

Shining Light on Quantum Technologies: A Bibliometric Analysis on Quantum Technology Research in the Energy Sector

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Abstract. *Quantum technology is bound to reshape the way problems are solved surpassing classical computing limits. This paper conducts a bibliometric analysis of the burgeoning quantum research connecting quantum technologies with the energy sector using data from Scopus. Using the bibliometric software VOSviewer and the Bibliometrix R package, the analysis maps knowledge domains and tracks publication trends from 2019 to the end of 2025 for two datasets with distinct keywords (Dataset A – quantum related keywords & Dataset B – quantum and energy related keywords) verifying three research questions (RQ) and one hypothesis. The results of the analysis reveals an expanding research field in quantum (Dataset A) with an impressive annual growth rate and a comparable low paper age. The energy specialized research field (Dataset B) shows an early stage but an even higher annual growth rate than the general quantum research field (Dataset A). The keyword analysis reveals a bibliometric map concentrated around more technical topics, like optimization, application of quantum computing to artificial intelligence (AI) and securing critical energy infrastructures. Although less prevalent than the technical clusters the keyword search also revealed some management and business-oriented clusters. The insights revealed by the RQ confirm the hypothesis (H1) that current quantum applications in the energy sector although novel, show signs of significant development, with future applications to solve complex optimizations that need stronger computing power, like grid optimization, renewable energy forecasting, and material innovation.*

Keywords: Quantum Technologies, Energy Sector, Bibliometric Analysis, Quantum Applications, Optimization, Emerging Technologies.

Introduction

The paper looks at the link between quantum technologies and the energy sector analyzing the emergence of quantum computing's impact on multiple industry sectors while concentrating on energy sector applications. It uses data from Scopus to perform a bibliometric analysis using two different bibliometric tools: VOSviewer and the Bibliometrix R package. The three research questions progress from mapping the quantum technologies field, to identifying the key outlets in quantum technology research in business, to examining the sector-specific coverage of business-related quantum technology in the energy sector. The maturity and future path of quantum technologies in the energy sector are tested using a hypothesis.

Quantum technology introduces a novel computational paradigm by leveraging the basic principles of quantum mechanics of superposition and entanglement. Quantum computers can potentially surpass the performance of advanced contemporary supercomputers (Giani & Eldredge, 2021). The introduction of this revolutionary approach is set to reshape the economy across all sectors, including the energy sector, especially during the times of the global transition towards sustainable energy sources (Baklage 2023). When combined with Artificial Intelligence (AI) for reaching Quantum Artificial Intelligence (QAI), this potential is positioned as a powerful solution for existing energy system challenges (Wang et al., 2025).

Literature review

The literature review in this paper explains the foundation of the two tools used in the bibliometric analysis. Bibliometric examination distinguishes between three distinct types of citation techniques: co-citation, bibliographic coupling and co-authorship networks. Co-citation analyzes the citations, bibliographic coupling looks at the content of the paper and finally co-authorship networks will draw conclusions by looking at collaboration networks. It is very important to note that such metric types must be interpreted cautiously because citation patterns vary across disciplines and do not always indicate the same research quality.

Co-citation analysis (Small, 1973) looks at the frequency with which two publications are cited together by other publications. When that is the case, it means that they most likely contribute to the same research stream, so they are considered conceptually related. This type of analysis examines documents, authors, or journals. In documents, it identifies seminal works and research streams; with authors, it reveals knowledge communities and lastly; in journal co-citation it shows disciplinary knowledge flows between publications. Bibliographic coupling (Kessler, 1963), is different than co-citation analysis, as it relies on the assumption that two papers that cite similar sources can be considered connected, which means they rely on similar foundational knowledge. Especially in emerging fields, like the one discussed in this paper, where patterns are not yet mature this method can bring interesting results. Lastly, direct citation analysis reveals temporal development and diffusion patterns by following the flow of knowledge contributions over a period of time.

Bibliometric research can also analyze the content of the academic research. Here, we separate between two possible approaches for content analysis: co-word analysis and text mining. Co-word analysis looks at the co-occurrence of keywords, terms, and sentences from the publications to derive themes and conceptual relationships. It is very useful, especially in novel research because it can detect rising topics before they become substantial citation patterns. Text mining and natural language processing have advanced the possibilities of text analysis using advanced algorithms. They can highlight, for example, semantic relationships, changes in terminology, or paradigm shifts in a research field.

Finally, co-authorship analysis identifies collaboration networks over different groups. It provides insight into the most prominent authors, institutions or geographical regions over a given topic, revealing e.g. if specific authors are main drivers of domain or rather a bridge between disciplines.

Tools used

Multiple tools, with different strengths and analytical approaches are available today. The following study provides a detailed overview of current research trends and highlights key areas for future exploration in the field of quantum technologies in the energy sector using two different bibliometric tools, namely VOSviewer software and Bibliometrix package in R. Thus, by using this combination, the study takes advantage of VOSviewer's visualization capabilities and complements it with the analytical depth and statistical integration of Bibliometrix package.

VOSviewer is a powerful tool that facilitates the creation and visualization of bibliometric maps. The analyses performed in VOSviewer include keyword co-occurrence network, co-occurrence analysis of author keywords, co-authorship by countries, and bibliographic coupling. Biblioshiny, a web-based bibliometric analysis tool that is part of the bibliometrix R package, is used for data processing and statistical insights (Ghorbani, 2024). In short, Bibliometrix is mainly used for bibliometric data curation and the generation of quantitative metrics, whereas VOSviewer offers enhanced capabilities for a more interactive visualization of bibliometric networks.

VOSviewer

VOSviewer (Visualisation of Similarities) was introduced by van Eck and Waltman at Leiden University and became one of the most widely used bibliometric visualization tools, mostly because of the power to create intuitive network visualizations of bibliometric data using the VOS mapping technique. The software constructs networks based on co-occurrence, citation, bibliographic coupling, or co-authorship relationships using data from standardized formats from databases.

The association strength normalization of mapping the position of keywords used in VOSviewer produces more meaningful clustering than a simple co-occurrence counting (Van Eck & Waltman, 2009): so that in the VOS clustering algorithm items with stronger connections will appear closer together in the two-dimensional visualization space, grouped using color coding. The item size reflects frequency or importance metrics like publication counts or citation frequencies. More information on VOSviewer (version: 1.6.20) and its analysis capabilities can be found in the VOSviewer manual (van Eck & Waltman, 2023).

Bibliometrix package in R

Bibliometrix is a comprehensive R package, introduced by Aria and Cuccurullo (2017) that is used for bibliometric (and scientometric) analysis, offering both computational power and flexibility. It also offers a web interface, biblioshiny, which aids non-technical users in performing the analysis in a user-friendly web interface with less programming knowledge.

Since it integrates into the R programming environment, it enables researchers to advance the bibliometric analysis, including data importing, cleaning, analysis, and visualization with statistical methods, custom data manipulations, and reproducible research workflows. The package supports several scientific databases in a standardized format. The strength of Bibliometrix lies in its comprehensive and detailed analysis (Aria & Cuccurullo, 2017).

Methodology

Based on literature sourced from the Scopus database, this study investigates the following research questions (RQ1, RQ2, RQ3):

RQ1: How is quantum technology being researched within business-related academic literature?

RQ2: In which journals is business-related quantum technology research most published?

RQ3: To what extent does the business-related quantum technology literature include applications in the energy sector?

To further develop the analysis, it is hypothesized that quantum technologies in the energy sector are in their infancy but show signs of evolving within the energy sector (*H1*).

H1: Quantum technologies are at an early but rapidly developing stage of application within the energy sector.

To address these questions, the study has retrieved papers published from the Scopus database and examined them using the VOSviewer software, complementing it using the Bibliometrix R package. The database search was conducted on November 15th, 2025, and covers publications from 2019 to 2025, inclusive, resulting in an initial dataset of 454 documents that were then pre-processed through data cleaning and filtering in R. The reason for choosing the said period is because the rapid evolution of technology, especially in the field of quantum technologies, might deem older material outdated and less useful (Sevilla & Riedel, 2020). Moreover, there were not

enough relevant publications before 2019 to provide a solid basis for analysis. Spanning over that six year period, the research highlights nascent trends in quantum technologies in various industries especially in relation to the energy field.

Bibliometric analysis was coined by Pritchard (1969) as a quantitative method that has evolved from a simple citation counting into a sophisticated approach to map knowledge domains, identifying research trends and collaboration networks. In emerging technology markets, especially where interdisciplinary bounds are fuzzy (here: quantum technologies and energy sector), bibliometric analysis can prove to be a valuable tool in examining these high volumes of publications to unravel patterns that do not seem obvious at first glance (Rejeb et al., 2022).

The journal articles were queried from the Scopus database, because of the broad coverage and complete metadata structure of the database. Two focused queries were used to obtain two distinct datasets (A and B) aligned with the three research questions outlined above:

Dataset A: Records where quantum-related keywords appear in the title, abstract, keywords, or text (434 papers after data cleaning)

Dataset B: Records where quantum-related keywords and energy-related keywords appear in the abstract, keywords, or text (26 papers after data cleaning)

The below analysis is organized in two interconnected layers. All Scopus query searches were performed on November 15th, 2025. The first step to create Dataset A consisted of a search using quantum related keywords in the Scopus data base. The keywords used in the filtering are: "Quantum technology", "Quantum as a service", "Quantum computing", "Quantum algorithm", "Quantum ecosystems", "Quantum business model". The publications only included papers, from 2019 to 2025, inclusive, for the fields of Energy, Business, and Economics. The query used in Scopus for filtering can be seen below:

TITLE-ABS-KEY ("Quantum technology" OR "Quantum as a service" OR "Quantum computing" OR "Quantum algorithm" OR "Quantum ecosystems" OR "Quantum business model") AND DOCTYPE (ar) AND PUBYEAR > 2018 AND PUBYEAR < 2026 AND (SUBJAREA (ENER) OR SUBJAREA (BUSI) OR SUBJAREA (ECON))

The 454 resulting papers were downloaded as a .csv document, which was then included in R. The reporting for the bibliographic analysis was performed according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram (Liberati et al. 2009). The cleanup consisted of removing exact duplicate rows, removing rows with missing titles, abstracts, or missing dates. The resulting document, Dataset A, contained 434 papers.

To create Dataset B, an additional search was carried out in the Scopus Database, with the same filters but a different set of keywords. The search was for one quantum-related term in the title, abstract, or keyword, and one energy-related term in the title, abstract, or keyword. The resulting document, Dataset B, included 26 papers. The query can be seen below:

TITLE-ABS-KEY("Quantum technology" OR "Quantum as a service" OR "Quantum computing" OR "Quantum algorithm" OR "Quantum ecosystems" OR "Quantum business model") AND TITLE-ABS-KEY("Energy Market" OR "Smart Grid" OR "Distributed Energy" OR "Energy Storage" OR "Energy Ecosystems" OR "Demand Response" OR "Energy digitalization" OR "Energy strategies" OR "Energy Trading") AND DOCTYPE(ar) AND PUBYEAR > 2018 AND PUBYEAR < 2026 AND (SUBJAREA(ENER) OR SUBJAREA(BUSI) OR SUBJAREA(ECON))

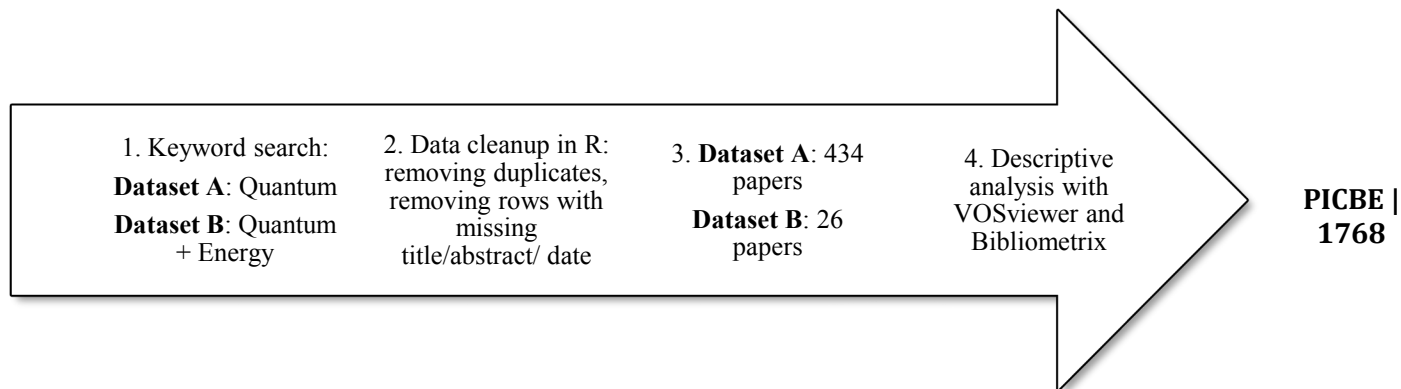


Figure 1. Steps of bibliometric search and analysis of Dataset A & B. Own illustration

Results and discussions

To answer *RQ1* (How is quantum technology being researched within business-related academic literature?) a bibliometric analysis was carried out to identify publication trends and growth patterns using the papers in Dataset A.

The Table below reveals a high-level summary of key bibliometric indicators and collection features. The collection reveals a rather recent body of research of 434 papers over the span of 6 years, over the period 2019-2025, in the fields of Economics, Business and Energy in the quantum-related business from 203 different sources. Despite of the topic being relatively new and niched, the number of papers is considered large enough for an initial analysis. The high annual growth rate of 47,24% seen in Table 1 suggests an emerging field of study. The average age of the papers of 1,57 years corroborates the high growth rate, which could indicate that the more influential work was done recently.

The average citation of 13,29 per paper is most likely due to the fact that the age of the papers is relatively low. The number of 1588 authors corroborates the growing interest and involvement from the research community. With an above-average collaboration rate of around 92,4% it points to the complexity of the topic, maybe demanding multidisciplinary expertise. International co-authorships are at 28,34% implying that the topic is being researched in more countries.

**Table 1. Information about data, based on Dataset A (Quantum Keywords).
Own conceptualization from bibliometrix. Accessed on 01.12.2025**

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2019-2025
Sources	203
Documents	434
Annual Growth Rate (in%)	47,24 %
Document Average Age	1,57
Average citations per article	13,29
AUTHORS COLLABORATIONS	
Singled Authors docs	44
Co-authors per document	4,08
International Co-authorships (in%)	28,34%

Figure 2 below reveals the number of papers published each year. It indicates a growing trend, from 16 articles in 2019 to 163 papers in 2025. The compound annual growth rate is in this case 47,24%. The jumps between 2023 to 2024 (+69%) respectively 2024 to 2025 (+63%) exhibit an obvious increase in the scientific production. This upward trend could reflect either a rapidly expanding research competence, greater strategic research focus or a maturing of international partnerships. It remains to be seen whether this growth rate in the research will persist, or will decline in the coming years.

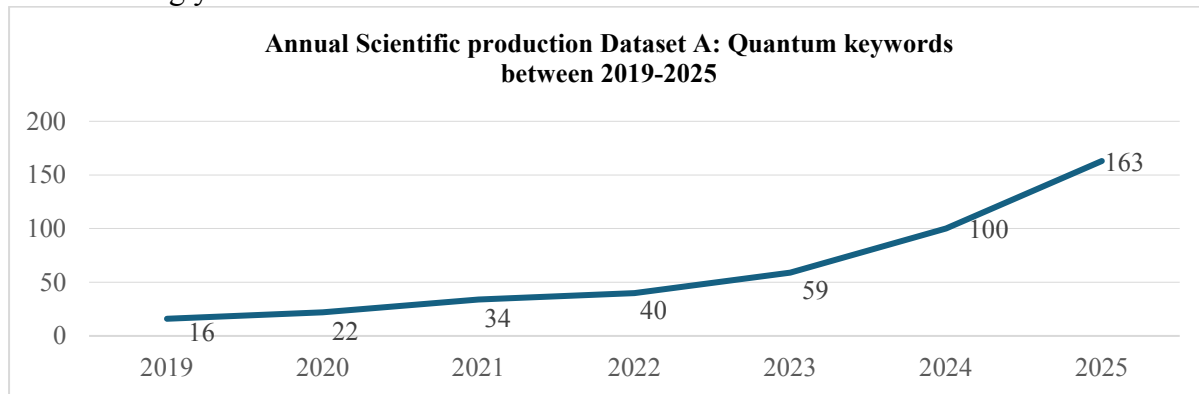


Figure 2. Annual Scientific production between 2019-2025. Based on Dataset A (Quantum Keywords). Own conceptualization from bibliometrix. Accessed on 01.12.2025

A co-occurrence analysis was conducted on Dataset A using VOSviewer with all keywords and a full-counting method. The minimum number of occurrences was set at 10, to capture patterns without too much noise. Out of the 3755 keywords, 43 met the threshold. The VOSviewer thesaurus map was applied to keywords to consolidate synonyms (e.g., cybersecurity - cyber security; smart grid - smart grids, microgrid - microgrids). The network visualization can be seen in Figure 3, and the keywords and clusters in Table 2. To increase transparency, each cluster has been assigned a brief description.

The analysis in VOSviewer reveals six clusters (Figure 3). The most predominant one is the **Red cluster (decision in managerial control systems)**, with around 80% of the keywords and the most prominent occurrences, e.g. quantum computers (148 Occurrences) and quantum computing (221 Occurrences). The research topography is dominated by the term quantum computing, which links all the keywords. The grouping connects the foundational quantum computing to applications of quantum computing, especially quantum algorithms of optimization and security.

The **Green cluster (defensive solutions)** focuses more on the network implications that advancements in quantum technology can bring. It shows the infrastructural and risk management dimension of the analyses, that, for example, quantum computers can change the in-cryptography ecosystem. This reveals a significant academic investment and interest in novel defensive solutions that can be achieved with new computational capabilities.

The **Blue and the Turquoise clusters (disruptive technologies in businesses)** reveal the management side of the co-word analysis. The word innovation (17 Occurrences) stands out, showing that innovation is closely connected to the quantum technology field. This indicates the foresight of businesses to integrate the disruptive technology of quantum.

The **Yellow and the Purple cluster (practical applications)** illustrate the hands-on, hard science. Density functional theory is a subset of quantum chemistry methodology. Applications of quantum using quantum chemistry can advance the pharmaceutical and energy sectors among others (Patel et al., 2025).

In summary, the collection of papers in Dataset A confirms a rapidly growing set of articles from internationally connected research areas. The annual production reveals that the topic is now incipient and is yet to mature, given the low average age of the papers. The keywords reveal different clusters: one with a focus on quantum and AI optimization, one that prioritizes security and infrastructure, as well as smaller ones with a management and business focal point.

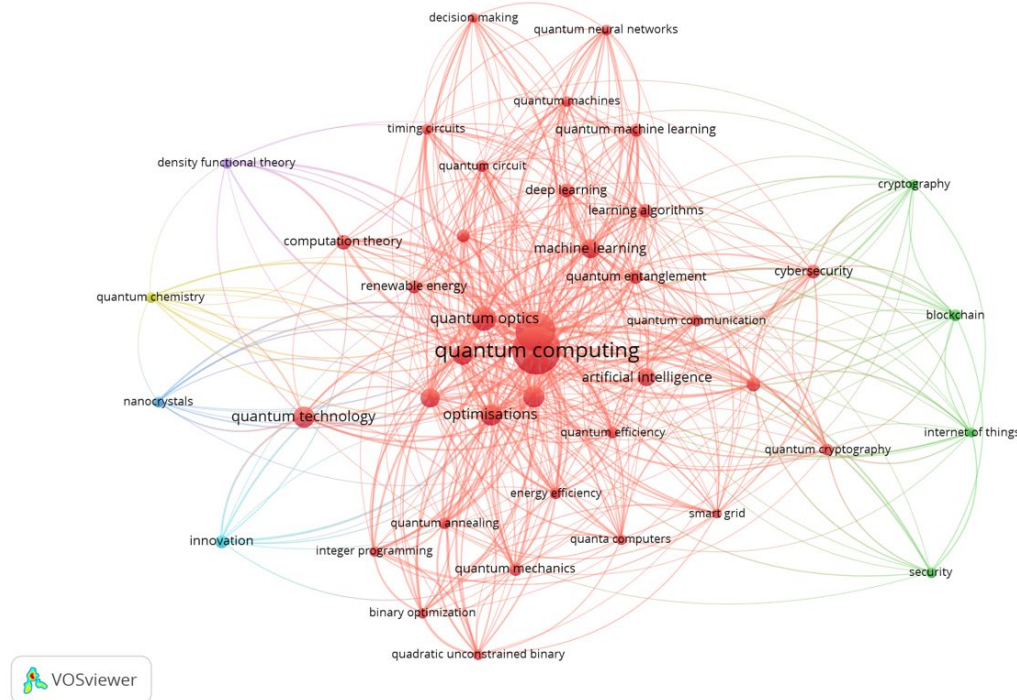


Figure 3. Word density of the 43 words that have at least 10 co-occurrences. Based on Dataset A (Quantum Keywords). Own conceptualization from VosViewer. Accessed on 05.12.2025

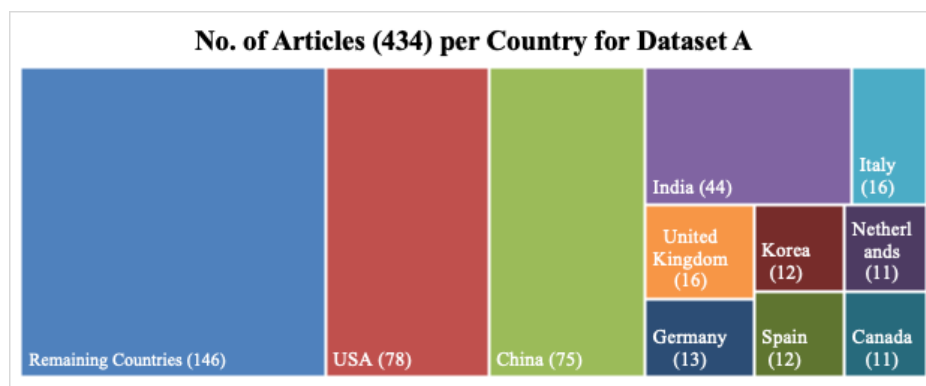
To answer *RQ2* (In which journals is business-related quantum technology research most published?), Dataset A was utilized to identify leading contributors and foundational papers in the field, country productivity, and also the citation impact. As illustrated in Figure 4, the two leading contributors in paper production are the USA (78) and China (75) and India (44) in third place.

Table 2. Selected keywords and number of occurrences in the four VosViewer Clusters. Own conceptualization from VosViewer using Dataset A. Accessed on 01.12.2025

Cluster 1 – Red (35)	No.	Cluster 2 – Green (4)	No.
quantum computing	221	blockchain	14
quantum computers	148	cryptography	10
quantum optics	61	internet of things	10
optimisations	47	security	11
quantum technology	44		
quantum theory	44	Cluster 3 – Blue (1)	
quantum electronics	41	Nanocrystals	12
machine learning	35		
qubits	35	Cluster 4 – Turquoise (1)	
artificial intelligence	31	Innovation	17
computation theory	22		

deep learning	20	Cluster 5 – Purple (1) Density functional theory	12
learning algorithms	20		
network security	20	Cluster 6 – Yellow (1) Quantum chemistry	11
cybersecurity	19		
quantum entanglement	19		

The analysis of the most cited journals shows the various scholarly domains in which the topic is being researched. As can be seen in Table 3, the field is dominated by physics and engineering-oriented journals like: Applied Energy, IEEE Transactions on Power Systems, The Journal of Physical Chemistry C, and Knowledge-Based Systems, which show that, although only the Business, Economics and Energy fields were filtered in the query, the topic of quantum technologies is still highly technical. There are still some management journals in the top 10 like IEEE Transactions on Engineering Management, Technology Analysis & Strategic Management, or Nanoethics.



**Figure 4. Number of articles per Country. Based on Dataset A (Quantum Keywords).
Own conceptualization from bibliometrix. Accessed on 01.12.2025**

This illustrates clearly that while the topic is being researched in management journals it is still underrepresented and in an early state of development. An opportunity arises for researchers in business to close the gap and shape the emerging technologies on quantum which will transform innovation processes and business applications. When the quantum field will get closer to its maturity different applications will move towards commercialization. It will be then crucial business understanding and ecosystem coordination will matter most, from achieving competitive advantage, to business models, and strategic insights.

**Table 3. Top Cited Papers and their field for Dataset A (Quantum Keywords).
Own conceptualization from bibliometrix and own research. Accessed on 01.12.2025**

Sources	Articles	Field
Journal Of Physical Chemistry C	36	Physical Chemistry
Ieee Transactions On Power Systems	19	Electrical Engineering
Internet Of Things (The Netherlands)	17	Computer Science
Energies	16	Energy Research
Knowledge-Based Systems	11	Computer Science

Sources	Articles	Field
Ieee Transactions On Engineering Management	10	Electrical Engineering
Ieee Engineering Management Review	9	Engineering Management
Nanoethics	9	Ethics
Technology Analysis And Strategic Management	8	Innovation Studies
Applied Energy	7	Energy Engineering

To answer *RQ3* (To what extent does the business-related quantum technology literature include applications in the energy sector?), the paper has looked at publication trends and growth patterns in the papers of Dataset B using Bibliometrix. Table 4 reveals a high-level summary of key bibliometric indicators and collection features. The collection reveals a rather recent body of research of 26 papers over the span of 6 years, from 2020 until 2025, in the fields of Economics, Business, and Energy in the quantum-related business from 16 different sources. The low number of documents indicates either a niched search or a highly selective search query.

The high annual publishing growth rate of 64,38% suggests a very rapid expansion, probably because a greater interest in the subject area. The average paper age of 1,27 years reinforces the high growth rate, implying that the research is in its infancy. The average citation of 17,04 per paper is relatively low. It is safe to assume that the average paper citation will increase in the next years, when the topic will reach its maturity. International co-authorships of 23,08% reflect a moderate international collaboration.

**Table 4. Information about data. Based on Dataset B (Quantum and Energy Keywords).
Own conceptualization from bibliometrix. Accessed on 01.12.2025**

<i>Description</i>	<i>Results</i>
MAIN INFORMATION ABOUT DATA	
Timespan	2020-2025
Sources	16
Documents	26
Annual Growth Rate (in%)	64,38 %
Document Average Age	1,27
Average citations per article	17,04
AUTHORS COLLABORATIONS	
Singled Authors docs	1
Co-authors per document	4,77
International Co-authorships (in%)	23,08%

Figure 5 below illustrates the yearly distribution of papers in Dataset B. The numbers are very small, yet a clear upward trend is visible. Publications increased from a single article in 2020 to 12 articles in 2025, showing a growth rate of more than 50% over the five years chosen for this paper. The increases between 2022-2023 and 2024-2025 are the sharpest ones, as pointed out in Figure 5. These jumps point to an increased academic research in the intersection between quantum technologies in business and the energy sector.

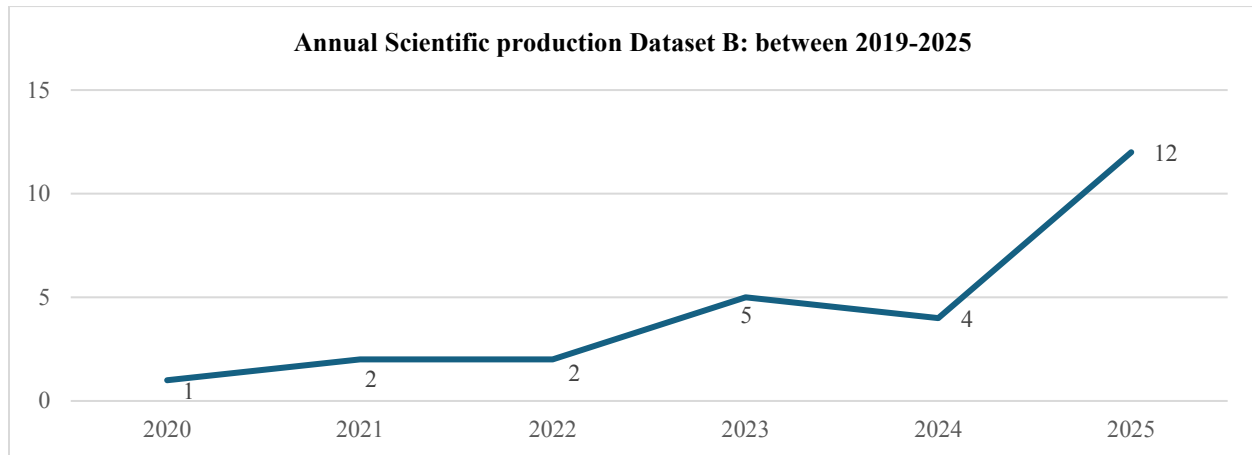


Figure 5: Annual Scientific production between 2020-2025. Based on Dataset B (Quantum and Energy Keywords). Own conceptualization from bibliometrix. Accessed on 01.12.2025

A co-occurrence analysis was performed on Dataset B using VOSviewer including all keywords and a full-counting method. Given that Dataset B only contains 26 papers, the minimum number of occurrences was set at 4 occurrences. Out of the 366 keywords, 12 met the threshold. The VOSviewer thesaurus map was applied to keywords to consolidate synonyms (e.g., cybersecurity-cyber security; smart grid-smart grids, microgrids-microgrids). The network visualization can be seen in Figure 5 and the keywords and clusters in Table 4. The analysis in VOSviewer reveals three clusters. Each cluster has been assigned a brief summarization to reflect the dominant theme.

The **Red cluster (resilient energy infrastructure)** is characterized by Energy Management and Optimization. It shows the operational and managerial aspects of energy systems, as a method to optimize decision making resource allocation, like energy management and energy storage. Having a strong representation in energy storage and renewables, the theme is the transition towards a cleaner and more resilient energy infrastructure.

The **Blue cluster (mathematic foundations)** looks more into foundations in quantum and advanced mathematical foundations for future applications.

The **Green cluster (defensive solutions)** groups quantum computing and cybersecurity, revealing the concern that critical energy infrastructures and their quantum application need protection, as smart grids include a high level of automation, more prone to cyberattacks. The keyword smart grid indicates the connection between these areas.

When connecting the dots between energy and advanced computation, the co-occurrence map shows a future research field. The clusters display the potential of quantum technology for future sustainability applications while at the same time revealing practical constraints due to technological (i)maturity, operational feasibility and most importantly, security concerns.

Overall, the analysis from Dataset B reveals that the quantum technology field within the energy sector is in its early stages but show clear signs of growth, thus supporting the hypothesis:

H1: Quantum technologies are at an early but rapidly developing stage of application within the energy sector

The field shows exponential growth, characterized by a annual growth rate of 64.38%, (Dataset B) suggesting a quite rapid expansion, even compared to the other Dataset A 47,24%. The clusters identified in the VOSviewer software show that the topic is still more technology oriented

than business oriented. Nevertheless, the loose boundaries imply that the research is not siloed. The connections reveal the growing need for strategic perspectives, as quantum technologies might enter the practical application part, thus validating *H1*.

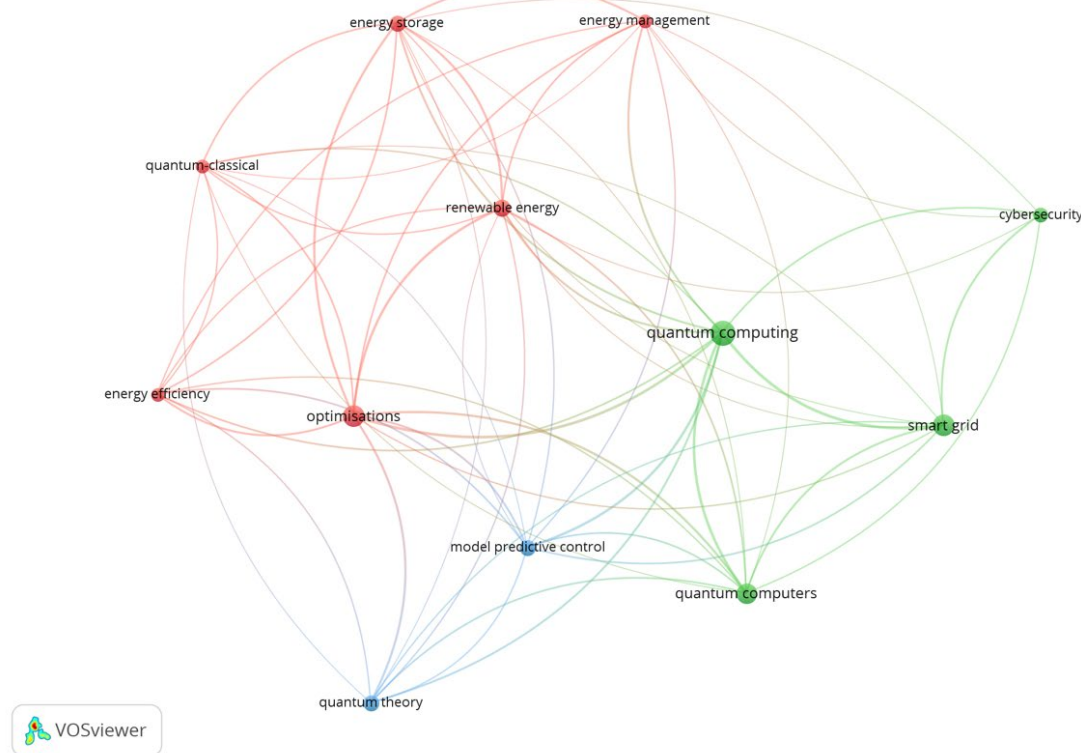


Figure 6: Word density of the 12 words that have at least 4 co-occurrences. Based on Dataset B (Quantum and Energy Keywords). Own conceptualization from VosViewer. Accessed on 01.12.2025

Looking closely at the abstracts of the 26 papers from dataset B, we notice that most of them share three core characteristics. Firstly, they leverage quantum computing to tackle difficult optimization challenges that classical computing systems cannot handle (Deng et al., 2025; Ajagekar; & You, 2025; Kansara, et al., 2025; Wang et al., 2025; Deng et al., 2025). Secondly, they link these technological advancements with green transition topics like decarbonization, renewable energy and sustainability (Ajagekar & You, 2025, Deng et al., 2025.; Sarker, 2025).

Table 5. Keywords and number of occurrences in the three VOSviewer Clusters. Own conceptualization from VosViewer using Dataset B (Quantum and Energy Keywords). Accessed on 03.12.2025

Cluster 1 – Red (5)	No.	Cluster 3 – Green (4)	No.
Energy efficiency	4	Cybersecurity	5
Energy management	4	Quantum computers	9
Energy storage	6	Quantum computing	14
Optimisations	10	Smart grid	10
Quantum-classical	4		
Renewable energy	7		
Cluster 2 – Blue (2)	No.		
Model predictive control	6		
Quantum theory	6		

Vereno et al. (2023) refer to the limitations of quantum hardware and technologies. They argue that the existing quantum hardware/systems cannot independently solve large-scale optimization problems, because they have yet to reach their maturity (Vereno et al., 2023). The abstracts of the 26 papers paint a pragmatic picture of this research area: the promise for sustainability-oriented quantum applications but also the practical constraints due to the infancy of the topic.

Conclusion and Limitations

The following paper has quantitatively explored the current body of research on of quantum technologies across various industries as well as on the intersection between quantum technology and energy landscapes using three guiding research questions (RQ1, RQ2, RQ3). RQ1 has tried to look at quantum technology research within the business-related academic literature. It revealed a rapidly accelerating field characterized by several research clusters: decisions I managerial control systems, defensive solutions, disruptive technologies in business, and practical applications. RQ2 identified key publications where business related quantum technology research is being carried out, showing a physics dominated research landscape with specialized energy and computer journals taking precedence over management oriented ones. RQ3 investigated the level to which business-related quantum technology literature includes applications within the energy sector, revealing a clear growth, despite the novelty of the topic.

By examining the quantum technology research field, incl. identifying key publication journals and looking at the quantum applications across the energy sector this paper can provide support for H1 (Quantum technologies are at an early but rapidly developing stage of application within the energy sector). The growth rate of both Dataset A and Dataset B over the past five years combined with the development of clusters show increased academic interest. Moreover, the interest in practical applications like grid optimization, renewable energy forecasting and material innovation speaks for the topic entering early stages of maturity to start solving complex optimization challenges.

The current state of quantum technology research in the energy sector resembles a small, intensely hot fire starting in a remote research lab. Although the flames (papers) are few, they are growing exponentially (high growth rate), and their light is already casting big shadows revealing new avenues (e.g. complex optimizations, energy management). The next step is to move the fire from the isolated theory into the wider world of business and management, where the true strategic and commercial power can be harnessed to address current global energy challenges

This bibliometric analysis on quantum technologies in the energy sector, especially because of the novelty of the topic, is subject to several methodological limitations inherent to this type of research. Solely relying on Scopus, it underrepresents research from non-Western regions and non-English publications due to database coverage biases. Low citation counts (average document age 1.27-1.57 years) limit the assessment of the impact of the research, as metrics require around 2-3 years to stabilize in newly evolving fields. Not yet mature terminology in quantum energy research is prone to introduce query noise, and thus inflating irrelevant results despite validation efforts.

Future research can track this evolving research field and discuss the direction in which it develops by observing which of the clusters persist and which ones fade away. As quantum technology transitions from theory to practice, monitoring this shift will become crucial for stakeholders to leverage the potential of quantum technologies in solving complex optimization problems, also in the energy sector.

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Appendix (if needed)