

Systematic Review

Economic Representation in Water–Energy–Food Nexus Models: A Systematic Review of System Dynamics Approaches

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Abstract: Water, food, and energy are vital for individual well-being and national development. However, population growth and economic expansion have significantly increased the demand for these resources, while climate change has put pressure on their availability. To address these challenges, the Water–Energy–Food (WEF) Nexus framework highlights their interconnected nature, promoting systemic management approaches. System dynamics, a methodology designed to analyse complex and interrelated systems, is well-suited for modelling the WEF Nexus, capturing feedback loops and dynamic interactions. This study evaluates the use of system dynamics in WEF Nexus modelling and examines how economic systems, a key driver of resource demand, are represented in these models. A systematic literature review was conducted following the PRISMA framework. Of 280 articles initially identified, 237 remained after removing duplicates, with 36 relevant studies analysed. The results show a dominance of water-focused and balanced WEF models but limited representation of economic systems. Among 20 studies with economic representation, 17 treated the economy as an exogenous input to estimate demand, while only 3 integrated endogenous feedback linking resource availability to economic growth. These findings reveal a significant gap in current research and underscore the need for further studies to explore the dynamic interdependence between the economy and WEF resources.

Keywords: water–energy–food nexus; system dynamics; economic modelling; energy–economy integration; energy transition



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1. Introduction

Water, energy, and food are indispensable resources for individual well-being and national development. By 2050, the global population is projected to reach approximately 9.8 billion, increasing from 8.1 billion in 2024 and ultimately peaking at over 10 billion later this century, according to the United Nations [1]. Simultaneously, global economic growth projections under the Shared Socioeconomic Pathways (SSPs) highlight a consistent trend of global economic expansion despite notable variations across scenarios. By 2050, projected Gross Domestic Product (GDP) values range from approximately USD 169 trillion in SSP3, which reflects slower expansion, to over USD 348 trillion in SSP5, characterised by rapid growth [2].

These trends are expected to drive higher demands for water, energy, and food. For instance, global water demand for domestic, industrial, and agricultural uses, currently around 4600 km³ per year, is projected to increase by 20–30% by 2050 due to socioeconomic changes [3]. Similarly, worldwide energy consumption is projected to grow by 34% under the Energy Information Administration (EIA) reference scenario, with total marketed energy

use reaching 855 quadrillion British thermal units by 2050 [4]. Regarding food, projections vary. The Food and Agriculture Organization of the United Nations (FAO) estimates that global food demand will increase by 60–110% by 2050 [5], driven by population and economic growth. A meta-analysis conducted by van Dijk et al. [6] reviewed these projections and compared them with estimates from the SSPs scenarios. Under SSP2, most used as a business-as-usual scenario, the meta-analysis found a projected increase of 51% in food demand by 2050.

While the SSP2 estimate is lower than the FAO's upper range, it underscores significant growth in food demand. These findings highlight the escalating challenge for policymakers to ensure the accessibility, availability, affordability, and stability of those valuable resource supplies in the face of mounting pressures from population growth and economic expansion.

While global demand for these critical resources is projected to rise rapidly, the supply side faces challenges due to the effects of climate change. Water systems, for instance, are highly sensitive to climatic variability. Annual stream flows have shown decreasing trends in regions such as western and central Africa, eastern Asia, southern Europe, western North America, and eastern Australia, driven by regional precipitation and temperature changes [3]. Moreover, increasing agricultural and ecological droughts, particularly in the Mediterranean and western North America, have been attributed to anthropogenic warming, highlighting their heightened frequency and severity over recent decades, which could become a threat to water supply in a demand-growing world [3].

Since agriculture accounts for almost 70% of freshwater withdrawals [7], agricultural systems are increasingly vulnerable to climatic stressors. Projections suggest that drought-driven yield losses could reach 9–12% for wheat, 5.6–6.3% for maize, 18.1–19.4% for rice, and 15.1–16.1% for soybeans by 2071–2100 under a high-emissions scenario [8].

In the energy sector, the current reliance on fossil fuels—oil, coal, and natural gas—dominates the global energy mix. These energy sources are the most widely used today and are significant contributors to CO₂ emissions, intensifying climate change. Additionally, their finite nature raises concerns about long-term resource availability [9]. Given the dominance of fossil fuels in the global energy mix and their significant contribution to CO₂ emissions, the transition to a low-carbon energy system has become imperative. However, this shift is not solely a technological challenge; it is fundamentally shaped by economic policies and regulatory frameworks.

The expansion of renewable energy depends not only on technological factors but also on subsidies, infrastructure investments, and carbon pricing mechanisms, which influence both the pace and viability of this transition. At the same time, the large-scale deployment of renewable energy sources introduces additional resource constraints.

Photovoltaic power plants, for instance, require substantial water for their operation, while wind and solar farms demand vast land areas. Similarly, biofuel production competes with food agriculture, affecting land availability and potentially driving up food prices.

Beyond the energy sector, economic forces play a crucial role in shaping the availability, accessibility, and distribution of water and food resources. Infrastructure investments, pricing mechanisms, and agricultural subsidies directly impact resource security, while market dynamics, consumer behaviour, and economic growth further influence production and consumption patterns. These economic factors determine how resources are allocated and managed, ultimately influencing their sustainability and resilience in the face of growing environmental and socioeconomic pressures.

Collectively, these challenges underline the urgent need for integrated management approaches to ensure the sustainable supply of these essential resources under climate-induced pressures.

Addressing these complexities requires a holistic analytical framework capable of capturing the dynamic interdependencies among water, energy, and food systems. One such approach is the Water–Energy–Food (WEF) Nexus framework, which emerged prominently in policy and academic discourse during the 2011 Bonn Conference on the Nexus, marking a pivotal moment in resource management [10]. This framework emphasises the interconnected nature of these three systems, advocating for systemic approaches to manage these resources sustainably.

Water, energy, and food are inherently linked. Water is critical for food production, whether through irrigation or as a component in agricultural processing, and plays a fundamental role in energy systems. It is essential for hydropower generation, serves as a key resource in the cooling and maintenance of solar power plants, and is heavily required in the cultivation and processing of biofuels. Energy, in turn, is essential for water extraction, treatment, and distribution as well as for agricultural processes like planting, harvesting, and storage. Food production depends on both water and energy to ensure yield stability and supply chain functionality [10,11].

For example, Bazilian et al. [11] highlighted how policy shifts in one sector, such as promoting bioenergy, can create cascading effects across water and food systems, illustrating the need for cross-sectoral coordination. Figure 1 illustrates how the relationships within the WEF Nexus have been conceptualised since its inception and how they could be reinterpreted when considering the economy as both a driving force and a connecting element among these systems.

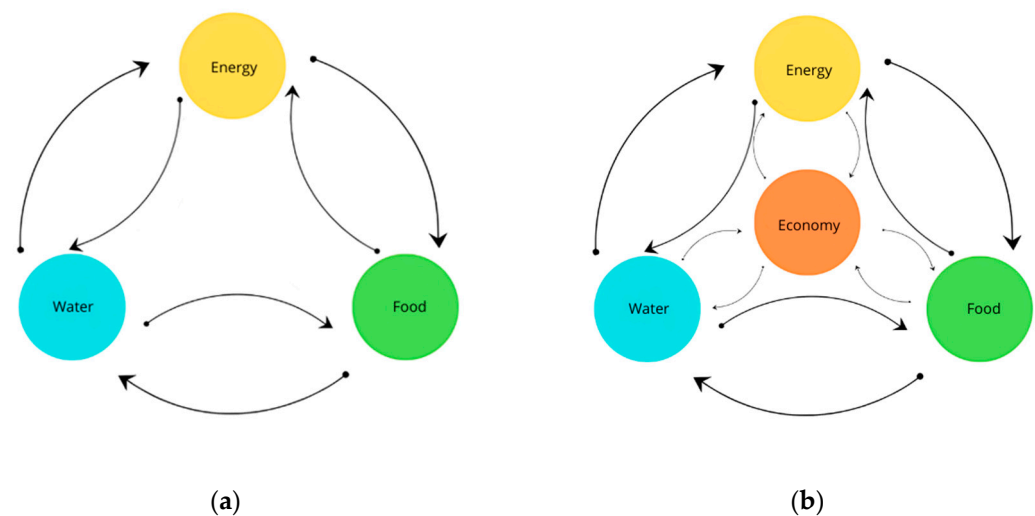


Figure 1. (a) Common WEF Nexus diagram. (b) Water, Energy, and Food Nexus including the economy.

FAO’s perspective enriches this understanding by situating the WEF Nexus within the context of global food security. It underscores that water and energy are central to ensuring sufficient agricultural outputs, particularly under the pressures of climate change, which intensifies competition for these resources [12]. Zhang et al. [13] further elaborate on the operational challenges of implementing the Nexus approach, noting that its success relies on addressing spatial and temporal trade-offs, particularly in regions experiencing resource scarcity.

The adoption of the WEF Nexus framework signals a paradigm shift from siloed resource management to integrated strategies that promote synergies and minimise trade-offs. Hoff [10] articulates this as a transition toward optimising resource efficiency and resilience while simultaneously supporting broader development goals, such as the Millennium Goals, later translated to the Sustainable Development Goals (SDGs). For instance, managing

trade-offs between water allocation for hydropower versus agricultural irrigation exemplifies the complexities of Nexus thinking and its potential to mediate competing demands.

Building on the historical and conceptual foundation of the WEF Nexus, researchers have developed and applied numerous methodologies to quantitatively analyse the intricate interactions among these interconnected systems. To synthesise the growing body of work, many authors have assessed the diverse range of methodologies employed in Nexus studies [13–16]. These reviews identify key approaches that frequently appear in the literature, reflecting their relevance and utility in addressing the complexities of the WEF Nexus. Among the most commonly applied methodologies are life cycle assessment (LCA), integrated assessment models (IAMs), agent-based modelling (ABM), and system dynamics modelling (SDM).

Life cycle assessment is a widely used approach to quantify environmental impacts associated with resource systems throughout their entire life cycle. Albrecht et al. [15] highlighted studies such as those by Pacetti et al. [17] and Irabien and Darton [18], which used LCA to evaluate water and carbon footprints in integrated systems. Similarly, Zhang et al. [13] cited Al-Ansari et al. [19] as an example of using LCA to evaluate water, energy, and food supply chains. While LCA provides valuable insights into resource efficiency and sustainability, its static nature often necessitates its integration with more dynamic methodologies for a comprehensive analysis [14].

Integrated assessment models are a cornerstone in WEF Nexus research, combining multiple resource systems such as water, energy, land, and climate to simulate their interactions and feedback. Albrecht et al. [15] emphasised the Climate, Land (Food), Energy, and Water (CLEW) systems framework [20], which integrates sectoral models to evaluate trade-offs and inform policy decisions. Susnik [14] highlighted how Bijl et al. [21] used the Integrated Model to Assess the Global Environment (IMAGE) model to assess the long-term water demand in the electricity, industrial, and household sectors. IAMs excel in providing system-wide, long-term perspectives, making them indispensable for strategic decision-making in complex resource contexts [22,23]. Although IAMs provide valuable insights and outcomes for understanding dynamics within the WEF Nexus, the magnitude and complexity of these models can pose challenges when attempting to analyse the three sectors—water, energy, and food—in a more focused and detailed manner.

Agent-based modelling complements these approaches by simulating the behaviours of individual agents—such as households, industries, or policymakers—and their interactions within the broader system. Albrecht et al. [15] highlighted the application of ABM in a study by Smajgl et al. [24] to model adaptive responses to resource constraints. Zhang et al. [13] discussed its relevance in modelling decentralised decision-making in agricultural systems. Susnik [14] illustrated ABM's capacity to analyse social and economic behaviours alongside environmental processes. ABM captures heterogeneity and emergent phenomena, offering unique insights into localised dynamics and their systemic impacts.

System dynamics modelling offers a dynamic framework for understanding feedback loops and time-dependent behaviours within the WEF Nexus. This approach is particularly suited to capturing the non-linear interactions and cascading effects among resource systems. Albrecht et al. [15] offered limited insights into the application of system dynamics modelling. Zhang et al. [13] discussed its utility by referencing studies such as that by Chhipi-Shrestha et al. [25], who applied SDM to identify critical factors constraining the sustainability of the urban water system. Their findings revealed that hot water usage was the primary contributor to energy consumption and carbon emissions during the operational phase of the system, showcasing SDM's capacity to uncover key interdependencies in resource systems.

System dynamics, introduced by Jay W. Forrester in the mid-20th century, was initially developed to study feedback loops and time-dependent behaviours in industrial systems [26]. System dynamics is based on the understanding that systems are inherently interconnected and complex. It emphasises the existence of stocks, flows, and feedback loops as key components of systems while recognising that information flows differ fundamentally from physical flows. Additionally, it highlights the significance of nonlinear processes and delays as critical system elements, which ultimately drive system behaviour through their structure [27].

Susnik [14] addressed several advantages of SDM, including its “bottom-up” approach, which allows for the creation of models that integrate multiple disciplines and enable true systems thinking. This makes SDM particularly effective for analysing the interconnections within the WEF Nexus and assessing their responses to external drivers, such as population growth or policy implementation. Additionally, SDM is highly flexible, accommodating various spatial and temporal scales.

However, Susnik [14] also pointed out some limitations of SDM. It is less effective for addressing spatially distributed phenomena, fine-grained analyses of individual systems, and complex interactions between people and the environment. These limitations suggest that while SDM is a powerful tool for WEF Nexus analysis, it is best complemented by other modelling approaches to address its shortcomings.

SDM is uniquely suited to the WEF Nexus due to its ability to model complex, interdependent systems with feedback loops and time delays—characteristics inherent to water, energy, and food interactions. Its capacity to integrate multiple sectors and scales while accounting for temporal dynamics offers significant advantages in addressing the intricate trade-offs and synergies of the Nexus.

Although SDM has been cited as a valuable tool for analysing the WEF Nexus, there is a notable lack of robust and detailed models in the literature. This scarcity limits the ability to perform comprehensive and reliable analyses of the complex interconnections between water, energy, and food systems, highlighting the need for either the further development of SDM models or a more thorough analysis of their application to the WEF Nexus.

Given the complexity of the WEF Nexus interconnections and its novelty, it is essential to assess how current modelling studies address these challenges. Therefore, this study aims to systematically review the application of system dynamics in WEF Nexus modelling, identifying existing models and their main trends.

Considering that economic factors are key drivers of both resource demand and supply, this study also assesses how the economy is represented in these models—whether as an exogenous force or through endogenous feedback loops—since its inclusion is essential for capturing market dynamics, policy impacts, and investment decisions that shape resource availability.

Furthermore, as the transition to a low-carbon economy increasingly places energy–economy interactions at the centre of sustainability discussions, this study also examines whether and how these models integrate such interactions, considering their critical role in guiding policies toward decarbonisation and long-term energy security.

2. Materials and Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework [28] is a well-established and widely recognised methodology designed to ensure transparency, rigour, and reproducibility in systematic reviews. Its use is crucial in structuring the process of identifying, selecting, and synthesising studies in a systematic, unbiased manner. By adhering to the PRISMA guidelines, this review ensures that every

stage, from the initial search for relevant studies to the final analysis, is conducted in a standardised and methodologically coherent way.

The framework fosters the reproducibility of the review process by providing clear guidelines for study selection, data extraction, and synthesis. This allows other researchers to follow the same steps and assess the consistency and reliability of the findings. Additionally, the systematic nature of PRISMA minimises the risk of selection bias and ensures that no relevant studies are overlooked, promoting comprehensive and objective analysis.

Although no pre-registered protocol was used for this study, a detailed methodological framework was developed and strictly followed throughout the review process. This framework outlined each step, from defining the research questions to study selection and data analysis, ensuring transparency and methodological rigour.

For this review, the PRISMA framework guided the development of a comprehensive search strategy aimed at identifying relevant studies on the application of system dynamics models to the WEF Nexus. It ensured that studies focusing on the integration of economic representation—whether exogenous or endogenous—were captured and analysed. The structured approach facilitated the identification of trends, patterns, and gaps in the literature, ensuring that this review provides an accurate and detailed overview of current research in this field.

To identify relevant studies for this systematic review, a comprehensive search was conducted across three major academic databases: Scopus, Web of Science, and ScienceDirect (see Table 1). The search focused on articles related to the application of system dynamics models within the WEF Nexus, with an initial intention to filter studies that included any form of economic representation (either endogenous or exogenous). However, due to the low number of results when attempting to filter specifically for economic aspects, it was decided to first capture studies on system dynamics models applied to the WEF Nexus more broadly.

Table 1. Search prompts used across databases.

Database	Search Prompt ¹
Scopus	("wef nexus" OR "efw nexus" OR "few nexus" OR "wefe nexus" OR "wefc nexus") AND ("System dynamics" OR "Dynamic modelling" OR "System dynamics modelling")
ScienceDirect	("wef nexus" OR "efw nexus" OR "few nexus" OR "wefe nexus" OR "wefc nexus") AND ("system dynamics" OR "dynamic modelling" OR "system dynamics modelling")
Web of Science	("wef nexus" OR "efw nexus" OR "few nexus" OR "wefe nexus" OR "wefc nexus") AND ("System dynamics" OR "Dynamic modelling" OR "System dynamics modelling")

¹ Different prompts were used across databases due to variations in their search tools.

After identifying the relevant models, the analysis proceeded in three steps: first, examining the broader trends in their application; second, assessing how the economy is represented within these models; and, finally, if applicable, investigating how economic dynamics interact with the energy sector.

To ensure a broader search scope, acronyms such as Energy–Water–Food (EWF) and Water–Energy–Food–Ecosystems (WEFE) [29] were included as studies addressing the Nexus concept may employ different terminologies depending on the specific focus of the analysis. However, this review specifically focuses on the Water–Energy–Food sectors as they represent the core of the Nexus perspective adopted here.

While other conceptualisations exist, such as Water–Energy–Nutrients [30,31] or Water–Energy–Carbon [25], they emphasise different sectoral interconnections and thus fall outside the scope of this study.

These approaches align with the broader understanding of the Nexus as a flexible framework, where different disciplines and stakeholders may define its boundaries according to specific sustainability challenges [32]. Consequently, while this study captures key variations of the WEF Nexus, it acknowledges that other sectoral configurations may be present in the literature.

The search was filtered to include only peer-reviewed articles and book chapters published between 2014 and 2024 in English.

As a result of this search strategy, a total of 280 articles were identified:

- 210 articles from ScienceDirect;
- 35 articles from Scopus;
- 35 articles from WebOfScience.

After removing 43 duplicates, 237 articles remained and were selected for the next phase, which involved the application of the inclusion and exclusion criteria. These 237 articles were then exported to a reference management tool, Zotero, where they were organised for further review.

Following the initial search and removal of duplicates, the remaining 237 articles were subjected to a screening process, where the titles and abstracts were reviewed to determine their eligibility for inclusion in the review, and only full, open-access articles were selected. This process was guided by a set of inclusion criteria to ensure that only studies most relevant to the research questions were included.

The following criteria were applied to determine which studies would be included in this review:

1. **System Dynamics Methodology:** The study needed to employ system dynamics as one of the modelling methodologies to analyse interactions within the WEF Nexus. Studies that utilise multiple methodologies were also considered if system dynamics was one of the approaches applied in the analysis.
2. **WEF Nexus Focus:** The study needed to focus on the WEF Nexus, addressing the connections between at least two of its components.
3. **Peer-Reviewed Articles:** Only peer-reviewed journal articles or book chapters were considered to ensure the quality and reliability of the studies.
4. **Open Access Requirement:** Articles that were not available as open access were excluded from this review. This decision was made to ensure that the studies could be fully replicated by any researcher, guaranteeing transparency and reproducibility. However, we acknowledge that this criterion may have limited the scope of the analysis by excluding relevant studies that were not freely accessible.
5. **Language and Publication Date:** The study needed to be written in English and published between 2014 and 2024 to ensure the relevance and timeliness of the information.

These criteria defined the inclusion parameters for this review. Consequently, the exclusion criteria were their logical counterparts, meaning that any study that did not fulfil the inclusion requirements was excluded from the analysis.

The abstracts of the 237 articles were carefully examined to assess their relevance to the inclusion criteria. The focus was to ensure that the studies did the following:

- Addressed the interdependencies between these components, either individually or in combination;
- Applied system dynamics to model the interactions within the WEF Nexus.

The analysis of economic representation in the models was not performed at this stage but was addressed in the detailed analysis of the selected studies. During the full-text review phase, the studies were examined to determine whether they included any form of economic representation, either endogenous or exogenous, as part of the system dynamics framework and how it was modelled.

Studies that met the inclusion criteria were retained for full-text review, while those that did not were excluded. This initial abstract screening ensured that only studies with a relevant focus on the WEF Nexus and system dynamics as one of the methodologies were included in the subsequent stages of the review process. The full review process can be seen in Figure 2.

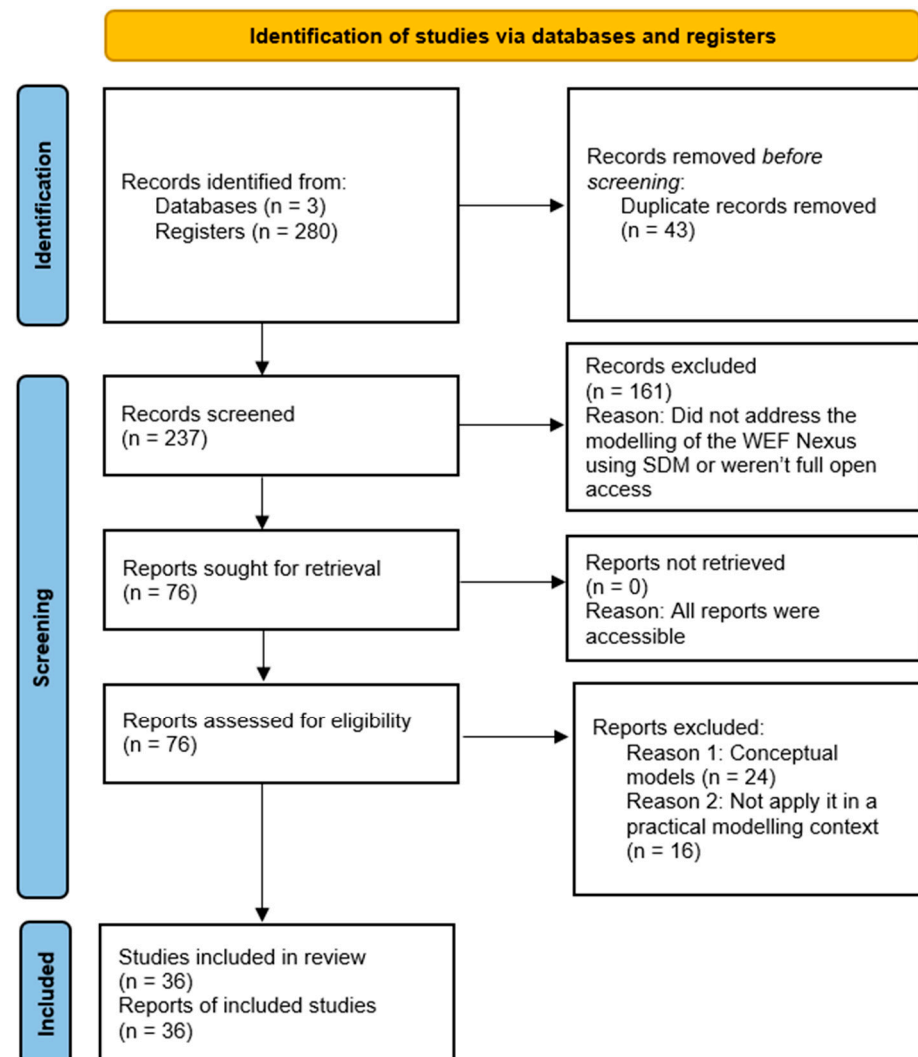


Figure 2. PRISMA flow diagram for the identification, screening, and inclusion of studies in this systematic review. Source: Page, M.J. et al. [28].

After the initial screening of the articles based on titles and abstracts, 76 studies were selected for full-text review. These studies met the inclusion criteria regarding the use of system dynamics modelling applied to the WEF Nexus. During the full-text review phase, the studies were further assessed to determine if they met the final inclusion criteria, including the requirement for an actual model, rather than a purely conceptual approach.

As a result of this full-text review, 36 studies were retained for inclusion in the final analysis. The exclusion of studies at this stage occurred for the following reasons:

- 24 studies were excluded because they were conceptual models that did not provide actual system dynamics models or simulations. These studies did not include detailed modelling or practical applications but instead focused on theoretical frameworks or conceptual discussions.
- 16 articles discussed the WEF Nexus and referred to system dynamics as a potential approach but did not apply it in a practical modelling context. Their focus was primarily theoretical or exploratory, without engaging in actual system dynamics modelling of the Nexus.

After the selection of the 36 studies for the final analysis, data extraction was conducted for each study. The goal of this step was to systematise the most relevant information from the studies to allow for comparative analysis and the identification of patterns and gaps in the literature. The data extraction was carried out in a structured manner using a data extraction table, which organised the information into key categories, as shown in Table 2, the full table is available in the Supplementary Materials.

Table 2. Categories of data extracted for this review.

Category	Description
Author(s)	Identification of the study's authors, including the country of the first author.
Year of Publication	Year the study was published, to check for temporal trends.
Title of the Study	Full title of the study for easy reference.
Objective of the Model	Description of the main purpose of the system dynamics model (e.g., policy evaluation, trade-off analysis, scenario simulation).
Priority Component(s)	Components of the WEF Nexus represented in the model (water, energy, food, or others).
Economic Representation	Details on how the economy was represented in the model: <ul style="list-style-type: none"> - Endogenous: When economic variables are modelled internally, such as GDP, consumption, investment, etc. - Exogenous: When economic variables are treated as fixed inputs or external to the model.
Software Used	Tools or software used to build the model (e.g., Vensim, Stella, AnyLogic, etc.).
Spatial Scale	The spatial level at which the model was applied (local, regional, national, global).
Temporal Scale	The temporal horizon and time resolution used in the model (e.g., annual, monthly).
Main Findings	Summary of the key results reported in the study (e.g., policy impacts, consumption trends, climate change effects, etc.).

The Zotero tool (7.0.8) was used to organise the studies and manage references, while the data extraction was performed in an Excel spreadsheet, ensuring consistency and ease of comparison across studies.

The data extraction was conducted in a structured manner, organising all the collected information in an Excel table. This table was useful for the next stages of analysis, allowing

patterns and trends in the system dynamics models applied to the WEF Nexus to be easily identified.

3. Results

This section presents the main findings of this systematic review. The data analysed, as introduced in the methodology section, were compiled following Table 2 as a guideline to ensure consistency and alignment with this study's framework, offering an overview of the aspects to be evaluated. The results are divided into three parts.

The first subsection addresses the first general objective, evaluating the overall trends in system dynamics models applied to the WEF Nexus. This includes an analysis of publication years, countries of origin, and other general trends, followed by a closer examination of the models as case studies, including their temporal and spatial scales.

The second subsection focuses on the second objective, assessing how the economy is represented in the reviewed models, whether as an exogenous force or through endogenous feedback mechanisms.

Finally, the third subsection addresses, where applicable, how the economy interacts with the energy sector within these models and explores the methodological approaches used to capture this relationship.

3.1. General Trends in WEF Nexus System Dynamics Models

The WEF Nexus framework is a relatively new concept, gaining prominence in the past decade as a response to growing concerns over resource insecurities and the need for integrated approaches to sustainability [33]. Given its novelty, the application of system dynamics modelling to analyse the Nexus is even more recent, which is both understandable and expected. Figure 3 illustrates the temporal distribution of publications in this field, showing a clear upward trend.

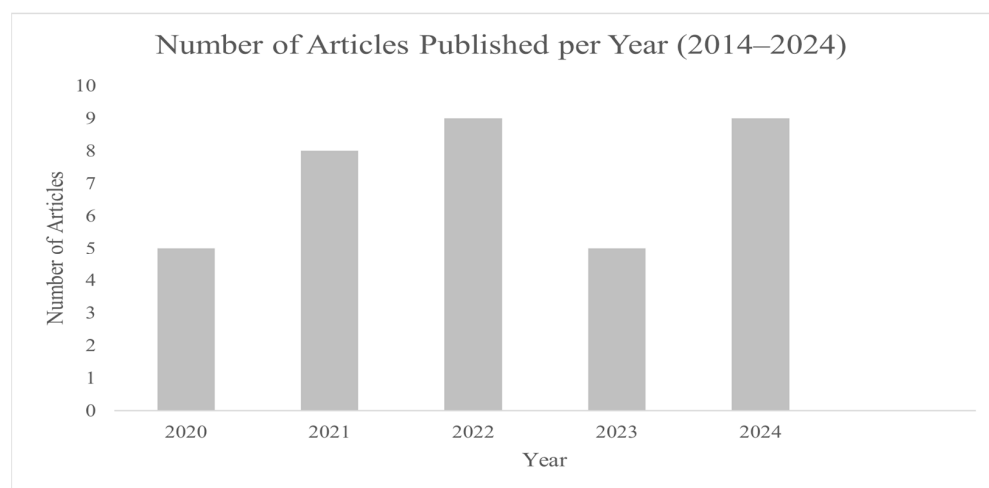


Figure 3. Number of articles published by year.

The first studies applying system dynamics to the Nexus appeared in 2020, and an increase was observed from 2021 onward. The peak years, 2021 and 2024, recorded nine publications each, indicating an expanding recognition of system dynamics as a critical tool to address the complexities of the WEF Nexus. This growth reflects the increasing academic and policy interest in leveraging dynamic models to better understand and manage interrelated resource systems.

The geographic distribution of publications, as depicted in Figure 4, highlighted a clear regional focus. China dominated with ten publications, followed by Iran with six,

showcasing their prominent engagement in applying system dynamics within the WEF Nexus framework in Asia. The Netherlands also emerged as a significant contributor with four studies, reflecting its long-standing expertise in integrated resource management in Europe. Countries such as Brazil, Greece, Malaysia, Taiwan, and the United States contributed two publications each, while Algeria, Australia, Canada, Japan, South Africa, and Sweden each accounted for one study.

Number of Publications by Country (2014–2024)

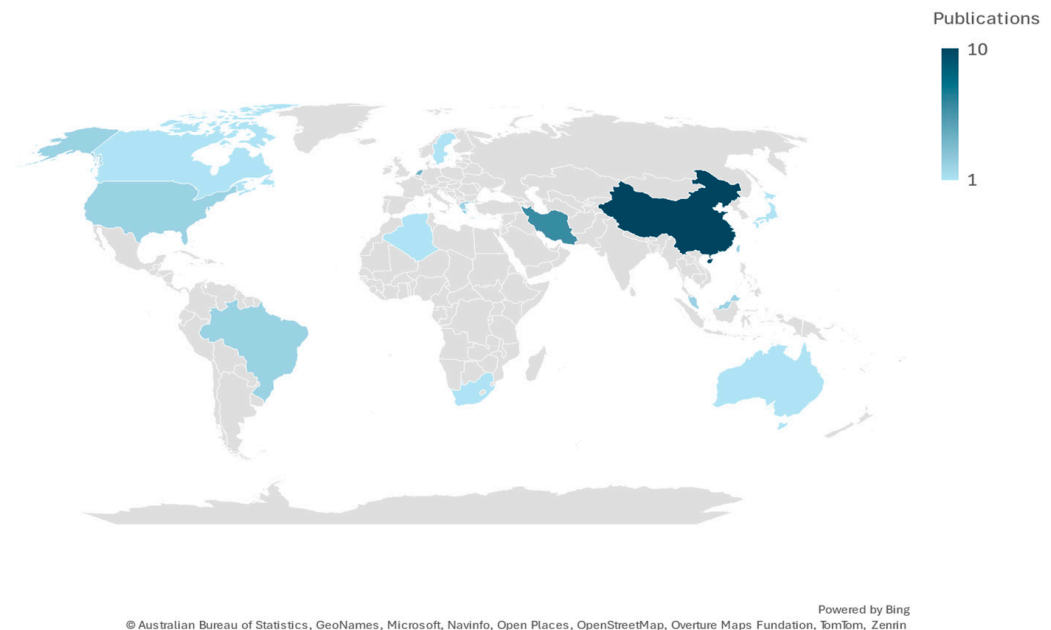


Figure 4. Number of publications by country (2014–2024). This map was created using Microsoft Excel. The source of the map base includes the Australian Bureau of Statistics, GeoNames, Microsoft, NavInfo, Open Places, OpenStreetMap, Overture Maps Foundation, TomTom, and Zenrin. The gradient represents the number of publications, with darker shades indicating higher publication counts.

This distribution reveals a strong concentration in specific regions, particularly in Asia and Europe, while regions like Africa (excluding South Africa) and Latin America (excluding Brazil) remain underrepresented. The uneven geographic coverage underscores the need to expand research efforts to underexplored regions, ensuring broader applicability of findings and addressing diverse Nexus challenges globally.

The analysis of software utilised in system dynamics modelling for the WEF Nexus highlighted a clear preference for established tools, reflecting their robustness and suitability for complex simulations.

The software Vensim (<https://vensim.com/software/> accessed on 20 December 2024) emerged as the most widely used software, adopted in 18 studies, which underscores its flexibility and capacity to model dynamic systems with high precision. Its preference was further justified by Chen and Chen [34], who emphasised Vensim’s capability to graphically illustrate system dynamics models, analyse data sets effectively, and ensure high authenticity. The authors specifically selected Vensim due to these advantages, distinguishing it from other system dynamics platforms in terms of functionality and user experience.

Stella (<https://www.iseesystems.com/store/products/stella-professional.aspx> accessed on 20 December 2024) followed as the second most popular tool, with 13 studies utilising it, reflecting its strength in visual modelling, particularly for educational and conceptual purposes. While AnyLogic (<https://www.anylogic.com/use-of-simulation/system-dynamics/> accessed on 20 December 2024), a specialised platform offering multi-

method modelling, appeared in three studies, its relatively limited adoption suggests untapped potential for more advanced and integrated analyses in the WEF Nexus field.

Regarding cost and accessibility, Vensim provides a free basic version for students, making it widely accessible for academic purposes. Similarly, AnyLogic offers a free version for educational use. Stella, however, is exclusively paid-for software, which may limit its accessibility for researchers and students with financial constraints. Additionally, two studies did not specify the software utilised, which could indicate reliance on custom-built or less mainstream tools.

The case studies and their geographical distribution, as shown in Figure 5, revealed interesting patterns and correlations with the countries of publication. China dominated not only in the number of publications (ten) but also as the most frequently analysed case study location, accounting for nine instances. This alignment underscores China's proactive role in both producing research and applying system dynamics to address its own Nexus challenges. Similarly, Iran stood out with eight case studies, closely matching its six publications, indicating a strong focus on domestic applications of the WEF Nexus framework.

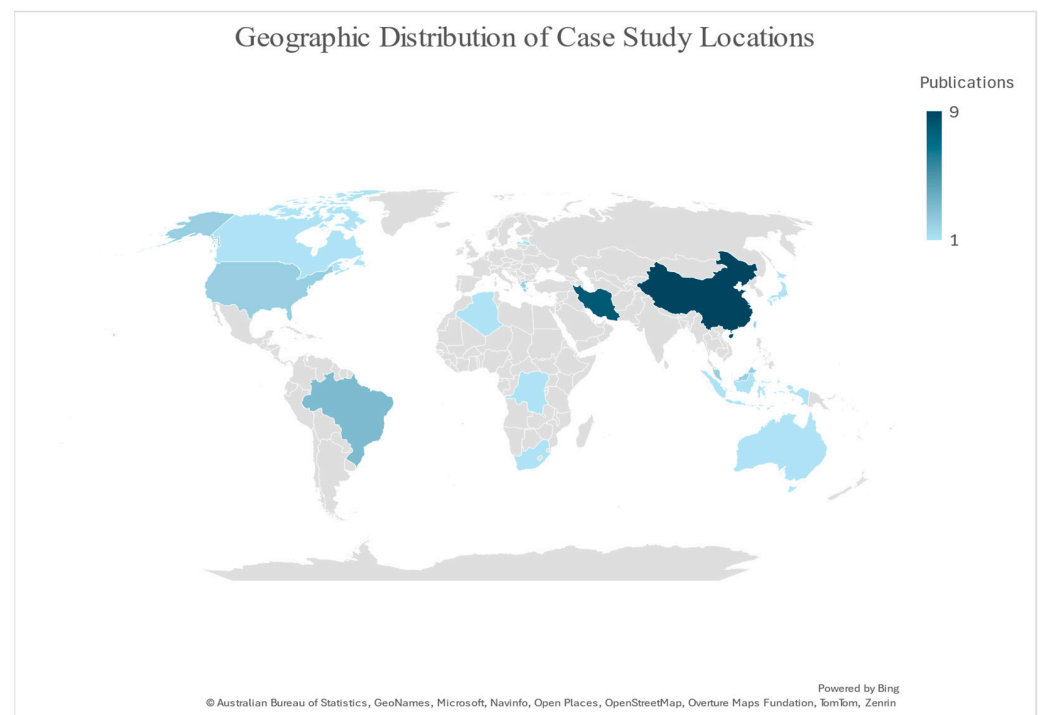


Figure 5. Geographic distribution of case study locations. This map was created using Microsoft Excel. The map base sources include the Australian Bureau of Statistics, GeoNames, Microsoft, NavInfo, Open Places, OpenStreetMap, Overture Maps Foundation, TomTom, and Zenrin. The gradient represents the number of case studies, with darker shades indicating a higher concentration of publications focused on specific locations.

Other countries like Brazil and the United States contributed two publications each but showed different patterns in case study focus. Brazil included three domestic case studies, slightly exceeding its publication count, reflecting a concerted effort to address local challenges through international collaborations. The United States, in contrast, balances its two publications with two domestic case studies, indicating a more proportional focus.

The Netherlands, despite contributing four publications, demonstrated a distinct pattern by focusing on international case studies rather than domestic applications. Dutch institutions analysed cases in Latvia, Indonesia, and the Democratic Republic of Congo, reflecting their emphasis on global collaborations and the development of transferable

methodologies. This highlights the Netherlands' role as a key player in advancing WEF Nexus research beyond its borders.

In regions with fewer publications, research tended to be more localised. For instance, South Africa, Indonesia, and Japan had case studies aligned directly with their respective contexts. The Democratic Republic of Congo was represented in a case study led by Dutch institutions, illustrating the collaborative nature of research efforts in underrepresented regions.

Conversely, countries like Greece and Malaysia showed an equal balance between their number of publications and case studies (two each), while others like Latvia and Algeria featured single case studies, reflecting limited but targeted research. Notably, Algeria was represented through a focused study on water resources, highlighting the critical resource challenges faced in arid regions.

These findings suggest a dual trend: major contributors like China and Iran demonstrate strong alignment between research outputs and domestic challenges, while countries like the Netherlands prioritise global collaborations. This pattern underscores the need for broader geographic diversification to ensure that WEF Nexus research addresses global resource challenges comprehensively.

The analysis of geographic scales highlighted a predominant focus on local-level studies, particularly at the city scale, which accounted for 13 of the reviewed publications, as seen in Figure 6. This emphasis on urban environments reflects the increasing importance of addressing WEF Nexus challenges in densely populated areas where resource interdependencies are most pronounced. At the national scale, seven studies investigated broader policy implications and systemic interactions, underscoring the relevance of Nexus approaches for large-scale resource governance.

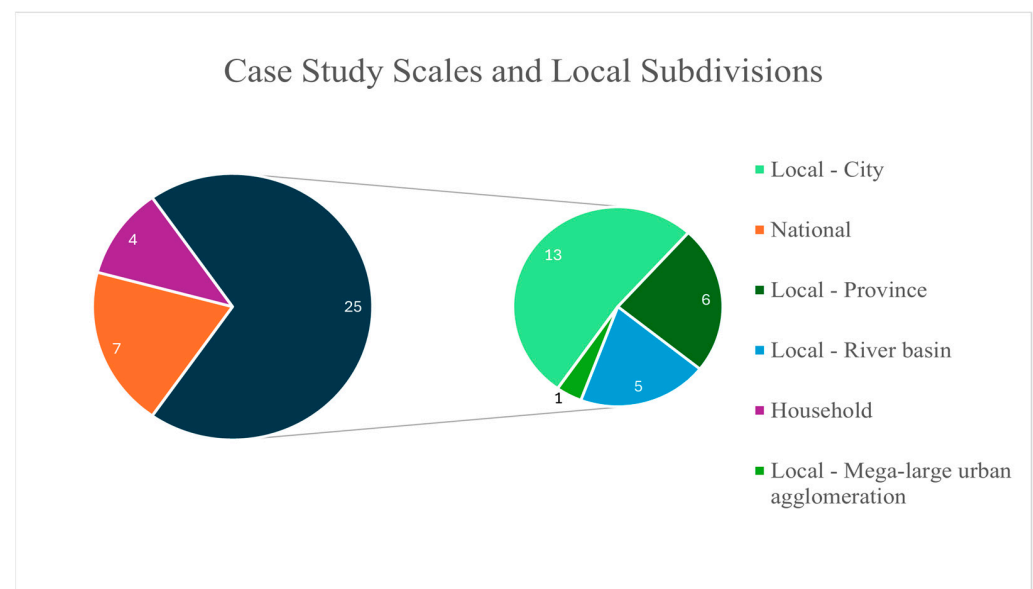


Figure 6. Case study scales and local subdivision.

At the sub-national level, six studies focused on provincial regions, while five targeted river basins, illustrating the critical need for resource management strategies tailored to specific hydrological or administrative boundaries. These studies often emphasised localised trade-offs and synergies within smaller-scale systems.

The "Others" category, comprising five studies, presented unique perspectives. Three of these focused on resource management within buildings, exploring the internal dynamics of WEF Nexus interactions in controlled environments such as urban housing or

institutional settings. Another study examined a megacity, reflecting the complexity of Nexus interdependencies at a metropolitan scale, where population density, infrastructure, and economic activities demand integrated resource management strategies.

Notably, there were no studies addressing the WEF Nexus at a global or regional/continental scale. This absence could be attributed to several factors, including the inherent complexity of modelling such expansive systems, the dominance of larger IAMs in addressing global-scale challenges, and the significant difficulties associated with obtaining and harmonising data across multiple countries and regions. These barriers highlight the potential for future research to expand into this underexplored area, leveraging advancements in data availability, computational tools, and interdisciplinary collaboration.

The temporal scale used in the models reviewed demonstrated significant variability, reflecting the diversity in research objectives and the complexity of the systems modelled. Most studies spanned a time frame of several decades, with the majority focusing on the 21st century. For instance, numerous studies analysed periods between 2000 and 2050, aligning with global sustainability agendas such as the mid-century climate action targets like the Paris Agreement, as illustrated in Figure 7.

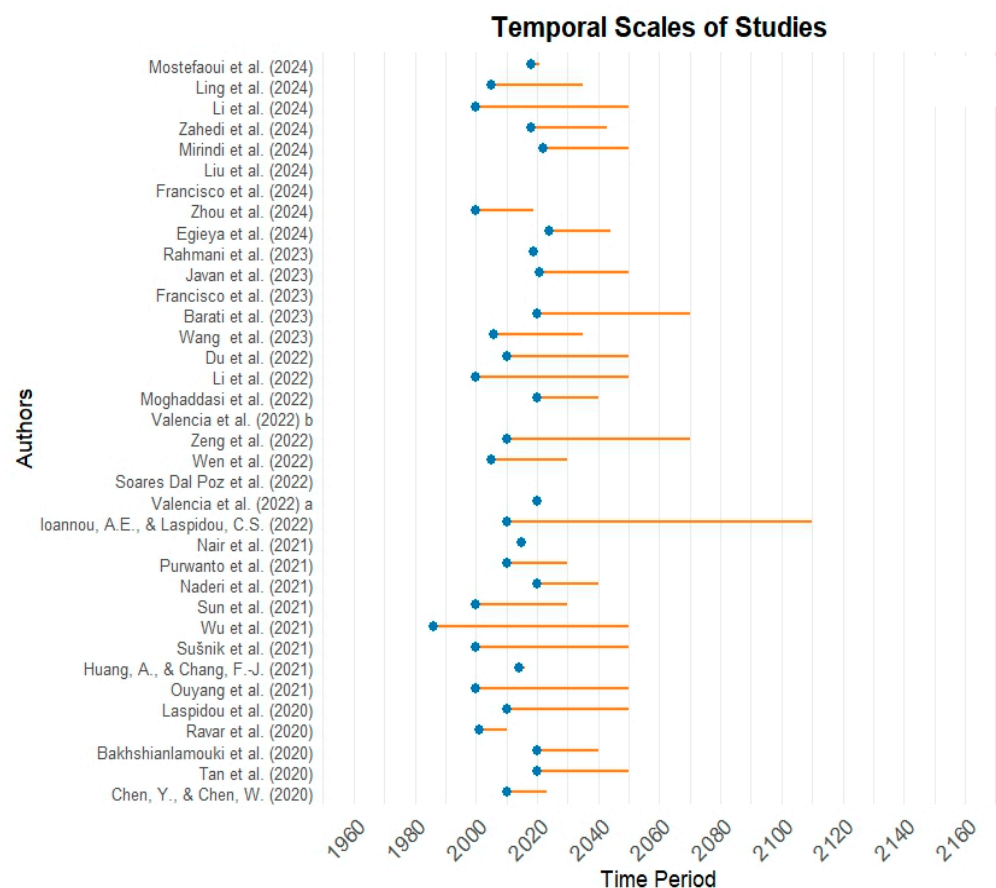


Figure 7. Temporal distribution of studies based on start year and simulation time period. The studies shown in the figure correspond to the references [34–69].

However, some studies adopted considerably shorter temporal scales, particularly those that investigated specific scenarios or localised systems. For example, three studies employed monthly or daily temporal steps to capture finer dynamics within their models, such as seasonal variations in water, energy, or food demands. Similarly, studies with annual steps aimed to provide actionable insights for medium-term planning horizons, typically spanning 20 to 30 years.

On the other hand, long-term projections were less common but noteworthy, with one study extending its temporal scale to 2110, indicating an effort to explore distant future outcomes and their implications under extreme scenarios.

Interestingly, five studies did not explicitly specify their temporal scale. These studies shared a common feature: they focused on smaller scales, with four modelling at the city level and one at the household level. In such cases, it was found more practical or appropriate to use temporal scales measured in months or days, without specifying particular years or conducting long-term simulations.

The lack of studies explicitly extending across multiple centuries or focusing on pre-2000 periods reflects the novelty of the WEF Nexus as a research framework and the focus on contemporary and future challenges. This underscores the opportunity for future research to explore more extensive temporal horizons to capture historical trends and their implications for future Nexus interactions.

The identification of predominant components within the WEF Nexus framework required a detailed examination of the studies' methodologies and outcomes. While most studies included causal loop diagrams that represented all three components—water, energy, and food—the assignment of priority to specific components was based on a thorough analysis of policies, scenarios, and results discussed in each publication.

This approach ensured that the classification reflected not just the structural representation of the Nexus but also the emphasis given by the studies to particular resource interdependencies. For instance, studies that heavily focused on water management policies or explored scenarios addressing water scarcity challenges were categorised as prioritising the water component.

Among the 36 studies analysed, Figure 8 shows that 17 publications focused on a balanced approach, addressing water, energy, and food components holistically. This represented the majority, highlighting a growing trend toward integrated WEF Nexus studies.

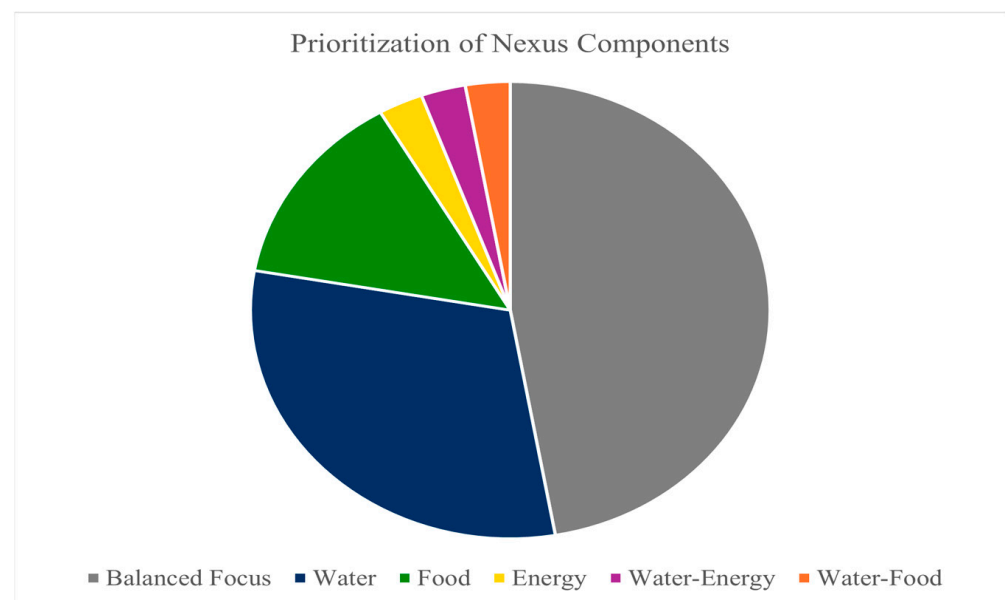


Figure 8. Prioritisation of Nexus components.

Water-focused analyses formed the second-largest category, accounting for 11 studies, emphasising the challenges of water security and resource management. Food-centric studies, although fewer, accounted for five publications, focusing primarily on sustainable agricultural practices and their interlinkages with other Nexus components.

Conversely, energy-focused research was significantly underrepresented, with only one study focusing energy-related issues. Similarly, combinations such as Water–Energy and Water–Food were rare, with just one study each. This distribution indicates a clear preference for addressing multiple components simultaneously, with individual elements receiving less isolated attention.

The balanced focus category represented efforts to integrate water, energy, and food systems, highlighting their interconnectedness and trade-offs. Studies such as that by Wang et al. [48] exemplified this approach, demonstrating in Hunan Province, China, how promoting renewable energy mitigates energy shortages while addressing water and food demands.

Valencia et al. [56] presented another example, showcasing green building retrofitting strategies in Orlando, Florida, which integrated renewable energy, rooftop farming, and water reuse to enhance urban resilience. Similarly, Zhou et al. [42] combined SDM with AI-based surrogates to optimise water, energy, and food production, achieving significant improvements in resource efficiency under optimal scenarios. These findings emphasised the importance of integrated policies for maximising resource synergies while minimising unintended trade-offs.

Water-focused studies underscored the critical importance of water security and its implications for other Nexus components. For instance, Rahmani et al. [44] analysed water stress in Iran and identified aquifer recharge and solar-powered water pumping as key strategies for mitigating groundwater depletion.

Ioannou and Laspidou [57] developed a resilience framework for Greece's water systems, demonstrating how renewable energy adoption can enhance system recovery from droughts. Similarly, Bakhshianlamouki et al. [68] examined Lake Urmia in Iran, highlighting the trade-offs between improving irrigation efficiency and the increased energy demand for groundwater abstraction. These studies reflect the urgent need for integrated water management strategies to address challenges posed by resource scarcity and climate change.

Food-focused studies explored innovative solutions for enhancing agricultural sustainability within the WEF Nexus framework. Huang and Chang [64], for example, investigated urban rooftop farming in Taipei, demonstrating its potential to enhance food security while minimising water and energy consumption. In São Paulo, Brazil, Soares Dal Poz et al. [55] compared agroecological and conventional food production systems, showing superior sustainability outcomes for the former, particularly in terms of water and carbon footprints. These findings highlight the role of alternative agricultural practices and supportive policies, such as Community-Supported Agriculture (CSA), in fostering sustainable food systems.

Energy-focused research was notably underrepresented, with only one study, conducted by Nair et al. [58]. This study analysed Malaysia's transition to renewable energy, demonstrating how increasing the share of renewables in the energy mix reduces greenhouse gas emissions, enhances energy security, and reduces dependency on imported fossil fuels. These findings highlight the potential for integrating renewable energy strategies into broader WEF Nexus frameworks.

The interactions between water and energy, as well as water and food, were explored in a limited number of studies. Sun et al. [61] analysed hydropower development in China, highlighting the role of technological progress in reducing carbon emissions while improving resource efficiency. Zahedi et al. [38] investigated water and food interactions, emphasising the importance of irrigation efficiency and crop pattern adjustments to balance resource demands and improve sustainability in Iran.

These studies collectively illustrate the diverse ways in which system dynamics modelling has been applied to understand and optimise resource interactions within

the WEF Nexus. While some emphasised sector-specific challenges, others adopted a more integrated approach to highlight synergies and trade-offs across water, energy, and food systems.

However, despite the growing attention to cross-sectoral dynamics, the role of the economy as a driver of resource demand and supply remained less explored. The following section examines how economic factors were represented in these models and, finally, how those that incorporated an economic component established its relationship with energy.

3.2. Representation of the Economy in WEF Nexus System Dynamics Models

The integration of economic variables in WEF Nexus models was uneven across the 36 studies analysed. A total of 20 studies explicitly incorporated economic factors, while 16 omitted them entirely, relying on population or other demographic variables as proxies for resource demand, as seen in Table 3. Among the studies that included the economy, 17 studies adopted an exogenous approach, where economic variables, such as GDP, were treated as external inputs.

Table 3. Overview of economic representation and energy connections.

Ref.	Authors	Economy Represented in Model (Yes/No)	How was the Economy Modelled	Economy–Energy Connection
[34]	Chen, Y., and Chen, W. (2020)	Yes	Endogenous	No clear connection
[69]	Tan et al. (2020)	No	N/A	N/A
[68]	Bakhshianlamouki et al. (2020)	No	N/A	N/A
[67]	Ravar et al. (2020)	No	N/A	N/A
[66]	Laspidou et al. (2020)	No	N/A	N/A
[65]	Ouyang et al. (2021)	Yes	Exogenous	The production in various economic sectors—primary (agriculture), secondary (industry and construction), and tertiary (services)—directly influenced energy consumption in these sectors
[64]	Huang, A., and Chang, F.-J. (2021)	No	N/A	N/A
[63]	Sušnik et al. (2021)	No	N/A	N/A
[62]	Wu et al. (2021)	Yes	Exogenous	Economic output determined energy demand
[61]	Sun et al. (2021)	Yes	Exogenous	GDP influenced electricity consumption in each economic sector (primary, secondary, and tertiary industries)
[60]	Naderi et al. (2021)	Yes	Exogenous	No clear connection
[59]	Purwanto et al. (2021)	Yes	Exogenous	No clear connection
[58]	Nair et al. (2021)	Yes	Exogenous	Economic output determined energy intensity and prices
[57]	Ioannou, A.E., and Laspidou, C.S. (2022)	No	N/A	N/A
[56]	Valencia et al. (2022)	No	N/A	N/A

Table 3. Cont.

Ref.	Authors	Economy Represented in Model (Yes/No)	How was the Economy Modelled	Economy–Energy Connection
[55]	Soares Dal Poz et al. (2022)	No	N/A	N/A
[54]	Wen et al. (2022)	Yes	Endogenous	Economic output determined energy consumption
[53]	Zeng et al. (2022)	Yes	Exogenous	No clear connection
[52]	Valencia et al. (2022)	No	N/A	N/A
[51]	Moghaddasi et al. (2022)	Yes	Endogenous	Economy and energy were related to energy prices
[50]	Li et al. (2022)	Yes	Exogenous	Economic output determined energy demand
[49]	Du et al. (2022)	No	N/A	N/A
[48]	Wang et al. (2023)	Yes	Exogenous	The economy and energy subsystems were interconnected unidirectionally, where the production levels in the primary, industry, construction, and tertiary sectors directly determined the energy consumption within these sectors
[47]	Barati et al. (2023)	No	N/A	N/A
[46]	Francisco et al. (2023)	No	N/A	N/A
[45]	Javan et al. (2023)	Yes	Exogenous	No clear connection
[44]	Rahmani et al. (2023)	Yes	Exogenous	Economic output determined energy consumption
[43]	Egieya et al. (2024)	Yes	Exogenous	Economic output determined energy demand
[42]	Zhou et al. (2024)	Yes	Exogenous	No clear connection
[41]	Francisco et al. (2024)	No	N/A	N/A
[40]	Liu et al. (2024)	No	N/A	N/A
[39]	Mirindi et al. (2024)	Yes	Exogenous	No clear connection
[38]	Zahedi et al. (2024)	Yes	Exogenous	The economy and energy were linked through the value added (VA) in the energy sector and GDP, which was used to calculate energy demand
[37]	Li et al. (2024)	Yes	Exogenous	Economic output determined energy consumption
[35]	Mostefaoui et al. (2024)	No	N/A	N/A
[36]	Ling et al. (2024)	Yes	Exogenous	Economic output determined energy demand

In some cases, GDP was influenced by growth rates, as seen in [38], while, in others, the economy was disaggregated by sectors, as demonstrated by Ouyang et al. [65]. In these studies, there was no observable feedback between the WEF Nexus and the economy, as the economic variables were not dynamically influenced by the other system components. This distinction emphasises the predominant reliance on external economic drivers and

highlights the challenges of modelling the complex interdependencies between economic activity and resource dynamics within the WEF framework.

As shown in Table 3, models that incorporated the economy as an exogenous factor primarily used it as a determinant for calculating resource demands. GDP or related metrics were often employed as static inputs to estimate the consumption of water, energy, and food, reflecting a unidirectional influence of economic factors on the WEF Nexus without feedback mechanisms.

For instance, Wu et al. [62] used exogenous GDP to estimate energy demand, while Zhou et al. [42] utilised economic growth rates to project resource demands across scenarios. Similarly, studies like that by Egieya et al. [43] relied on fixed GDP inputs to simulate demands for water, energy, and food. Although these models provided valuable insights into resource allocation and demand trends, their reliance on externally determined economic variables limited their ability to capture feedback mechanisms, such as how resource scarcity might constrain economic growth or how sectoral trade-offs might alter economic trajectories.

On the other hand, endogenous models, though less prevalent, offered a more integrative perspective by embedding economic dynamics within the system. For example, Wen et al. [44] presented a dynamic approach where GDP was calculated as the cumulative output of primary, secondary, and tertiary sectors and connected them with water and energy availabilities.

This endogenous formulation allowed the model to explore how constraints in water and energy availability can restrict sectoral growth and, consequently, overall economic performance. Similarly, Naderi et al. [60] integrated GDP as a function of value-added contributions from agricultural and energy sectors, demonstrating how resource inputs influence economic growth rates over time. These models underscored the importance of considering feedback loops between resource availability, sectoral performance, and economic growth, providing a richer understanding of the trade-offs inherent in WEF Nexus management.

Despite the advantages of endogenous approaches, they remained underutilised due to their increased complexity and data requirements. Many studies simplified economic representation to focus on resource dynamics, prioritising tractability over comprehensiveness. However, this simplification often came at the cost of overlooking critical interactions, such as how water shortages might influence agricultural output and, in turn, GDP growth. Conversely, studies like that by Wen et al. [54] highlighted the potential of endogenous models to reveal such feedback, showing, for example, how policies promoting agricultural productivity can simultaneously strain water resources and environmental sustainability.

In addition to methodological variations, significant gaps persisted in how economic dynamics were conceptualised and represented. While several studies adopted sectoral disaggregation, many failed to fully explore the interdependencies across agricultural, industrial, and service sectors, treating GDP as a monolithic entity. Moreover, few models accounted for spatial and temporal variations in economic impacts, further limiting their applicability to real-world policy scenarios. Addressing these gaps will require a concerted effort to harmonise data inputs and enhance model scalability, leveraging advances in system dynamics and computational modelling.

3.3. Economy–Energy Interlinks in the WEF Nexus System Dynamics Models

Regarding the relationship between the economy and energy, out of the 20 studies with economic representation, 13 presented a connection between economic activities and the energy sector, while 7 studies did not present a clear link. Among these 13 studies with

identified connections, the majority (9) found that economic output determined energy consumption or demand.

These studies emphasised how changes in the economic performance of various sectors influenced energy use. Additionally, two studies highlighted the role of economic output in determining energy intensity and prices, which further reinforced the relationship between economic performance and energy demand. These findings suggest that economic growth plays a significant role in shaping energy consumption patterns, reflecting the complex interplay between the two subsystems.

Notably, one study [54] not only addressed the impact of economic output on energy consumption but also explored the reverse relationship, where energy limitations could constrain GDP growth. Another study [41] linked the economy and energy through the value added (VA) in the energy sector, using GDP as a key input to calculate energy demand. This highlighted the bidirectional relationship between economic activities and energy, indicating that energy availability not only responds to economic output but also serves as a factor influencing economic growth. Overall, these studies underscored the importance of considering both the demand-side and supply-side dynamics when analysing the relationship between the economy and energy.

The representation of economic dynamics in WEF Nexus models is evolving, with a growing recognition of the need to integrate feedback mechanisms and sectoral interactions. While exogenous approaches dominate the current landscape, the increasing prevalence of endogenous models signals a shift toward capturing the complex interplay between economic growth and resource sustainability. The relationship between energy and economy in modelling is evolving, largely driven by the current needs of the energy transition.

Some models, for example, represented this relationship in a complex manner but with similar objectives, such as those by Nieto [70] and D'Alessandro [71]. In these models, not only did the economy influence energy demand dynamics but there was also feedback from energy to the economy, highlighting how the dependence on energy for economic growth is evident in the concept of scarcity. Incorporating the concept of economic scarcity from ecological economics could enrich these models further.

Economic scarcity emphasises the biophysical limits of resource availability and the unequal access to these resources, integrating both ecological constraints and socio-economic inequities [72]. Applying this perspective within the WEF Nexus could improve the understanding of systemic trade-offs and enable more equitable and sustainable policy design. Not only energy but also connections could be explored through water and food/land resources. By considering the interdependencies between these subsystems, policies could be better designed to address the complex challenges of resource management, ensuring that the balance between water, energy, and food production is optimised for long-term sustainability.

For example, resource constraints could be modelled not just as inputs but as thresholds that influence economic outputs and social well-being, aligning the Nexus framework with sustainability goals. Beyond scarcity, the connections within the WEF Nexus can be extensive and multifaceted. For instance, investments in specific sectors can directly influence GDP, with subsequent impacts on economic growth and resource demand. Additionally, calculations of jobs generated by the deployment of infrastructure within the WEF components can influence household income, thereby affecting consumption patterns and resource needs.

The way prices are modelled—such as energy, water, or food prices—can also act as a feedback mechanism, adjusting based on supply and demand or economic policies. Furthermore, increasing the complexity within economic models could aid in creating distinct growth scenarios, including degrowth or post-growth scenarios, which could

provide a better understanding of how these alternative economic pathways impact the WEF Nexus.

Such approaches offer valuable insights into how different economic trajectories, whether focused on growth, stagnation, or contraction, affect resource management, sustainability, and social welfare, ultimately enabling more informed and adaptive policymaking. Future research should aim to operationalise these concepts, ensuring that WEF Nexus models evolve into tools capable of addressing the multifaceted challenges of resource scarcity and economic development in an increasingly resource-constrained world.

4. Discussion

Although relatively recent, the WEF Nexus framework has become increasingly common in research and policy discussions. As the challenges of global sustainability become more complex, the application of modelling approaches to address these issues has increased. The literature review on WEF Nexus models shows a clear trend in the field. Specifically, system dynamics has increasingly been employed as a key methodology to model the interconnections between water, energy, and food systems. However, the literature review also shows a wide variety of methodological approaches that fall under the WEF Nexus umbrella. Models often focus on one of the three sub-modules (water, energy or food) and the representation of the other two sub-modules is rather simplified. This raises the question of whether a more precise definition and framework could enhance its clarity and practical application.

Out of the 280 articles assessed, 36 studies were chosen for inclusion in this review, with a notable geographic concentration in Asia, which accounted for most publications. The models in these studies were spatially divided, with a significant portion focused on local scales, as illustrated in the spatial distribution graph. Regarding the thematic focus, the predominant area of interest was the balanced focus of the Nexus, with water often being the most studied component.

Despite this, there remains considerable potential for further research, particularly in regions facing higher pressures, such as southern Europe, Latin America, and parts of Africa. Moreover, there is a noticeable gap in national, regional, and even global case studies, highlighting the need for more comprehensive approaches that address the complex interactions within the WEF Nexus at broader scales.

Out of the 36 studies reviewed, more than half (20) included the economy as a key component, highlighting a clear trend in the literature. This reinforces the idea that the economy plays an important role within the WEF Nexus, driving the way resources are managed and used.

In most of the works analysed, the economy was modelled exogenously, with economic variables, such as GDP, treated as fixed inputs. This approach reflects the use of external economic data or growth rates to drive the model's behaviour, rather than integrating economic variables endogenously within the system. This exogenous modelling approach was prevalent, particularly in studies that focused on the impact of economic growth on resource demand.

However, there were also a few studies that attempted to model the economy endogenously, where economic variables were influenced by the dynamics of other system components, such as energy and water. Despite this, many models lacked explicit feedback loops between the economy and other subsystems, limiting the depth of understanding regarding how changes in one subsystem—such as energy availability—might impact economic performance.

Regarding the relationship between energy and the economy, it was primarily analysed through energy demand and consumption. As economic output increased, particularly in

the primary, secondary, and tertiary sectors, energy consumption changed, reflecting the direct dependence of economic activities on energy resources.

As highlighted earlier, the concept of the WEF Nexus is relatively new, and the use of acronyms has been evolving in innovative ways. A key limitation of this study is the inability to comprehensively identify all acronyms currently in use, which may have led to the exclusion of recent studies employing novel terminologies. Additionally, the lack of access to the codes or complete datasets of the analysed models represents another limitation. By relying solely on published articles, certain information embedded within the models but not explicitly documented in the articles may have been overlooked, potentially affecting the depth of the analysis.

Looking ahead, there are several important steps to improve the integration of the economy within the WEF Nexus. First, future models should move toward a more endogenous representation of the economy, where economic variables are influenced by interactions with other subsystems, such as energy, water, and food.

This shift could provide a more dynamic and accurate representation of how changes in resource availability impact economic performance and vice versa. Additionally, incorporating feedback loops between economic growth and energy consumption could help model more realistic scenarios, particularly in regions facing energy constraints or those undergoing transitions to low-carbon economies.

Beyond improving the theoretical representation of economic interactions within the WEF Nexus, these findings have significant policy implications. The predominance of exogenous economic modelling in existing studies suggests that current approaches may overlook critical feedback mechanisms between economic policies and resource availability. Moving toward a more endogenous integration of the economy in WEF models would allow policymakers to better anticipate the effects of economic fluctuations on resource consumption and vice versa.

This is particularly relevant for energy transition policies, where changes in energy pricing, subsidies, or infrastructure investments can have cascading effects on food and water systems. Additionally, incorporating alternative economic pathways, such as post-growth and degrowth scenarios, could help decision-makers explore sustainable long-term strategies for resource management beyond conventional economic expansion models.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/en18040966/s1>: Table S1: Summary of Data Extracted for the Systematic Review.

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