In this context, a recent scenario extensively analysed and developed by specialised literature results in the role of energy source solutions and climate protection by polarising the intensifying analysis of complex variables such as environmental policies and sustainability (Holdren, 2007), climate concerns and the dependent priorities of energy production and energy consumption, as well as the need to configure a fundamental reorganisation of the energy sector and the need to guarantee energy security (Arndt, 2023).

In the same context, other analyses launched in the last five years address the topic of energy security and the assessment of the use of fossil fuels. Axon and Darton (2021) extended the applied debate on the institutional and organisational policy agenda during energy security crises. Giuli and Oberthür (2023) focused on the importance of climate neutrality objectives and the need to reconfigure the regional energy system. The regional context of analysis also involves restructuring financial instruments by providing related monitoring and evaluation sectors, such as social innovation and the role of human factors (Olimid et al., 2024a).

In this sense, an important weight supports the growth of the national economy sector related to the energy mix in direct correspondence with climate change mitigation (Guesmi et al., 2024).

Additionally, the role of human security and demographic factors is analysed by analysing the impact of four factors: climate variability, the status of global food security, demographic variations, and technological changes (Molotoks et al., 2021). Other complex studies have evaluated the link between net energy consumption and indicators associated with environmental concerns using research techniques and methods based on energy performance analysis (Ehsanullah et al., 2021). This perspective also integrates studies on the interaction between institutional governance and periodic reports on the links between organisational security, citizen protection, and environmental sustainability (Olimid et al., 2024b).

Thus, several studies in the 2020s highlight the importance of energy security and energy transition, placing the essential role of energy security risks (Olimid et al., 2024), climate change, and investment as key determinants for new policy agendas, focusing on energy security objectives and the role of decision-makers in the global economy (Belaïd et al., 2023). A recent approach in specialised studies identifies methods for screening risks in energy systems in urban areas by estimating the role of input and output factors (Koval et al., 2025).

Another theoretical dimension contextualises energy optimisation and conversion measures by presenting developments in the renewable energy market that impact the environment and health policies (Olabi & Abdelkareem, 2022). Research connecting the relationship between climate change, energy transition, and green energy financing activities against the likelihood and threats of energy security is associated with data from energy-intensive fields and activities (Bashir et al., 2025).

Another complementary perspective engages the functional-integrative link between energy security and the multifactorial framework of the energy supply cycle (Kim et al., 2025). In this context, policy assessment aligns with other approaches regarding technological progress, renewable energy, and the adaptive capacity of national economies (Sohail et al., 2025).

3. Methodology.

This study proposes a modelling analysis of the legal and conceptual nexus between energy transition, security, and climate change policies aimed at evaluating the frequencies provided by the Google Ngram Viewer platform by determining the various levels of associated concepts (ngrams) used by the scientific literature digitalised between 1985 and 2022. Thus, the proposed methodology is applied for four decades, operating a selection of concepts in the field of energy advances using content analysis tools and methods.

3.1. Concepts for Ngrams Search.

The selection of concepts is an important part of this study. Thus, this study carried out a large spectrum of terminological sources and resources for the energy transition, security, and climate change terms used for Ngram searches on the Google Books platform. For the stylistic and terminological approach, the analysis included relevant glossaries of terms to improve the selection of concepts adopting a four steps research approach: (1) relevancy and quality of terms within the energy transition vocabulary; (2) combination of terms choice point on the appropriateness and conciseness of concepts to the security and climate change domains; (3) systematic-oriented selection of concepts and combination of terms for words list of concepts based on corpus-based glossaries such as: "Glossary of core energy specific terminology" launched on 10 November 2022 by European Union Agency for the Cooperation of Energy Regulators (2022) the Glossary terms of the United States Environmental Protection Agency (2025) and the Glossary of the International Energy Agency (2025).

3.2. Data Methodology and Collection.

The content analysis employs both perspectives: the conceptual analysis examines the evolution and occurrence of terms in the scientific literature by quantifying the selected words during the chosen period, and the relational analysis is employed to examine the frequency of explicit terms and meanings mainly used to sample the contextual relationships between concepts and content categories of the research.

For the relational analysis, the research used the Google Books Ngram Viewer graphic tool for words, the combination of words and expressions charting the yearly measurement of a selected Ngram from a text based on the search on the Google Ngram search database for digitalised literature. The selection of ngrams as a linguistic structure encodes a series of n words that appear concurrently in the same text selection, using the following categorical units of ngrams: 1-grams (one word, unigrams); 2-grams (two words, bigrams); 3-grams (three words, trigrams) and 4-grams (four words, quadgrams).

The content analysis highlighted and targeted six main research categories: (i) climate change and the dynamics of energy markets targeting economic transformation, technological innovation, and policy focus on security risks; (ii) energy transition, green energy sources, and production; (iii) climate adaption and related domains: mitigation, resilience, development, and sustainability; (iv) carbon offsetting and related planning sectors: carbon neutral, biodiversity and renewable energy sources, greenhouse effects, and net-zero emissions; (v) global warming, extreme events, and fossil fuels; and (vi) climate justice, human rights, and human security.

The six categories reveal various trends in the international communication content of the transition energy, security, and climate change nexus by describing the institutional and behavioural trends and aspects leading to new interpretations, conclusions, and generalisations. Based on the relational analysis within the six categories, the analysis balances the cognitive mapping of the selected concepts based on graphic visualisation and the proximity analysis based on an evaluation analysis of the co-occurrence of terms within each category.

3.3. Content Mining Tools and Searching.

The results of the research frame a concept co-occurrence matrix based on a time-frame determination (period analysis between 1985 and 2022) and affect-frame determination (the evaluation is based on the interrelation and meanings of selected concepts searched on the Google Ngram Viewer website).

Content mining tools are primarily outlined by entering search concepts in the search box at the top of the web page. The supported search is also operationalised using advanced searches containing a combination of terms, entering a specified period, or limiting the period range of searches. A focused content mining tool explores terminological variations following a selected word sequence by displaying the most frequent selections of words in the search options box.

These research steps provide valuable social, economic, and political insights between 1985 and 2022, corresponding to specific terminological categories and providing accuracy and reproducibility of the general overview of the conceptual variables in a determined period.

In particular, ngrams comprise a category of n sequential words, and the amount of data and information extracted based on computer algorithms allows for a complex analysis of analytical and conceptual connections in the energy transition-security-climate change nexus. The selection of the analysis period between 1985 and 2022 considers two central arguments.

First, following an extensive analysis of the frequencies of occurrence of the selected terms, an accelerated trend of occurrence was observed in the second half of the 1980s. Second, and as an argument for the first justification, the energy field was marked by a succession of political, geopolitical, and security events with an impact on the frequency of occurrence of terms in the digitised literature, such as:

a) The oil crisis of the 1980s led to significant fluctuations in the price of oil and a sharp decline in the economy (Painter, 2014).
b) The development of new programs based on energy defence and technologies in the period 1980-1983) (Draca, 2013).

c) The decline in oil production in certain regions led to an increase in the level of imports and a growing dependence on other regions (the early 1980s).

d) The collapse of oil prices in 1986 as a result of overproduction and falling global demand (1985-1986) (Gately et al., 1986).

The selection of 2022 as the cut-off year for the period to be analysed is justified by the limitations of the literature digitised by Google Ngram Viewer.

3.4. Modelling Analysis Methods.

Ngrams' analysis for the energy transition sector is a crucial technique for selecting and processing relevant data, concepts and information, as it highlights the linguistic patterns by approaching an innovative language frequency analysis predicting the probability of a sequence of concepts to appear in a given digitalized text as a conditional probability [$P((w_n)|$ n = total number of words selected for Google Ngram search count] during a period as follows:

a) for unigrams, the formula assumes the probability of a single word to occur in a text: $P(w_n)$, where (w_n) occurs separately and independently from other combinations of words [$Eq._{(1)}$]:

$$Eq._{(1)}=P(w_n), \quad (1)$$

where (w_n) occurs independently;

b) for bigrams, the formula assumes the probability of word (w_n) to occur in a text selection given a previous selection of one word in the text [$Eq._{(2)}$]:

$$Eq._{(2)}=P(w_n|w_{n-1}), \quad (2)$$

where (w_n) occurs dependently to a previous one word [w_(n-1)].

c) for trigrams, the formula assumes the probability of a word (w_n) to occur in a text selection given a previous selection of two words in the text [$Eq._{(3)}$]:

$$Eq._{(3)}=P(w_n|w_{n-1}, w_{n-2}), \quad (3)$$

where (w_n) occurs dependently to previous two words {[w_(n-1)] and [w_(n-2)]}.

d) for quadgrams, the formula assumes the probability of a word (w_n) to occur in a text selection given a previous selection of three words in the text [$Eq._{(4)}$]:

$$Eq._{(4)}=P(w_n|w_{n-1}, w_{n-2,} w_{n-3,}), \quad (4)$$

where (w_n) occurs dependently to previous three words {[w_(n-1)], [w_(n-2), [w_(n-3)]}.

e) for sequences with five words (n=5), the formula assumes the probability of a word (w_n) to occur in a text selection given a previous selection of four words [Eq.$_{(5)}$]:

$$Eq._{(5)}=P(w_n|w_{n-1}, w_{n-2}, w_{n-3}, w_{n-4}), \quad (5)$$

where (w_n) occurs dependently to previous four words {[w_(n-1)], [w_(n-2)], [w_(n-3)], [w_(n-4)}.

f) for sequences with six words (n=6), the formula assumes the probability of a word (w_n) to occur in a text selection given a previous selection of five words in the text:

$$Eq._{(6)}=P(w_n|w_{n-1}, w_{n-2}, w_{n-3}, w_{n-4}, w_{n-5},), \quad (6)$$

where (w_n) occurs dependently to previous five words {[w_(n-1)], [w_(n-2)], [w_(n-3)], [w_(n-4), [w_(n-5)]}.

This analysis reveals the probabilities of the association of concepts in word combinations within the functional context of:

1. Unigrams (n=1, basic information focuses on a single word) and bigrams (n=2, basic information focuses on two words): "CO2 emissions", "gas emissions", "GHG emissions", "dioxide emissions", "exhaust emissions", and "carbon emissions").

2. Trigrams (n=3, the basic information reveals the linguistic context arranged by three words – e.g. "green energy and", "green energy sources", "green energy production", "green energy technology", "green energy projects").

3. Quadgrams (n=4, the basic information reveals the linguistic context arranged by four words – e.g. "green energy and climate", "green energy and sustainable", "green energy and value", "energy transition", "energy transition in Germany", "energy transition in Europe", "energy transition in rural", "energy transition in developing", "green energy and technology", "green energy and green", "green energy and climate").

4. Sequences with more than four words (n > 4, the basic information reveals the linguistic context arranged by more than four words, e.g. "climate change and the role of", "climate change and the role of human", "climate change and the adverse effects", "climate change and the loss of biodiversity", "climate change and the loss of biological", "climate change and the need to reduce".

The proposed analysis model for the presentation of the trigrams and quadgrams study values the linguistic arrangement of the selected word combination. The study of models of frequencies distributed in grams focuses on analysing linguistic terms in the field of energy transition. It is observed that the higher the value of *n* in ngrams is, the more the analysis establishes a broader context of coverage of dependencies in text generation, such as efficient management of energy resources, resource typology and operationalisation of consumption and production practices with reduced impact on the environment.

Thus, for ngrams with n > 4 (n = 5, 6, ...), the technique for selecting the word sequences that make up the respective Ngram will rely on configuration models and terminological representation in the contextual relationship starting from the hypothesis of a lower limit of sequential elements (n≥5). In this case, *n* represents the inclusive lower limit of this type of sequence, and the systematic collection of ngrams models in the current analysis terminological units having:

5. n=5 (e.g. "climate change and sustainable development"; "climate crisis and global warming").

6. n=6 (e.g. "climate change and the adverse effects").

7. n=7 (e.g. "climate change and the role of fossil", "climate change and the role of policy".

3.4. Research Questions and Hypotheses.

Consequently, the methodology of the analytical process requires the launch of research questions (RQ) and hypotheses (H).

RQ1. When did climate change, security, and energy transition-related concepts emerge?

RQ2. What conceptual associations have been established regarding climate change, security, and energy transitions?

H1. The configuration of concepts related to climate change, security, and energy transition coincided with the interest in climate change, especially after 1980.

H2. Concepts developed, and new conceptual associations emerged recently, actively formed, and integrated into research and political discourse, specifically after 2000.

e-ISSN 2786-8958
ISSN-L 2616-7107

4. Results.

The first research phase focused on the search for the phrase "climate change", included in the category: climate change and the dynamics of the energy market targeting economic transformation, technological innovation, and policy focus on security risks. Consequently, the search for the phrase "climate change" followed the conjunction "and" in academic literature in English. The findings highlight the emergence of these terms after 1985 and an evolution in usage after the 2000s.

These results align with the methodological advancements targeting the research period after the emergence of these concepts in the academic literature in the 1980s, thus aiming to test the first research hypothesis that relates this timing to the evolution of climate change, security, and energy transition concepts. Especially for the phrase "climate change and the environment", the values tend to rise after 2005 and peaking in 2022.

Thus, throughout the selected period of 1985-2022, climate change was most frequently associated with the following ten concepts: environment, need, adverse, impact, role, potential, loss, economic, global, and effects.

The online wildcard search for the associated need for action concerning climate change revealed the use of verbs to reduce, take, address, adapt, protect, act, save, and develop, which is in line with the established connections between climate change and the need for adaptation, sustainability, and action featuring during 1985-2022 (Fig. 1).

In terms of related roles in the process of climate change, Google Ngram Viewer identified the roles of policy, humans, and fossils. Thus, it graphically represents the identified associations between climate change and global warming, the global economy, the global environment, global carbon, and global finances, showing the evolving research field of climate change and global issues (Fig.2).

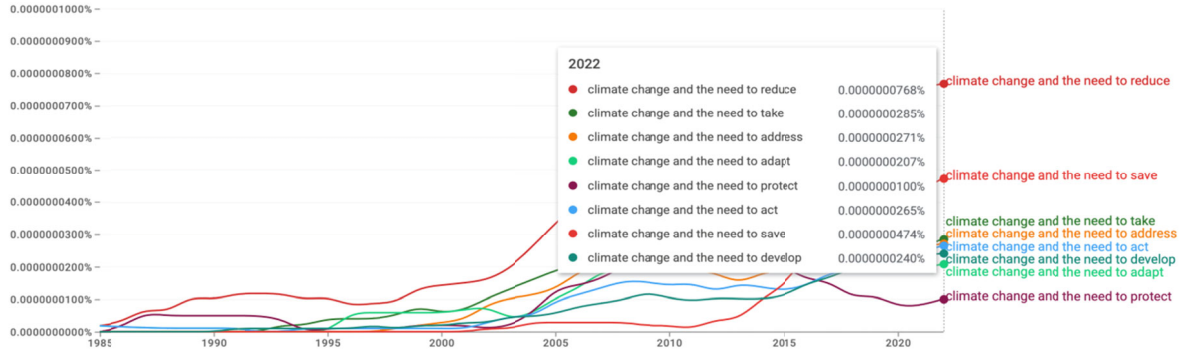

Fig. 1. Associations between climate change and the need for specific action, 1985-2022.

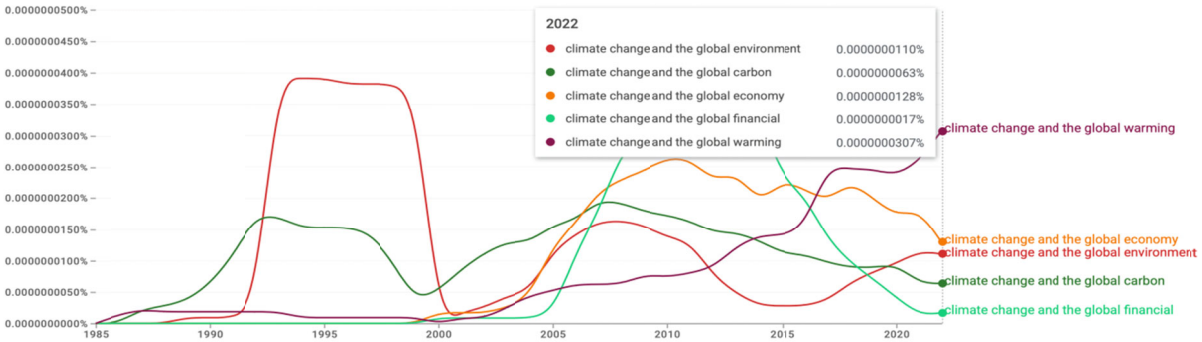

Fig. 2. Climate change and globally related concepts, 1985-2022.

e-ISSN 2786-8958
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The following search questioned the association between climate change and economic crisis, which registered the highest frequency in 2012, in line with the scientific literature (Bazilian et al., 2020; Tiwari et al., 2024) (Fig. 3).

An interesting note of the research was the identification of the conceptual associations of climate change and the security of demand and supply, with a strong emphasis on literature and research (Koval & Mikhno, 2020) (Fig. 4).

The analysis of the terminological extent spans the associations with the terms' climate change policies'. Consequently, it identified a strong relationship with the energy field, showing that references in the scientific literature on climate change and energy policies peaked in 2013.

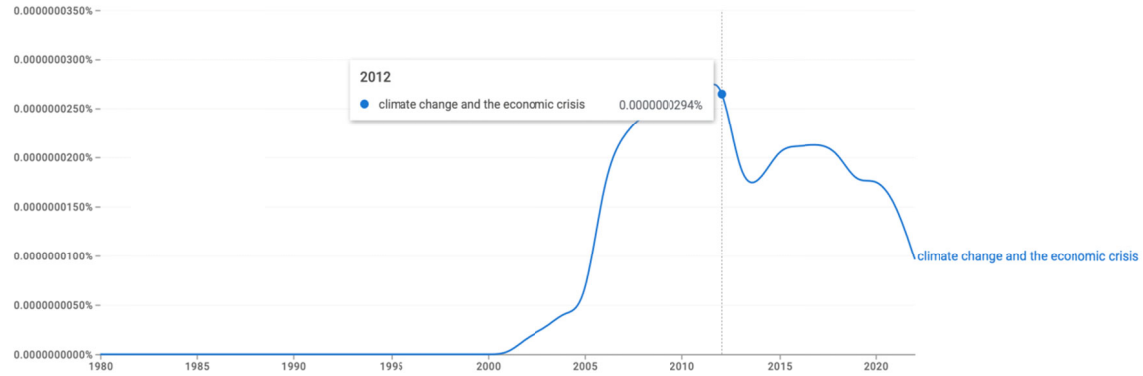

Fig. 3. Association of climate change with the economic crisis, 1985-2022.

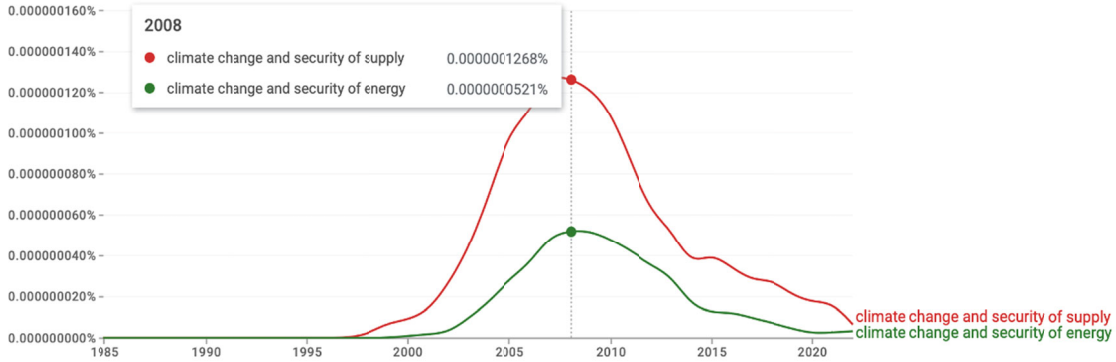

Fig. 4. Association of climate change with the security of demand and supply, 1985-2022.

The analyses also showed values for references to the relationship between environmental change and sustainable development, which attained the highest frequency at the end of the 2000s. The second stage introduced the search for concepts included in category associated with energy transition, green energy sources, and production. This research stage was centred on the concept of environmental change, aiming at individualising the values in the English corpus of digitised academic literature concerning human and social aspects and sustainability. The results show the appearance and dynamics of the usage of these concepts after 1980, focusing on their emergence and potential risks, health issues, impact, and effects. The search in the English corpus has influenced the results insofar as the identification of geographical targets is concerned with.

Climate change policies were most frequently associated with English-speaking countries, such as the US, Australia, and Canada. However, regarding energy transition and geographical mentions in the scientific literature, conceptual associations identify references to Germany, Europe, China, India, and developing countries.

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ISSN-L 2616-7107

The research further targeted the identification of special interest in references to energy transition in rural areas. Another search identified the association between energy transition to renewable energy and sources, which appeared more intensely in the literature after 2015 and reached the highest frequency in 2022 (Fig. 5). The Ngram "energy transition from fossil fuels" registered a similar trajectory towards 2022 (Fig. 6).

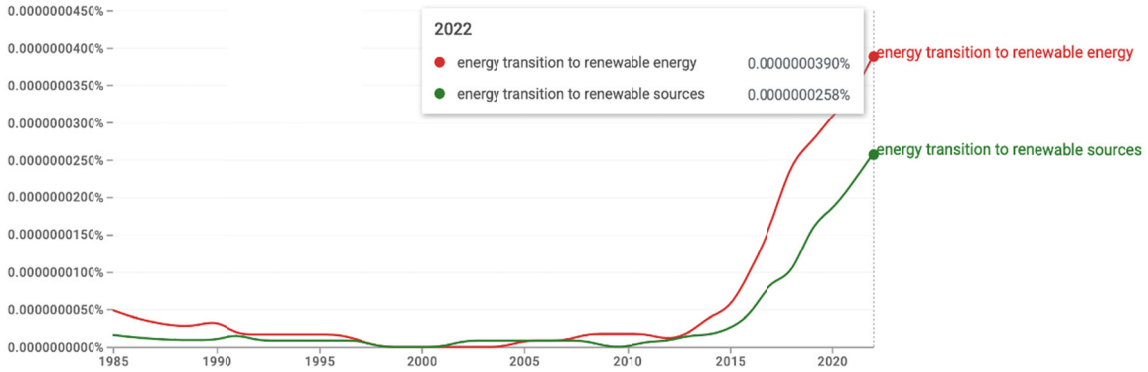

Fig. 5. Energy transition to renewable energy and sources, 1985-2022.

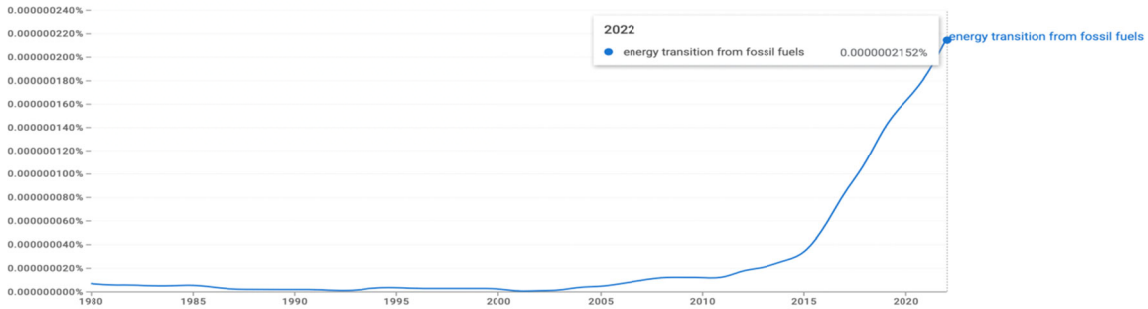

Fig. 6. Energy transition from fossil fuels, 1985-2022.

However, another search spotlighted the Ngram of the five words sequence "energy transition to enhance productivity", which cropped up after 1987 to its highest frequency as early as 1995 and an abrupt drop towards 2000 (Fig. 7). The next steps relied on performing wildcard searches for the most frequent associations between renewable energy and energy-related concepts, wildcard searches for the most frequent associations between renewable energy and sustainability-related concepts, and an interrogation aimed at identifying the appearance and associations with the concept of renewable energy (Fig. 8).

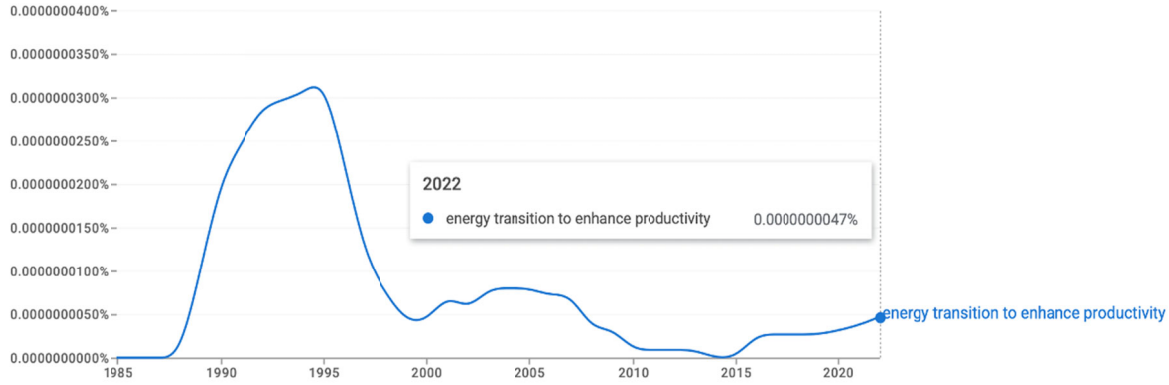

Fig. 7. Frequency of usage for energy transition concept, 1985-2022.

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ISSN-L 2616-7107

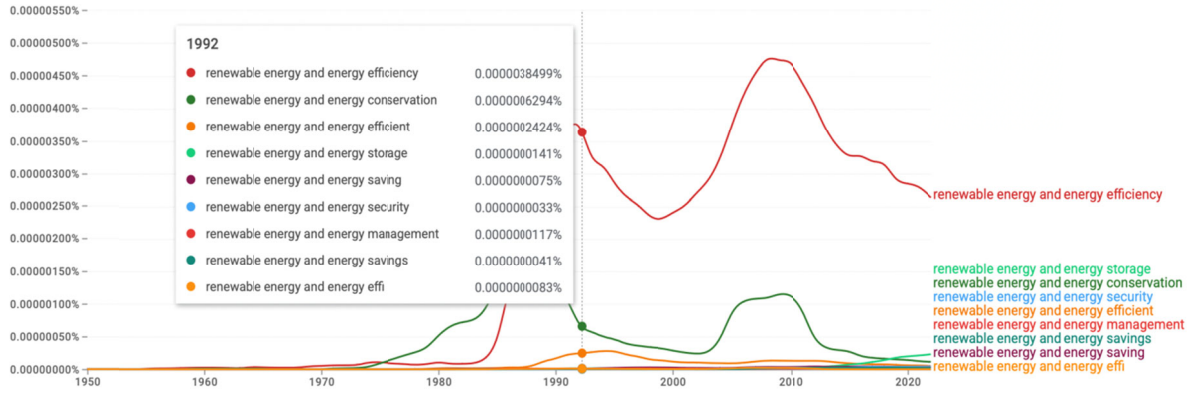

Fig. 8. Frequency of usage for renewable energy concept, 1985-2022.

Google Ngram viewer returned the concepts of technology, environment, energy, sustainability, climate, and value rising after 1995, encompassing the highest frequency at the end of the monitoring period. The resulting grams of the six-word sequence focused on mentioning green energy sources, such as wind and solar, in the Google digitised literature (Fig. 9). Green energy was also referred to alongside production and storage (Fig.10).

The third stage targeted the conceptual cluster of climate adaptation and related domains: mitigation, resilience, development, and sustainability. The interrogation of the conceptual linkages between climate change and sustainability has shown ramifications towards development, energy, agriculture, nutrition, living, consumption, forest, and tourism, suggesting a nuanced development of research interest towards analysing these related issues.

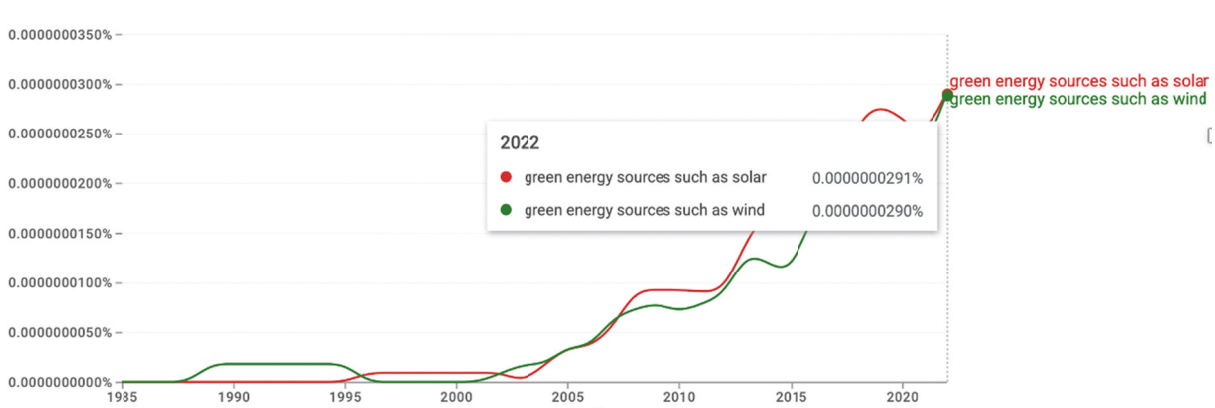

Fig. 9. Frequency of usage for green energy sources concept, 1985-2022.

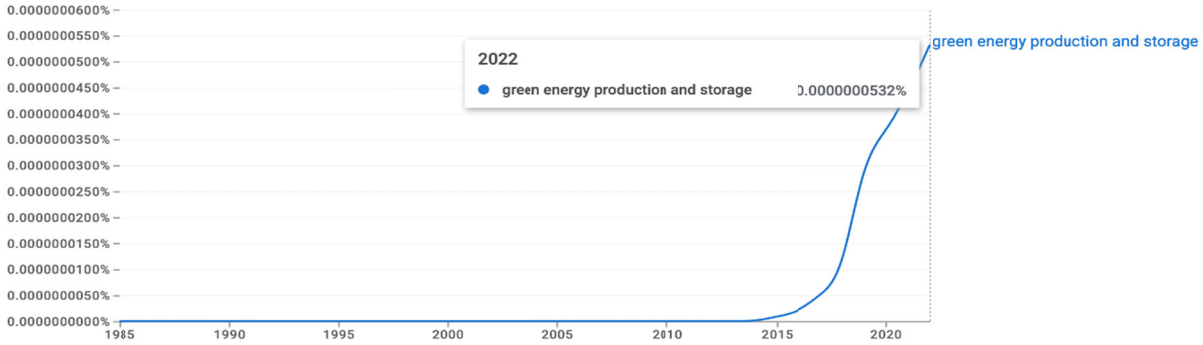

Fig.10. Frequency of usage for green energy production and storage concepts, 1985-2022.

e-ISSN 2786-8958
ISSN-L 2616-7107

Moreover, the analysis discovered conceptual associations between sustainability and social-related concepts, and further associations between climate change and sustainable-related concepts (Fig. 11), renewable energy and sustainable-related concepts (Fig. 12), and sustainability and climate-related concepts (Fig. 13). Likewise, recently emerging associations with the concept of climate adaptation appeared after 2005 and increased in frequency towards 2022 in the formula "climate adaptation and mitigation" and after 2015 with the occurrence of "climate adaptation and resilience", "climate adaptation and disaster", "climate adaptation and development", "climate adaptation and risk", "climate adaptation and water".

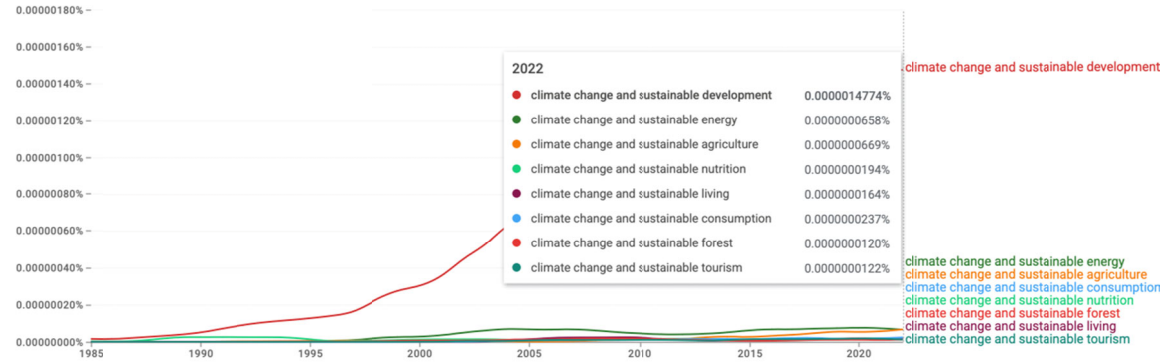

Fig. 11. Appearance and frequency of usage for climate change and sustainable-related associations, 1985-2022.

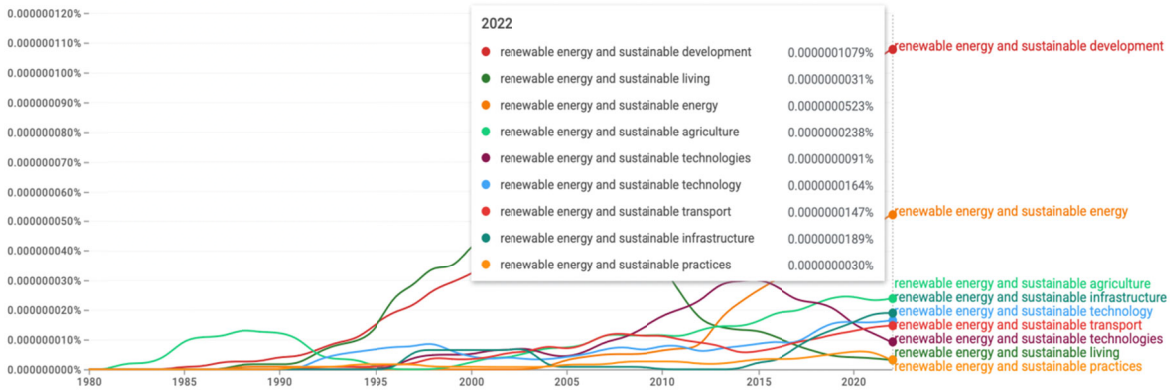

Fig. 12. Appearance and frequency of usage for renewable energy and sustainability-related associations, 1985-2022.

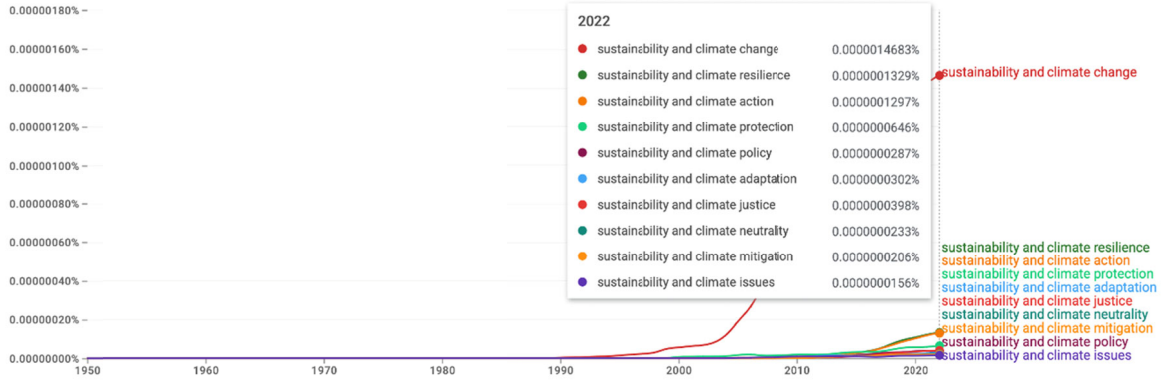

Fig. 13. Appearance and frequency of usage for sustainability and climate-related associations, 1985-2022.

e-ISSN 2786-8958
ISSN-L 2616-7107

Furthermore, the fourth research category of concepts pinpoints the analysis of carbon offsetting and related planning sectors: carbon neutral, biodiversity and renewable energy sources, greenhouse effects, and net-zero emissions. The frequency of usage for the concept of emissions and the identification of bigrams "gas emissions", "CO2 emissions", "carbon emissions", "dioxide emissions", and "carbon emissions" manifest an increasing occurrence also towards 2022. Another relatively new concept, "carbon offsetting", registered important values after 2000 and a dynamic rise in frequency, especially in 2010, while the appearance and use of the carbon-neutral concept in the scientific literature return a similar trajectory with the highest frequency towards 2022 (Fig. 14).

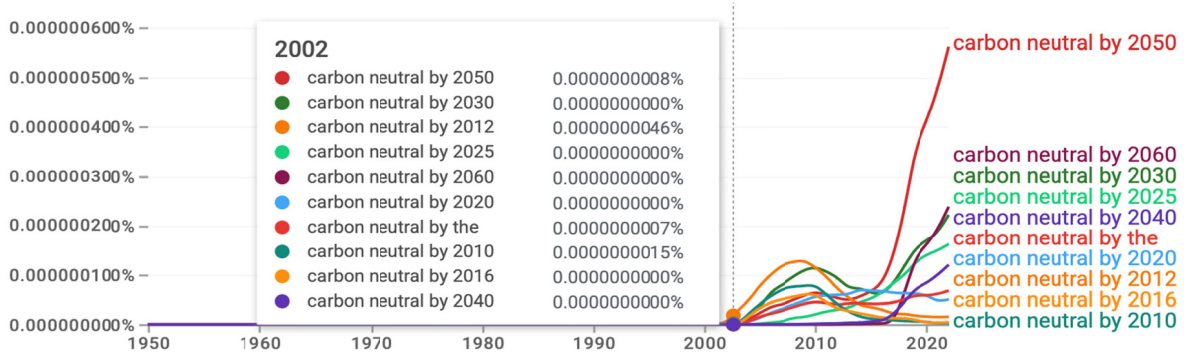

Fig. 14. Appearance and dynamics of carbon neutral concepts, 1985-2022.

The appearance and use of greenhouse gases, greenhouse effect concepts, global warming, and climate associations were investigated from a comparative perspective. Regarding net zero emissions, the most frequent references are associated with negotiated net zero targets (Fig. 15).

The fifth concept category aimed to identify references to global warming, extreme events, and fossil fuels. The subsequent investigation addressed the relationship between climate change and its adverse effects, with Ngram frequencies showing that the association reached its highest frequency in 2015.

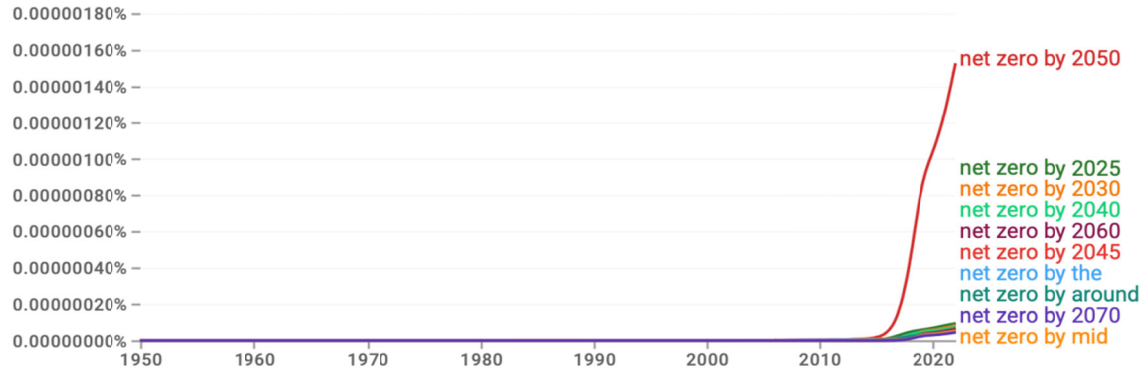

Fig. 15. Appearance and use of net zero targets concept, 1985-2022.

Another search returned the values for climate change and specific biological and biodiversity losses where their use in literature reached the highest value in 2022. The search interest steered research towards the concept of the climate crisis and its link with global warming, which aligned with an increasing frequency after 2005 and peaked in 2022.

Performing wildcard search of a different concept related to climate change returned the six words sequence Ngram "global average temperature and sea level" with relatively few mentions during the 1950s and a recurrence in the 1990s towards the 2000s (Fig. 16). The search determined the results on the language use of extreme weather-associated concepts.

Furthermore, the analysis performed wildcard searches for associations with global warming, its possible effects and consequences, associations with global warming, extreme consequences such as acid rain and acid deposition, and the appearance and use values for the carbon footprint concept. Subsequent, the wildcard search for associations with fossil fuels showed the following relationships: nuclear, biomass, deforestation, electricity, minerals, uranium, fossil fuels, and nuclear-related concepts linking nuclear power, energy, fuel (s), reactors, sources, plants, and materials; fossil fuels; and associated concepts, such as other sources, energy, human, natural, resources, industrial, minerals, organic, and non-renewable.

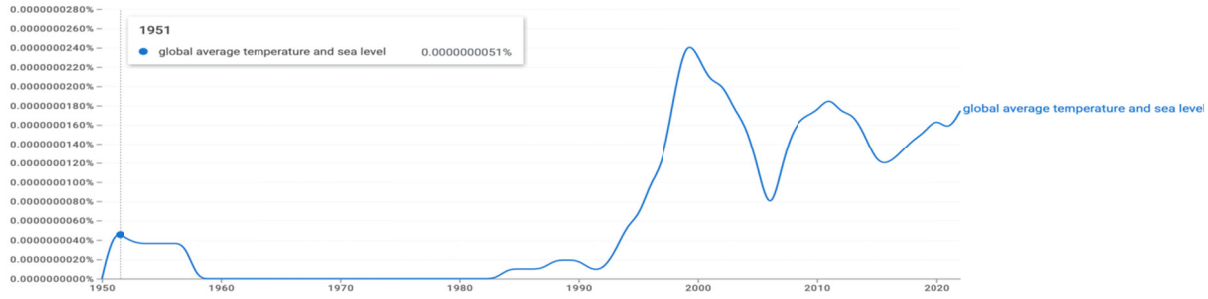

Fig. 16. Appearance and use of global average temperature and sea level association, 1985-2022.

Among them, associations between fossil fuels and other energy sources and resources were observed, enabling a comparison between the frequencies of fossil-fuel-associated concepts. The analysis further showed associations between fossil fuels and industrial activities and processes and between fossil fuels and other organic matter and materials (Fig. 17).

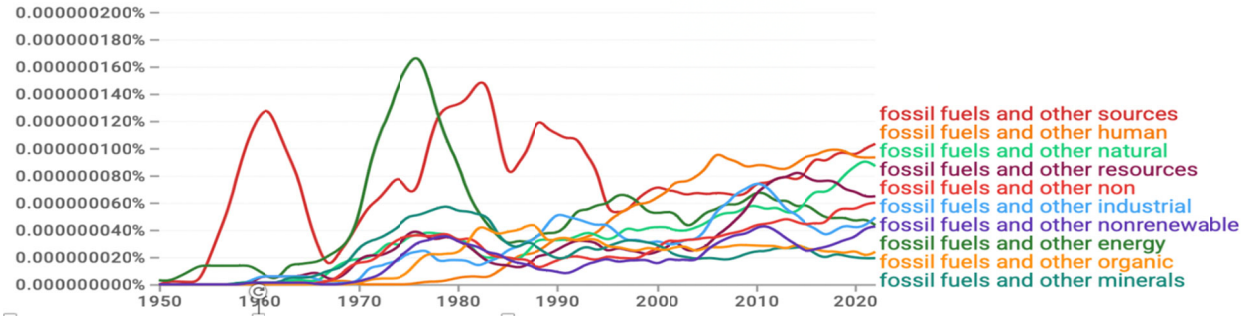

Fig.17. Appearance and use of fossil fuels and associated concepts, 1985-2022.

The sixth stage concentrated on cluster climate justice, human rights, and human security. Thus, the wildcard search returned results regarding the associations between biodiversity and human-related concepts, such as human wealth, human well-being, human rights, human livelihoods, human population, human activities, and human development (Fig. 18).

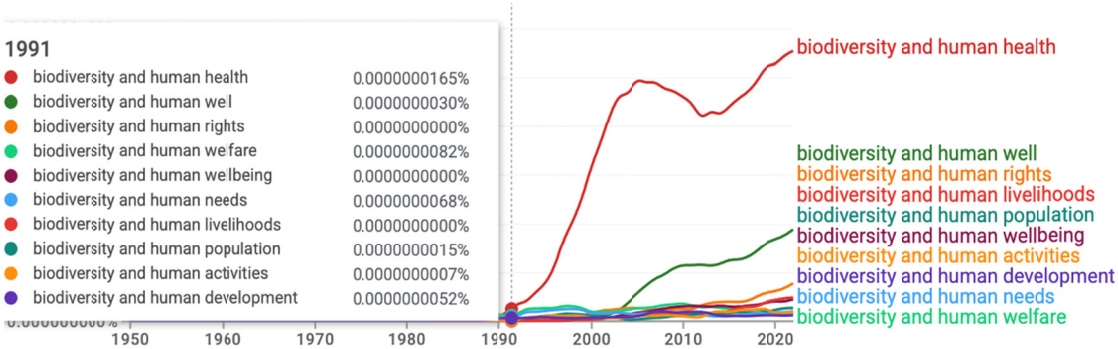

Fig. 18. Wildcard search for biodiversity and human-related concepts, 1950-2022.

The subsequent analytic action used the Google Ngram viewer wildcard search tool to test whether there was an association between climate change and human-related concepts. The results showed a firm relationship between climate change and the following concepts: human rights, human activity or activities, human health, human mobility, human settlements, human impact and its plural form, human security, and human development. The analysis also took great interest in the decarbonisation of climate justice and in identifying the associations and use of climate justice and human rights concepts (Fig.19).

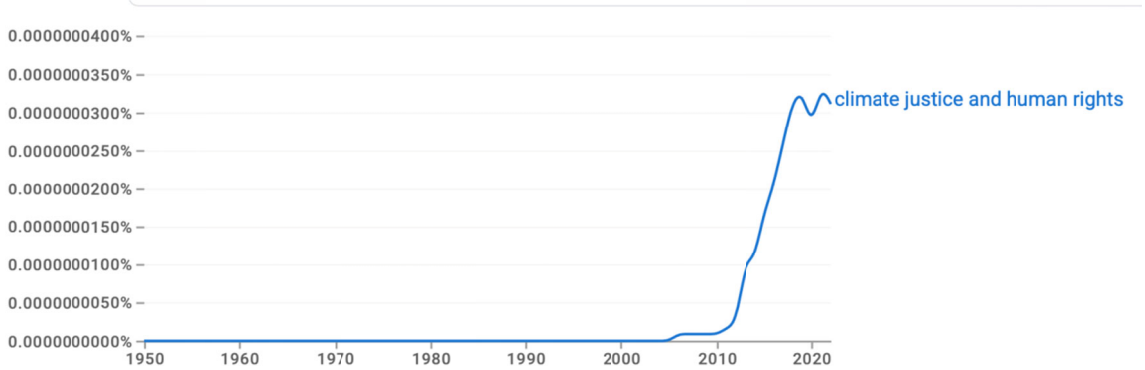

Fig. 19. Frequency of usage for climate justice and human rights concepts, 1985-2022.

The Pearson correlation for the statistical analysis of the data dependencies presented in the figures is consistent with the preceding findings. The results show the strength (results range between 0 and +/-1) and the direction of the connection between variables, highlighting a strong-to-very strong dependency between concepts. The selected variables in focus are related to different degrees: "climate change and sustainable development" appears to be strongly and directly related to "renewable energy and sustainable development" (0,9327), "sustainability and climate change" (0,9749) and "climate justice and human rights" (0,9683). In contrast, its relation to "biodiversity and human health" appears relatively strong, with the results pointing towards (0,62735), suggesting a direct dependency between selected concepts. Likewise, the "renewable energy and sustainable development" variable is strongly directly correlated to "sustainability and climate change" (0,93154), "biodiversity and human health" (0,8018) and "climate justice and human rights" (0,91337).

Pearson correlation coefficient values show a direct and moderately strong correlation between "sustainability and climate change" and "biodiversity and human health" (0,5843), yet a very strong direct correlation with "climate justice and human rights" (0,9522).

Lastly, the results show a moderately strong correlation between "biodiversity and human health" and "climate justice and human rights" (0,6453). The outcomes show a statistically significant dependence among the variables. The findings revealed that climate change has impacted research interests and scientific literature; Ngram Viewer data show upward shifts in the value of concept occurrences. Associations between climate change and sustainability, sustainable development, renewable energy, adaptation, climate justice, human rights, and human health have become frequent topics in online digitised literature.

New conceptual associations also developed during the 1980s-1990s and emerged in the 2000s. The increase in climate change issues has consequently pressured raising awareness and the need to scale up exploratory and explanatory interdisciplinary scientific research. The results discussed above contribute to understanding how climate change, security, and energy transition-associated concepts have appeared and evolved in the online scientific digitised literature for the English corpus. The research concludes with perspectives on legal coverage that reflect the emergence of these terms after 1985 and an acute increase in their usage throughout the 2000s or even after 2010.

These results share and validate the first research hypothesis, which relates this timing to the evolution of climate change, security, and energy transition concepts, mirroring a period of European and international policy options and challenges in building a consensus for addressing climate change.

Ngram search results identified the association of energy transition and climate issues with various challenges, appearing more intensely in the literature after 2015 and reaching the highest frequency in 2022 to validate the second research hypothesis.

Table 1. Pearson Correlation Coefficients for Data Dependency Analysis.

	Climate change and sustainable development	Renewable energy and sustainable development	Sustainability and climate change	Biodiversity and human health	Climate justice and human rights
Climate change and sustainable development	r=1				
Renewable energy and sustainable development	r=0,9327 R^2 = 0,869 p<0,05	r=1			
Sustainability and climate change	r=0,97499 R^2 = 0,95 p<0,05	r=0,9315 R^2 = 0,867 p<0,05	r=1		
Biodiversity and human health	r=0,62736 R^2 = 0,3936 p<0,001	r=0,801832 R^2 = 0,6429 p<0,001	r=0,584398 R^2 = 0,3415 p<0,05	r=1	
Climate justice and human rights	r=0,96834 R^2 = 0,9377 p<0,5	r=0,91338 R^2 = 0,8342 p<0,5	r=0,952214 R^2 = 0,9067 p<0,5	r=0,645307 R^2 = 0,4164 p<0,01	r=1

5. Discussion.

This study highlights the nexus between energy transition, security, and climate change at the centre of debates over the last four decades regarding the decreasing supply and demand for fossil fuels and perspectives in which geoeconomic trends interrelate with regional governance and global interests.

In this context, the research results offer an integrated theoretical and analytical perspective of the global energy system from the second half of the 20th century until 2022. The first dimension highlights the results of the analysis exploring new conceptual-analytical challenges of global policies in the climate sphere and the assumption of long-term governance mechanisms at the beginning of the 21st century (Figures 1 and 2), green energy (Figure 5), and environmental conditions (Figure 9, 10, 11, 12, 13, 14, and 16).

Additionally, the analysis reveals that the intensive use of terminology in the energy sector has gradually increased since the 1980s, moreover stimulated by competing developments in the spectrum of technological innovation as well as the sustained trend of decarbonisation of the global economy sector (Figure 3, 4, 7, and 8).

From a third perspective, the emergence of decentralised energy systems is associated with complementary technological advances and strategies focused on low-carbon emissions, dynamics of carbon offsetting, and carbon-neutral concepts (Figure 15).

The fourth pillar engages a triple dependency relationship that connects geopolitical actors, strategic positions on the energy market, and the security agenda, especially sustainability, biodiversity and renewable energy targets (Figures 17 and 18).

The fifth conclusion refers to the fundamental practices in the terminological analysis associated with energy transition and its relationship with climate change, resource conservation, and climate justice (Figures 6, 19).

6. Conclusions.

The study demonstrates a constantly increasing tendency after 1985 in the academic literature to focus on cost-cutting practices and technologies to identify new solutions for lower energy consumption and security. This tendency became much more consolidated after 2010 and marks a new stage of analysis of the nexus of energy transition, security, and climate change by stimulating new proactive directions for limiting climate effects and efficient management of energy resources.

According to the successive findings graphically represented in 12 figures, the conceptual and legal theory nexus between energy transition, security, and climate change policies reflects alternative conceptual and legal semantics based on Ngrams' occurrence in academic literature. The proposed theoretical approach extracted unitary associations of conceptual and legal constructions, stipulating auxiliary-focused positions in the search configuration of all figures. The theory and research findings state the necessity of parallel linguistic and semantic constructions of the nexus domain between energy transition, security, and climate change policies.

Potential limitations of the study can be attributed to the pre-eminence of the English language in the Google digitised literature, international regulations, treaties, reports, and scientific databases archiving research. As the findings suggest, the conceptual configurations exposed in the 12 figures received major attention in the digitalised scientific literature from 1985 to 2022 based on interactions, semantic values, and corresponding findings.

Nomenclature.

$P(w_n|w_{n-1})$ – represents the probability that (w_n) to occur after a previous sequence ([w_(n-1)]).

$P(w_n|w_{n-1}, w_{n-2})$ – represents the probability that (w_n) to occur after two previous sequences, namely {[w_(n-1)] and [w_(n-2)]}.

$P(w_n|w_{n-1}, w_{n-2}, w_{n-3})$ – represents the probability that (w_n) to occur after three previous sequences, namely {[w_(n-1)], [w_(n-2)] and [w_(n-3)]}.

$P(w_n|w_{n-1}, w_{n-2}, w_{n-3}, w_{n-4})$ – represent the probability that (w_n) to occur after four previous sequences, namely {[w_(n-1)], [w_(n-2)], [w_(n-3)] and [w_(n-4)]}.

$P(w_n|w_{n-1}, w_{n-2}, w_{n-3}, w_{n-4}, w_{n-5})$ – represents the probability that (w_n) to occur after five previous sequences, namely {[w_(n-1)], [w_(n-2)], [w_(n-3)], [w_(n-4)], [w_(n-5)]}.

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