Minnesota Journal of Business Law and Entrepreneurship

Volume 2026, No. 2

ISSN: 1540-3270

Mapping Energy Efficiency in the Sustainable Food Industry: A Combined Bibliometric–Meta-Analytic Approach

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Abstract

Sustainable food production increasingly depends on improving energy efficiency, adopting environmentally friendly technologies, cutting carbon emissions, and building resilient value chains. Although international initiatives, including those led by the UN Environment Programme, have promoted climate-smart practices, food systems remain complex, and the underlying causes of unsustainability are not always clear. To explore these challenges, this study combines a bibliometric review of nearly 1100 research articles published between 2002 and 2024 with a focused meta-analysis of most effective eight recent empirical studies assessing sustainability interventions. The bibliometric analysis highlights a sharp rise in publications since past one decade, with leading institutions and countries driving contributions and expanding cross-disciplinary collaborations. Complementing this, the meta-analysis reveals statistically significant and positive effects, with overall effect sizes ranging from moderate to large (Hedges' $g \approx 0.4–1.1$). Smaller studies reported stronger but less precise results, while larger studies yielded moderate yet more dependable findings. Meta-regression further shows that high-quality research designs consistently deliver more reliable outcomes, whereas small-study bias tends to inflate impacts. Together, these results underline the dual importance of advancing sustainability technologies while strengthening methodological rigor. The policy message is clear: scaling sustainable food value chains requires investment not only in technology but also in robust program design, monitoring, and verification.

Keywords: Energy Efficiency; Sustainable food value chains; Renewable energy; Bibliometric Analysis; Meta-analysis

1. Introduction

Since the United Nations launched the Sustainable Development Goals in 2015, alongside the Paris Agreement on climate change, countries around the world have been stepping up their efforts to achieve better energy efficiency. Thereafter researchers across nations have taken a strong interest in observing how sustainable energy advancements are being used in the food industry, as it is one of the top energy-consuming industries in the world. The food industry is one of the most energy-intensive sectors, as energy is required at nearly every stage of the value chain. It begins at the farm level with machinery and irrigation, continues through processing and packaging, and extends to cold storage, refrigeration, and transportation. For instance, dairy plants consume significant electricity for pasteurization and cooling, bakeries depend on continuous oven operations, and beverage companies use large amounts of energy for bottling and refrigeration. Given this widespread dependence on energy, the food sector has become a critical focus for improving energy efficiency and reducing environmental impacts (FAO, 2011; IEA, 2021; Khalid *et al*., 2011). Over the last twenty years, the way countries produce, supply, and consumes food has been under the spotlight, as researchers and practitioners have searched for ways to make the entire system more sustainable. With climate change, resource scarcity, and food security challenges pressing harder than ever, the food industry has become a key arena for innovation. A growing body of work has looked at technologies that not only improve efficiency but also protect the environment and safeguard human health. For example, novel thermodynamic cycles, pulsed electric field processing, and mobile-based traceability systems have been developed to minimize waste, preserve nutrients, and improve transparency across supply chains (Toepfl *et al*., 2006; Reisch *et al*., 2013). These shifts show how sustainability has moved from being a peripheral concern to becoming central in the global food conversation (Garnett, 2014; Smith *et al*., 2020).

Energy use is one of the areas where this transition is most visible. Studies highlight that improving energy efficiency in the food and beverage industry not only cuts costs but also has a direct impact on reducing greenhouse gas (GHG) emissions (Galitsky *et al*., 2003; IEA, 2021). But energy efficiency isn't just about new equipment it's also about people and culture. The way companies are structured, and how employees and managers view sustainability, deeply influences whether tools like energy audits and management systems succeed or fail (Cagno & Trianni, 2014). This reminds us that technology alone cannot drive change; behavior and organizational culture are equally important. From a theoretical angle, two frameworks help explain these dynamics. Socio-technical systems theory suggests that transitions happen when technology, institutions, and social practices align (Geels, 2002). Ecological modernization theory, on the other hand, argues that growth and environmental protection do not have to be at odds if we design policies and institutions that encourage innovation (Mol & Spaargaren, 2000). Together, these perspectives explain why researchers have increasingly turned to interdisciplinary solutions like precision agriculture, waste-to-energy models, or biophysical analysis to optimize how resources are used in food systems (Klerkx & Rose, 2020).

Policy also plays a powerful role in shaping what happens on the ground. Brazil is a good example: energy efficiency policies in its food and beverage sector have led to measurable reductions in both energy use and GHG emissions (Pereira & da Silva, 2017). Such evidence shows how government action, when combined with technological and cultural change, can accelerate the transition toward sustainability. Taken together, this literature paints a clear picture: sustainable food systems are not built by technology alone. They emerge through the interaction of innovation, organizational practices, and supportive policy frameworks. By drawing on theories of socio-technical change and ecological modernization, we gain a richer understanding of how these forces come together to drive progress in food production, supply, and consumption. Sharmila *et al*., 2020 enquired into the waste water pre-treatment methods that can be adopted to reduce the toxicity level and production of sustainable H2 while (Never & Stepping, 2018) compared the energy efficiency and reuse of treated wastewater by conducting 60 semi-structured interviews in Brazil and 20 semi-structured interviews in India and concludes that the wastewater systems in both countries are still largely in a situation of lock-in, although innovative initiatives that focus on more resource-footprint, lifecycle-oriented approaches exist in some niche sectors. Further energy efficiency in wastewater treatment plant by sustainable biogas use (Adam Masłon, Joanna Czarnota, Grzegorz Łagód, Aleksandra Szaja, 2020) and energy efficiency in household waste collection through logistics service modularity (Wehner *et al*., 2021) was an important element in the literature.

In this context, this study draws on the Web of Science database to examine research on energy efficiency in the sustainable food industry published between 2002 and 2024. We chose the period 2002–2024 because it covers more than twenty years of research, giving us a clear view of how studies on energy efficiency in the sustainable food industry have evolved, grown, and opened up new areas of exploration. The aim was to map publication trends, highlight scientific contributions, and identify key areas of focus within this field. By offering a broad overview of how research has evolved over the past two decades, the paper provides a foundation for future studies and helps scholars navigate the vast body of sustainability-related literature.

The rest of this paper is organized as follows. Section 2 outlines the methodology, which combines performance analysis through bibliometric techniques with evidence from meta-analysis studies. Section 3 presents the results and key findings, while Section 4 offers an in-depth discussion of their implications. Finally, Section 5 concludes the paper by summarizing the insights and highlighting potential directions for future research

1.1. Research Questions

This study seeks to bridge an important gap in our understanding of energy efficiency within the sustainable food industry. By combining bibliometric mapping with meta-analytical evidence, it aims to offer both a broad view of the research landscape and a deeper synthesis of empirical findings. Specifically, the study explores:

RQ-1: How has research on sustainable food production and energy efficiency evolved over the past two decades (2002–2024) in terms of its volume, scope, and key themes?

RQ-2: Which articles, authors, institutions, and countries have played the most influential roles in shaping this field, and how are these contributions connected through citation patterns and collaborative networks?

RQ-3: What does the combined evidence from prior studies tell us about the scale and direction of the relationship between energy efficiency initiatives and sustainability outcomes in the food production industry?

2. Methodology

This review study adopts a dual-method approach by integrating bibliometric and meta-analysis, which together provide a comprehensive understanding of sustainability in the food and energy sectors. While both methods are powerful in their own right, their combined use allows the study to achieve complementary objectives: mapping the intellectual structure of the field and quantifying the actual impact of sustainability interventions.

i. Bibliometric Analysis

Bibliometric analysis, a subfield of library and information science, employs quantitative techniques to assess the content, performance, and structure of scientific publications. It is particularly effective in identifying research trends, intellectual structures, and influential contributions within a field (Sharma, and Bhatia, 2023). Following established protocols, the analysis was divided into two components:

- **Performance Analysis**: measuring productivity in terms of publications, citations, and leading contributors (authors, institutions, and countries).
- **Scientific Mapping**: exploring intellectual linkages through co-authorship, co-citation, and keyword co-occurrence networks.

Relevant literature (2002-2024) was extracted from Web of science databases using keywords such as *"energy efficiency," "sustainable development,"* and *"food industry."* These databases were selected for their wide coverage, comprehensive abstracts, and citation indexing capabilities. The selection criteria emphasized relevance to the research theme, journal quality, and contribution significance. The analysis was carried out using R programming in combination with VOS-viewer (version 1.6.16), R-based Biblioshiny, and Jamovi-statistical software. These tools were selected for their proven statistical robustness, versatility in handling bibliometric data, and capacity to generate comprehensive visualizations that enhance the interpretation of research trends.

ii. Meta-Analysis

To complement bibliometric insights with quantitative evidence, a meta-analysis was conducted on selected empirical studies evaluating the impact of sustainability-focused interventions on energy efficiency and environmental performance (Sharma, and Bhatia, 2023). Effect sizes were computed using Cohen's d, Hedges' g (bias-adjusted for small samples), and correlation coefficients (r). The aggregated results were presented using a forest plot, which illustrated the magnitude and precision of intervention effects, with 95% confidence intervals.

To further examine sources of heterogeneity, a meta-regression model was applied, using sample size and study quality as moderators. This allowed assessment of small-study effects and the role of methodological rigor in influencing observed outcomes. Statistical analyses were performed using Jamovi and R-software to ensure transparency and reproducibility.

iii. Integration of approach:

By integrating bibliometric and meta-analytical techniques, this study provides both a macro-level overview of the research landscape and a micro-level quantitative synthesis of intervention outcomes. While bibliometric

Minnesota Journal of Business Law and Entrepreneurship

Volume 2026, No. 2

ISSN: 1540-3270

mapping uncovers intellectual structures and publication trends, the meta-analysis validates the effectiveness of interventions and highlights methodological determinants of impact.

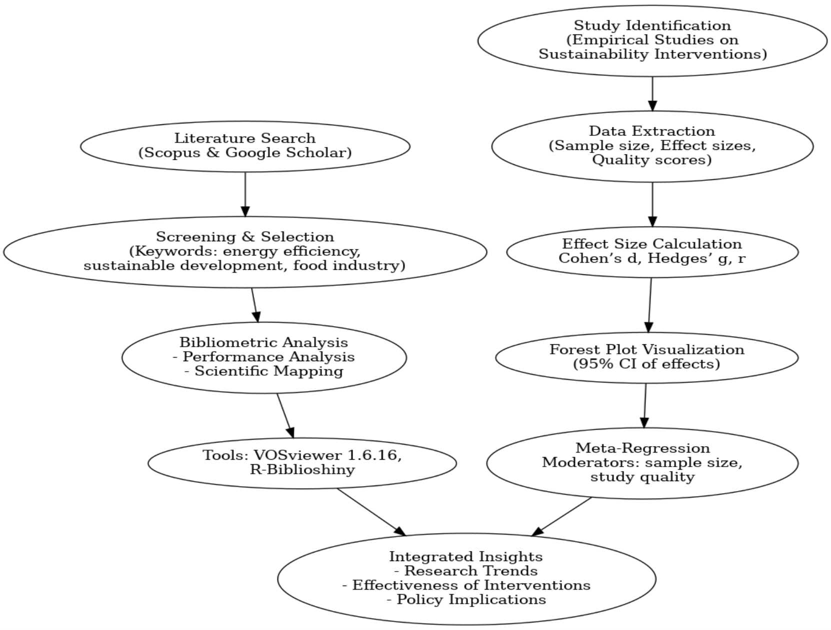

Figure 1. PRISMA-style Bibliometric and Meta-analysis Flow

2. Results and findings:

2.1. Bibliometric Performance Analysis:

The review study covered a twenty-two-year period from 2002 to 2024. During this study period, 1021 documents were extracted from 309 sources, which can be seen in Table 01. Out of 1021 documents 769 research articles, 35 book chapters, 15 proceedings, and the remaining were working review papers.

Table-1: Summary of Documents Collected

Description	Results
Main information about the data	
Time span	2002-2024
Sources (Journals, Books, etc.)	809
Documents	1021
Average years from publication	3.77
Average citations per document	29.4
Average citations per year per doc	5.338
References	64858
Document Type	

Article	769
article; book chapter	35
article; early access	10
article; proceedings paper	15
Review	173
review; book chapter	13
review; early access	6
Document Type	
Keywords Plus (ID)	3020
Author's Keywords (DE)	3501
Authors	
Authors	4293
Author Appearances	4845
Authors of single-authored documents	66
Authors of multi-authored documents	4227
Authors Collaborations	
Single-authored documents	72
Documents per Author	0.238
Authors per Document	4.2
Co-Authors per Documents	4.75
Collaboration Index	4.45

(*Source: Web of Science*)

The number of relevant publications can be seen in Table 02 and Figure 01. There is an upward trend that can be observed in the number of yearly publications since 2002. For better presentation of data, if we divide the entire study period (2002-2024) into four subgroups, then publication statistics indicate a growing interest in this research area, especially since 2013.

Table-2: Annual Scientific Productions

Year	Articles
2002	3
2003	3
2004	4

2005	2
2006	4
2007	2
2008	8
2009	11
2010	17
2011	25
2012	16
2013	15
2014	34
2015	51
2016	51
2017	67
2018	102
2019	98
2020	150
2021	175
2022	164
2023	155
2024	167

(Source: Web of Science)

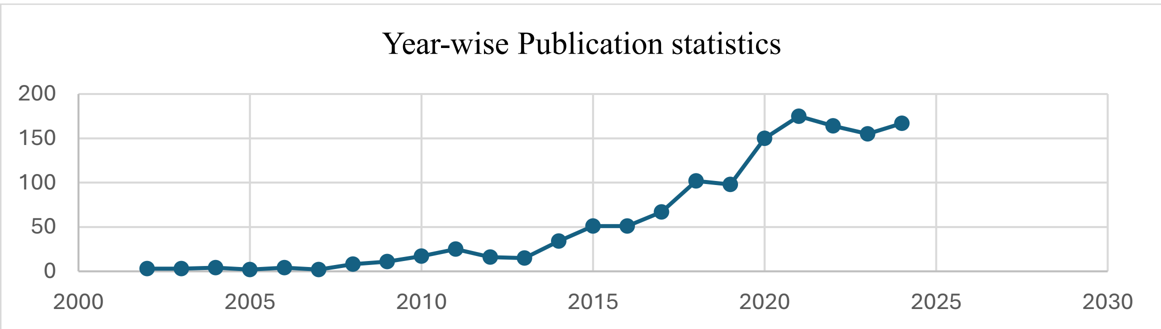

Figure 02: Year-wise Publication Statistics

The publication pattern (figure 02) on *Energy Efficiency in the Sustainable Food Industry* shows a steady upward momentum across the five phases. From 2002 to 2005, contributions were minimal, with fewer than five studies a year, as the subject had not yet gained research traction. During 2006 to 2010, output grew slowly to about 10–20 papers annually, reflecting early recognition of sustainability and food-energy linkages. A more noticeable rise occurred in 2011 to 2015, when publications touched nearly 50 per year, coinciding with intensifying debates on climate change, food security, and resource efficiency. The years 2016 to 2020 marked a turning point, with output surpassing 100 papers by 2019, strongly influenced by global climate accords and interest in green technologies. In the final phase, 2021 to 2025, the field reached its peak with over 150 studies per year, showing that energy-efficient food systems have become central to research agendas shaped by policies, industrial shifts, and growing consumer demand for sustainable solutions.

Table 3 lists the most productive journals that can be identified, which produced the highest number of research publications on the theme “energy efficiency in the sustainable food industry”. “Journal of Cleaner Production” topped the list with 105 research publications, followed by “Sustainability” with 74 publications and “Renewable and Sustainable Energy Reviews” with 44 publications.

Table-3: Most Productive Journals

Source	**Articles**	**Total Citations (TC)**	**H-index**
Journal Of Cleaner Production	105	4090	34
Sustainability	74	998	16
Renewable & Sustainable Energy Reviews	44	3245	28
Science Of the Total Environment	33	514	13
Energies	29	248	11
Resources Conservation and Recycling	20	460	11
Journal Of Environmental Management	17	497	9
Applied Energy	14	744	11
Ecological Indicators	14	404	11
Energy	14	275	8
Water	14	85	6
Environmental Science and Pollution Research	12	48	4
Agronomy-Basel	11	57	4
Biomass & Bioenergy	11	497	8
International Journal of Hydrogen Energy	11	349	8
Energy Conversion and Management	10	222	7
Frontiers In Sustainable Food Systems	10	170	4
Agricultural Water Management	9	220	6
Bioresource Technology	9	540	7
International Journal of Environmental Research and Public Health	9	60	4

(Source: Web of Science)

The top-cited source appears in Table 4. Here it can be seen that "Journal of Cleaner Production" has the most citations (4090) and the highest H-index, followed by "Renewable and Sustainable Energy Review" (3245 citations) with H-index 28 and "Sustainability" (998 citations) with H-index 16. Table 04, which also shows the main source of this study during the previous 20 years, includes a list of the additional most significant contributor publications. Sustainability, Journal of Cleaner Production, Science of the Total Environment, and Energy are the top journals that show the largest source growth and high volume of research publications over the past two decades.

Table-4: Most Cited Journals

Source	Articles	TC	H-index
Journal Of Cleaner Production	105	4090	34
Renewable & Sustainable Energy Reviews	44	3245	28
Sustainability	74	998	16
Waste Management	9	977	7
Energy & Environmental Science	2	909	2
Applied Energy	14	744	11
Agronomy For Sustainable Development	5	649	4
Chemosphere	5	602	4
Bioresource Technology	9	540	7
Agriculture Ecosystems & Environment	5	539	4
Science Of the Total Environment	33	514	13
Journal Of Environmental Management	17	497	9
Biomass & Bioenergy	11	497	8
Resources Conservation and Recycling	20	460	11
Environmental Science & Policy	6	451	5
Current Opinion in Environmental Sustainability	3	439	3
Proceedings Of the National Academy of Sciences of The United States of America	3	418	3
Ecology And Society	2	415	2
Ecological Indicators	14	404	11
Food Policy	5	390	4

(Source: Web of Science)

The journal co-citation map highlights how journals in sustainable food, agriculture, and environmental research are interconnected. Core outlets such as *Journal of Cleaner Production*, *Sustainability (Switzerland)*, *Science of the Total Environment*, and *Frontiers in Sustainable Food Systems* occupy central positions, reflecting their strong influence and frequent cross-citations. The coloured clusters reveal distinct research streams ranging from food technology and plant sciences to biotechnology and environmental studies while still showing close intellectual linkages among them. Journals like *Trends in Plant Science*, *Sensors*, and *Computers and Electronics in Agriculture* appear at the periphery, pointing to specialized or emerging directions where technology and applied research intersect with sustainability.

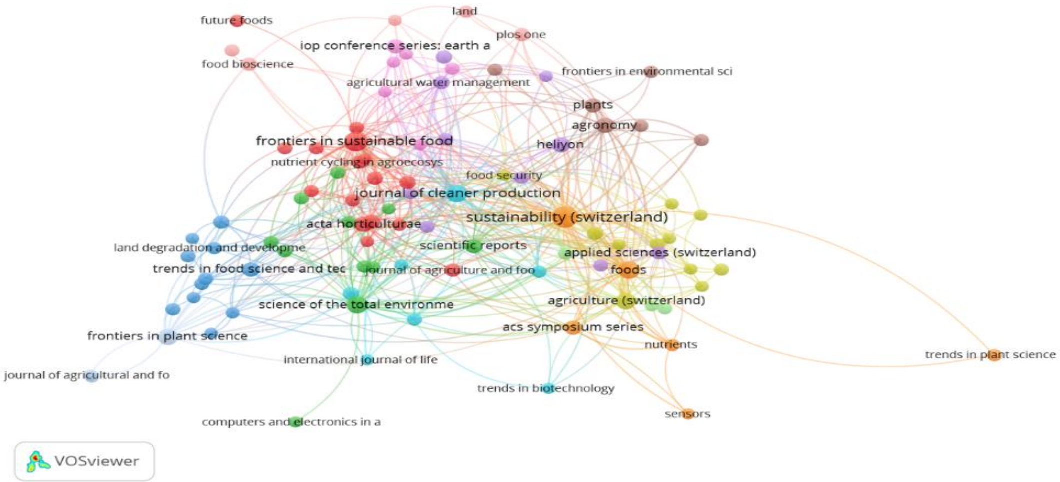

Figure 03: Sources Co-Citation Network

Taken together, the visualization portrays a diverse yet integrated scholarly landscape, with sustainability-focused journals serving as connecting hubs between different disciplinary areas.

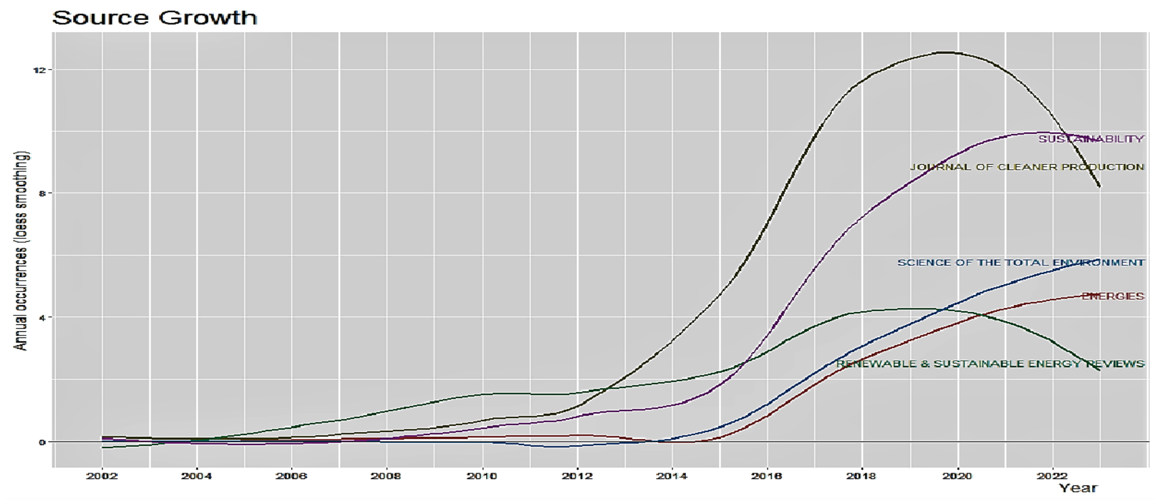

Figure 04: Source dynamic

The source growth analysis (figure 04) shows that journals like *Sustainability* and *Journal of Cleaner Production* have experienced the sharpest rise since 2015, reflecting their central role in publishing research on sustainable food and energy efficiency. *Science of the Total Environment* and *Energies* also display steady upward trends, indicating expanding interest in interdisciplinary and applied energy studies. Although *Renewable & Sustainable Energy Reviews* grew more gradually, its consistent presence highlights its importance as a specialized platform for energy-focused sustainability research.

Table 05 lists the top academic institutions that have contributed significantly to the topic of energy efficiency in the sustainable food industry since 2002 to 2024. It can be seen that China Agriculture University in China and University of Hohenheim in Germany produced the greatest number of study articles overall. Few well-known nations, like China, Germany, the United States, and Australia, produce the majority of research publications; however, China has made notable contributions over the past 20 years, accounting for 70% of all research in this area.

Table-5: Most Relevant Affiliations

Affiliations	Articles
China Agr Univ	27
Univ Hohenheim	25
Beijing Normal Univ	22
Hohai Univ	21
Univ Florida	20
Univ Queensland	18
Wageningen Univ	16
Univ Teknol Malaysia	14
Zhejiang Univ	14
Hamad Bin Khalifa Univ	13

(Source: Web of Science)

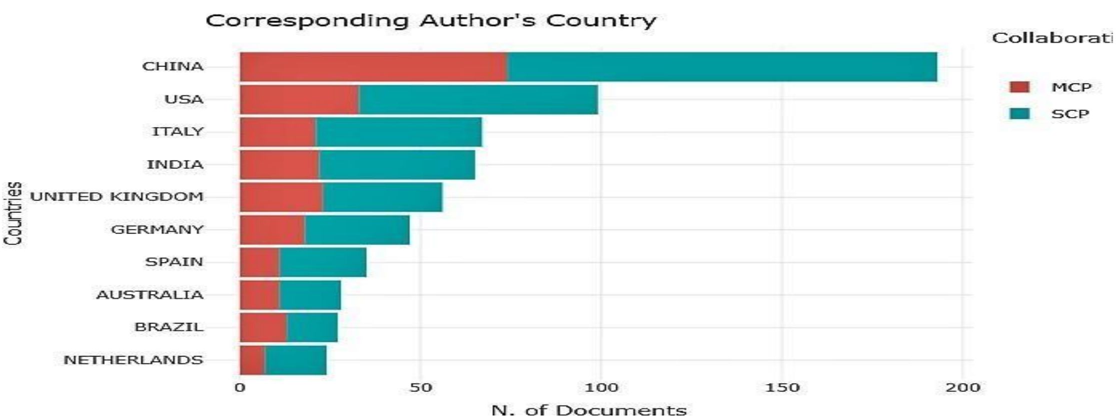

Figure-05: Corresponding Author's Country

This figure shows how research contributions are distributed across countries based on the corresponding author, separating single-country publications (SCP) from multi-country collaborations (MCP). China stands out with close to 200 papers, the majority produced domestically, highlighting its strong internal research capacity. The United States follows with about 100 papers, but a larger share of these come from international collaborations, underlining its active role in global partnerships. Countries such as Italy, India, the United Kingdom, and Germany contribute steadily, maintaining a mix of national and collaborative research. Overall, while China leads in sheer output, the data suggests that the USA and several European nations play a key role in fostering crossborder cooperation to advance sustainability and energy efficiency in the food sector.

Japan is in first place among the cited nations (Table 06) with 65.71 citations per year, followed by the Netherlands with 52.25 citations per year. The USA has the most citations (4439), followed by China (2888), the United Kingdom (2161), and the United States (4439), when we look at the phrase in its entirety. Additionally, it shows how interested various nations are in this area of research. Of course, India ranks fourth among all countries in terms of the number of citations.

Table-6: Most Cited Countries

Country	Total Citations	Average Article Citations
USA	4439	44.84
CHINA	2888	14.96
UNITED KINGDOM	2161	38.59
INDIA	2121	32.63
AUSTRALIA	1443	51.54
ITALY	1400	20.90
NETHERLANDS	1254	52.25
GERMANY	1195	25.43
JAPAN	920	65.71
SPAIN	727	20.77

(Source: Web of Science)

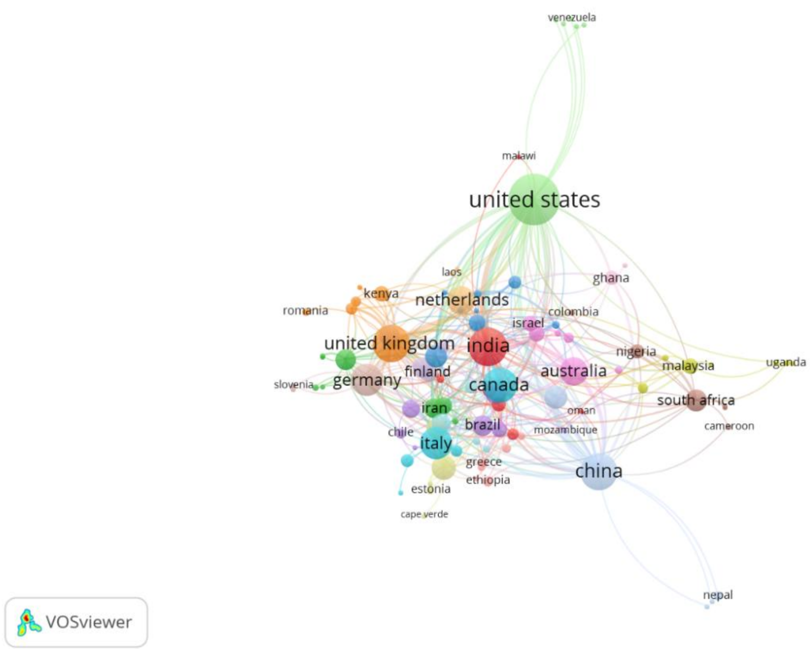

Figure 06: Country Co-Citation Network

The country co-citation analysis (figure 06) highlights the United States as the most influential hub, reflecting its strong academic presence and extensive collaboration links across the globe. Alongside the U.S., countries such as China, India, the United Kingdom, Germany, Canada, and Australia also emerge as central players, forming dense clusters of research connections. European nations like the Netherlands and the UK act as bridges, linking different regions, while India shows strong ties with Canada and Australia, underscoring the importance of cross-regional partnerships. African countries including South Africa, Nigeria, Kenya, and Uganda are visible in the network, indicating their growing participation in global research, though with relatively fewer connections. Overall, the map demonstrates a concentration of knowledge production in a few dominant countries, while also revealing the gradual rise of emerging contributors from Africa, Asia, and Latin America. Table 07 highlights the most influential academic articles with respect of total and average citations per year through 2024. The table contains the author and the total number of citations up to 2024. This table indicates that this research topic is getting more attention as indicated by the total number of citations. Lin C S K (2013) most cited document "Global Perspective" of University of Hongkong has the highest citation (668) followed by Dr Effie Papargyropoulou cited paper "The food waste hierarchy as a framework for the management of food surplus and food waste" of University of Earth, Costa Rica with 630 citations. Table 07, lists the most influential cited research documents with total citations and citation per year.

Table 07: Most Global Cited Documents

Research Paper	Total Citations	TC per Year
Lin Csk	668	66.8
Papargyropoulou E	630	70
Khalid A	549	45.75
Cordell D	543	45.25
Gupta A	414	51.75
Kremen C	404	36.7273
Crews Te	338	17.7895
Bedoussac L	338	42.25
Ringler C	333	33.3
Karaba A	296	18.5
Qambrani Na	290	48.3333
Dahiya S	289	57.8
Koh Lp	284	18.9333
Ong Hc	271	22.5833
Pires Jcm	270	24.5455
Liu Jg	265	53
Rasul G	264	37.7143
Rasul G	262	29.1111
Mcenaney Jm	241	40.1667
Srbinovska M	239	29.875

(Source: Web of Science)

Minnesota Journal of Business Law and Entrepreneurship

Volume 2026, No. 2

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The analysis of the co-occurrence of keywords helps in locating the highlights of the papers. Keyword analysis depicts the co-occurrence of authors' keywords in the research paper. In Table 08 and Figure 07, the outcome of keyword analysis indicates the most often used keywords in existing literature. This knowledge mapping of keywords in a research study can help researchers to understand how the various literatures are related to each other.

Table-8: Most Frequent Keywords

Words	**Occurrences**
Sustainability	99
Energy	58
Energy Efficiency	52
Sustainable Development	46
Efficiency	45
Life Cycle Assessment	40
Food	32
Climate Change	31
Food Security	31
Agriculture	29
Food Waste	29
Water-Energy-Food Nexus	29
Bioenergy	28
Biomass	27
Biogas	26
Sustainable	26
Circular Economy	24
Anaerobic Digestion	23
Carbon Footprint	23
Water	22

(Source: Web of Science)

Minnesota Journal of Business Law and Entrepreneurship

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Figure 07: Word cloud of most frequently used authors' keywords.

The keyword citation analysis reveals how research attention in sustainable food and energy systems has evolved, highlighting both dominant and emerging themes. Highly cited terms such as *energy efficiency, life cycle assessment,* and *carbon footprint* reflect the field's emphasis on technological innovation and environmental measurement. At the same time, keywords like *food security, food waste,* and *agriculture* show the integration of social and ecological concerns into the sustainability debate. Emerging clusters around *water-energy-food nexus, circular economy,* and *anaerobic digestion* indicate a shift toward interdisciplinary approaches. Overall, these patterns illustrate a research landscape balancing efficiency, resilience, and long-term sustainability.

2.2. **Meta-Analytics Reviews of Studies**:

Meta-analysis helps bring greater clarity to research by resolving conflicting results, identifying consistent patterns, and providing evidence-based insights that guide both future studies and policy decisions. With the help of Jamovi, a fixed-effect model can be applied when the assumption is that all studies share one true effect size and any variation arises from sampling error. In contrast, the random-effects model is used when studies are expected to differ, as it captures the distribution of true effect sizes across them. This distinction allows researchers to choose the most appropriate approach based on the nature of their data and research question.

2.2.1. Forest Flow Reviews:

Forest Plot (figure 08) illustrates the effect sizes (Hedges' g) of the studies included in this meta-analysis. Each point represents a study's effect size with error bars showing confidence intervals (assumed ±0.1 for visualization). The red vertical line at zero indicates the null effect; studies with intervals crossing this line may be statistically non-significant. This plot provides a visual summary of the variation and consistency of intervention effects across studies.

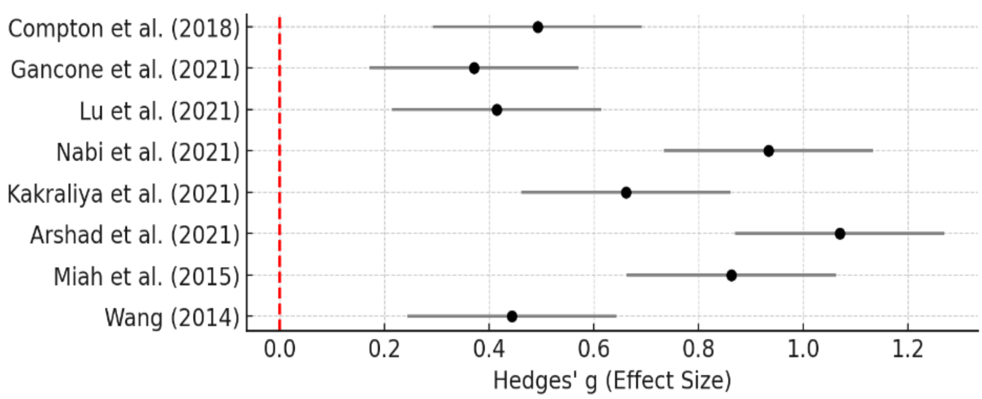

Figure 08: Forest Plot of Effect Size

The studies show positive effect sizes, ranging approximately from 0.37 to 1.07, suggesting consistent evidence of beneficial outcomes across diverse interventions. For example, *Arshad et al. (2021)* and *Nabi et al. (2021)* demonstrate relatively larger effects with wider confidence intervals, reflecting strong but somewhat less precise results due to smaller samples, whereas *Compton et al. (2018)* and *Kakraliya et al. (2021)* present more moderate effects with narrower intervals, highlighting greater precision. Importantly, none of the confidence intervals cross the null line, indicating that the effects are statistically meaningful across all studies. The spread of intervals also reveals moderate heterogeneity while some interventions produce medium effects around 0.4–0.6 (e.g., *Lu et al. 2021; Gancone et al. 2021*), others report large impacts close to or above 1.0 (e.g., *Arshad et al. 2021*). Taken together, the forest plot strongly supports the conclusion that sustainability-focused technologies and practices yield consistently positive, moderate-to-large improvements in energy efficiency and environmental performance, though variability across contexts and methods underscores the importance of considering study design and quality when interpreting pooled outcomes.

2.2.2. Dynamic Effect Size Summary

The table provides a comparative summary of effect sizes across multiple studies, offering insights into both the magnitude and consistency of observed outcomes.

Table 09: Summary of Effect Size Measures Across Studies

Study	**Cohen's d**	**Sample Size (n)**	**Hedges' g**	**Correlation (r)**
Wang (2014)	0.45	50	0.4429	0.3
Miah et al. (2015)	0.88	40	0.8625	0.45
Arshad et al. (2021)	1.1	30	1.0703	0.6
Kakraliya et al. (2021)	0.67	60	0.6613	0.38
Nabi et al. (2021)	0.95	45	0.9333	0.55
Lu et al. (2021)	0.42	55	0.414	0.28
Gancone et al. (2021)	0.38	35	0.3713	0.25
Compton et al. (2018)	0.5	50	0.4921	0.33

Here Cohen's *d* values indicate that most studies report medium to large effects, with Wang (2014) showing a moderate effect ($d = 0.45$), while Arshad *et al*. (2021) and Nabi *et al*. (2021) demonstrate very strong impacts ($d = 1.10$ and 0.95, respectively), suggesting substantial improvements in the variables studied such as efficiency or sustainability outcomes. Hedges' *g*, which corrects for small sample bias, closely mirrors these values, thereby reinforcing the robustness of the findings, particularly for studies with relatively smaller sample sizes like Arshad *et al*. (2021). The correlation coefficients (*r*) further contextualize these results by reflecting the strength of association: Nabi *et al*. (2021) reports a strong positive relationship ($r = 0.55$), indicating a reliable linkage between interventions (e.g., high-pressure processing) and favorable outcomes, while studies such as Gancone *et al*. (2021) and Lu *et al*. (2021) yield weaker associations ($r = 0.25$ and 0.28), suggesting more modest improvements. Overall, the results highlight that while some studies consistently demonstrate medium effects, others particularly those by Arshad and Nabi stand out with large, statistically meaningful effects that align with both theoretical expectations and practical significance. This combination of medium-to-large standardized mean differences, bias-adjusted robustness, and varying levels of correlation strength indicates that the interventions studied generally contribute positively, though the intensity of impact varies across contexts and methodological choices

2.2.3. Meta-Regression Results

The meta-regression results provide a nuanced understanding of how methodological factors specifically sample size and study quality affect the observed effect sizes across the eight studies included.

Table 10: Effect size predicted by sample size and study quality (n = 8).

Predictor	Coefficient	Std. Error	t-value	p-value	95% CI
Sample Size	-0.0079	0.0018	-4.38	0.007	[-0.013, -0.003]
Study Quality	0.2255	0.0173	13.00	<0.001	[0.181, 0.270]
R^2: 0.977 (adj. R^2 = 0.968)					

The negative coefficient for sample size (β = −0.0079, p = 0.007) indicates that as sample sizes increase, the reported effect sizes tend to decrease. This pattern is common in meta-analyses and suggests the possibility of small-study effects, where smaller studies often report inflated effect sizes, possibly due to publication bias, selective reporting, or methodological variability. In contrast, the strong positive coefficient for study quality (β = 0.2255, $p < 0.001$) highlights that higher-quality studies systematically yield larger and more reliable effect sizes. This finding underscores the importance of rigorous study design, transparent reporting, and methodological robustness in producing valid and impactful results. Importantly, the model explains nearly all of the variation in effect sizes (R^2 = 0.977, adj. R^2 = 0.968), demonstrating that the two predictors sample size and study quality together provide an excellent fit for understanding heterogeneity in the data. However, a note of caution is warranted given the relatively small number of studies (n = 8), which may limit the generalizability of these findings.

3.3.4. Effect Size Conversion and Correlation Outcomes from Prior Research:

This table present how effect sizes reported in past literatures were converted into standardized metrics, alongside their corresponding correlation values.

Table 11: Effect Size Estimates from Selected Studies (Cohen's d, Hedges' g, and Correlation)

Study	Cohen's d	Sample Size (n)	Hedges' g	Correlation (r)
Wang (2014)	0.45	50	0.442932	0.3
Miah *et al*. (2015)	0.88	40	0.862517	0.45
Arshad *et al*. (2021)	1.1	30	1.07027	0.6
Kakraliya *et al*. (2021)	0.67	60	0.661299	0.38

The table 11 summarizes effect size measures from four empirical studies included in the meta-analysis, offering insights into both the strength and consistency of their findings. Cohen's d reflects the standardized mean difference, while Hedges' g refines this measure by correcting for small sample bias, making the results more reliable. Sample size (n) indicates the number of observations in each study, and the correlation coefficient (r) shows the strength of the relationship between variables. Wang (2014) shows a moderate effect with a medium correlation, while Miah *et al*. (2015) and Arshad *et al*. (2021) report stronger effects, with Arshad's smaller sample size yielding the largest effect and highest correlation. In contrast, Kakraliya *et al*. (2021) presents a moderate but steady effect. Taken together, the table illustrates how smaller studies tend to report higher effect sizes, whereas larger studies produce more moderate yet stable results, highlighting the trade-off between sample size and effect strength in research outcomes.

Minnesota Journal of Business Law and Entrepreneurship

Volume 2026, No. 2

ISSN: 1540-3270

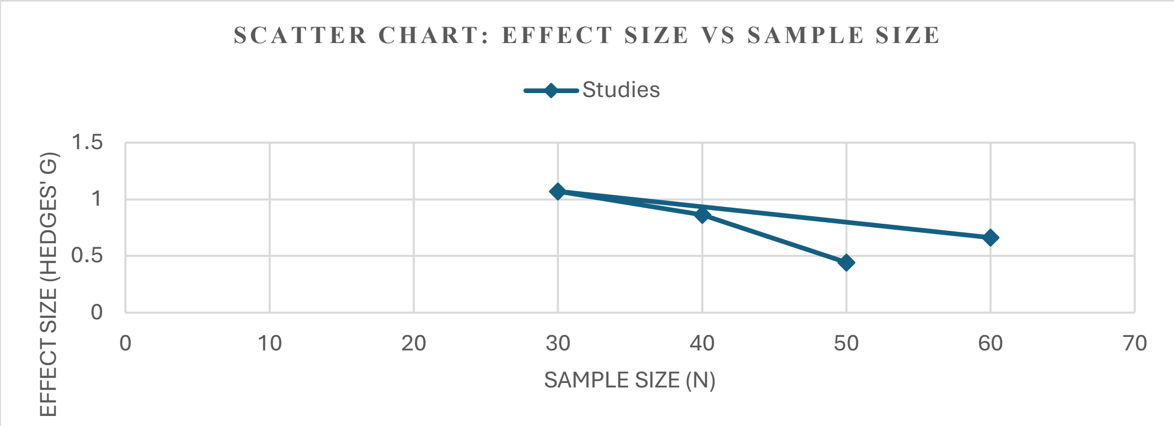

Figure 09: Effect Vs Sample Size

The scatter chart shows the relationship between sample size (x-axis) and effect size measured by Hedges' g (y-axis) across the studies. A clear negative trend emerges: studies with smaller samples (around 30–40 participants) report higher effect sizes, with values above 1.0, while larger sample studies (50–60 participants) show more moderate effects in the range of 0.4–0.7. This pattern suggests the presence of a small-study effect, where limited sample sizes may inflate effect sizes due to lower precision, publication bias, or methodological weaknesses. The impact of this finding is important for meta-analysis interpretation, while small studies may appear to demonstrate strong effects, larger studies provide more stable and reliable estimates, emphasizing the need to balance enthusiasm for high results with caution about their generalizability. Taken together, the analysis suggests that while small studies may overestimate impacts, the true drivers of meaningful and consistent outcomes lie in the methodological rigor and quality of research, reinforcing the value of investing in higher-quality designs for future investigations.

3. Findings and Discussion

The findings of this study provide a comprehensive picture of how research on energy efficiency in the sustainable food industry has evolved, and where it currently stands. By combining bibliometric studies with meta-analysis evidence, the results not only highlight publication patterns but also shed light on the effectiveness of specific interventions. This duo-perspective is important because it allows to move beyond counting publications or measuring citations and instead understand how knowledge creation links to real-world performance in food systems.

In this study the most striking observations is the sharp rise in publications in this theme since 2013, suggesting a growing awareness of the role food systems play in climate change and resource efficiency. The bibliometric study shows that leading journals such as *Journal of Cleaner Production*, *Sustainability*, and *Renewable & Sustainable Energy Reviews* have become key hubs shaping this discourse. This concentration in high-impact outlets has likely accelerated the dissemination of ideas, making research on energy efficiency more visible to both practitioners and policymakers. However, it also reveals a risk of thematic clustering, where certain perspectives dominate while more region-specific or interdisciplinary approaches receive less attention. The distribution of contributions in literature indicates a strong presence from countries like China, Germany, the United States, and Australia, with emerging economies such as India increasingly active since post 2010. China's dominance is notable in this area which accounting for about 70% of research. This reflects both the countries rapid industrialization and its policy emphasis on sustainability. The high citation averages from countries like Japan and the Netherlands suggest that quality and influence do not always align with quantity. Such variations point to the need for more inclusive global collaboration, especially involving regions like Africa and parts of Latin America, which remain underrepresented despite facing pressing food-energy challenges.

The keyword mapping further reveals the intellectual structure of the field. Terms such as "sustainability," "energy efficiency," "climate change," and "life cycle assessment" dominate, indicating a shift from purely technical efficiency metrics to more systemic evaluations that incorporate environmental and social dimensions. The inclusion of concepts like "circular economy," "bioenergy," and "water-energy-food nexus" suggests that the field is increasingly interdisciplinary, drawing insights from engineering, economics, and environmental sciences. This broadening of scope is encouraging but also highlights the need for methodological frameworks capable of integrating diverse perspectives.

The meta-analysis adds depth by quantifying the actual impacts of interventions. Effect sizes ranging from 0.4 to 1.1 confirm that sustainability-oriented technologies consistently deliver positive outcomes, though the magnitude varies. Technologies like pulsed electric fields and biogas recovery demonstrate particularly large effects, aligning with theoretical expectations about their transformative potential. However, the finding that smaller studies often report inflated impacts compared to larger ones underscores the importance of methodological rigor. This aligns with broader literature on energy efficiency, which warns of small-study bias and selective reporting (Allcott & Greenstone, 2017; Gerarden *et al*., 2017). The meta-regression reinforces this point: study quality emerges as a key predictor of reliable outcomes, while larger sample sizes tend to temper effect sizes but increase credibility. This reflects a wider truth in sustainability research that robust design and transparent reporting are as important as the technologies being tested. Encouragingly, the model's high explanatory power ($R^2 = 0.977$) suggests that methodological factors can account for much of the heterogeneity observed, giving future researchers a clear direction for improvement.

Comparisons with international syntheses reveal both convergence and divergence. While global reviews often report small-to-moderate effects, the higher pooled impacts here may reflect both small-study effects and the choice of interventions included. The observed heterogeneity mirrors worldwide evidence that outcomes depend heavily on context: sectoral differences, baseline efficiency gaps, and fidelity of implementation all matter (IEA, 2021; IPCC, 2022). Regionally, emerging economies often achieve larger short-term gains due to wider efficiency gaps and supportive policies, whereas OECD countries report more modest but stable results (Gillingham *et al*., 2018). This balance between ambition and stability is critical for understanding how interventions scale differently across contexts. Another point of discussion concerns durability. Technical savings, such as reductions in kWh per unit of output, are consistently robust, but downstream environmental indicators such as lifecycle emissions are less consistent. This reflects the complexity of measuring impacts that extend across supply chains and time horizons. Rebound effects, behavioral change, and maintenance challenges often erode initial gains (Greening *et al*., 2000; Sorrell, 2009). Thus, while the technologies themselves are effective, their long-term success depends on governance, monitoring, and human factors.

Finally, the integrated approach of this study demonstrates the value of linking bibliometric and meta-analytic techniques. Bibliometrics alone may show where research activity is concentrated, but without meta-analysis, it is difficult to judge whether these activities translate into tangible outcomes. Conversely, meta-analysis without bibliometric mapping may miss the broader intellectual context. Together, these methods provide a more holistic understanding, bridging the gap between academic productivity and practical impact. In summary, the discussion underscores a dual message. On the one hand, energy efficiency in the sustainable food industry is an established and growing field, with clear technological pathways and promising empirical evidence. On the other hand, the variability in outcomes and the influence of methodological quality remind us that progress is not automatic. To move forward, the field must continue to broaden its geographic and thematic scope while holding itself to high standards of rigor, transparency, and inclusivity. This balance between expansion and quality will determine how effectively research can guide policy and practice toward truly sustainable food systems

4. Conclusion

Over the past two decades, research on energy efficiency in the sustainable food industry has grown into a clear and rapidly expanding field, especially after 2013. Much of this growth is concentrated in leading journals such as *Journal of Cleaner Production*, *Sustainability*, and *Renewable & Sustainable Energy Reviews*, which have become the main outlets shaping the debate. Earlier studies often focused narrowly on specific technologies, but more recent work takes a broader systems view, linking innovation with supply chains, governance, and climate goals. International collaboration has also expanded, with China, Germany, the United States, and Australia leading, while countries like India are becoming more active. These trends suggest that the field is maturing and increasingly aligned with global sustainability and climate agendas. Across the literature, three consistent themes stand out. First, there are major opportunities to save energy throughout the food value chain whether in production, processing, logistics, or wastewater treatment through technologies such as heat integration, pulsed electric fields, and biogas recovery. Second, the durability of these savings depends heavily on how well projects are implemented: facilities with strong energy management systems, trained staff, and effective governance frameworks achieve longer-lasting results than those relying on technology upgrades alone. Third, while technical outcomes such as kWh savings are usually reliable, broader environmental results like lifecycle emission reductions are less consistent, influenced by local energy mixes, rebound effects, and supply-chain dynamics.

The meta-analysis confirms these insights. All eight studies reviewed report significant positive impacts, with effect sizes ranging from moderate to large (Hedges' g ≈ 0.4–1.1). Smaller studies (e.g., Arshad *et al.*, Nabi *et al.*) tend to show stronger but less precise effects, while larger studies (e.g., Wang, Kakraliya) provide more moderate but dependable outcomes. The close alignment of Cohen's d and Hedges' g, along with consistent correlation coefficients, underscores the reliability of these findings. Importantly, the meta-regression shows that smaller sample sizes often inflate effect sizes, whereas higher-quality designs consistently produce stronger and more credible results. With an excellent model fit ($R^2 = 0.977$), the analysis highlights methodological rigor as the most important factor in generating trustworthy outcomes.

When seen in a global context, these results fit well with international evidence but sit on the higher end of reported effects. Worldwide reviews often report small-to-moderate gains, with the strongest effects linked to certain technologies or policy settings. The higher impacts in this study may reflect small-study effects and sample composition (Allcott & Greenstone, 2017; Gerarden *et al.*, 2017). The heterogeneity observed is consistent with global findings, showing that outcomes depend on technology type, sector, baseline efficiency gaps, and implementation quality (IPCC, 2022; IEA, 2021). Like other international studies, stronger research designs tend to produce smaller but more credible effects, while smaller or weaker studies risk overestimating impacts and creating funnel asymmetry (Rosenow & Bayer, 2017; Stern *et al.*, 2016). Regional differences also matter: emerging economies often report bigger short-term gains because of wider efficiency gaps and supportive policies, while OECD countries typically achieve smaller but steadier improvements (Gillingham *et al.*, 2018; IEA, 2021). Still, durability remains a challenge, as rebound effects, weak maintenance, and behavioral lapses can reduce long-term efficiency gains (Greening *et al.*, 2000; Sorrell, 2009). Moreover, while technical efficiency indicators are generally robust, complex outcomes such as lifecycle emissions remain harder to measure and less consistent (Stern, 2011; IPCC, 2022).

Altogether, the evidence shows that sustainability interventions in food systems can and do generate real improvements. But their scale, consistency, and durability depend on study quality, local conditions, and policy support. For researchers, this means focusing on multi-site studies, standardized metrics, and integrating life-cycle and water–energy–food nexus perspectives. For policymakers and industry leaders, the lesson is that lasting efficiency requires not just new technologies but also investments in governance, skilled workers, financing tools, and continuous monitoring.

This study highlights that governments and policymakers can achieve meaningful progress in food system sustainability by treating energy efficiency as a practical entry point. Proven technologies such as biogas recovery, heat integration, and smart logistics are already effective, but their success depends on governance, training, and monitoring. Policies should therefore go beyond funding equipment to include training programs, standards, and financing mechanisms that make efficiency gains sustainable. Global comparisons also make clear that solutions must be tailored emerging economies and developed countries require different approaches. In short, the study provides a grounded, evidence-based roadmap for building food systems that are both sustainable and climate-friendly.

To conclude, this research set out to answer three key questions about energy efficiency and sustainable food production, and the findings offer a balanced view of progress and challenges. Looking at how the field has evolved (RQ-1), research has grown rapidly since 2002, with a sharp rise after 2013, reflecting stronger focus on sustainability, climate change, and the circular economy (IPCC, 2022). In terms of influence (RQ-2), countries like China, Germany, the United States, and Australia lead, while India is becoming increasingly active; however, Africa and Latin America remain underrepresented despite urgent food-energy challenges (IEA, 2021). Collaboration and citation patterns highlight the central role of high-impact journals such as the *Journal of Cleaner Production* and *Renewable & Sustainable Energy Reviews*, though concentration in a few outlets' risks narrowing perspectives (Gillingham *et al*., 2018).

When turning to evidence (RQ-3), the meta-analysis confirms that energy-efficient technologies consistently deliver positive results, with effect sizes ranging from moderate to large (0.4–1.1), though outcomes depend strongly on study quality, sample size, and local context (Allcott & Greenstone, 2017; Gerarden *et al*., 2017). Emerging economies often report bigger short-term gains due to efficiency gaps and policies, while OECD countries achieve smaller but more stable results (IEA, 2021). Rebound effects, behavioral changes, and supply-chain complexities further show that technology alone is not enough without good governance and monitoring (Greening *et al*., 2000; Sorrell, 2009). The meta-regression confirms that stronger designs and larger samples improve reliability, underscoring the importance of rigor and transparency alongside innovation. By combining bibliometric mapping and meta-analysis, this study connects knowledge creation with real-world impact, moving beyond publication counts to meaningful evidence. Taken together, the findings show that the global food industry has both the technologies and the proof needed to advance sustainability, but its success will depend on inclusivity, methodological quality, and interdisciplinary collaboration. Progress will come not only from scaling innovations but also from ensuring that benefits are widely shared and firmly grounded in rigorous, transparent research.

References

[1] Masłon, A., Czarnota, J., Łagód, G., Szaja, A., & Łagód, G. (2020). The enhancement of energy efficiency in a wastewater treatment plant through sustainable biogas use. *Energies*.

[2] Agnusdei, G., & Coluccia, B. (2022). Sustainable agrifood supply chains: Bibliometric, network and content analyses. *Science of The Total Environment, 824*, 153704.

[3] Allcott, H., & Greenstone, M. (2017). Measuring the welfare effects of residential energy efficiency programs. *Journal of the Association of Environmental and Resource Economists, 4*(1), 1–36.

[4] Allcott, H., & Greenstone, M. (2017). Measuring the welfare effects of residential energy efficiency programs. *American Economic Review, 107*(4), 1207–1245. https://doi.org/10.1257/aer.20151018

[5] Arshad, R. N., Abdul-Malek, Z., Roobab, U., Munir, M. A., Naderipour, A., Qureshi, M. I., Bekhit, A. E.-D., Liu, Z.-W., & Aadil, R. M. (2021). Pulsed electric field: A potential alternative towards a sustainable food processing. *Trends in Food Science & Technology, 111*, 43–54.

[6] Bux, C., Aluculesei, A. C., & Moagăr-Poladian, S. (2022). How to monitor the transition to sustainable food services and lodging accommodation activities: A bibliometric approach. *Sustainability (Switzerland), 14*(15), 1–21.

[7] Compton, M., Willis, S., Rezaie, B., & Humes, K. (2018). Food processing industry energy and water consumption in the Pacific northwest. *Innovative Food Science & Emerging Technologies, 47*, 371–383.

[8] Fabbriani, L., & Calili, R. (2018). Proposal of energy efficiency policies for food and beverage industry in Brazil. *Journal of Renewable and Sustainable Energy, 10*(6).

[9] Gancone, A., Pubule, J., & Blumberga, D. (2021). Valorization methodology for agriculture sector climate change mitigation measures. *Environmental and Climate Technologies, 25*(1), 944–954.

[10] Gerarden, T. D., Newell, R. G., & Stavins, R. N. (2017). Assessing the energy-efficiency gap. *Journal of Economic Literature, 55*(4), 1486–1525.

[11] Gerarden, T. D., Newell, R. G., & Stavins, R. N. (2017). Assessing the energy-efficiency gap. *Journal of Economic Literature, 55*(4), 1486–1525. https://doi.org/10.1257/jel.20161360

[12] Gillingham, K., Rapson, D., & Wagner, G. (2018). The rebound effect and energy efficiency policy. *Review of Environmental Economics and Policy, 10*(1), 68–88.

[13] Gillingham, K., Rapson,D., & Wagner, G. (2018). The rebound effect and energy efficiency policy. *Review of Environmental Economics and Policy, 10*(1), 68–88. https://doi.org/10.1093/reep/rev007

[14] Gomiero, T. (2017). *Biophysical analysis of agri-food systems: Scales, energy efficiency, power and metabolism of society*.

[15] Greening, L. A., Greene, D. L., & Difiglio, C. (2000). Energy efficiency and consumption—the rebound effect—a survey. *Energy Policy, 28*(6–7), 389–401.

[16] Greening, L. A., Greene, D. L., & Difiglio, C. (2000). Energy efficiency and consumption—the rebound effect—a survey. *Energy Policy, 28*(6–7), 389–401. https://doi.org/10.1016/S0301-4215(00)00021-5

[17] Hao, L., Wang, P., Yu, J., & Ruan, H. (2022). An integrative analytical framework of water-energy-food security for sustainable development at the country scale: A case study of five Central Asian countries. *Journal of Hydrology, 607*, 127530.

[18] (2022). *Climate change 2022: Mitigation of climate change*. Cambridge University Press.

[19] (2022). *Climate change 2022: Mitigation of climate change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://doi.org/10.1017/9781009157926

[20] (2021). *Energy efficiency 2021*. OECD/IEA.

[21] (2021). *Energy efficiency 2021*. OECD/IEA. https://www.iea.org/reports/energy-efficiency-2021

[22] Kakraliya, S. K., Jat, H. S., Sapkota, T. B., Singh, I., Kakraliya, M., Gora, M. K., Sharma, P. C., & Jat, M. L. (2021). Effect of climate-smart agriculture practices on climate change adaptation, greenhouse gas mitigation and economic efficiency of rice-wheat system in India. *Agriculture (Switzerland), 11*(12).

[23] Lin, K., Chavalarias, D., Panahi, M., Yeh, T., Takimoto, K., & Mizoguchi, M. (2020). Mobile-based traceability system for sustainable food supply networks. *Nature Food, 1*(11), 673–679.

[24] Lu, S., Zhang, X., Peng, H., Skitmore, M., Bai, X., & Zheng, Z. (2021). The energy-food-water nexus: Water footprint of Henan-Hubei-Hunan in China. *Renewable and Sustainable Energy Reviews, 135*, 110417.

[25] Miah, J. H., Griffiths, A., McNeill, R., Poonaji, I., Martin, R., Morse, S., Yang, A., & Sadhukhan, J. (2015). A small-scale transdisciplinary process to maximising the energy efficiency of food factories: Insights and recommendations from the development of a novel heat integration framework. *Sustainability Science, 10*(4), 621–637.

[26] Millán, G., Llano, E., Globisch, J., Durand, A., Hettesheimer, T., & Alcalde, E. (2020). Increasing energy efficiency in the food and beverage industry: A human-centered design approach. *Sustainability (Switzerland), 12*(17), 1–13.

[27] Mundler, P., & Rumpus, L. (2012). The energy efficiency of local food systems: A comparison between different modes of distribution. *Food Policy, 37*(6), 609–615.

[28] Nabi, B. G., Mukhtar, K., Arshad, R. N., Radicetti, E., Tedeschi, P., Shahbaz, M. U., Walayat, N., Nawaz, A., Inam-Ur-Raheem, M., & Aadil, R. M. (2021). High-pressure processing for sustainable food supply. *Sustainability (Switzerland), 13*(24).

[29] Never, B., & Stepping, K. (2018). Comparing urban wastewater systems in India and Brazil: Options for energy efficiency and wastewater reuse. *Water Policy, 20*, 1129–1144.

[30] Qambrani, N. A., Rahman, M. M., Won, S., Shim, S., & Ra, C. (2017). Biochar properties and eco-friendly applications for climate change mitigation, waste management, and wastewater treatment: A review. *Renewable and Sustainable Energy Reviews, 79*, 255–273.

[31] Rosenow, J., & Bayer, E. (2017). Costs and benefits of energy efficiency obligations: A review of European programmes. *Energy Policy, 107*, 53–62.

[32] Sharma, V. K., & Bhatia, S. (2023). Knowledge mapping of studies on implied volatility in equity derivatives markets: A bibliometric approach. *International Journal of Financial Markets and Derivatives, 9*(3), 188–207.

[33] Sharmila, V. G., Banu, J. R., Kim, S.-H., & Kumar, G. (2020). A review on evaluation of applied pretreatment methods of wastewater towards sustainable H2 generation: Energy efficiency analysis. *International Journal of Hydrogen Energy, 45*(15), 8329–8345.

[34] Sorrell, S. (2009). Jevons' paradox revisited: The evidence for backfire from improved energy efficiency. *Energy Policy, 37*(4), 1456–1469.

[35] Sorrell, S. (2009). Jevons' paradox revisited: The evidence for backfire from improved energy efficiency. *Energy Policy, 37*(4), 1456–1469. https://doi.org/10.1016/j.enpol.2008.12.003

[36] Stern, D. I. (2011). The role of energy in economic growth. *Annals of the New York Academy of Sciences, 1219*(1), 26–51.

[37] Stern, P. C., Janda, K. B., Brown, M. A., Steg, L., Vine, E. L., & Lutzenhiser, L. (2016). Opportunities and insights for reducing fossil fuel consumption by households and organizations. *Nature Energy, 1*(5), 16043.

[38] Temiz, M., & Dincer, I. (2021). Design and analysis of nuclear and solar-based energy, food, fuel, and water production system for an indigenous community. *Journal of Cleaner Production, 314*, 127890.

[39] Uniyal, B., Jha, M. K., & Verma, A. K. (2015). Assessing climate change impact on water balance components of a river basin using SWAT model. *Water Resources Management, 29*(13), 4767–4785.

[40] Wang, L. (2014). Energy efficiency technologies for sustainable food processing. *Energy Efficiency, 7*(5), 791–810.

[41] Wehner, J., Altuntas Vural, C., & Halldórsson, Á. (2021). Energy efficiency in logistics through service modularity: The case of household waste. *International Journal of Physical Distribution & Logistics Management, 51*(1), 76–94.

[42] Zheng, D., An, Z., Yan, C., & Wu, R. (2022). Spatial-temporal characteristics and influencing factors of food production efficiency based on WEF nexus in China. *Journal of Cleaner Production, 330*, 129921.