WAPRIME

https://welchacademy.com/index.php/prime

e-ISSN: 3062-2743

Sustainable energy applications in stenter machines in Germany a bibliometric analysis of research trends

Dilek Sümer *[1]

[1] *Niederrhein University of Applied Sciences, Engineering Faculty, Department of Textile Engineering, Germany, dileksuemer@gmail.com*

Cite this study: Sümer, D. (2025). Sustainable energy applications in stenter machines in Germany a bibliometric analysis of research trends. WAPRIME, 2(1), 1-12

https://doi.org/10.5281/zenodo.16980641

Keywords
Stenter machines
Sustainable energy
Bibliometric analysis
German textile industry
Energy efficiency

Research Article
Received: 01 April 2025
Revised: 20 April 2025
Accepted: 23 April 2025
Published: 27 August 2025

Abstract

The textile industry is among the most energy-intensive sectors, with stenter machines playing a critical role in drying, heat-setting, and finishing. These machines consume significant thermal energy and represent an essential focus for sustainability and decarbonization. Although numerous studies have addressed heat recovery, efficiency, and emission reduction, no bibliometric evaluation has targeted Germany. This study applies bibliometric methods to examine sustainable energy applications in stenter machines in Germany from 1990 to 2025. Data were retrieved from Web of Science and Scopus using a topic–country strategy and analyzed with the Bibliometrix R package. The analysis considered publication output, leading authors, institutions, journals, keyword networks, citation structures, and collaboration patterns. Results indicate three phases: an early stage (1992–2004), a local peak (2005), and renewed growth (2018–2023), consistent with Germany's Energiewende framework. Industrial journals such as Melliand Textilberichte dominate publication venues, while Brückner Trockentechnik GmbH and Monforts Textilmaschinen GmbH emerge as central contributors. Keyword analysis reveals two thematic axes: equipment–process optimization (airflow, drying, heat transfer) and energy recovery–efficiency (heat exchangers, waste heat utilization, energy conservation), increasingly tied to decarbonization. Citation analysis shows a right-skewed distribution, where a few methodological papers provide long-term visibility and guide applied studies. Overall, German research on stenter machines is industry-driven and practice-oriented, closely aligned with national energy transition policies. Yet gaps remain in benchmarking protocols, low-carbon heat integration, advanced control strategies, and life cycle assessment. These findings highlight both the strengths of current research and the opportunities for future contributions to industrial sustainability.

1. Introduction

The textile industry is prominent in global sustainability debates due to its high energy intensity and significant environmental impacts. According to the International Energy Agency (IEA), the textile and apparel sector

accounts for more than 6% of global industrial energy consumption [1]. A considerable share of this consumption arises from finishing processes, in which drying, finishing, and heat-setting machines are widely employed [2]. Among these, stenter machines are particularly critical, as they are extensively used for fabric drying, dimensional stabilization, and heat-setting, while representing one of the most thermally energy-intensive units in textile finishing [3].

Thermodynamic analyses have demonstrated that the majority of energy losses in stenter machines occur through exhaust air [3,4]. Therefore, recovering exhaust heat has become a priority in energy efficiency strategies. Cay [5], for instance, performed an exergy analysis of a stenter machine, revealing that reusing exhaust air heat could significantly improve process efficiency. Similarly, Patel et al. [6] developed an energy model of the drying zone, reporting that exhaust heat recovery could achieve savings of up to 7%. Experimental studies also confirm this potential: Gelir and Ceylan [7] achieved a 13.6% annual reduction in fuel consumption by applying a shell-and-tube heat exchanger in a natural gas-fired stenter line. Ciappi [8], using computational fluid dynamics (CFD), showed that air curtain applications could reduce infiltration losses and improve energy efficiency by up to 30%. Hussain et al. [9] emphasized that integrating heat recovery systems in stenter operations could reduce CO_2 emissions by 15–20%, highlighting both economic and environmental benefits. Comparable approaches are also evident in other industrial contexts; for example, Erdoğan and Şentürk Acar [10] conducted an energy and exergy analysis of a tunnel-type biscuit oven, demonstrating that waste flue gas could be utilized for power generation via an Organic Rankine Cycle, thereby significantly increasing energy and exergy efficiencies.

At the policy level, Germany's Energiewende strategy aims to enhance industrial energy efficiency and achieve net-zero carbon by 2045 [11]. This framework promotes the use of renewable energy, electrification of heat systems, and integration of waste heat recovery in industrial processes. Gawel et al. [12] argue that efficiency measures play a central role in Germany's energy transition and highlight the importance of technological innovation, particularly in energy-intensive industries.

Nevertheless, although numerous technical and experimental studies on stenter machines have been published, no bibliometric analysis focusing specifically on Germany has yet been conducted. Bibliometric methods provide a powerful means of identifying research evolution, dominant themes, leading institutions, and the structure of international collaboration networks [13]. Therefore, this study aims to map the scientific production concerning sustainable energy applications in stenter machines in Germany through bibliometric analysis, thereby outlining the current state of the field and identifying future research opportunities.

To the best of our knowledge, this study represents the first systematic bibliometric analysis dedicated to sustainable energy applications in stenter machines with a specific focus on Germany. By combining quantitative mapping of research trends with a critical assessment of thematic structures, institutional leadership, and collaboration patterns, the paper provides a novel contribution to the literature. The findings are expected to guide researchers, industry stakeholders, and policymakers in aligning future research and innovation with Germany's Energiewende objectives and broader global sustainability targets.

2. Material and Methods

Bibliometric methodology offers a systematic and quantitative approach to mapping the intellectual structure and developmental dynamics of a research field. Unlike narrative reviews, which may be prone to subjectivity, bibliometric analyses employ reproducible algorithms to evaluate publication outputs, citation structures, and collaboration networks, thereby providing a holistic overview of scientific activity [14,15]. In the context of

energy-intensive textile processes such as stenter machines, this approach is particularly valuable as it enables the identification of dominant research themes, technological innovations, and institutional leadership within a policy-driven landscape [16]. By combining descriptive indicators with network-based visualizations, bibliometric methods allow not only the tracking of research evolution over time but also the detection of thematic clusters and knowledge gaps that shape future agendas [17,18]. Against this background, the present study applies a structured bibliometric framework to investigate sustainable energy applications in stenter machines in Germany.

2.1. Data Sources and Search Strategy

The dataset for this study was obtained from the Web of Science Core Collection (WoS) and Scopus databases. Bibliometric records covering the period 1990–2025 were retrieved. The search query was constructed using the combination of keywords "stenter OR tenter OR heat-setting OR textile finishing" with "energy OR efficiency OR heat recovery OR sustainability OR CO_2." To ensure geographical relevance, only publications affiliated with German institutions were selected. This procedure follows the widely adopted "topic + country" matching strategy in bibliometric research [19].

2.2. Data Cleaning and Pre-processing

To enhance the reliability of the bibliometric analysis, retrieved records were subjected to systematic cleaning and standardization. Variations in author names (e.g., "Basu, S. K." vs. "S. Basu"), inconsistencies in institutional nomenclature (e.g., "Univ Erlangen Nuremberg" vs. "FAU Erlangen-Nürnberg"), and differences in keyword spelling (e.g., "heat setting" vs. "heat-setting") were harmonized. Records lacking publication year or source title were excluded from the dataset. Such data homogenization steps are considered critical for ensuring accuracy and reproducibility in bibliometric studies, as emphasized in the literature [20].

2.3. Analytical Techniques

The bibliometric analysis was performed using the Bibliometrix package in R [13, 21]. Descriptive statistics were calculated for publication output by year, prolific authors, institutions, and journals, as well as for the most frequently used keywords. In addition, advanced bibliometric mapping techniques—including co-citation analysis, co-authorship networks, and keyword co-occurrence analysis—were employed to identify thematic clusters and visualize research collaboration patterns.

2.4. Limitations

This study relies exclusively on records retrieved from the WoS and Scopus databases. Local publications indexed in alternative sources such as TR Dizin or Google Scholar were not included. Moreover, certain cleaning and disambiguation steps (e.g., standardization of author names and institutions) involved the researcher's judgment, which may introduce minor inaccuracies, particularly at the author and institutional levels. These limitations should be taken into account when interpreting the findings.

3. Findings

The bibliometric analysis of sustainable energy applications in stenter machines in Germany provides a comprehensive overview of the temporal, thematic, and institutional dynamics of the field. By systematically examining publication outputs, journals, authorship patterns, institutional affiliations, keyword networks, and

citation structures, the study uncovers both the strengths and the limitations of the existing knowledge base. The results reveal not only how scientific activity has evolved over time but also how industrial stakeholders and academic institutions have interacted to shape the research landscape. Furthermore, the findings highlight the dual character of the field: strongly practice-oriented due to the involvement of machinery manufacturers, yet increasingly connected to global sustainability debates through concepts such as energy efficiency, heat recovery, and decarbonization. This section presents the main results in six parts: annual publication trends, journal distribution, author productivity, institutional contributions, keyword analysis, and citation and collaboration networks.

3.1. Annual Publication Trends

Between 1992 and 2023, a total of 22 publications affiliated with German institutions were identified, exhibiting three distinct phases of temporal development. The early phase (1992–2004) was characterized by sporadic and irregular output, with annual publications fluctuating between one and two articles. A local peak occurred in 2005, when four publications were recorded, representing the highest single-year output in the dataset. This short-lived surge was followed by a decline, as publication activity gradually fell back to lower levels in subsequent years. After a period of relative stagnation, a renewed momentum emerged from 2018 onwards, coinciding with the growing prominence of energy efficiency and sustainability in Germany's industrial and policy agenda, as illustrated in Figure 1.

The shape of the time series suggests a "policy-triggered research dynamic," as the resurgence of publications aligns with the goals of Germany's Energiewende program, which emphasizes industrial decarbonization and energy efficiency [11,12]. The right-skewed distribution, marked by small fluctuations in recent years, reflects the applied and niche character of the field. It also indicates that, in several years, individual studies have disproportionately shaped the overall visibility of research outputs. This pattern illustrates both the dependence of the field on specific industrial or collaborative projects and its strong alignment with practical problem-solving in textile finishing processes.

Figure 1. Annual number of publications on stenter machines and energy in Germany (1992–2023).

3.2. Journal Distribution

The distribution of publication outlets reveals a strong orientation toward sector-specific and practice-driven journals. As shown in Table 1, Melliand Textilberichte accounts for the largest share of output with six articles, followed by International Dyer with three publications. Both International Textile Bulletin and Industrie Textile contributed two articles each, while Technische Textilien featured one. This concentration illustrates that the majority of German research on stenter machines has been disseminated through machinery-focused and industrially oriented platforms, where technical notes, process descriptions, and equipment developments dominate. While such venues provide effective channels for knowledge transfer to practitioners and industry stakeholders, their limited academic reach helps explain the relatively low-to-medium citation levels observed in the dataset. Taken together with the forthcoming author and institutional analyses, the journal distribution confirms that German contributions in this field are largely industry-driven and characterized by a pragmatic orientation toward technological implementation.

Table 1. Leading journals by number of publications (1992–2023).

Rank	Journal Title	Number of Publications
1	Melliand Textilberichte	6
2	International Dyer	3
3	International Textile Bulletin	2
4	Industrie Textile	2
5	Technische Textilien	1

3.3. Author Productivity

The distribution of author productivity exhibits a pattern consistent with Lotka's law, where a small number of highly prolific researchers account for a disproportionate share of the output, while most contributors have only a single publication. As illustrated in Figure 2 and summarized in Table 2, Speck U. is the most productive author with three publications, followed by Prinzen H.P., Watzl A., Gottschalk K.H., and Städter D., each with two contributions. This core group has repeatedly addressed themes such as machine modernization, energy economics, and total cost of ownership (TCO), as well as the optimization of drying and heat-setting operations, thereby achieving greater visibility within the field.

The broader distribution of single-contribution authors reflects the fragmented nature of the domain, where industrial research and firm-specific R&D initiatives play a central role. Such structures not only generate isolated publication clusters but also explain the presence of recurring co-authorship ties that later emerge as central nodes in the collaboration networks (see Section 3.7). Overall, the pattern highlights how German research on stenter machines is shaped by the interplay between engineering design and field validation, aligning with the applied and practice-oriented character of the sector [13].

Table 2. Most productive authors (1992–2023).

Rank	Journal Title	Number of Publications
1	Speck U.	3
2	Prinzen H.P.	2
3	Watzl A.	2
4	Gottschalk K.H.	2
5	Städter D.	2

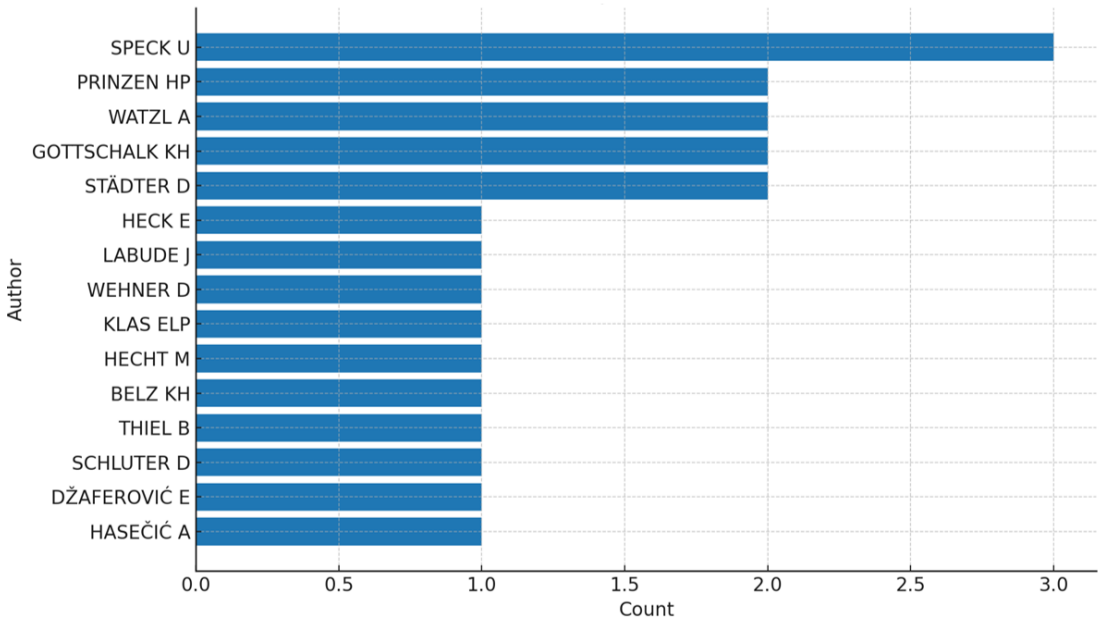

Figure 2. Most productive authors in Germany-focused publications on stenter machines (1992–2023).

3.4. Legal Regulations on Desalination Technologies in Turkey

The distribution of institutional contributions clearly reflects the industry-driven character of the field. As shown in Figure 3 and summarized in Table 3, Brückner Trockentechnik GmbH & Co. KG leads with three publications, followed by A. Monforts Textilmaschinen GmbH, Monforts Textilmaschinen GmbH, and Sonotronic Nagel GmbH with two each. Thorey Gera Textilveredlung GmbH appears with one publication. The prominence of machinery manufacturers highlights the central role of industrial actors in advancing research on stenter machines. This profile is not surprising, as stenter lines involve complex equipment and process integration modules—such as heat recovery exchangers, air curtains, and automation systems—that directly influence both energy consumption and operating costs.

The strong visibility of industrial companies demonstrates how prototype-to-pilot-to-field implementations are rapidly reflected in the literature. At the same time, co-authorships with universities and research institutes reinforce the modeling, measurement, and validation dimensions of these studies. This dual ecosystem—industry-driven development combined with academic verification—accelerates technology maturation while expanding case-based knowledge in the literature. The resulting publication and citation patterns, characterized by a wide low-to-medium range alongside isolated high peaks, are consistent with this application-oriented research architecture [11, 12, 13].

Table 3. Most productive authors (1992–2023).

Rank	Institution	Number of Publications
1	Brückner Trockentechnik GmbH & Co. KG	3
2	A. Monforts Textilmaschinen GmbH	2
3	Monforts Textilmaschinen GmbH	2
4	Sonotronic Nagel GmbH	2
5	Thorey Gera Textilveredlung GmbH	1

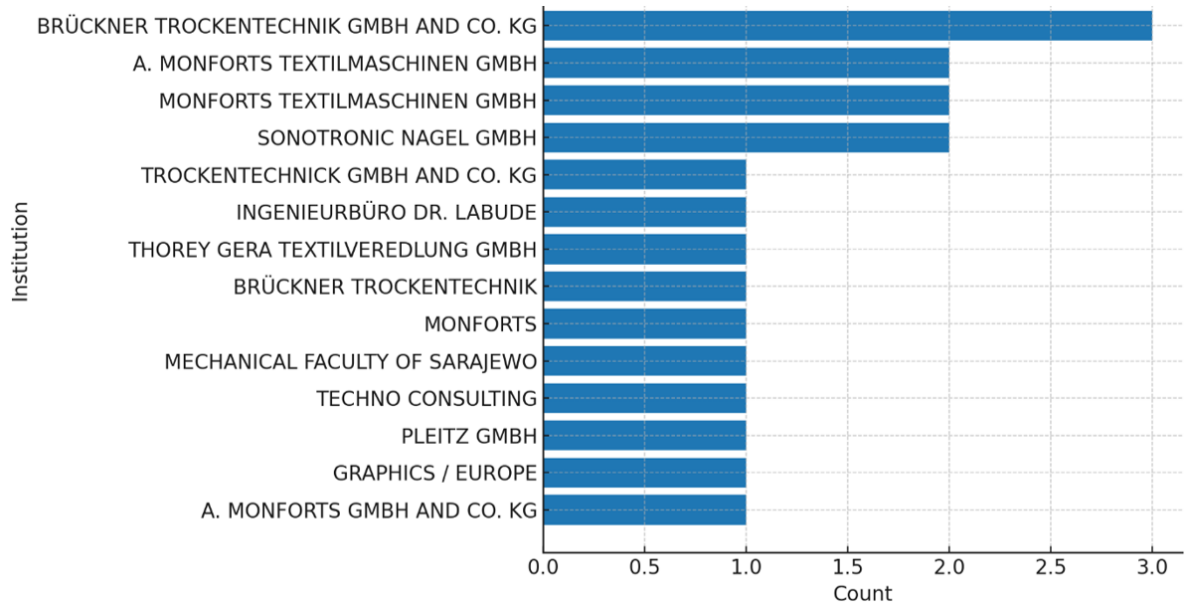

Figure 3. Institutions with the highest number of publications on stenter machines in Germany (1992–2023).

3.5. Keyword Analysis

The thematic structure of Germany-affiliated publications was examined through both author keywords (DE) and index keywords (ID), using frequency counts and a co-occurrence network generated with Bibliometrix [13]. As shown in Table 4, the most frequently used terms include stentering machine (9 occurrences), heat recovery (6), energy conservation (6), stentering (5), and drying (5). These results indicate that the literature is primarily concentrated on waste heat recovery and the reduction of specific energy consumption during drying and heat-setting processes.

The co-occurrence network presented in Figure 4 provides further insights into the thematic clusters underlying this keyword distribution. Three main research axes can be identified: (i) heat recovery and process heat, including terms such as heat exchangers and waste heat utilization; (ii) energy efficiency and emissions, encompassing energy conservation, energy efficiency, GHG, and decarbonisation; and (iii) process physics and operations, involving airflow, heat transfer, drying, finishing, and automation. The centrality of the stentering machine and heat recovery within the network underscores their role as the core thematic anchors of the field. Meanwhile, bridging connections to environmental terms such as GHG and decarbonisation demonstrate the alignment of stenter-related research with Germany's broader Energiewende agenda, particularly its emission reduction targets [11,12].

Together, Table 4 and Figure 4 offer complementary perspectives by quantifying the relative weight of individual terms while simultaneously mapping their interconnections. This integrated approach provides a comprehensive yet concise representation of the keyword landscape without inflating article length.

Table 4. Most frequently used keywords (1992–2023).

Rank	Keyword	Frequency
1	Stentering machine	3
2	Heat recovery	2
3	Energy conservation	2
4	Stentering	2
5	Drying	1

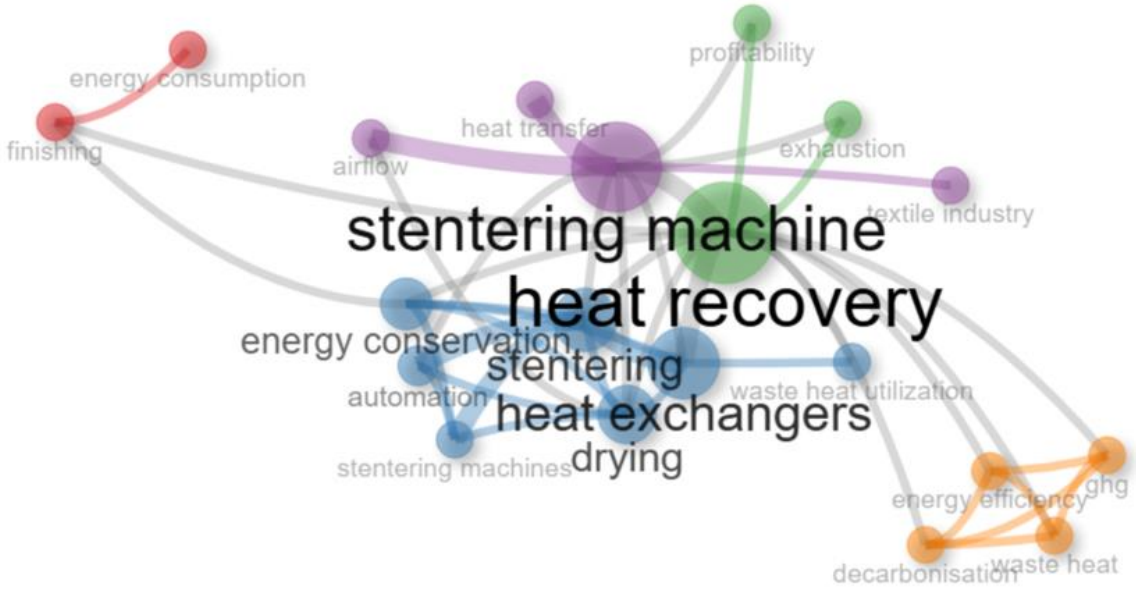

Figure 4. Keyword co-occurrence network of publications on stenter machines in Germany (1992–2023).

3.6. Most Cited Publications

Citation analysis sheds light on the intellectual core and methodological references of the field. The citation distribution of the dataset is right-skewed, with a small number of studies standing out while the majority remain within the low-to-medium citation range. As shown in Table 5, the most cited contributions include Belz and Hecht's (2007) work on energy-saving processes in textile finishing (Band- und Flechtindustrie, 2 citations) and Ramić et al.'s (2023) recent study on the energy efficiency of industrial drying machines (Lecture Notes in Networks and Systems, 1 citation). Other contributions, such as Prinzen's (2002) assessment of machine ownership costs, Schluter and Thiel's (1997) discussion of process optimization, and Speck's (2003) report on new stenter generations, received limited or no citations despite their technical relevance.

The common characteristics of the leading cited works can be summarized as follows: (i) a direct focus on energy efficiency and waste heat recovery, (ii) an emphasis on reducing specific energy consumption (SEC) during drying and heat-setting operations, and (iii) the integration of experimental or semi-industrial validation. These core studies have served as methodological anchors by combining exergy/energy balance modeling approaches with practical solutions such as heat exchanger design, reuse of exhaust air, and air curtain applications. Furthermore, the citation profile suggests that methodological papers—such as those introducing energy models or measurement/validation protocols—tend to sustain longer-term visibility compared to case-specific applications. This highlights the field's sensitivity to design principles and the need for standardization in energy efficiency assessment.

Table 5. Most cited publications (1992–2023).

Rank	Title	Authors	Year	Journal	Citations
1	New energy saving process for the finishing of textiles	Belz K.H., Hecht M.	2007	Band- und Flechtindustrie	2
2	Energy efficiency of industrial drying machines	Ramić M., Pleitz M., et al.	2023	Lecture Notes in Networks and Systems	1
3	The true cost of machine ownership	Prinzen H.P.	2002	International Dyer	0
4	Process and plant optimization in the use of energy	Schluter D., Thiel B.	1997	Melliand Textilberichte	0
5	New stenter generation sets high standards	Speck U.	2003	International Dyer	0

3.7. Collaboration Network Analysis

The co-authorship network, as illustrated in Figure 5, reveals that research in this field is organized into small, clustered groups rather than a single, integrated network. Node sizes correspond to author productivity, while the thickness of the links indicates the strength of co-authorship relations. As a result, a few central nodes emerge through repeated collaborations, while many authors remain isolated or connected only within small teams.

Several key patterns can be observed. First, an industry–academia composition is evident: clusters frequently combine machinery manufacturers and finishing plants with university- or research-institute-affiliated scholars, underscoring the applied orientation of the literature and its strong ties to practical problem-solving. Second, thematic differentiation is visible: certain clusters concentrate on exhaust-air heat recovery and energy-saving measures, whereas others focus on drying, airflow, and heat transfer processes. Finally, bridging nodes such as Pleitz M. and Ramić M. play a critical role by linking different subgroups, facilitating the transfer of knowledge across themes ranging from heat exchanger design to process control.

Overall, the network topology demonstrates that German research on stenter machines operates within a multidisciplinary and practice-driven ecosystem. Rather than large-scale academic collaborations, the field relies on repeated partnerships across industrial and academic actors, particularly within projects aimed at improving energy efficiency and supporting the broader Energiewende agenda.

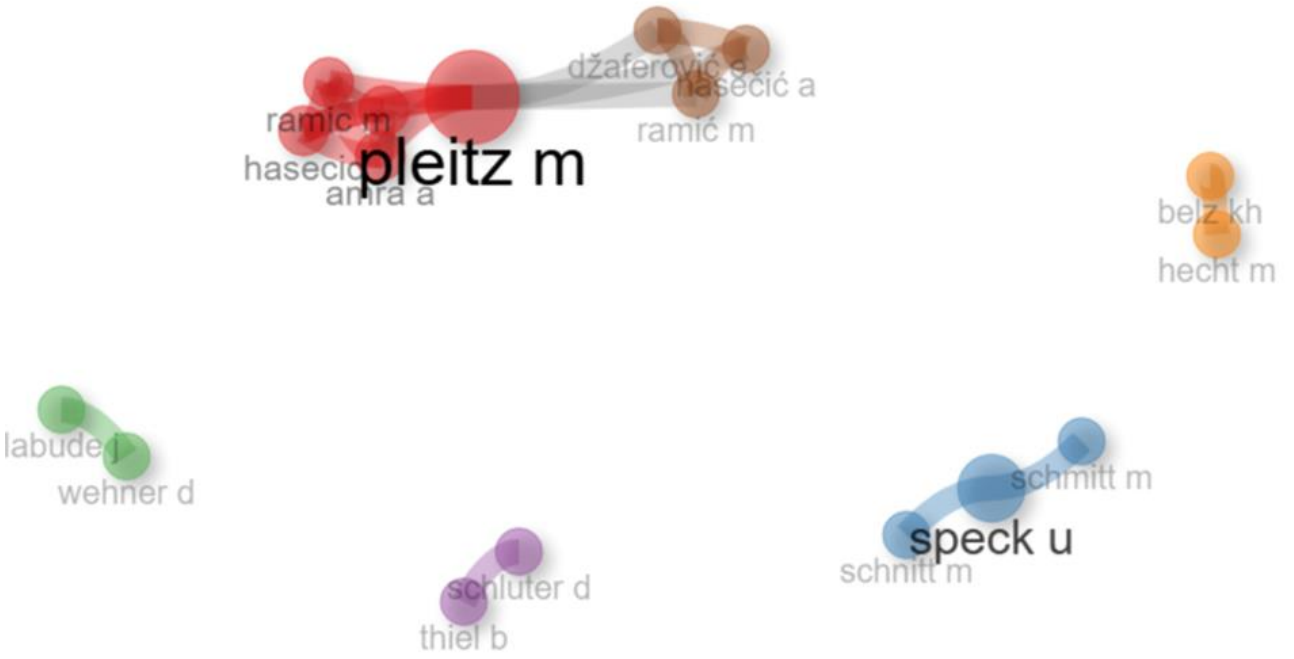

Figure 5. Co-authorship network of publications on stenter machines in Germany (1992–2023).

4. Discussion

This bibliometric mapping has shown that German research on stenter machines is predominantly application-driven, with much of the output concentrated in sectoral and technical journals (see Section 3.2). This orientation reflects the decisive role of stenter lines in shaping both energy costs and process quality. Consequently, machinery manufacturers and finishing plants often lead knowledge production through prototype–pilot–field-level contributions. At the same time, this orientation explains the relatively limited citation density (Section 3.6) and the field's narrow, problem-solving character.

The keyword analysis (Table 4, Figure 4) highlighted that the intellectual core of the literature revolves around two main axes: (i) **equipment–process performance** (*stentering machine, drying, airflow, heat transfer, automation*), and (ii) **recovery–efficiency strategies** (*heat recovery, heat exchangers, energy efficiency, energy conservation, waste heat utilization*). These axes are bridged by environmental nodes such as *GHG* and *decarbonisation*, confirming the integration of technical optimization with Germany's *Energiewende* and its emission reduction goals [11, 12, 13].

From a technical standpoint, two major research streams emerge. First, **heat recovery solutions** focus on reusing exhaust air through exchangers and auxiliary systems, or pre-heating process air and water [3, 5, 7]. Second, **process physics of drying and heat-setting** investigates airflow, temperature profiles, fabric moisture, and heat transfer coefficients as key factors influencing specific energy consumption (SEC) [3, 6]. Model-based approaches (e.g., energy–mass balances, benchmarking frameworks) generate transferable principles to guide design and control decisions [6], while experimental and case-based contributions provide evidence of actual savings and feasibility [3, 7]. The interaction between these two streams—*model → prototype/pilot validation → model refinement*—defines the maturation cycle of the field and explains the relatively long-lasting visibility of methodological works [1, 6, 13].

On the policy side, Germany's *Energiewende* framework has strengthened this research trajectory by promoting industrial energy efficiency, waste heat integration, and electrification of heat systems [11, 12]. The co-authorship network (Figure 5) further reflects the dual character of the field: industrial actors driving machine modernization, and academic institutions providing modeling, measurement, and validation. While this duality accelerates technology readiness, it also generates fragmented datasets, often limited to single facilities or case-specific trials, which constrains comparability.

Despite these achievements, the literature reveals several gaps and future opportunities:

- **Benchmarking and standardization:** Few studies define SEC metrics normalized by fabric type, line speed, and moisture/temperature targets, which reduces cross-comparison [1, 6, 13].
- **Low-/zero-carbon heat options:** Although heat recovery dominates, systematic techno-economic evaluations of heat pumps, electrification (resistive/induction), and hybrid stenter configurations remain scarce [1, 3, 11].
- **Advanced control and sensing:** Promising approaches such as model predictive control (MPC), real-time humidity/quality sensors, and multivariable closed-loop optimization are underrepresented in replicable datasets [6].
- **Holistic environmental assessment:** Life cycle assessment (LCA) is rarely integrated with exergy/energy analysis; such integration is essential for optimizing energy–emission–quality trade-offs [3, 11, 12].
- **Scalability and external validity:** Replication across different fabrics, stenter configurations, and operating conditions is needed to enhance generalizability.

5. Conclusion

This study provides the first systematic bibliometric analysis of sustainable energy applications in stenter machines in Germany. The findings reveal a research field that is highly industrial in orientation, strongly application-driven, and yet anchored in scientifically traceable methods. Two thematic backbones emerge as defining features: equipment–process optimization, focusing on drying, airflow, and heat transfer, and recovery–efficiency measures, centered on heat exchangers, waste heat utilization, and energy conservation. Together, these axes form the intellectual and technological foundation of the field.

The analysis highlights not only how research activity has evolved in response to industrial challenges and policy drivers but also how collaboration between manufacturers and academic institutions has shaped the knowledge base. Despite the fragmented nature of the literature, a clear trajectory is visible: from prototype development to pilot-scale validation and eventual industrial implementation.

Looking forward, the results underscore three critical directions. First, methodological standardization—particularly in defining and reporting specific energy consumption—will be vital for comparability and progress. Second, scaling up advanced technologies such as heat pumps, electrification, and predictive control systems is necessary to bridge efficiency gains with low-carbon pathways. Third, stronger integration across industry, academia, and policy frameworks will determine whether the full energy-saving potential of stenter machines translates into measurable contributions to industrial decarbonization.

By mapping the evolution, structure, and gaps of this research landscape, the study not only provides a roadmap for future investigations but also positions stenter machine efficiency as a key lever in the broader pursuit of sustainable industrial transformation.

Author contributions
Dilek Sümer: Conceptualization, Methodology, Software, Data curation, Writing-Reviewing and Editing.

Conflicts of interest
The authors declare no conflicts of interest.

References

1. International Energy Agency. (2020). *Energy technology perspectives 2020*. Paris: IEA.
2. Hasanbeigi, A. (2010). *Energy-efficiency improvement opportunities for the textile industry* (Report No. LBNL-3970E). Lawrence Berkeley National Laboratory.
3. Hussain, T., Khan, M. A., & Ali, F. (2020). Waste heat recovery and energy saving potential in textile stenter machines. *Journal of Cleaner Production, 245,* 118132. https://doi.org/10.1016/j.jclepro.2019.118132
4. Yildiz, H., Kaya, A., & Kaplan, M. A. (2021). Experimental investigation of thermal performance in textile stenter machines with heat recovery system. *Heat and Mass Transfer, 57*(2), 131–142. https://doi.org/10.1007/s00231-020-02914-4
5. Cay, A. (2007). Exergetic performance assessment of a stenter system in textile finishing. *International Journal of Energy Research, 31*(3), 248–258. https://doi.org/10.1002/er.1249
6. Patel, N. G., Shendage, D. J., Doctor, S., & Basu, S. K. (2021). Energy model-based benchmarking of the drying process in the stenter machine. *Drying Technology, 39*(8), 964–976. https://doi.org/10.1080/07373937.2020.1740819
7. Gelir, B. Ç., & Ceylan, H. (2021). The effect of the heat recovery on fuel consumption in the stenter machine. *Thermal Science, 25*(2A), 1047–1055. https://doi.org/10.2298/TSCI200211046G
8. Ciappi, D. (2019). Air curtain-based energy saving in textile stenter dryers. *Energies, 12*(3), 482. https://doi.org/10.3390/en12030482

9. Hussain, T., Khan, M. A., & Ali, F. (2020). Carbon emission mitigation potential in stenter processes through waste heat recovery. *Journal of Cleaner Production, 245,* 118133. https://doi.org/10.1016/j.jclepro.2019.118133
10. Erdoğan, M., & Şentürk Acar, M. (2024). Thermodynamic analysis of a tunnel biscuit oven and heat recovery system. *WAPRIME, 1*(1), 1–15. https://doi.org/10.5281/zenodo.14930792
11. International Energy Agency. (2020). *Germany 2020: Energy policy review*. Paris: IEA.
12. Gawel, E., Strunz, S., & Lehmann, P. (2014). The German Energiewende under pressure: Is Germany on track to achieve its climate targets? *Energy, Sustainability and Society, 4*(1), 1–10. https://doi.org/10.1186/2192-0567-4-10
13. Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics, 11*(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007
14. Small, H. (1973). Co-citation in the scientific literature: A new measure of the relationship between two documents. *Journal of the American Society for Information Science, 24*(4), 265–269. https://doi.org/10.1002/asi.4630240406
15. Garfield, E. (1972). Citation analysis as a tool in journal evaluation: Journals can be ranked by frequency and impact of citations for science policy studies. *Science, 178*(4060), 471–479. https://doi.org/10.1126/science.178.4060.471
16. Callon, M., Courtial, J. P., & Laville, F. (1991). Co-word analysis as a tool for describing the network of interactions between basic and technological research: The case of polymer chemistry. *Scientometrics, 22*(1), 155–205. https://doi.org/10.1007/BF02019280
17. Aria, M., & Cuccurullo, C. (2021). Bibliometrix: Comprehensive science mapping analysis. *R Core Team: Vienna, Austria*.
18. Aksnes, D. W., Langfeldt, L., & Wouters, P. (2019). Citations, citation indicators, and research quality: An overview of basic concepts and theories. *Sage Open, 9*(1), 1–17. https://doi.org/10.1177/2158244019829575
19. Small, H. (1973). Co-citation in the scientific literature: A new measure of the relationship between two documents. *Journal of the American Society for Information Science, 24*(4), 265–269. https://doi.org/10.1002/asi.4630240406
20. Deng, Z., Chen, Y., & Li, M. (2022). Data cleaning strategies in bibliometric analysis: A review. *Scientometrics, 127,* 123–142. https://doi.org/10.1007/s11192-022-04492-3
21. Arruda, H., Silva, E. R., Lessa, M., Proença Jr, D., & Bartholo, R. (2022). VOSviewer and bibliometrix. *Journal of the Medical Library Association*: *JMLA*, 110(3), 392.