TYPOLOGY OF PATHWAYS FOR DECARBONIZATION

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Overview

Climate change mitigation demands urgent implementation of decarbonization strategies. However, a detailed characterization of these strategies is often lacking, which hinders their effective implementation. This study aims to fill this gap by developing a comprehensive typology of decarbonization strategies and examining their underlying dimensions. The research objectives include identifying and organizing approaches for decarbonization found in literature, investigating connections between scientific articles and their relationship with decarbonization strategies, and analyzing regional trends and limitations of conventional dichotomies in decarbonization strategies. This in-depth understanding of pathways and dimensions contributes to the ongoing efforts to tackle climate change and foster industrial and economic transformation towards a more sustainable future.

Methods

The research design incorporates a combination of computational literature review, citation networks analysis, and expert elicitation to analyze decarbonization strategies found in scientific literature. The computational literature review uses over 1M research articles from Scopus and WoS, literature selection with the ASReview tool, and pathway identification via Latent Dirichlet Allocation (LDA) topic modeling. The BERTopic library is employed for dimension analysis, combining topic modeling, advanced dimensionality reduction, and hierarchical clustering techniques.

Expert elicitation is utilized to gain insights into broad and representative topics generated using the BERTopic algorithm. An expert is tasked with analyzing, describing, and classifying each topic under several accepted dichotomies, allowing for a better understanding of the underlying patterns and themes present in the data.

Citation networks analysis is conducted to understand the arrangement of scientific literature based on network science principles. A citations network is constructed using 79,922 DOIs, and statistical inference is performed using the nested stochastic block model provided by the graph-tool Python module. This strategy helps validate the typology by revealing the structure of the research without considering the linguistic content of the articles.

Results

The study identifies six main categories of decarbonization strategies: integrated systems, technology breakthroughs, demand and co-benefits, decarbonization of electricity, electrification of uses, and land use and circularity. These pathways emphasize the need for diverse strategies and tools to achieve decarbonization goals across sectors and geographies.

Five dimensions of the decarbonization typology are explored: energy services, economics, planning, infrastructure, and transition. These dimensions provide a framework for understanding the essential characteristics of the identified pathways within the broader context of climate action. The pathways and dimensions are interpreted by grouping frequent and representative terms and keywords, as well as extracting representative titles from the most relevant abstracts within each axis.

Analysis of citation communities reveals well-defined groupings and coherent bounded regions within the decarbonization literature, resembling the identified decarbonization pathways. Hierarchical analysis shows five levels of aggregation, with the third level containing seven partitions closely resembling the six pathways.

Geographical trends are analyzed between 2011 and 2021, focusing on the United States, the European Union, China, and Japan. Each region exhibits distinct patterns in decarbonization pathway importance, reflecting their unique contexts and priorities. The study also critically examines the shortcomings of accepted dichotomies in decarbonization strategies, such as lumpy-vs-granular technologies and supply-vs-demand approaches, providing valuable insights into potential areas for further exploration.

Conclusion

This research offers valuable insights into decarbonization strategies and emphasizes the importance of the typology, pathways, and dimensions in understanding these approaches in the broader context of climate change mitigation. The comprehensive framework developed in this study enables governments and organizations to adopt tailored decarbonization strategies that consider the specific needs of their regions and sectors, integrating different pathways and tools for the most effective outcomes. The exploration of how real-world implementations may combine various strategies will be the subject of future work, as well as a more thorough characterization of these pathways.

References

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