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Book of Abstracts

Building Resilience to Global Challenges

International Conference on the Water-Energy-Food Nexus for a low-carbon Economy in Europe & beyond
Brussels, Belgium, 04.06.2025

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BUILDING RESILIENCE TO GLOBAL CHALLENGES

Book of Abstracts of the International Conference on the Water-Energy-Food Nexus for a low-carbon Economy in Europe & beyond

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Preface

Launched in 2021, the COST Action Network on the Water-Energy-Food Nexus for a Low-Carbon Economy in Europe and Beyond (NexusNet, CA20138) set out to build a transdisciplinary platform to better understand and operationalize the Nexus approach across Europe and internationally. The Action's overarching aim has been to synthesize empirical knowledge, foster integrated resource management, and provide intellectual and methodological tools that link scientific evidence with governance and policymaking for sustainability. By doing so, the NexusNet has sought to support the transition towards a circular and low-carbon economy, strengthen resilience to global challenges, and advance coherence across water, energy, food, and ecosystem domains.

Over its four years of implementation, the NexusNet has established itself as a dynamic hub of collaboration and knowledge exchange. Through its working groups, geographical focus groups, training schools, mentoring programs, and diverse funding opportunities, it enabled cross-sectoral learning and created opportunities for early career researchers to engage with senior experts. A rich portfolio of case studies and methodological developments has been generated, alongside scientific publications, policy briefs, and living documents that illustrate the complexity of the Nexus interlinkages while providing actionable guidance. Collectively, these achievements demonstrate how the Action has contributed to bridging science, policy, and practice.

The International Conference "Water-Energy-Food Nexus for a Low-Carbon Economy in Europe & Beyond: Building Resilience to Global Challenges", held in Brussels on 4 June 2025 as an EU Green Week Partner Event, represents the culmination of this journey. The Conference aimed at highlighting the breadth of research and applications that emerged through the NexusNet and at gathering scientists, policymakers, practitioners, innovators, and early career researchers in a dialogue that not only reflected on the NexusNet's results but also set the stage for future collaboration and the advancement of the Nexus approach.

This publication contains the abstracts of a wide array of contributions presented during the Brussels Conference. The book is organized into 5 chapters, each covering aspects of the following thematic tracks:

- Methodological foundations of WEF Nexus
- Governance, policy and institutional challenges
- Data, tools, and modelling for Nexus analysis
- Economic and financial perspectives
- Environmental protection management
- Social dimensions and equity
- Sustainable waste management
- WEF Nexus and climate crisis
- Climate-neutral transition of systems and social innovation
- Water-Energy-Food-Ecosystems Nexus planning under extreme events
- Urban resilience and circular economy
- Renewable and clean energy solutions

Addressing important developments, achievements, and best practices in the Nexus approach, this book serves as a testimony that integrated, systems-based thinking has evolved from being merely a useful option to becoming an indispensable necessity for safeguarding a more resilient future for the planet.

With deep appreciation for the authors, reviewers, committees, and all participants who have made this possible, we emphasize that the success of NexusNet lies not only in the knowledge produced but also in the vibrant community it has created. We trust that this publication will inspire continued innovation and dialogue, strengthening the application of the Nexus approach to address the pressing sustainability challenges of our time.

December 2025

Chrysi Laspidou
Floor Brouwer
Giannis Adamos

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CHAPTER I

MODELLING THE NEXUS

A Quantitative Framework for Assessing the WEFE Nexus: Indicator Harmonization and Policy Integration for Climate Resilience in the EU

Mohammed Assaf[1], Abdelrahman Habash[2], Vladimir Kitanovski[3], Nikolaos Mellios[4], Chrysaida-Aliki Papadopoulou[5], Milena Rajić[6], Virginia Rosa Coletta[7], Maria Vrachioli[8]*

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Abstract

This study introduces a quantitative framework to assess the interlinkages within the Water-Energy-Food-Ecosystems (WEFE) Nexus, with a focus on climate resilience and cross-sectoral policy relevance in the European Union. More than 80 datasets have been identified and harmonized to capture Nexus-relevant metrics and indicators. To enable comparability across EU Member States, all indicators are standardized on a per capita basis using two normalization methods: min-max normalization and Z-score standardization. These techniques provide a consistent basis for identifying efficiency thresholds, resilience hotspots, and sectoral trade-offs. In addition to normalization, correlation analysis and scenario modelling are employed to highlight interdependencies and potential synergies across sectors. A review of existing modelling approaches (including system dynamics and integrated assessment models) reveals gaps in representing complex sectoral interactions and managing uncertainty under climate extremes. Finally, a compilation of EU-level policies across water, energy, food, land, and ecosystem sectors is

conducted. The policy layer is analysed to detect governance gaps, institutional overlaps, and areas for better integration, bridging scientific insights with actionable policy guidance. This integrative approach aims to inform coherent, adaptive governance strategies aligned with Sustainable Development Goals.

Keywords: *WEFE Nexus; indicator harmonization; climate resilience; policy integration; EU governance.*

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A Risk-Informed Modelling Framework of the Water-Energy-Food Nexus for Water Resources Management

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Abstract

Integrated management of surface and groundwater resources is vital for enhancing resilience in agricultural systems, especially under conditions of increasing resource stress and climate variability. This study introduces a comprehensive modelling framework that advances Water-Energy-Food (WEF) Nexus analysis through a risk-based, scenario-driven approach. At its core, the framework employs a hybrid Bayesian Network to model probabilistic dependencies among key water, food, energy, and risk indicators, allowing for robust representation of system dynamics and uncertainty.

To evaluate irrigation operation strategies, a composite Nexus indicator was developed using a multi-criteria decision-making approach, incorporating expert judgment and empirical data across economic, technical, and environmental dimensions. This enabled a comparative assessment of alternative operational scenarios ranging from traditional to automated control systems, under both normal and water-shortage conditions.

The framework supports decision-making by identifying trade-offs and synergies between performance, risk exposure, and resource sustainability. Its application to an agricultural district in Iran facing acute water stress demonstrated how integrated modelling can inform

modernization choices that enhance equity, reduce groundwater dependence, and improve overall system efficiency.
By combining risk assessment, scenario analysis, and Machine Learning, this work provides a novel methodological contribution to WEF Nexus studies. It offers a practical and adaptable tool for supporting evidence-based decisions in water resources management, particularly in settings that demand integrated surface and groundwater planning, risk-informed operations, and Nexus-aligned policy development.

Keywords: *WEF Nexus, Risk Modelling; Water Management; Bayesian Network.*

Acknowledgments: *Part of this publication is based upon work from the COST Action <CA20138: Network on water-energy-food nexus for a low-carbon economy in Europe and beyond – NEXUSNET>, supported by COST (European Cooperation in Science and Technology).*

A Nexus Approach to Assessing Anthropogenic Impact: Integrating Soil Invertebrate Diversity and Space Syntax in Urban Parks

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Abstract

This work highlights the interdisciplinary collaboration between the Faculty of Science and the Faculty of Architecture at the University of Zagreb, Croatia, focusing on urban ecology in public spaces. It presents findings from a study on soil biodiversity in urban parks in Zagreb, specifically along major park promenades. The research introduces a novel methodological approach by applying space syntax tools to assess anthropogenic impacts on soil invertebrate communities.

The study aimed to examine invertebrate distribution in relation to human movement corridors, considering key soil properties and space syntax metrics, and to assess the potential of combining soil biodiversity and spatial configuration data as indicators of pedestrian intensity and its ecological impacts. Two contrasting urban parks were examined: the historical Maksimir Park, with its baroque allée, and the modern recreational area of Lake Jarun, characterized by a circular walkway. Soil biodiversity was assessed at four locations (two per park), with samples collected at three distances (10 m, 20 m, and 30 m) perpendicular to the main walkways, resulting in 12 sampling points. Biological measurements were conducted three times over a 50-day period. Soil physico-chemical parameters (pH, humidity, texture, temperature, and organic matter) were statistically analysed alongside space syntax metrics (integration,

connectivity, choice, and entropy), derived from axial and segment analyses of a spatial model of Zagreb including Maksimir and Jarun.
Results indicate that invertebrate abundance and diversity increased with distance from main human movement corridors. While some correlations with space syntax metrics were found, higher integration values did not consistently correspond to reduced diversity. The combined analysis of biological and spatial data proved effective in indicating urban anthropogenic impact and its ecological impact. Overall, space syntax emerges as a valuable proxy for quantifying human influence on biodiversity patterns in urban environments.

Keywords: *Urbanisation; urban resilience; community structure; pedestrian corridors; land use.*

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Optimizing Water-Energy-Food-Ecosystem Trade-offs in the Mediterranean: A Multi-level Approach

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Abstract

In the Mediterranean, rising demands for energy, food, water, alongside decreasing freshwater availability, threaten food security. This study, part of the PRIMA-funded AWESOME project, aims to mitigate these issues by creating a decision-analytic platform to optimize WEFE trade-offs and synergies from local to regional levels. The platform models the impacts of different WEFE strategies, including regional policies, river basin planning, and innovative technologies.

The research employs a multi-level, case-study methodology to analyse the WEFE Nexus at three levels: macro (Mediterranean), meso (river basin), and micro (demonstration sites). At the macro level, it examines the processes and policies affecting critical resources and ecosystem services. The meso level involves strategic planning and testing soilless agriculture methods like hydroponics and aquaponics. The micro level focuses on detailed technological solutions for water and food production. This paper explores the use of the MAWGs as a participatory approach towards investigating interconnected WEFE nexus challenges in the context of the Mediterranean and the potential for soilless technologies as an adaptive strategy. The paper examines key factors including climate

change, ecosystem services, food security, hydropower dams, and policy frameworks promoting synergistic irrigation and storage. The paper presents crucial challenges including water scarcity, climate change, management practices, ecosystem stress, political conflicts, and rising energy costs, while adopting a systems approach towards identifying emergent opportunities which leverage innovative and synergistic solutions.

Finally, the paper explores the policy implications of the findings drawn from the preceding analysis and the potential for novel management, capacity development and financing strategies to bridge the gap between these challenges and opportunities effectively.

Keywords: *Food security; water-energy-food-ecosystem (WEFE) trade-offs; system approaches; stakeholder engagement; living labs.*

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Embedding Marine Ecosystem Services in the WEFE Nexus: A Mediterranean Framework for Integrated Resource Management

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Abstract

The Water-Energy-Food-Ecosystem (WEFE) nexus provides a valuable lens for integrated resource management, yet its application in marine systems remains underdeveloped. This study seeks to contribute to filling this gap by suggesting a marine-specific nexus framework centred on ecosystem services, with a geographic focus on the Mediterranean Basin, a region marked by intense anthropogenic pressures and ecological value.

Rather than viewing the sea as an external stressor, our approach positions marine systems as active components within nexus interlinkages. Marine ecosystem services (MES), including fisheries, aquaculture, climate regulation, nutrient cycling, and habitat provisioning are treated as dynamic connectors linking water, energy, food, and ecosystem domains. Through conceptual synthesis and mapping exercise, these services are translated into quantifiable interlinkages using Earth Observation proxies such as sea surface temperature, chlorophyll-a, salinity, net primary productivity, and coastal erosion indicators.

Graph theory is applied to represent and analyse these connections, identifying critical nodes and pathways that structure interdependencies. The framework is complemented by a policy overlay that matches MES hotspots with the presence or absence of relevant policy instruments (e.g.,

MSFD, WFD, CFP), allowing for the classification of areas into action and opportunity zones.

This nexus-based MES framework enables a systemic understanding of marine interlinkages, supports spatially targeted interventions, and promotes policy coherence across marine resource sectors. The approach contributes to advancing sustainable planning in marine and coastal environments by embedding ecological functions at the core of nexus thinking.

Keywords: *Ecosystem; marine; coastal; nexus.*

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CHAPTER II

APPLICATIONS OF THE NEXUS IN REAL WORLD

Understanding Nexus Interlinkages in Extreme Events: A Task Force Initiative Towards Resilience

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Abstract

This NEXUSNET task force investigates the way in which nine types of extreme events—floods, droughts, wildfires, earthquakes, tsunamis, volcanic eruptions, heatwaves, tornadoes, and landslides—disrupt interconnected systems through cascading Nexus effects. Using over thirty case studies from Europe and beyond, we apply the Nexus Tree methodology to analyse interlinkages across eleven Nexus dimensions: Water, Energy, Food, Ecosystems, Health, Climate, Soil, Land Use, Transport, and Information and Communication Technology (ICT).

For each case, a literature review on nexus implications across all dimensions is conducted, including grey literature. The extent and depth of disruptions are mapped across different timeframes (short-, medium-, and long-term). For example, flood events damage ecosystems through sedimentation and contamination, interrupt food supply by inundating agricultural land, disrupt transport through debris flow, washed-out roads and bridges, disable ICT networks due to infrastructure exposure, and pose serious health risks through the spread of waterborne diseases and reduced access to clean water and healthcare services. Each of these implications triggers a series of cascading effects that multiply risk exposure. Such Nexus implications highlight systemic vulnerabilities extending beyond direct physical damage.

We synthesize findings into a Nexus Interlinkage Matrix generating a distinct Nexus Signature for each extreme event type and identify decoupling strategies across operational, tactical, and strategic levels.

Systemic and transformative approaches such as Nature-based Solutions (NbS) and circular economy strategies are increasingly recognized as effective long-term measures for enhancing resilience. Indicative examples include wetland restoration, which buffers floodwaters and supports biodiversity, and the reuse of treated urban wastewater for agricultural irrigation, which contributes to drought mitigation. These practices illustrate the potential of integrated resource management to address multiple Nexus challenges simultaneously.
This work delivers a robust analytical framework for understanding the multisectoral impacts of extreme events, supporting evidence-based resilience planning in alignment with the Sustainable Development Goals and the One Health Framework.

Keywords: *Extreme events; natural hazards; Nexus implications; resilience; Nature-based Solutions.*

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Contributions: *Dimitris Kofinas and Cevza Melek Kazezyılmaz-Alhan coordinate the task force. Dimitris Kofinas, Cevza Melek Kazezyılmaz-Alhan, Giannis Adamos, Serena Caucci, and Tamara Radjenovic co-develop the overarching methodological framework. Tamara Radjenovic, Dijana Likar, Jairo Guzman, Müge Akın, Kaan Ilker Demirezen, Georgios Alexandros Chatzistefanou, Giannis Adamos, Monika Suskevics, and Rocío Pineda-Martos with Violeta Vasilić lead the flood, drought, wildfire, earthquake, tsunami, volcano, heatwave, tornado, and landslide subgroups, respectively. Chrysi Laspidou and Stefania Munaretto contribute to scientific coordination and provide oversight of the project's outcomes. All authors are involved in multiple subgroups. Part of the investigators' efforts is voluntary.*

WEFE Nexus Interlinkages of Tsunami-Type Natural Hazards: Case Studies in the Aegean and Marmara Sea, and Baffin Bay

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Abstract

The aim of this study is to understand and evaluate the WEFE Nexus interlinkages related to tsunami-type natural hazards incorporating the Nexus dimensions of Water, Energy, Food, Ecosystems, Climate, Soil, Land Use, Health, Transport, and Information and Communication Technology (ICT). The Nexus tree approach is employed in analyzing the case studies of three tsunami events. The case studies are selected based on the location and the triggering mechanism. İzmit tsunami occurred in 1999 in Marmara Sea due to the Izmit Earthquake; Samos tsunami occurred in 2020 in Aegean Sea due to the Samos earthquake; and Karrat Fjord tsunami occurred in 2017 due to the landslide to Karrat Isfjord. To develop the nexus interlinkage matrix for tsunamis, the implications of interlinkages are determined according to the short-term, mid-term and long-term time scales for each case study. Then, the synthesis of the interlinkages of all case studies are performed to determine the common nexus interlinkages

among the case studies. Finally, an inventory of recommendations for decoupling the interlinkages is developed under the categories of operational, tactical, and strategic levels. Analyses of the three tsunami events show that tsunamis impact Water-Transport, Water-Soil, Water-Health, Water-Food, Water-Energy and Water-Ecosystem Interlinkages significantly. Both the ports and coastal roads are severely damaged and inundated with flood waters resulting in major disruptions in sea and ground transportation. Moreover, enormous amounts of debris flow and sediment transport are observed during tsunamis, disturbing the soil cover and causing erosion and deposition in the seabed, which negatively affect biodiversity and the ecosystem. Implementation of coastal forest as Nature-based Solutions (NBS) to control tsunami sediment movement and construction of barrier structures such as breakwaters and seawalls, coastal dike, water gates to block the tsunami are among the featured recommendations as effective long-term measures.

Keywords: *Tsunami; natural hazards; Nexus tree; Nexus interlinkages; Nature-based solutions.*

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Integrating Transportation and Disaster Risk Management to the WEFE Nexus through a Systems Thinking Approach

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Abstract

In the face of escalating global challenges and the impacts of climate crisis, the integration of the Water-Energy-Food-Ecosystems (WEFE) Nexus with Disaster Risk Management (DRM) and Transportation is increasingly critical for enhancing urban resilience and promoting sustainable development. The WEFE Nexus has advanced the understanding of cross-sectoral interdependencies and resource optimization, with literature pointing towards the incorporation of DRM and Transportation to the WEFE Nexus without, however, providing a clear conceptual basis. Regarding the latter, even though its disruption can propagate cascading impacts, amplifying vulnerabilities and significantly impeding DRM processes, the integration of transportation to WEFE Nexus research and planning has not yet been systematically explored. Through a systematic literature review and synthesis of existing WEFE-DRM intersections, this study reveals substantial gaps in current frameworks, particularly the lack of transportation integration within WEFE Nexus-aligned urban strategies. Specific shortcomings include weak cross-sectoral coordination, fragmented governance, and limited consideration of infrastructure resilience. Our analysis underscores the necessity of adopting a systems thinking approach that recognizes transportation as both a facilitator of infrastructural interconnections within the WEFE Nexus and a determinant of resilience. This study proposes the identification and categorization of transport-related indicators relevant to resilience within this context. Additionally, it integrates socio-cultural dimensions, equity considerations, and behavioural insights as essential components in shaping inclusive, and

climate-resilient urban systems. In doing so, this study advocates for a paradigm shift in Nexus thinking from isolated sectoral optimization to holistic, interconnected systems planning. In this sense, transportation is positioned as a strategic component in co-designing resilient, equitable, and sustainable urban futures aligned with the Sustainable Development Goals.

Keywords: *Adaptive transportation systems; climate crisis; disaster risk management; infrastructure resilience.*

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Integrating Circular Economy and the WEF Nexus: A Structured Review of Concepts, Synergies, and Gaps

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Abstract

Linking Circular Economy (CE) principles with the Water-Energy-Food (WEF) Nexus offers transformative potential for achieving sustainability, enhancing system resilience, and fostering integrated resource governance. This study presents a structured review of how CE-WEF integration is addressed in peer-reviewed literature, identifying conceptual synergies, analytical gaps, and strategic opportunities.

Using a targeted search strategy across the Web of Science, Scopus, and ScienceDirect, we identified 164 relevant articles published between 2000 and 2025. Following a two-stage selection process, 57 studies were fully reviewed, including 8 recommended by experts. Each was assessed against 14 review criteria spanning six thematic areas: conceptual

foundation, integration rationale, methodological design, sectoral scope, indicator use, and policy relevance.

Our analysis reveals that, while CE and WEF are individually well-defined, their integration is often implicit, fragmented, or conceptually underdeveloped. Few studies articulate a clear rationale for CE-WEF integration or provide operational frameworks. While various methods such as LCA and MFA are applied, innovation and transparency remain inconsistent. Most studies focus on water-energy dynamics, with food systems and cross-sector circularity underexplored. Moreover, the use of measurable indicators and system-wide metrics is limited, and policy discussions tend to be general rather than action-oriented.

We conclude that advancing CE-WEF integration requires clearer conceptual models, harmonized assessment methods, and stronger alignment between research, policy, and practice. This review forms part of a broader collaborative effort that also includes structured case study analyses, aimed at producing a peer-reviewed open access publication to support integrated resource management and policy coherence.

Keywords: *Circular Economy; WEF Nexus; Sustainability indicators; Resource governance.*

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The role of "nature" in the Water-Energy-Food Nexus: insights from an interdisciplinary process of knowledge creation

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Abstract

Integrated approaches to managing natural resources are increasingly needed in a complex and interconnected world to meet growing demands for water, energy, and food, while preserving ecosystem integrity and promoting equitable access to resources. One such approach is the Water-Energy-Food (WEF) Nexus, which offers a cross-sectoral framework to navigate trade-offs and leverage synergies across interlinked sectors. Although ecosystems were not originally considered a formal component of the Nexus, their vital role in supporting water, energy, and food systems -and in regulating the interactions between them- is gaining recognition among Nexus scholars and practitioners. To review and discuss existing efforts that integrate ecosystems into the WEF Nexus, we -a multidisciplinary team of natural resource management researchers and systems thinkers from the European network NEXUSNET COST Action- undertook a collaborative process of knowledge creation.

Researchers from both the Nexus and Ecosystems community were involved in literature analysis, expert elicitation during workshops, and collaborative writing. Our analysis revealed a wide range of concepts used in the literature to represent "nature" within the Nexus, including terms like "environment," "ecosystems," "ecosystem services," and "biodiversity." Three main conceptual paradigms on the role of "nature" in the Nexus were also isolated: (i) ecosystems as a fourth component of the Nexus, i.e., the Water-Energy-Food-Ecosystems (WEFE) Nexus; (ii) ecosystems as the foundational layer underpinning the Nexus; and (iii) the WEF Nexus as a central component of social-ecological systems (SES).

We put forward a WEFE Nexus hybrid paradigm that expands the mutual interlinkages among water, energy and food to the entirety of SES, thus acknowledging the social-ecological processes that are affected by and affect the WEF Nexus. The hybrid paradigm represents a piece of common and integrated knowledge that has emerged from the sharing of individual viewpoints and mental models, ultimately providing researchers with means to better understand the WEFE Nexus.

Keywords: *Ecosystems; Interdisciplinarity; WEFE Nexus; Natural resources management; Social-ecological systems.*

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A systematic mapping approach to represent and analyse the Water-Energy-Food Nexus interlinkages for sustainable planning

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Abstract

In recent years, there has been a growing area of research centred on the Water-Energy-Food (WEF) Nexus, which highlights the need to study the interdependences between water, energy, and food components. This integrated approach is crucial for understanding how actions or policies in one component can impact others either positively or negatively. Such insights are vital for designing strategies that are not only sustainable but also resilient to climate change.

However, a major challenge in the field is the lack of standardization. Researchers often use different frameworks, methodologies, and terminologies, making it difficult to compare, build upon, or replicate studies. This fragmentation limits progress and undermines the potential of WEF Nexus research to guide real-world solutions.

Under this perspective, the current work focuses on developing a unified conceptual and semantic framework for describing the main components and relationships within the WEF Nexus. The objective is to provide a solid baseline for the description of the WEF Nexus approach that can be adopted by interdisciplinary scientists and support the modelling and analysis of complex socio-environmental systems (SES). We provide a graph-based representation of these concepts based on a labelled property graph. This method allows us to visually and semantically map

out the key entities (like water resources, energy infrastructure, food systems) and the interconnections between them (e.g. water needed for energy production, energy used for agriculture, etc.). Following the provided representation, we detail specific examples for the representation of SES models, based on case studies for the development of climate-resilient regions in Greece.

Keywords: *Nexus; components; ontology; semantics; entities.*

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CHAPTER III

POLICY IMPLICATIONS OF THE NEXUS IN EUROPE AND BEYOND

Bridging Policy and Practice in WEF+ Nexus Projects in Europe: Towards More Effective Impact Indicators

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Abstract

This work discusses how to increase the real-world impact of Water-Energy-Food (WEF) Nexus Projects (NPs), focusing on the broader WEF+ dimensions including Climate, Land Use, and Biodiversity. Although the European WEF+ Nexus approach promotes holistic and policy-oriented frameworks, its practical implementation is often constrained by fragmented regulations and policy incoherence. This misalignment limits the integration of WEF+ NPs with the SDGs and hinders their long-term sustainability and societal relevance. Based on a survey of more than 50 European Nexus experts, we identified key factors influencing the impact of WEF+ NPs, including their current status, impact dimensions and indicators, and existing challenges and opportunities. Key barriers highlighted include limited understanding of the Nexus approach, gaps in impact measurement, insufficient policy implementation and resistance to systemic change. The experts proposed specific impact indicators and

actionable recommendations, emphasizing the need for greater cross-sectoral collaboration, integrating WEF+ principles into policy and education, and securing sustainable financial resources. This presentation invites WEF+ Nexus experts to actively reflect on and refine the proposed indicators and recommendations, especially in terms of sustainability of impact beyond the project duration. Through this interactive discussion, we aim to co-develop improved impact indicators and strategies that better reflect the complexity and transformative potential of WEF+NPs in Europe.

Keywords: *Cross-sectoral collaboration; impact assessment; policy coherence; experts; resource management.*

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Integrating Intersections of Climate Resilience and School Education for Holistic Sustainable Development: Insights from Bangladesh

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Abstract

This research examines the complex relationship between climate resilience and school education in Bangladesh, a disaster-prone country in South Asia. The study employs a mixed-methods approach, combining geospatial analysis of student-teacher ratios from 2021-2023 with thematic analyses of documentaries and stakeholder interviews. It explores how inequities in education facility distribution, measured by student-teacher ratios, can hinder disaster risk reduction, and emphasizes the need for multi-stakeholder interventions in areas with limited access to education. The research highlights Bangladesh's vulnerability to climate disasters, ranking 15th out of 163 countries in the Children's Climate Risk Index, and investigates the feedback mechanism between climate resilience and school education. It is anchored to the hypothesis that reduced vulnerabilities due to poverty reduction and increased educational access can result in improved community-based adaptation to climate hazards. The study's objectives include understanding the distribution of education facilities across Bangladesh, observing changes in student and teacher distribution between 2021 and 2023, exploring the role of school education in building adaptive capacities, examining the importance of climate resilience in ensuring educational access, and analysing the challenges faced by vulnerable communities. The methodology involves geospatial analysis using QGIS software, documentary analysis, and semi-structured stakeholder interviews. By triangulating these methods, we provide insights into evidence-based policy implications and contribute to the

existing literature on this topic by offering reflections into the dynamics between climate resilience and education aiming to inform actionable solutions for advocating children's rights and community empowerment in climate-vulnerable countries and regions.

Keywords: *Climate resilience; social justice; equity; intersectionality; community-based adaptation.*

Acknowledgments: *This work is adapted from the master's thesis "Assessing the Interplay Between School Education and Climate Resilience in Flood-prone Areas of Bangladesh" as part of the United Nations University-Climate Resilience Initiative (UNU-CRI) Thesis Project at UNU-MERIT for the master's program in Public Policy and Human Development by Shuddha Srimoyee Das with thesis supervisor Dr. Nidhi Nagabhatla.*

Enhancing Policy Coherence in the WEF Nexus: Opportunities for Integrated Governance in the Republic of Croatia

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Abstract

Effective governance of the Water-Energy-Food (WEF) Nexus requires coherent policy frameworks that balance trade-offs, enhance synergies, and ensure the long-term sustainability and security of critical resources. A lack of policy coherence within this nexus can lead to systemic inefficiencies, misaligned strategies, and increased socio-economic vulnerabilities. Within the WEF Nexus context, policy coherence encompasses the alignment of regulatory frameworks, institutional coordination mechanisms, and harmonized decision-making processes across sectors. In the Republic of Croatia, water resources are relatively abundant but unevenly distributed across regions. Simultaneously, agriculture and energy production represent essential pillars of the national economy. In such a setting, the implementation of a coherent WEF Nexus approach is critical to preventing resource misuse and fostering long-term resilience. Taking this into account, the primary objective of this study is to contribute to ongoing efforts in Croatia aimed at formulating more coherent, cross-sectoral WEF policy strategies. Also, this research aims to examine the concept of policy coherence within the WEF Nexus by analysing the key challenges, opportunities, and strategies for integrated governance, using the Republic of Croatia as a case study.

Methodologically, the research is grounded in the application of a screening matrix approach, complemented by a semi-narrative literature review to contextualize findings and support analysis.
The insights generated through this research are intended to support improved management of WEF Nexus resources and to align national efforts with broader objectives promoted under the NEXUSNET COST Action. By applying the screening matrix methodology and incorporating a contextual review of relevant literature, this work offers a set of targeted recommendations to enhance policy integration. These recommendations emphasize the necessity of aligning water, energy, and food policy processes to foster mutual benefits, reduce conflict potential, and promote sustainable, resilient governance practices within the Croatian context.

Keywords: *WEF nexus; governance; policy; screening matrix; Republic of Croatia.*

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Nexus approach and Sustainable Tourism in Europe: challenges and opportunities under high environmental pressure contexts

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Abstract

Sustainable tourism is one of the pillars of the European Union's (EU) environmental and economic policies, particularly in light of the European Green Deal and the 2030 Agenda. However, the intensification of tourism activities in certain EU regions has led to increasing environmental pressures, requiring integrated resource management approaches. This paper aims to analyse how the Nexus approach - which integrates the water, energy, and food sectors - can contribute to the development of more effective policies and practices for sustainable tourism in the EU.

The research begins with the observation that European tourist destinations often face multiple simultaneous tensions, such as water scarcity during peak seasons, spikes in energy consumption, dependence on intensive food supply systems, excessive waste generation, water pollution, air pollution from transport, and degradation of sensitive ecosystems. Considering these challenges, the Nexus approach offers a conceptual framework to understand the interdependencies among resources and to propose solutions that avoid harmful trade-offs between sectors.

The study is based on documentary analysis of EU policies - such as the Green Deal, the Water Framework Directive, the EU Tourism Strategy for 2030, and climate action plans - combined with a literature review and case studies in regions under high environmental pressure. The research aims to highlight good practices, institutional gaps, and opportunities for integration across policy instruments. As a contribution, it proposes

guidelines to incorporate Nexus thinking into public policy design for sustainable tourism, strengthening the coherence and resilience of the EU's environmental strategies.

Keywords: *Nexus approach; sustainable tourism; environmental policies; European Union policies; eco-innovation.*

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Quantifying water sustainability by integrating the WEFE Nexus: Implications for the EU Taxonomy

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Abstract

The EU Taxonomy regulation came into force in 2020 with the aim of directing investments towards economic activities that align with the UN SDGs and the objectives of the European Green Deal. Taxonomy is a classification system that defines criteria for economic activities that are consistent with a net zero trajectory by 2050 and broader environmental goals. However, the definition of sustainability and the criteria used to measure it are vague. Key phrases used in the regulation, such as "do no significant harm" to the environment, and "ensure good 'quantitative' status" of water bodies, have been left open for (mis)interpretation.

We created a mathematical model to quantify sustainability that is consistent with WEFE Nexus principles and applied it to a case study: a Norwegian owned flower farm located around Lake Naivasha, Kenya, and which is liable for Taxonomy reporting. We found that any economic activity that relies heavily on water, such as agriculture, will have an adverse impact on ecosystems if the activity is not moderated in accordance with the climate. Addressing the Taxonomy nomenclature, we provide examples of cases of economic activities which indeed do 'significant harm' to the environment and propose reparatory measures. For example, if natural water availability reduces by 20%, the amount available for non-essential activities like flower farming would need to be reduced by 45.5% while keeping water-use for essential functions constant. Given that over 600,000 jobs are connected to the flower industry around Lake Naivasha, we conclude that it is not possible to achieve sustainability in the short term if we are to avoid job losses resulting from moderating water-use according

to climatic conditions. However, by adopting a WEFE perspective, the model can be used to inform the long-term spatial strategic planning of economic activities that have a heavy reliance on water.

Keywords: *EU taxonomy; WEFE Nexus; water sustainability; groundwater recharge.*

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Incorporating Geopolitical Vulnerabilities into Energy Transition Planning for Enhanced Resilience: A Geopolitical Vulnerability Index for EU Member States

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Abstract

European Union member states strategically employ energy transition scenarios within their National Energy and Climate Plans (NECPs) to achieve their 2030 energy and climate targets. While these scenarios typically account for economic, material, and technological considerations, they often neglect the significant geopolitical risks inherent in global supply chains. This oversight is particularly critical given Europe's increasing reliance on imported raw materials essential for key energy transition technologies such as solar cells, wind turbines, and electric vehicle batteries, many of which depend on resources not readily available within Europe.

Addressing this gap, this paper introduces a Geopolitical Energy Vulnerability Index (GEVI) as a tool to integrate geopolitical risks into energy transition planning. GEVI was developed through a multi-step process involving various steps such as factor and indicator selection, data collection and normalization. The variables were subsequently weighted through expert consultation, aggregated, validated, and tested for robustness.

As a case study, the GEVI is applied to Spain, a nation with ambitious plans to expand its already substantial renewable energy production, transition its significant automotive industry to electric vehicles, and establish itself as a leading semiconductor manufacturing hub. The GEVI analysis reveals

the extent to which these critical economic objectives are exposed to geopolitical vulnerabilities.

The GEVI framework enables stakeholders to better assess vulnerabilities and build more resilient energy and climate strategies. While not directly addressing the WEF Nexus, integrating geopolitical risks via the GEVI aligns with the conference theme of building resilience to global challenges. Understanding and mitigating these vulnerabilities in energy supply chains is vital for a secure and sustainable energy transition, impacting interconnected WEF systems and relevant SDGs. This work highlights the need to consider external risks for a more secure and resilient low-carbon European economy.

Keywords: *Geopolitical Risk; Energy Transition; Vulnerability Index; European Union; Energy Security.*

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CHAPTER IV

URBAN RESILIENCE AND CIRCULAR ECONOMY

Systemic Approaches to Low Carbon Food Production: A Symbiosis-Based Assessment

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Abstract

The transition to low-carbon food systems is increasingly recognized as a strategic priority in addressing the global climate crisis. Traditional food production models are not only resource-intensive but also major contributors to greenhouse gas emissions, necessitating integrated, system-level interventions. This study explores the potential of Industrial Symbiosis (IS) as a transformative framework to redesign food production and distribution processes through cross-sectoral collaboration, waste valorisation, and circular resource flows. By embedding sustainability principles within symbiotic configurations - linking agriculture, food processing, waste management, and renewable energy systems - the research aims to uncover innovative pathways toward carbon reduction and long-term resilience. A multi-criteria decision-making approach which is Measurement of Alternatives and Ranking according to Compromise Solution (MARCOS) is adopted to evaluate alternative strategies that align with environmental, economic, social, and regulatory goals. Drawing from an interdisciplinary body of literature and stakeholder insights, a comprehensive evaluation model is developed to systematically assess the relative performance of symbiotic scenarios. The model supports decision-makers in identifying context-sensitive, scalable solutions that not only minimize emissions but also enhance resource efficiency, stakeholder cooperation, and socio-economic viability. The findings indicate that integrated approaches grounded in circular economy logic can significantly improve sustainability outcomes across food supply chains. Industrial symbiosis, when strategically implemented, offers a viable route to close nutrient and energy loops, reduce environmental externalities, and

foster localized innovation. This research contributes to the evolving discourse on sustainable food transitions by providing a structured assessment framework applicable to various regional contexts. It also offers practical insights for policymakers, practitioners, and researchers seeking to operationalize low-carbon development strategies in the agri-food sector.

Keywords: *Low-carbon food production; Sustainable food systems; industrial symbiosis; circular economy; MARCOS*

Acknowledgments: *Part of this publication is based upon work from the COST Action <CA20138: Network on water-energy-food nexus for a low-carbon economy in Europe and beyond – NEXUSNET>, supported by COST (European Cooperation in Science and Technology).*

Untangling water-energy-food systems at local level – The case of CitySelfy project

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Abstract

Addressing the interconnected challenges of water, energy and food systems (WEF) is vital in the balance between increasing population, urbanization as well as economic activity, with the increasing pressure on natural resources. This research investigates the development of a local-level approach to the WEF systems using the municipality of Cascais (Portugal) as a case study. The CitySelfy project was carried out under an interdisciplinary framework that integrated technical-economic modelling and the various associated social dimensions through citizens and stakeholder engagement. The TIMES_CityWEF model was built to simulate medium and long-term scenarios for the optimization of local WEF resources, emphasizing the adoption of technologies and behavioral changes in consumption patterns. Comprehensive socio-economic data was collected through a survey completed by more than 600 residents, targeted interviews, workshops and focus groups involving various local stakeholders. This information served as the basis for WEF system components characterization as well as the development of scenarios to assess the cost-effectiveness and sustainability of various pathways to climate neutrality by 2050. The scenario narratives considered socio-environmental preferences and technological acceptance.

The results revealed a significant willingness among citizens to adopt solar photovoltaic technologies and a food transition towards plant-based foods, with the potential to reduce greenhouse gas emissions associated with imported food. However, trade-offs between energy demand and localized food production highlight the need for integrated planning. The project also highlighted the complexity of modelling various levels of integration of WEF system components, e.g. the challenges of fully integrating food systems done using a hybrid approach with soft links between energy-water modelling and external food demand models.
The study concludes that localized approaches to the WEF nexus, when supported by interdisciplinary research and community participation, can increase resource self-sufficiency and resilience in urban areas. The findings contribute to evidence-based policy making for sustainable local planning and have been disseminated through public engagement events and key policy briefs.

Keywords: *Scenarios; Transition; Climate mitigation; Integrated; Cascais; Modelling.*

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Examining the Water-Energy-Food nexus at the building scale, using Environmental Performance Assessment Methods

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Abstract

The Water-Energy-Food (WEF) Nexus framework provides a systemic and integrated approach to sustainability by highlighting the interlinkages among three fundamental resources: Water, Energy, and Food. While the nexus concept is mostly applied at larger scales like national, regional, or local, it is becoming more important for buildings, where design and operational decisions directly affect resource consumption. Buildings consume a significant amount of water and energy, and emerging practices like urban agriculture also bring food into the built environment. This study examines how environmental performance assessment methods – especially BREEAM, LEED, DGNB, and SBTool - support the integration of WEF nexus principles during the use stage of the building life cycle. This study uses a theoretical and comparative approach to show how these certification frameworks support systems thinking, improve resource efficiency, and encourage optimizing long-term performance. Although none of the methods directly apply the WEF nexus framework, they reflect many of its key principles through broad sustainability criteria, lifecycle thinking, and trade-off analysis. By identifying overlaps between environmental assessment tools and the Nexus strategies, this study shows the potential of these tools to support the practical use of Nexus strategies at the micro (building) level. The findings suggest that including Nexus-

focused indicators can help improve resource efficiency, decrease negative synergies of resources with each other, promote circular economy, and strengthen the resilience and sustainability of buildings. This alignment provides meaningful opportunities to improve holistic resource governance even further and to support climate adaptation in the built environment.

Keywords: *Water-Energy-Food Nexus; Environmental Performance Assessment; Sustainable Buildings; System thinking; Resource efficiency*

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Evaluating Circular Water Economy Models at the Watershed Scale: A Carbon Emissions-Based Framework within the Water-Energy-Food-Ecosystem Nexus

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Abstract

The Porsuk Sub-basin is subject to intense urbanization, agriculture, and industrial activities. These sectors exert considerable pressure on the basin's water resources, threatening the availability of its already limited freshwater reserves due to increasing water stress. To address this issue in a more sustainable manner, various strategies have been proposed. Among them, the Circular Economy approach promoted by the EU Green Deal aims to retain resources in use for as long as possible, maximize their value, and enable their recovery, renewal, and reuse. There exists a strong interconnection between water, energy, food, and ecosystems, referred to as the Water-Energy-Food-Ecosystem (WEFE) Nexus. This concept underscores the interdependent nature of these components and recognizes that interventions in one sector have direct implications for the others. Although literature evaluates the benefits of circular systems using a variety of indicators, such indicators often fail to directly capture basin-specific characteristics. To address this limitation, the present study introduces a methodological framework for assessing circular water economy models within the WEFE Nexus, with an emphasis on sustainable water management at the basin scale. Within this framework, 52 alternative scenarios were developed, representing different configurations across agricultural, industrial, and urban sectors. The environmental performance of these scenarios was assessed using a climate related indicator: CO_2 emissions. Scenario outputs - such as volumes of reused water, treatment requirements, and alternative water sources - were quantified in terms of

their associated CO_2 emissions to facilitate a consistent and meaningful comparison. This approach enables the identification of environmentally favourable circular water economy alternatives at the macro-basin scale, based on their emission-related impacts.

Keywords: *Circular Water Economy; WEFE Nexus; Climate; Watershed; CO2 Emission.*

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A Performance-Based Evaluation Model of the WEFE Nexus in the Public Utilities Sector: Advancing Circular and Resilient Cities

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Abstract

This paper presents a performance-based evaluation model that integrates the Water-Energy-Food-Ecosystems (WEFE) Nexus approach into the assessment of public utility services at the local level. Rooted in the disciplines of environmental protection engineering and communal engineering, the model emphasizes the critical role of municipal utility companies in advancing sustainable, circular, and resilient urban systems. It is specifically designed to evaluate the environmental protection performance of key communal sectors - water supply, wastewater treatment, waste management, and energy services - while accounting for their interdependencies within the WEFE Nexus. The model utilizes a structured set of measurable performance indicators that align with the principles of the circular economy and the United Nations Sustainable Development Goals (SDGs), particularly Goals 6 (Clean Water and Sanitation), 7 (Affordable and Clean Energy), 11 (Sustainable Cities and Communities), and 12 (Responsible Consumption and Production). Applying multi-criteria decision-making (MCDM) techniques, the framework enables a comparative assessment of municipalities, supporting the ranking and benchmarking of local performance and the identification of best practices. Special focus is placed on the reuse of treated wastewater in urban areas, optimization of energy consumption in public utility operations, and integrated waste and resource management as practical levers for implementing Circular Economy principles. In addition, the model encourages the development of coherent, cross-

sectoral strategies that consider local potentials, trade-offs, and synergies, particularly under conditions of environmental stress and climate change. The findings aim to contribute to evidence-based policymaking and capacity-building at the local level, offering a scalable and transferable tool for planning, monitoring, and enhancing sustainability performance in cities. This approach fosters urban resilience and supports the transition toward climate-neutral, resource-efficient, and socially inclusive communities across Europe and beyond.

Keywords: *Environmental protection engineering; public utilities; circular economy; performance indicators; evaluation model.*

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CHAPTER V

EXPLORING THE NEXUS IN RESEARCH AND IN PRACTICE

Part A

Innovative Approaches to the Nexus: Advances in Concepts, Methods & Capacity Building

Advancing Nexus Thinking: Innovations in Integrated Systems Modelling with JUNIPER

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Abstract

In the context of escalating global disruptions - from climate stress to ecological degradation and public health vulnerability - there is a growing need for dynamic models that can simulate interconnected systems across sectors over time. Nexus thinking has become a key framework for addressing such complexity.

To meet this challenge, we present the Joint Utilization of Nexus Indicators for Policy and Environmental Resilience (JUNIPER), a system dynamics model that expands the core Water–Energy–Food (WEF) nexus by formally integrating Transport, Biodiversity, and Human Health as equally critical and interacting subsystems.

This expanded WEFTHB nexus enables the simulation of non-linear dynamics, feedback loops, and cross-sectoral dependencies that shape both systemic risk and resilience. Transport is modelled as a sector that directly impacts both Human Health and Biodiversity, primarily through air pollution and exposure to PM2.5.

The Biodiversity module addresses the systemic pressures exerted by all other sectors, using data from the IUCN Red List of Threatened Species and the Red List of Ecosystems. It simulates how infrastructure expansion,

land-use change, water withdrawals, agricultural intensification, and emissions affect ecosystem integrity and species survival. PM2.5 pollution from transport is explicitly modelled as a driver of ecosystem degradation and species vulnerability.

The Human Health module focuses on how environmental and infrastructural variables - including air quality, water access, food systems, and biodiversity - influence life expectancy, quality of life, and overall well-being. Health is embedded as a responsive and dynamic subsystem within the broader nexus, rather than treated as an isolated outcome.

By embedding Health and Biodiversity into the structural logic of the model, JUNIPER advances the scope and realism of nexus modeling. It enables scenario analysis, policy testing, and tipping point identification, serving as a dynamic decision-support tool for navigating converging global crises.

Keywords: *Water-energy-food-transportation-health-biodiversity Nexus; environmental sustainability, system dynamics modelling.*

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Advancing Interdisciplinary Capacity through the Nexus EXCELLENTIA Mentoring Programme

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Abstract

Addressing complex sustainability challenges within the Water-Energy-Food+ (WEF+) Nexus requires a transdisciplinary research framework and enhanced collaboration across generations and sectors. Despite increasing recognition of these needs, structured opportunities for capacity development, especially for early-career researchers, remain insufficient across European and international research communities. To bridge this gap, the COST Action CA20138 NEXUSNET has launched Nexus EXCELLENTIA, a formal mentoring programme designed to foster intergenerational exchange, strengthen interdisciplinary skillsets, and support early-career integration into the Nexus research landscape. The programme establishes tailored mentor-mentee relationships between experienced researchers and young professionals working across Nexus-relevant sectors, including climate resilience, biodiversity, energy, agriculture, land use, etc. Implemented through structured matching, thematic workshops, and hybrid mentoring sessions linked to NEXUSNET activities, the programme provides targeted support in scientific writing, proposal preparation, stakeholder engagement, and career development. A first round of implementation in 2023-2024 matched 18 mentoring pairs from diverse academic and policy backgrounds, based on shared research interests and professional goals. Initial feedback indicates enhanced research productivity, improved access to collaborative networks, and increased engagement of mentees in Nexus-related COST activities, such as short-term scientific missions (STSMs), virtual mobilities (VMs) and

working group outputs. Beyond advancing competences, the programme has fostered mutual learning, trust-building, and long-term cooperation opportunities. By integrating mentorship with active participation in NEXUSNET activities, the EXCELLENTIA programme contributes to the development of a resilient research community equipped to address complex sustainability challenges. The initiative is envisioned as a sustainable model for integrated capacity building within and beyond the duration of NEXUSNET.

Keywords: *WEF Nexus; Mentorship; Interdisciplinary Research; Sustainability; Capacity Building.*

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SMART-WaterDomain: Impact-Oriented Framework for Enhancing Water Reuse in Complex Systems

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Abstract

This research presents an impact-oriented framework for advancing water reuse practices in industrial and agricultural settings. The approach is grounded in the understanding that technological solutions alone are insufficient without supportive organizational strategies and informed decision-making processes. To address this, a decision support tool was developed, integrating real-time monitoring data, risk assessment models, and climate resilience projections. The tool enables system actors to evaluate the feasibility, benefits, and trade-offs of water reuse under varying environmental and operational conditions.

Empirical studies and case analyses identified common barriers to reuse implementation, including institutional fragmentation, regulatory

misalignment, and limited public trust. The framework responds to these challenges by incorporating adaptive governance models, value chain integration strategies, and scenario-based planning techniques. Emphasis is placed on circular water practices that enhance resource efficiency and environmental sustainability. The research contributes to closing the implementation gap by linking technical feasibility with organizational readiness and system-wide coordination. It advances the role of water reuse in sustainable resource management, particularly in regions facing increasing water stress and variability due to climate change.

Keywords: *Water Reuse; Decision Support; Circular Economy; Adaptive Governance; Integrated Water Management*

Thematic tracks: *Urban resilience and circular economy; Sustainable waste management*

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Water-food-energy Security Nexus Approach

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Abstract

The Water-Energy-Food (WEF) Nexus framework highlights the intricate interconnections between water, energy, and food systems, emphasizing their mutual dependencies and the need for integrated management. As global pressures from population growth, climate change, and economic development intensify, understanding these linkages becomes essential for ensuring sustainable resource use and policy coherence. This approach facilitates the identification of synergies and trade-offs, particularly in the context of evolving trade dynamics, investment flows, and climate policies. By adopting a nexus perspective, policymakers and stakeholders can develop strategies that optimize resource efficiency, enhance resilience, and support long-term sustainability goals.

The goal was to enhance comprehension of how the water, energy, and agricultural sectors are interconnected, while taking into account the impacts of trade, investment, and climate policies, in order to promote synergies and avoid potential conflicts.

The main problem was the depletion of resources as a result from climate change. Using mixed methods, we explored the interconnection between the three resources and how they can be sustained for future use.

The application of the Water-Food-Energy (WEF) Nexus approach has led to several important findings and outcomes in sustainability, resource management, and policy implementation. Key results include improved resource efficiency, climate change adaptation and mitigation, socioeconomic and policy impacts

However, competing demands between sectors still exist, requiring cross-sector collaboration. Furthermore, some renewable energy solutions are costly, limiting access for small-scale farmers.

While these resources are crucial for development, their exploitation can negatively affect the environment. Agriculture contributes to soil and water contamination and energy production releases greenhouse gases, worsening climate change. Sustainable strategies are necessary to mitigate these impacts, including efficient irrigation systems, renewable energy sources, and genetically modified crops that require less water and resist pests. Implementing these measures will enhance resource sustainability and ensure long-term food and energy security. The WEF Nexus approach is essential for balancing development and environmental conservation.

Keywords: *Water; Food; Energy; Sustainability; Climate.*

One Health in Climate Change Adaptation: Scoping Interlinkages with the Water–Energy–Food–Ecosystems Nexus

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Abstract

The One Health framework has evolved from early concepts of unifying human and veterinary medicine in the 1960s to a planetary health paradigm encompassing ecological, social, and climatic dimensions. Key milestones include Daszak et al.'s 2000 call to treat diseases as ecological phenomena and the 2004 Manhattan Principles, which formally introduced One Health as an interdisciplinary approach. Institutional developments such as the 2010 Tripartite collaboration (FAO, WHO, OIE) and the 2015 integration of One Health into the Sustainable Development Goals broadened its scope to include food safety, antimicrobial resistance (AMR), and environmental sustainability. In 2022, UNEP joined the collaboration, forming the Quadripartite and formally incorporating climate change, pollution, and social determinants of health into One Health governance. Recent operational tools—including WHO's wastewater surveillance guidelines and UNEP's guidance on urban biodiversity and the Water-Energy-Food-Health (WEFH) nexus—further demonstrate the mainstreaming of One Health in sustainability agendas.

While still critiqued for its anthropocentric emphasis, One Health now explicitly links human health with biodiversity protection, ecosystem function, and climate resilience. As climate change emerges as a key driver of health disruption—from vector-borne diseases to resource insecurity—

this paper explores how climate stressors affect One Health systems, with special emphasis on water as a central mediator of health risks.
This work draws on a selection of 20 case studies from EU-funded climate change adaptation projects to illustrate how climate-related stressors challenge One Health integration. Analyzed through a bottom-up lens, these cases reveal the complex interplay between human, environmental, and animal health. Common stress mechanisms include heat-related illness, water scarcity and contamination, agricultural runoff, biodiversity loss, coastal flooding, and vector expansion. Water emerges as a key connector across these domains, underscoring the need to integrate One Health approaches into local and regional climate adaptation strategies.

Keywords: *One Health approach; climate change adaptation; environmental health; water resources management; food security.*

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Assessing the effect of forest fires on forest cover using Remote Sensing Technology: A case study of Aberdare Forest

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Abstract

Monitoring forest fires dynamics over time is important for biodiversity conservation, especially within protected areas. The study aimed to investigate the impact of forest fires on forest cover in the Aberdare Forest, using pre-fire and post-fire Sentinel-2 datasets. Data analysis, which was carried out on Google Earth Engine (GEE), led to the realization of forest cover loss cover maps. Pre-fire and post-fire Normalized Burnt Ratio (NBR) obtained from the images were used in calculating the delta NBR (dNBR or ΔNBR), which is important for burn severity estimates. Moreover, the Normalized Difference Vegetation Index (NDVI) on pre and post fire datasets were also acquired for the sake of detecting the health of areas unaffected by the forest fires. Delta NBR revealed four burnt severity classes namely: High severity, low severity, unburnt, regrowth and bare ground. Quantitative analysis results revealed that Unburned category covered 89.57% of the total area (~203,574.42 hac), High severity, 0.01% (23.31hac) low severity, 2.33% (~5.291.2 hac), while Regrowth and bare ground, 8.09% (18,391.59hac). Visualization on the Post fire NDVI image indicated the NDVI ranges from -1 to 1. Moreover, areas with high NDVI indicated the presence of healthy vegetation (+1) while values closer to (-1), low NDVI values which indicate areas with unhealthy vegetation after the fire. In conclusion, it is critical to comprehend how remote sensing techniques are used to detect forest fires in order to determine fuel management plans, take preventative action, and detect fires early on. The

strategy may reduce the danger of fire outbreaks and save priceless forest ecosystems.

Keywords: *NBR; NDVI; Forest fire; Severity index; ecosystem sustainability.*

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Strengthening the WEFE Nexus through Sustainable Manufacturing: Evidence from Circular Economy Reengineering Integration

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Abstract

This paper presents a validated approach to strengthening the Water-Energy-Food-Ecosystems Nexus through sustainable manufacturing. It integrates business process reengineering with circular economy principles using the Plan-Do-Check-Act (PDCA) model. The proposed framework aims to align process efficiency with sustainability goals in the industrial sector. The study was conducted in 135 Serbian manufacturing organizations across various sectors, including food (25.19%), metal (23.7%), and wood processing (19.26%). Results show that the average level of model implementation was 44.70%. PLAN phase reached 49.37%, DO phase 56.04%, CHECK phase 47.70%, and ACT phase 37.11%. Only 1.5% of organizations achieved full implementation, while 58.52% scored below 50%. ISO 9001-certified organizations had a 61.86% implementation score, and ISO 14001-certified ones scored 68.56%, confirming that management systems enhance circular economy adoption. Energy use patterns were analysed. About 42.96% of organizations operated equipment older than 10 years. Only 16.30% used renewable energy. Water reuse cycles were implemented in 15.56%, while 24.44% practiced energy and water recovery. Waste sorting was practiced by 76.67%, but only 36.30% had return policies for packaging. Around 21.85% used secondary raw materials, and 22.59% promoted rational energy use in their products. The integration of the PDCA-based circular economy model into manufacturing also reveals the main gaps in the current industrial approach to the WEFE Nexus. Only 34.07% of organizations evaluate

product lifecycle impacts, and just 10.74% develop products related to renewable energy. These figures show the need for improved technical capabilities and systemic planning. The model supports integrating WEFE principles into industrial systems by improving resource efficiency, process monitoring, and circular innovation. It offers a practical basis for future management standards that address sustainability and resilience. This work contributes to achieving SDGs 6, 7, 12, and 13 by improving energy efficiency, reducing waste, and promoting ecosystem health through structured industrial transformation.

Keywords: *WEFE Nexus; circular economy; business process reengineering; PDCA model; sustainable manufacturing.*

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Enhancing nutrient recovery in wastewater treatment?

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Abstract

Volatility in global fertilizer markets underscores the urgency for sustainable, locally produced nutrient sources. This presentation explores enhanced nutrient recovery - particularly phosphorus and nitrogen - in water utilities as a strategy to improve resource resilience and environmental performance across Europe. Phosphorus recovery, a well-researched area, includes methods such as chemical precipitation (e.g., struvite, vivianite), wet-chemical extraction, and thermal treatments from various wastewater and sludge streams. Despite technological maturity, challenges persist due to high operational costs, scalability issues, and uncertain market dynamics for recovered products.

In parallel, nitrogen recovery offers an alternative to the energy-intensive Haber-Bosch process, which contributes significantly to global CO_2 emissions. Technologies like air stripping, precipitation, and membrane-based solutions (e.g., NPHarvest) offer promise, though low nitrogen concentrations in wastewater and limited direct recovery methods hinder widespread implementation.

EU policy developments - such as the Integrated Nutrient Management Action Plan (INMAP), the revised Urban Wastewater Treatment Directive (UWWTD), and the Fertilising Products Regulation (FPR) - provide regulatory support and market frameworks for nutrient recovery. Nonetheless, achieving economic feasibility requires improvements in product quality standards, reduction of harmful contaminants, better market information, and investment incentives to enable economies of scale.

Ultimately, nutrient recovery from wastewater represents a strategic opportunity for Europe to secure critical raw materials, reduce environmental burdens, and promote Circular Economy practices.

Keywords: *Fertilisers; Nitrogen; Phosphorous; Recovery; Wastewater.*

Sustainable use of fish by-products

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Abstract

This study presents a life cycle assessment (LCA) of a novel nutraceutical derived from fish protein hydrolysate (FPH), utilizing by-products from Norwegian salmon processing. With approximately 1 million tons of food-grade fish by-products generated annually in Norway, the potential to upcycle this biomass into high-value ingredients is significant. However, undesirable flavour and odor have limited its use in human nutrition. The novel innovation addresses this by employing oxygenase enzymes to process salmon by-products into odorless, nutrient-rich FPH.

As the novel product is still in the development phase, the LCA was based on lab-scale production data. Inputs comprised fish residues, enzymes, water, and electricity. Transportation, infrastructure, and downstream processing were excluded. Impact categories assessed include climate change, acidification, and eutrophication (freshwater and marine), using EF 3.1 methodology.

Results show that energy consumption dominates as the source of environmental impacts, especially during condensation and freeze-drying (up to 73% across categories). Raw materials contributed minimally due to economic allocation. Sensitivity analysis revealed that excluding freezer energy reduces climate impacts by 19%. Allocation between process co-products (FPH and fish oil) slightly altered impact shares but did not significantly affect overall results.

Compared to benchmark protein isolates, FPH had lower climate impact than whey protein concentrate but higher than soy and faba bean protein isolates. For eutrophication and acidification, FPH performed moderately,

better than whey but worse than plant-based alternatives. Due to reliance on lab-scale data, these results are preliminary.

The study concludes that while FPH holds promise as a sustainable protein source, industrial-scale data is crucial for accurate environmental assessment. Future research should focus on scaling up production to enable informed comparisons with other protein sources. Interviews with aquaculture representatives revealed that, although there are no regulatory barriers to scaling up, challenges are anticipated in terms of operational capacity and the fragmented nature of the industry, which is largely dominated by SMEs.

Keywords: *Nutraceutical; enzymatic treatment; sustainability; LCA; fish by-product.*

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Part B

In-situ Applications and Practical Insights on the Nexus

Integrating climate smart agriculture practices. An assessment of Uganda's lower secondary agriculture competence-based curriculum

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Abstract

In the face of increasing climate challenges, equipping young people with practical skills for sustainable farming is more important than ever. This study explores how Climate Smart Agriculture (CSA) practices are integrated into Uganda's lower secondary Agriculture Competence-Based Curriculum (CBC). It looks at how the curriculum introduces students to essential practices like soil and water conservation, agroforestry, and managing climate risks in farming. Using a mixed-methods approach, the research draws on curriculum analysis, interviews with education stakeholders, teacher surveys, and classroom observations to understand what's working and where gaps exist. The findings show that while there are promising efforts to include CSA concepts, there is still room to strengthen both the content and how it's taught. This study highlights the crucial role of early agricultural education in preparing young Ugandans to face climate change with confidence, resilience, and innovation - laying the foundation for a more sustainable future in agriculture.

Keywords: *Competence Based Curriculum; Climate Smart Agriculture; sustainable farming.*

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Environmental Protection as a shared Responsibility: Promoting Public Awareness for Sustainable Development in Tajikistan

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Abstract

Environmental protection is often seen as the responsibility of environmental engineers and policymakers. However, true progress towards sustainability demands active participation from all members of society. Without public understanding of environmental risks, especially those affecting human health, behavioural change remains limited. Evidence shows that many citizens remain unaware of how interconnected environmental systems are - pollution in one domain, such as soil, can transfer to humans via crops and groundwater, drinking water.

This abstract presents the experience of the Ecology department of the Mining-metallurgical institute of Tajikistan, which has implemented a series of public awareness and school outreach programs under the Comprehensive State Program for the Development of Environmental Education and Awareness of the Population of the Republic of Tajikistan for 2021-2025, ending in 2025. These initiatives aimed at bridging knowledge gaps and fostering a culture of environmental responsibility.

We argue that achieving the UN Sustainable Development Goals - particularly Goals 3 (Health), 6 (Clean Water), 11 (Sustainable cities), and 13 (climate action) - requires a foundation of ecological literacy. Only when the majority of the population understands the long-term consequences of environmental degradation can society collectively build resilience to

future global challenges. Tajikistan's example demonstrates how targeted education can translate into grassroots environmental action.

Keywords: *environmental education; public awareness, sustainable development; Tajikistan; ecosystem interconnectivity.*

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Food and Feed Safety Implications from Climate Change in Albania, the Mycotoxin Contamination

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Abstract

In recent decades, rising global temperatures have rendered Albania more vulnerable to extreme weather events, including droughts and floods. This situation jeopardizes water supplies, agriculture, and key sectors like tourism and hydropower. Agriculture remains the leading economic sector, employing a substantial workforce, especially in rural regions. Maize is one of the primary crops cultivated and is predominantly used as feed for the dairy and livestock industries.

The first incident of aflatoxin-contaminated maize in Italy occurred in 2003. Since then, reports of aflatoxin contamination in maize have been regularly recorded throughout Southern Europe, particularly in the Balkans. Mycotoxin contamination of maize in Albania began in 2014, while data from the harvesting years of 2023 and 2024 show a persistent occurrence of aflatoxins in maize, with over 70% of instances of aflatoxin B1 exceeding the EU maximum residue level (EU MRL) in feed. Aflatoxin B1 in maize, the primary feed for cattle, is linked to its metabolite, aflatoxin M1. Investigations into aflatoxin M1 in milk have revealed that it occurs in more than 62.4% of the sampled cases. A significant percentage from 2023 and 2024 indicates that 26.2% of the samples exceeded the EU maximum residue levels (50 ng/L) for two consecutive years. This data affects food safety. The nation's economy is strongly trending towards tourism, suggesting that food safety is at risk. The nation's attempts to focus on EU membership discussions align with the ongoing food and feed safety challenge, emphasizing the need for collaboration and collective efforts to address this issue.

Keywords: *Maize; climate change; milk, aflatoxins; Albania.*

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Energetic recovery of waste in Czechia: current trends and challenges

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Abstract

The EU's ambitious aims for sustainable waste management are in line with the principles of the circular economy: minimizing waste production and landfilling, maximizing reuse, material recycling and composting, and finally incineration (with a focus on energy recovery) for non-recyclable waste. According to Eurostat, 511 kg of municipal waste per capita was generated in average, of which 48% was recycled (through material recycling and composting), 22% was landfilled, 25% was incinerated, and 5% was disposed of in other ways in 2023. The energetic recovery of waste incineration (waste-to-energy, WtE) seems to be a progressive method of waste treatment and has become part of an integrated approach to integrated waste and energy management. However, in countries in Central and Eastern Europe, including the Czechia, high proportion of waste is still being landfilled.

This contribution aims to analyse the current situation and trends of waste management based on available statistical and spatial data in Czechia, focusing on WtE. The generation of communal waste in Czechia shows an increasing material demand. While it was 302 kg per capita in 1995, it increased by nearly 90% to 570 kg per capita in 2023, exceeding the European average. In light of the EU's climate and waste obligations, Czechia strives to support various infrastructure projects. The results show that currently 14% of waste is being WtE used, 42% is being landfilled and 43% is being recycled. The capacities of the four main incinerator plants have increased in recent years and additional plants for unsorted municipal waste and solid alternative fuels from treated non-recyclable waste are

under construction/planned. However, NGOs and local communities argue that these projects could threaten environmental justice and jeopardize other sustainable waste management objectives. This contribution thus offers a broader view on the current challenges of waste transition that CEE countries face.

Keywords: *Communal waste; sustainable waste management; waste-to-energy; circular economy; social acceptance*

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WEFE Nexus Implications of Geothermal Resources in the Konya Plain Project, Türkiye

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Abstract

Türkiye ranks among the top five countries worldwide in terms of geothermal energy direct-use capacity, with approximately 9% of the 227 identified geothermal fields located in the Konya Plain Project (KOP) region. The aim of the KOP is to enhance sustainability through the utilization of geothermal resources, and the project is supported by Konya Plain Project Regional Development Administration which is established and funded by the Ministry of Industry and Technology. This study examines the direct-use potential of geothermal resources in the Konya region within the Water-Energy-Food-Ecosystem (WEFE) Nexus framework. Because the geothermal resources in the KOP region have relatively low reservoir temperatures, their utilization is focused on low-temperature applications like residential heating and greenhouse cultivation. In addition to greenhouse heating, it is particularly essential during colder months to maintain optimal growing conditions and maximize yield. In light of climate and energy concerns, utilizing renewable geothermal resources instead of fossil fuels helps reduce environmental impact and enhances long-term sustainability. Hence, geothermal energy supports food production in KOP. Another benefit is that the cooled geothermal water, after being used for heating, serves as a source for irrigation, thus helping to protect and save groundwater resources that are normally relied upon for irrigation in the KOP region.

The KOP region's sustainable development strategies aim to reduce water loss from open canal irrigation systems, recover approximately 670 million cubic meters of water annually for agricultural use, and stop the decline of

groundwater levels. Moreover, transitioning from dry farming to irrigated agriculture and implementing high-value crop models are expected to increase both environmental and economic gains. By integrating KOP's five main development axes - natural resource management, economic structure, infrastructure, social development, and institutional capacity - into the WEFE Nexus approach, this study offers a holistic evaluation of the region's geothermal potential. The findings demonstrate that geothermal energy, when effectively managed, serves as a strategic tool for improving water use efficiency, strengthening food security, and advancing rural development within the broader scope of energy transition.

Keywords: *Geothermal energy; WEFE Nexus; greenhouse heating; sustainable agriculture; water use efficiency.*

Spain's Energy Transition: Local Benefits, Global Burdens?

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Abstract

The global energy transition seeks to reduce greenhouse gas emissions by replacing fossil-based power generation with renewable technologies. While this shift lowers emissions, it introduces complex trade-offs across interconnected resource systems, particularly water, energy, and land, placing the transition at the heart of the Water-Energy-Food (WEF) nexus. Renewable technologies redistribute environmental pressures through globalized supply chains involving water-intensive mining, material processing, and infrastructure deployment. These pressures are often displaced to resource-rich but consumption-distant regions, raising concerns about distributional justice.

This study evaluates Spain's energy transition under the National Energy and Climate Plan (PNIEC 2023), adopting a holistic approach that integrates Life Cycle Assessment and Social Metabolism. We assess how environmental impacts related to water use, land occupation, and material extraction are redistributed along the value chain, and across geographies. In doing so, we contribute to ongoing efforts to operationalize the WEF nexus by exposing how decarbonization strategies intersect with water, food, and land availability. We address the following question: *How does Spain's energy transition impact the links between water, energy, and land use, and how are these impacts spread across local and global regions?*

Preliminary results suggest that by 2030, operational environmental impacts per kWh will decline due to reduced fossil fuel reliance. However, improvements are uneven across impact categories. For instance, increased biomass use intensifies land occupation, potentially creating competition with food production. Additionally, PNIEC's transition demands

large-scale infrastructure expansion, resulting in increased offsite pressures (e.g., mining-related water and material use) and greater onsite land occupation. Regions phasing out coal and gas are expected to benefit from reduced local environmental burdens, while pressures shift elsewhere along the global supply chain.

This nexus-informed assessment reveals the broader socio-environmental implications of Spain's energy transition and underscores the benefits of integrating spatial, systemic, and justice considerations into energy and resource planning.

Keywords: *Energy transition; Distributional justice; Environmental trade-offs; Life cycle assessment (LCA); Water-Energy-Food Nexus.*

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