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Transforming Towards Regional Sustainability:

A Framework Based on Sustainability Transitions and Nexus Thinking

Full Report

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Full Report

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Contents

Paper Objectives and Structure

The twenty-first century confronts humanity with an unprecedented constellation of interrelated challenges and crises – environmental, economic, social, political, technological – that together demand far-reaching transformations in our modes of living, our societies and governance systems, and our ecological impacts on the planet. Because these multiple crises are interconnected across countries and continents, sectors and scales – recently described through the notion of "polycrisis" – our responses must be interconnected as well. Addressing them requires "**nexus thinking**", recognizing the multiple interdependencies, trade-offs, and synergies across energy, water, and food systems, climate and ecological changes, socio-economic settings, and geo-political conflicts. It also demands "transformation thinking", the capacity to reimagine and redesign systems so they transition from their current crisis trajectories toward sustainability and peace. Together, these two approaches form the foundation for the Nexus Transformations framework explored in this paper.

This paper develops a new conceptual framework of Nexus Transformations to support regional sustainability and peacebuilding efforts. It hopes to make several contributions to how sustainability is perceived within the fields of security and peace studies and adjacent policy fields. At the same time, the paper will be of interest to a wide range of stakeholders concerned with the fundamental question of our age: *how to contribute to transforming existing conflictual and detrimental systems into more stable and sustainable systems conducive to peaceful conditions* – in our region and beyond.

First, the paper introduces two of the most prominent approaches in the academic study of sustainability and in the fields of environmental and climate policy: namely, **Sustainability Transitions** (ST) and Nexus approaches. It offers a brief and accessible introduction to the main concepts and themes of these two approaches – intended to researchers

in security and peace studies, as well as to policymakers and practitioners working in post-conflict reconstruction or in sustainable development more broadly.

Second, the paper offers a conceptual yet practical synthesis of the Sustainability Transitions and Nexus approaches. Despite common concerns and potential synergies, these two influential approaches have, by and large, been addressed separately in the academic and policy literature. However, there are good reasons for combining them in different policy domains and in real world applications. We could think of their complementary qualities in a simple and practical way: The Nexus approach is concerned with the interrelations between **systems** that require integration and transformation. It focuses on what *to transform*, and offers technical, infrastructural, and spatial insights. However, it lacks a theory of systemic change and a detailed understanding of institutional and social-economic dynamics shaping these systems. Sustainability Transitions offers such a theory of **systemic change**. It focuses on *how to transform*, and adds important organizational, institutional, social-economic, and temporal insights. But, so far, it mostly lacks the powerful interrelational outlook of the nexus that connects these distinct socio-technical systems in real places. To bridge this gap, the paper introduces an integrated framework of Nexus Transformations as a systematic way to address these interrelated questions of how to transform and what to transform.[2]

Third, the Nexus Transformations framework offers an expanded and holistic articulation of nexus approaches, interconnecting the **FEW nexus** of food, energy, and water systems, critical at the urban scale, with the **MORE nexus** of regional mobility, economic, and ecological systems, and with the **PLENTY nexus** of security, prosperity, and peace within planetary boundaries. Nexus Transformations thus frames seemingly local and site-specific sustainable development challenges,

[2] Additional questions, such as the context-specific questions of where and when to transform or the normative question of transforming to what, are also important – but require more scope than is available in this paper.

including post-conflict reconstruction, as multi-level and multi-scale opportunities for systemic transformation.

To apply the Nexus Transformations framework and further specify the FEW-MORE-PLENTY path, the paper outlines a series of stages, considerations, and guiding questions. This is proposed as a roadmap to guide policy makers and practitioners in planning, shaping, and catalyzing multi-level sustainable transformations. In this way, the Nexus Transformations framework can be applied across diverse domains and scales of sustainable development, from integrated infrastructure, urban, and regional development, through post-conflict reconstruction, to the governance of transitions for living within planetary boundaries.

While the paper remains at a conceptual level, it connects to several recent *Mitvim* initiatives, including policy papers on a humanitarian strategy for Gaza and post-war reconstruction of the Gaza Region.[3] It wishes to push further the definition and the ambition of reconstruction – as a profound systemic transformation towards sustainability and peace. This is relevant not just for Gaza, but across the Middle East and the planet at large. The hope, therefore, is that this paper, together with its predecessors, could open a set of discussions with partners across the region and globally, who are committed to the principles of transforming holistically from conflict and climate emergency towards sustainability and peace.

The paper is structured in the following way:

Section 1 summarizes key learnings from the Sustainability Transitions literature, including its Multi-Level Perspective that explains the transformation of socio-technical systems through the relations between niches, regimes, and landscapes. In particular, the section highlights both processes of innovation and destabilization of existing systems and its relevance in contexts of conflict, war, and reconstruction and in relation to urban environments and infrastructures.

[3] Levy 2024; Magen 2025.

Section 2 similarly presents key learnings from the Nexus literature, starting with the well-known Food–Energy–Water (FEW) Nexus and expanding to nexuses relevant to the urban and regional scale and to situations of conflict and peacebuilding, such as the Humanitarian–Development–Peace Nexus and the Climate–Conflict Nexus.

Section 3 then presents the main contribution of the paper, the Nexus Transformations framework, combining the insights and strengths of the two hitherto separate approaches. It offers a simplified FEW-MORE-PLENTY roadmap: namely, how to proceed from FEW Transformations, which focus on the local scale and niche level, to MORE transformations, which expand the outlook to the regional scale and the regime level, finally reaching PLENTY Transformations, addressing planetary challenges at the global scale and the landscape level. This section also outlines the key stages and considerations for applying the Nexus Transformations framework.

Finally, the **Conclusion** suggests future directions to apply the Nexus Transformations framework, notably in the context of the post-war reconstruction of Gaza, in support of regional sustainability and peace.

1. Sustainability Transitions: *How to Transform?*

Across the world, societies are confronted with multiple, overlapping crises – social, economic, environmental, and political. From widespread poverty and inequality to the climate crisis and the transgression of planetary boundaries, these intertwined crises raise fundamental questions about transformation: How can we transform an adverse and unsustainable situation or system into is one that is viable, resilient, and broadly beneficial? How do we move forward from a set of conditions that is clearly harmful and damaging – even if it is regarded by some as inevitable, as "business as usual" – toward configurations that better support collective well-being? What obstacles stand in the way of such systemic change, and what strategies might help overcome them? Finally, what lessons can be drawn from historical cases in which systems consolidated, became dominant, and were later successfully transformed?

These questions point beyond incremental reform toward deeper structural change. They require attention not only to policies or technologies in isolation, but to the broader systems in which they are embedded. Such systems combine material infrastructures, institutional arrangements, economic interests, and cultural norms that evolve together over time. Understanding how these systems are stabilized over time – and how they can be deliberately destabilized and redirected – is essential for addressing contemporary sustainability challenges. The field of Sustainability Transitions offers a structured framework for engaging with these issues by focusing on how large-scale socio-technical systems emerge, persist, and, over time, change.

1.1. What are sustainability transitions

Sustainability Transitions (STs) is an influential academic and policy field that is central to debates on sustainability in the last two decades. The field evolved in the early 2000s from sociology, political science, evolutionary economics, and science and technology studies. It

seeks to understand how societies and systems change over time, particularly through technological innovations and institutional change. STs are understood as **long-term, structural changes in socio-technical systems** – such as energy, transportation, or food production – towards configurations that are environmentally sustainable, economically viable, and socially equitable. Socio-technical systems are complex assemblages that combine physical infrastructures, technologies, markets, policies, organizational forms, user practices, and cultural meanings. As a result, transitions are not limited to technological substitution or innovation alone but involve changes in regulation, business models, political priorities, social norms, and behavior.[4] ST researchers currently focus on transitions from fossil-fuel-dependent and high-carbon-emitting systems to renewable and low/zero-carbon alternatives, primarily in energy, mobility, and agri-food systems.[5]

One of the central challenges in changing existing socio-technical systems is their **path dependency**. Past decisions and investments, existing infrastructures and institutional arrangements, established ways of thinking and doing – all generate inertia or '**lock-in**'. This makes any transition slow and difficult, even when the shortcomings are widely recognized. STs seek to address these lock-ins by gradually introducing changes (e.g. new technologies, regulations, economic incentives) and by leveraging shifts in public attitudes and external crises (e.g. growing awareness to climate change) to push for substantial transformation. Yet this is never a simple undertaking.

ST research emphasizes that transitions unfold over long time horizons and across multiple scales and sectors. They typically involve numerous institutions and actors, including states, firms, financial institutions, civil society organizations, and users, whose interests and capacities often diverge or conflict. While transitions may evolve gradually through incremental adjustments, they can also accelerate rapidly in response to crises, technological breakthroughs, or shifts in public discourse.

[4] Köhler et al. 2019.

[5] Geels and Turnheim 2021.

Accordingly, the ST literature analyzes both historical processes through which socio-technical systems have stabilized and contemporary efforts to destabilize and redirect them toward sustainability (see the example of automated mobility in the next section). Over the last twenty years, ST scholarship has generated a substantial body of knowledge at the interface of science and policy, with an emphasis on climate change mitigation and decarbonization.[6] This perspective has influenced international and national policy agendas, including the Sustainable Development Goals (SDGs).

ST therefore offers a systemic "**theory of change**" that highlights how coordinated interventions can gradually reconfigure entrenched systems to align with sustainable goals – rather than relying on isolated policy instruments. At its core, the ST approach conceptualizes transformation as the reconfiguration of key system elements – technologies, infrastructures, regulations, markets, user practices, and cultural norms – so that they become mutually reinforcing around sustainability goals. This involves coordinated governance and policy interventions, innovation and experimentation in protected spaces, long-term and non-linear change processes, and explicit attention to agency, power, and politics.[7]

ST's "theory of change" is often formulated in the analytical framework of the **Multi-Level Perspective** (MLP). It explains how large-scale socio-technical changes occur through interactions across three analytical levels: landscape, regime, and niche.

- **Landscape (macro context)**: This level encompasses the broader, exogenous environment that influences socio-technical systems. It includes long-term trends such as climate change, demographic shifts, economic globalization, geopolitical dynamics, and evolving cultural values (e.g. increasing public awareness of sustainability or the current processes of democratic backsliding and distrust in

[6] Geels 2002; 2017; Grin et al. 2010.

[7] See Appendix for an archetypal example of automobility as a sociotechnical system and its transition towards sustainability.

science). Landscapes usually change slowly and provide a relatively stable backdrop for regimes, but abrupt shocks – such as wars, pandemics, economic crises, or major policy realignments – can exert strong pressure on existing systems and open windows of opportunity for change.

- **Regime (meso context)**: The regime encompasses the established and stable elements of a socio-technical system, including dominant technologies, infrastructures, markets, regulations, and social practices. Regimes are characterized by stability, existing institutional arrangements and routines, and mutual reinforcement among their components, which tends to favor incremental change and resist radical alternatives. However, when pressures from the landscape intensify or when internal contradictions accumulate, regimes can become destabilized and more receptive to alternatives. Over time, successful innovations can also alter market dynamics and public opinion, thereby weakening the regime's lock-in.
- **Niche Level (micro context)**: Niches are protected environments where radical innovations can emerge and mature. They serve as experimental spaces allowing new technologies, practices, and organizational models to be developed away from the full pressures of mainstream markets and regulations. Through processes of learning, experimentation, and coalition-building, niche innovations can gain momentum and, under favorable conditions, begin to challenge regime dominance. Importantly, niches are often supported by regime actors themselves through protective policies or special funding (e.g. military R&D, venture capital), allowing innovative ideas to develop in relative insulation before they are exposed to broader market dynamics. The innovation emerging from niches can be both beneficial and detrimental to society.

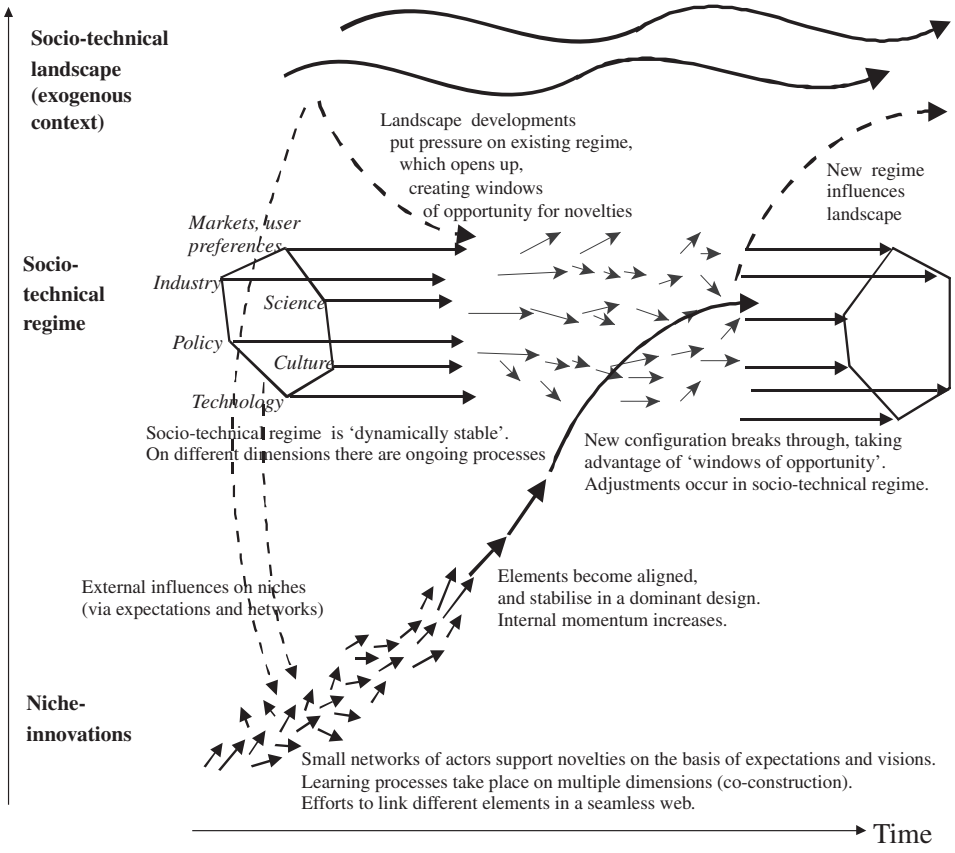

Figure: The Multi-Level Perspective showing dynamic relations between the sociotechnical regime and the landscape and niche levels (Source: Geels 2012.)

From an MLP perspective, transitions are the outcome of dynamic interactions across these levels, characterized by co-evolution rather than linear causality. As niche innovations accelerate, they interact with existing societal norms, regulatory frameworks, and business practices, and co-evolve over time. Conversely, major political, economic, or societal changes stemming from the landscape level create "windows of opportunity" when the established regime is destabilized and niche innovations have a higher chance of scaling up. Thus, the MLP framework shows that the transformation of socio-technical systems

involves simultaneous attention to small-scale innovations, medium-scale regime stability, and large-scale environmental pressures as they interact in a co-adaptive process. For an example

Although STs are complex, non-linear processes that cannot be predetermined and controlled, they can be guided through coordinated governance, policy interventions, and stakeholder engagement. Policymakers, businesses, civic organizations, and citizens can work together to adjust regulations, provide incentives, and develop supportive infrastructure – so as to align various system components toward a sustainable vision. The ST and MLP frameworks can offer strategy guidance by highlighting where interventions might be most effective.

1.2. Incumbents vs. Newcomers, Innovation vs. Destabilization

A key distinction in ST analysis is between incumbents and newcomers. **Incumbents** such as government administrations, public utilities, or large corporations typically control resources, infrastructures, and political influence. They generally resist systemic change due to sunk costs, institutional lock-in, and risk aversion – especially, when it threatens their dominant position. By contrast, **newcomers** are more flexible and less constrained by existing institutional commitments. They often operate from niches where they experiment with alternative technologies or business models and they frequently exploit crises or regulatory changes to introduce radical innovations. They can also disrupt regimes by creating "local transition pathways" that undermine incumbent rules at higher levels. Transitions may involve displacement of incumbents, but they can also emerge through collaboration between incumbents and newcomers, particularly in complex systems where mutual dependencies exist.[8]

Another important analytical distinction in STs (related to the tensions between incumbents and newcomers) is between processes of

[8] Matschoss and Heiskanen 2018; Alochet et al. 2021.

innovation and destabilization. Early ST research placed strong emphasis on **technological innovation** and **experimentation** as primary drivers of transformation. Innovation and experimentation enable systemic change through the development and diffusion of new ideas, technologies, practices, and governance models. Niche innovations play a crucial role in generating alternatives to incumbent regimes and catalyze learning, collaboration, and institutional change. They are often supported by public and private research and development (R&D) and demonstration projects, that help reduce risk for innovations, foster learning, and build legitimacy for emerging systems. These activities can align with broader societal goals through "**mission-oriented" policies** that coordinate innovation ecosystems around grand challenges like climate change.[9]

Historically, **state-led and military R&D** has been particularly influential in shaping socio-technical trajectories, with technologies such as nuclear power, the internet, and GPS later diffusing into civilian domains. Many large-scale socio-technical systems are thus historically embedded in state-led or militarized contexts, which shape not only technical priorities but also socio-political values. Military technologies and war-related experiences leave "socio-technical imprints" in different civilian systems through innovations, institutional logics, and infrastructures that persist across peacetime transitions.[10]

At the same time, innovation in STs extends beyond formal R&D to include **social, institutional, and grassroots experimentation**. Civil society organizations, universities, local communities, and social movements can pioneer alternative practices and governance arrangements, often embedding sustainability in everyday life. Recent research highlights the importance of local experimental governance arrangements such as "**urban living labs**" that pioneer more radical, participatory, and democratic approaches to innovation. Despite the gap and potential conflict between forms of "**top-down" and "bottom-up" innovation**

[9] Geels et al. 2017; Johnstone and McLeish 2020; Borrás and Edler 2020.

[10] Berkhout, Smith, and Stirling 2004; Johnstone and McLeish 2020.

processes, successful STs often require bridging and mediation across these levels.[11] Both dimensions – grassroots experimentation (e.g. living labs) and high-level technological development (e.g. formal R&D) are necessary to create, test, and scale transformative innovations.

More recent ST scholarship, however, highlights that technological innovation alone is insufficient. Transitions also require the **destabilization, decline, and phase-out** of unsustainable socio-technical systems. As important as it is to experiment and implement new technological solutions, it is imperative to address the unmaking and endings of existing systems that have become detrimental or obsolete. Examples include coal power, fossil fuel-based automobility, centralized energy monopolies, or intensive agri-business, all of whom contribute to environmental degradation and climate change. This idea of unmaking is reminiscent of Schumpeter's notion of "creative destruction", and might be especially pertinent in situations where physical, institutional, or environmental damage has already taken place.[12]

Destabilization of socio-technical systems is thus a critical intermediary phase in transitions, characterized by decreasing legitimacy of the incumbent regime, institutional incoherence, and mounting internal tensions. It can be seen as the "flipside" of innovation, and any transition involves a combination of the two: something new emerges and something old is being challenged. Turnheim suggests a useful terminological distinction between several dimensions or phases of this dynamic:

- **Destabilization**: a process through which system stability becomes challenged
- **Decline**: a reduction in systems resources, performance, or influence

[11] Fuenfschilling and Truffer 2016; Marvin et al. 2018; Rogge and Stadler 2023.

[12] This importance of unmaking and endings can be seen in a broader historical overview, whereupon the destruction of existing worldviews and social-political orders is a necessary prequel to the emergence of new ones (e.g. the European Reformation and related wars leading to the Enlightenment and the age of science).

- **Phase-out**: the intentional governance and management of system downsizing[13]

Destabilization occurs through a combination of external shocks (such as financial crises or environmental disasters), sustained internal political and social tensions, and intentional interventions. It can be accelerated through public protest, litigation, or discursive delegitimization.[14] Phase-out strategies are more deliberate efforts to dismantle entrenched systems, a purposeful discontinuation, which may or may not coincide with destabilization procceses. It involves deliberate policy and governance mechanisms to retire specific technologies or infrastructures, such as carbon pricing, technology bans, and sunset clauses.[15] However, phase-out is not merely technical but deeply political, often resisted by incumbent actors with vested interests in the existing regime. It requires proactive governance and coordination across regulatory, market, and social domains. Recognizing and managing the politics of decline is therefore essential for just and sustainable transitions.[16]

Overall, the interplay between incumbents and newcomers, and between destabilization and innovation, shapes STs as processes of simultaneously building up new systems and breaking down old ones. STs are shaped by complex interactions across a constellation of actors with different goals, resources, and capacities. While incumbents often dominate, newcomers can foster transitions by mobilizing innovative strategies – especially when they align with supportive actors and exploit institutional vulnerabilities and broader sociopolitical shifts. Understanding incumbent-newcomer actor dynamics is essential for designing effective transition strategies. It is necessary to identify the key institutions and actors at play, and their fundamental role as

[13] Turnheim 2023; Turnheim and Geels 2012.

[14] For example, the anti-nuclear movements in Germany and Japan played pivotal roles in shifting public discourse and political will, leading to tangible policy changes in the existing energy systems.

[15] Rinscheid and Wüstenhagen 2017; Rinscheid and Trencher 2022.

[16] Stegmaier et al. 2014; Joly, Barbier, and Turnheim 2023.

incumbents or innovators; to develop a realistic understanding of their relations, interests, positions and capabilities vis-à-vis hoped-for transformations; and to devise strategies to address power asymmetries and foster inclusive participation – as explored next.

1.3. Power, conflict and justice in sustainability transitions

STs are deeply embedded in **power structures and political dynamics**. They are not neutral processes of technological replacement but rather involve contentious struggles over the distribution of authority, resources, and legitimacy. Transitions become political battlegrounds where actors, including states, corporations, civil society, and marginalized communities, compete to advance their visions and interests. While early approaches such as MLP) have tended to underplay these dynamics, subsequent work has since foregrounded institutional power, discursive conflict, political economy, and political ecology. These studies have brought attention to the role of power asymmetries and to concepts such as regime resistance, particularly how regimes maintain their dominance by shaping institutional rules and socio-technical expectations; while others have highlighted the significance of empowerment and counter-power in enabling transformative agency.[17] In this framework, conflict is an essential component of systemic change.

Alongside the concern with (unequal) power, **justice and equity** considerations in STs have become increasingly prominent, focusing on who are the "winners" and "losers" of transition, who benefits from it and who bears its costs, how, and why. STs have a normative dimension since they can create, reinforce, or rectify injustices – but also because perceived injustices can lead to failure to secure social acceptance that can halt the progress of transitions. While the emphasis is often on the distributional consequences of transitions, issues of participation in policy processes and in decision making, and recognition of diverse

[17] Smith et al. 2005; Avelino and Rotmans 2009; Lawhon and Murphy 2012.

social groups are equally important.[18] Questions of justice have been tackled most explicitly in energy transitions, including the concept of energy justice and in the work on "just transitions", which advocates for STs that are simultaneously low-carbon and address socio-economic inequalities.[19] Attention is given to how more inclusive forms of transition can be designed and operationalized, and to the agency of non-traditional actors in transitions, such as marginalized groups and non-state-based actors in shaping transition processes. Overall, the ST literature now sees power, politics, and justice as intrinsic to understanding how transitions unfold. Conflicts over knowledge, technology, and governance reflect deeper struggles over material resources and social futures.

In some contexts, **armed conflict and post-conflict reconstruction** significantly shape STs, often in disruptive but generative ways. Military institutions and defense-industrial complexes represent especially powerful actors that can shape transition pathways through R&D, procurement, and infrastructure investment. Wars act as exogenous shocks that rapidly destabilize existing systems and open windows for technological and institutional experimentation. War also tends to destroy physical infrastructure, leading to breakdowns in the systems that underpin everyday life. This can take shape as collateral damage or as intentional targeting of infrastructures, especially in urban warfare.[20] However, these ruptures also create critical openings for the emergence of new socio-technical configurations and institutional reform. In some cases, the urgency and visibility of reconstruction efforts can accelerate innovation and governance shifts that might otherwise face resistance in stable contexts. In post-conflict settings, reconstruction becomes a socio-technical reconfiguration process; it is not simply a matter of physical rebuilding, but a deeply political process of renegotiating the governance, functionality, and cultural meaning of

[18] Newell and Mulvaney 2013; Moss et al. 2014; Sovacool et al. 2016; Köhler et al. 2019.

[19] Swilling and Annecke 2012; Newell and Mulvaney 2013; Jenkins et al. 2018.

[20] Graham 2011.

infrastructure systems such as energy, water, and transport.[21] Hence, infrastructure becomes a terrain of both contestation and collaboration, where competing actors (states, international donors, NGOs, local communities) struggle to redefine the direction and ownership of future systems. This dynamic makes post-conflict environments both highly volatile and unusually fertile grounds for transition.

These examples underscore that power, politics, conflict, and even wars are constitutive in STs. Understanding and designing transitions requires attention to the institutional legacies of militarism, the strategic use of innovation to reproduce or contest power, and the ways in which systemic change unfolds through both (violent) disruption and negotiation.

1.4. Spaces of transition: Infrastructure, cities and regions

Geographical and spatial dimensions are integral to sustainability transitions – even beyond the urgent context of conflict and reconstruction. Urban built environments, the different physical infrastructures that sustain them, and the wider regional systems in which they are embedded, are not passive backdrops or containers for transitions. Rather, they are active elements that shape what types of transitions are possible in specific locations, how they unfold, and which groups benefit or are excluded in the process.[22] Place-specific factors shape STs at local, urban, and regional scales in different ways.[23] For example, **urban and regional visions and policies** can mobilize a wide range of actors and provide collective direction to facilitate local development and regional innovation systems;[24] **formal and informal institutions**, values, norms and practices, can also play an important

[21] Özerdem 2015; Chaar et al. 2020; Roll and Entsminger 2023.

[22] Research on the geography of transitions includes Lawhon and Murphy 2011; Coenen and Truffer 2012; Raven et al. 2012; Binz et al. 2014; Truffer et al. 2015; Murphy 2015.

[23] Hansen and Coenen 2015; Köhler et al. 2019.

[24] Hodson and Marvin 2010; Bulkeley and Castán Broto 2011; Truffer and Coenen 2012; Carroli 2018.

role, such as allowing high levels of trust within local networks;[25] **natural resources** or scarcity can shape investment decisions in sustainable technologies and policies;[26] **technological and industrial specialization** and relevant skills in the regional labor market can condition the development of innovations needed for STs.[27]

Built environments also embody **historical legacies** of past and existing socio-technical systems, constraining and enabling future change. The spatial embeddedness of infrastructure and technological systems means that transitions cannot be decoupled from their physical and geographic contexts; innovations must often contend with inherited spatial patterns, ownership structures, and social meanings.[28] The built environment serves as a locus of lived experience, where transitions become tangible through changes in housing, transportation, public space, and everyday life. These changes influence public perceptions, shape behavioral norms, and determine the inclusivity of transition benefits.

Similarly, regional institutions and networks, geographical landscapes and cultural identities, and interactions with other (neighboring or more distant) regions – all play a role in how STs may scale up.

Cities and regions are therefore particularly important arenas for STs. They concentrate populations, infrastructures, governance capacities, and experimentation, and are increasingly central to sustainability and climate agendas. Indeed, the importance of urban STs has become more pronounced with rapid urbanization at a planetary scale – with nearly 60 percent of the world's population already residing in cities. The quest for climate action and sustainability thus largely becomes an urban challenge, recognized by urban actors themselves.[29] In this context, urban experimentation, and especially urban living labs, have

[25] Shove et al. 2012; Bridge et al. 2013; Wirth et al. 2013.

[26] Carvalho et al. 2012; Murphy and Smith 2013.

[27] Carvalho et al. 2012; Monstadt 2007; Ornetzeder and Rohracher 2013.

[28] Nielsen and Farrelly 2019.

[29] Köhler et al. 2019, Brenner and Schmid 2014.

become prominent tools for advancing transitions at the scale of local communities, the entire city, and beyond.[30] Yet, the capacity of cities and regions to transform is uneven and mediated by global economic and political contexts. Urban and regional transitions are a contested domain where socio-technical and political forces intersect and unfold through situated negotiations and unstable compromises – underscoring the importance of place-based politics.[31]

Urban and regional transitions also highlight the **interconnectedness of infrastructure systems**, creating both barriers to change and opportunities for synergy. Energy, water, food, mobility, and health systems are deeply interdependent, requiring coordinated, "multi-sector" transitions rather than siloed interventions. While ST research has traditionally focused on single systems, there is growing recognition of the need to address these interdependencies through multi-system and "nexus"-oriented perspectives[32] – a theme that is further explored in the next section.

Governing STs must therefore address the deeply spatial and place-connected nature of transitions. The built environment not only constrains but also offers opportunities for experimentation, adaptation, and systemic transformation. Understanding STs through the lens of infrastructure, cities, and regions underscores the material, local, and historical dimensions of transitions. This shifts our focus from abstract models of transition to situated analyses that reflect the diversity and complexity of real-world transitions embedded in specific places.

[30] Bulkeley and Castán Broto 2013; Evans et al. 2016; Marvin et al. 2018; Turnheim et al. 2018.

[31] Hodson and Marvin 2010; Rutherford and Coutard 2014.

[32] Monstadt 2009; Köhler et al. 2019; Gürsan et al. 2023.

In conclusion of Chapter 2, socio-technical transitions are complex, multidimensional processes encompassing technological, institutional, social, spatial, and political dimensions. Their trajectories are shaped by incumbent power, innovative niches, spatial configurations, conflicts and, on occasion, the disruptive dynamics of war and reconstruction. While innovation and experimentation provide positive mechanisms for systemic change, success depends on managing complex interactions among actors, navigating entrenched interests, destabilizing detrimental regimes, and aligning transition efforts with broader goals of sustainability, resilience, and justice. While the ST perspective offers a powerful frame to analyze institutional and processual dimensions – the "how" and "who" of systemic transformations – it remains less developed in addressing material, spatial, and infrastructural dimensions – the "what" and "where" of transformation. These gaps point toward the relevance of complementary approaches, such as the nexus perspective, which foreground the interconnections among systems and infrastructures in specific places, discussed next.

2. Nexus Thinking: *What to Transform?*

This chapter introduces nexus thinking as a complementary framework to sustainability transitions. Whereas sustainability transitions research focuses primarily on how socio-technical systems change over time – through innovation, destabilization, and governance – nexus thinking shifts attention to what interconnected systems must be addressed together in order to achieve sustainability, resilience, and social equity. It foregrounds the fact that food, energy, water, infrastructure, ecosystems, and social systems are deeply interdependent, and that interventions in one domain almost inevitably produce effects – often unintended – across others. In a world characterized by accelerating climate change, rapid urbanization, widening inequalities, and recurrent political and economic crises, these interdependencies have become more visible and more consequential. Nexus thinking responds to this condition of polycrisis by offering an integrative lens for identifying key system linkages, anticipating trade-offs and synergies, and designing coordinated interventions across domains and scales.

Importantly, nexus thinking does not replace the sustainability transitions perspective but complements it. While transitions research provides insight into the dynamics of long-term systemic change, nexus thinking helps clarify which systems must be transformed in tandem, and where misalignment between sectors may undermine transformation efforts. Together, these approaches offer a more complete framework for addressing contemporary sustainability challenges.

2.1. What is Nexus Thinking?

The term "nexus," derived from the Latin *nectere* ("to bind"), refers to a connection or series of connections that link multiple elements into a structured whole.[33] In contemporary research and policy, **nexus thinking** denotes an analytical and governance framework concerned with understanding and managing interdependencies among systems

[33] Estoque 2023.

that are often treated separately. While mostly associated with natural resource management, nexus thinking increasingly incorporates social, economic, political, and spatial dimensions.

The academic roots of nexus thinking lie in systems thinking, complexity theory, and integrated resource management. These traditions emphasize non-linearity, feedback loops, path dependency, and co-evolution between systems, challenging linear cause–effect assumptions. From this perspective, sustainability problems are not isolated failures but emergent properties of interacting systems. Nexus thinking therefore directs attention to relationships rather than individual components.

The term nexus emerged in policymaking in the late 1980s and consolidated in the 2000s as a response to growing concerns over resource scarcity, environmental degradation, and the limitations of siloed policies. It gained global prominence following the 2011 Bonn Conference on the Water–Energy–Food Nexus. This event marked a turning point, framing **the Food-Energy-Water (FEW) nexus** – three systems that are also at the core of ST research – as a prerequisite for sustainable development. Since then, the nexus concept – as a shorthand for intersectoral integration – has been widely adopted by international organizations, development agencies, and national and urban policymakers. Its appeal lies partly in its pragmatic orientation: rather than proposing a single normative solution, it encourages context-specific analysis of trade-offs and synergies.

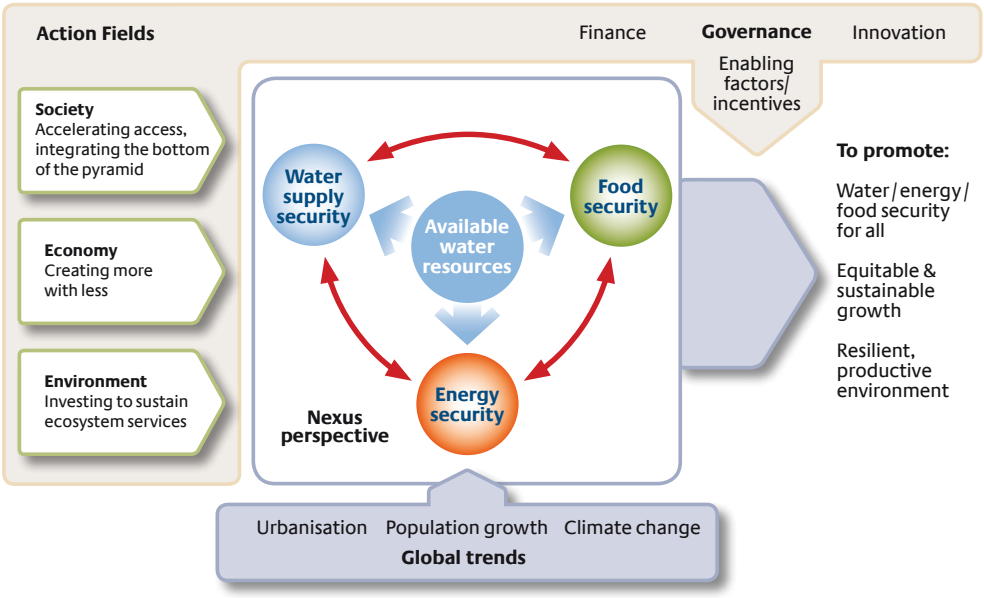

Figure: The Bonn 2011 Nexus Framework (Source: Hoff 2011)

At its core, nexus thinking critiques sectoral policymaking and governance. Historically, resource management was predominantly siloed, with water, energy, agriculture, and other sectors governed independently. This compartmentalization often led to inefficient use of resources and to conflicts between sectors. Policies designed within institutional silos seek to optimize outcomes in one domain while shifting costs, risks, or resource pressures to others. For example, energy policies that promote renewable generation without considering water requirements may increase water stress, while agricultural intensification strategies can raise energy demand and degrade water quality. These overlaps necessitate coordinated strategies to avoid policy mismatches and ensure resource sustainability. Nexus approaches seek to make these interdependencies visible and to promote more coherent, cross-sectoral decision-making. By highlighting synergies, cascading effects, co-benefits and trade-offs, nexus thinking enhances sustainability and resilience in development planning.[34]

[34] Schwanen 2018; Estoque 2023.

Over time, the scope of nexus thinking has expanded significantly in both research and policy debates. While the FEW nexus remains foundational, researchers have proposed additional nexus formulations incorporating additional infrastructural systems (e.g. waste) and specific industries; the specific attributes of urban systems (the "urban nexus"); social domains such as health and social development (e.g. Health–Environment–Development nexus); wider natural systems, ecological services, and climate change (e.g. Water–Food–Energy–Climate nexus); and political processes, conflict, security, and peacebuilding (e.g. Humanitarian–Development–Peace nexus). This expansion reflects growing recognition that sustainability challenges are multidimensional. At the same time, it raises concerns about conceptual overstretch. Accordingly, this chapter focuses on nexus formulations that are well established in the literature and demonstrably relevant for sustainability governance, urban contexts, and conflict-affected settings.

2.2 The Food–Energy–Water (FEW) Nexus

The Food–Energy–Water nexus is the most widely recognized and empirically developed expression of nexus thinking. It highlights the mutual dependencies among food production systems, energy systems, and water resources, which together underpin human well-being, economic activity, and ecological integrity. Globally, agriculture accounts for approximately 70 percent of freshwater withdrawals and 30 percent of energy, particularly for irrigation, fertilizer production, processing, and mechanization. Energy systems, in turn, depend heavily on water for extraction, processing, cooling, and hydropower generation. Water supply and wastewater treatment systems are themselves energy-intensive, especially in contexts reliant on desalination, groundwater pumping, or long-distance transfers. As a result, pressures or disruptions in one system can rapidly cascade across the others.

A frequently cited illustration of FEW trade-offs is large-scale biofuel production, also referred to as the "fuel vs. food" conflict. Policies promoting biofuels (from food crops, plants, or algae) as low-carbon

energy alternatives to fossil fuel have often intensified competition over land and water, contributed to rising food prices, and driven deforestation and biodiversity loss. In this case, ostensibly cleaner and renewable energy use of biofuels becomes a "FEW trigger" for unsustainable shifts in food and water systems, as well as detrimentally impacting ecosystems.[35] Similar dynamics are evident in industrial agriculture and palm oil production, where food and energy markets intersect with water pollution, ecosystem degradation, and greenhouse gas emissions.[36]

Beyond identifying trade-offs, nexus thinking emphasizes opportunities for synergy and co-benefits. Integrated approaches can reduce resource use, enhance resilience, and improve system efficiency. Examples include the reuse of treated wastewater for irrigation, which supports food production while reducing freshwater extraction and the energy load of water treatment and desalination facilities; energy recovery from wastewater treatment; integrated planning of hydropower and irrigation; and solar-powered irrigation systems that lower fossil fuel dependence while improving agricultural productivity. Realizing such synergies, however, requires coordination across institutions that are often fragmented.

The FEW nexus is increasingly salient in the context of climate change and disaster resilience. Droughts, floods, and heatwaves can simultaneously disrupt food production, water availability, and energy generation, while climate mitigation and adaptation strategies can introduce new trade-offs across these systems. Without a nexus perspective, responses in one sector risk amplifying vulnerabilities in others. Hence, there is a growing concern with the FEW-Climate nexus.[37] Despite growing analytical sophistication, operationalizing the

[35] Newell et al. 2019; Fargione et al. 2008; Searchinger et al. 2008.

[36] Obidzinski et al. 2012; Woiciechowski et al. 2016; Kubitza et al. 2018.

[37] Beck and Villarroel Walker 2013; Rasul and Sharma 2015; Zhou et al. 2022. Water-energy nexus approaches have been suggested also in the Middle East and other regions that suffer from water scarcity, e.g. Giordano and Quagliarotti 2020; Weinthal and Sowers, 2020.

FEW nexus remains challenging due to persistent institutional silos, governance fragmentation, data limitations, and insufficient stakeholder engagement. However, recent research has advanced tools and models for scenario analysis and stakeholder integration, offering promising directions.[38]

2.3. Social-Economic Dimensions of the Nexus

Early nexus research focused primarily on natural resource flows and technical efficiency. More recent work emphasizes that nexus interactions are deeply shaped by social relations, economic determinants, market regulations, power asymmetries, and good governance. Access to food, energy, and water is unevenly distributed within and across societies, making equity and justice central concerns for nexus analysis. Vulnerable populations – particularly low-income households, marginalized communities, and populations in developing regions or fragile or conflict-affected contexts – often experience multiple, overlapping forms of deprivation. In such settings, shortages of food, unreliable energy access, and unsafe water reinforce one another, exacerbating poverty, health risks, and social instability. Interventions that improve aggregate efficiency without addressing distributional outcomes may therefore deepen inequality, exacerbate social tensions, or displace local communities.

Nexus thinking should therefore include a clear social-economic analysis and engage affected communities in decision-making, addressing affordability and accessibility, and ensuring that benefits and risks are distributed fairly. It should address the role of labor markets, migration patterns, and gender relations, which further influence who benefits from and who bears the costs of FEW interventions. Economic instruments such as subsidies, taxation, pricing regimes, and trade policies also play a critical role in shaping nexus outcomes. Fossil fuel subsidies, for example, can encourage water-intensive energy production, while agricultural subsidies may promote unsustainable water use or monocropping.

[38] Liu et al. 2018; Hejnowicz et al. 2022.

Incorporating socio-economic analysis helps align sectoral policies and anticipate unintended social consequences. Tools such as cost-benefit analysis, social impact assessments, and participatory scenario planning can support more inclusive and effective nexus interventions.[39]

At the global policy level, the **UN Sustainable Development Goals** provide an ambitious agenda for 2030 through a framework that implicitly reflects nexus logic. Although articulated as 17 distinct goals, the SDGs are deeply interconnected. Advancing on any single goal is dependent on – and supports the advancement of – many other goals. For example, achieving food security (SDG 2) and clean water and sanitation (SDG 6) supports poverty alleviation (SDG 1), health (SDG 3), education (SDG 4), gender equality (SDG 5), and other goals. Conversely, isolated progress in one area (e.g. economic growth, SDG 8) can undermine others (climate action, SDG 13, biodiversity on land and in water, SDGs 13 and 14). Nexus approaches offer analytical tools for mapping SDG interactions, managing trade-offs, and promoting policy coherence across the 2030 Agenda. Some countries have adopted integrated national development plans aligned with the SDGs, operationalizing nexus thinking at scale.[40]

[39] Laspidou et al. 2020; Botai et al. 2021.

[40] Nilsson et al. 2016; Liu et al. 2018; Hejnowicz et al. 2022.

Figure: The Food-Energy-Water nexus and its potential synergies and trade-offs with all 17 SDGs. (Source: Liu et al. 2018.)

2.4. The Urban Nexus

Cities and urban regions are "hotspots" of the nexus challenge. Urbanization concentrates demand for food, energy, and water while generating large volumes of waste, GHG emissions, and environmental pressures. At the same time, cities concentrate infrastructure investment, governance capacity, and opportunities for experimentation, making them key sites for integrated approaches. It is crucial therefore to apply "nexus thinking" to cities.

The "urban nexus" perspective can be understood as a paradigm shift from optimizing individual urban infrastructures to managing the interdependencies that underpin urban life. It offers an integrated framework for studying and managing the interconnections among key resource systems – notably water, energy, food, waste, and land – within urban environments. This approach emerged in policy circles following the 2011 Bonn Conference as a way to "urbanize" the FEW nexus and adapt it to the spatial, institutional, and socio-political contexts of cities.[41] Its primary aim is to enhance resource efficiency, resilience, and sustainability in urban regions through systems-based integration and cross-sectoral policy alignment.

[41] GIZ and ICLEI 2014; Lehmann 2018; Newell et al. 2019.

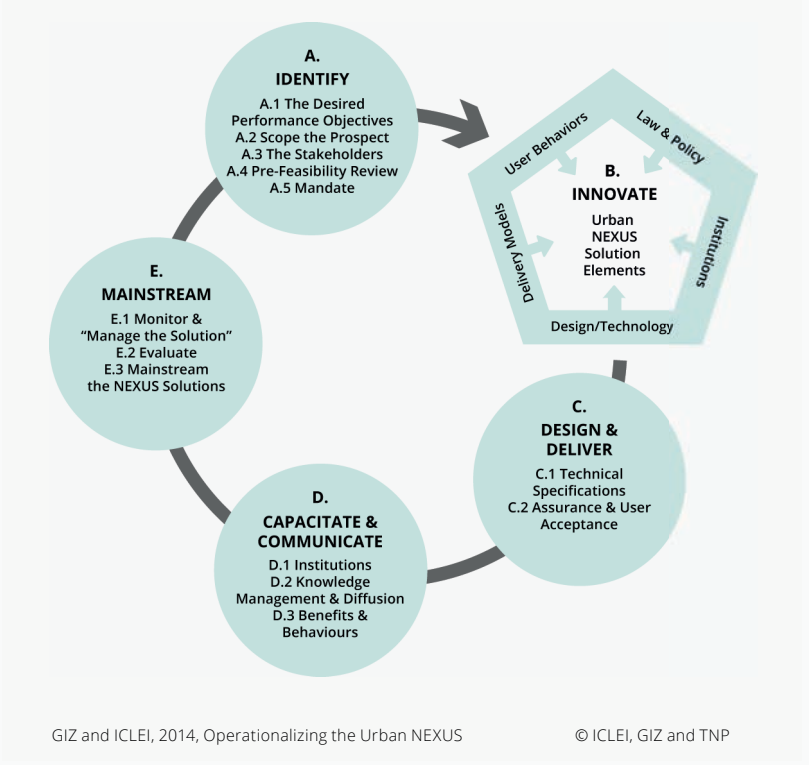

Figure: The Urban Nexus Development Cycle (Source: GIZ and ICLEI 2014.)

Academically, the urban nexus draws on **urban metabolism** and systems perspectives. It conceptualizes cities as complex socio-ecological systems defined by interconnected flows and feedback loops of energy, water, materials, people, and information.[42] Urban metabolism models quantify these different resource flows as they move in and out of an urban territory and the material stocks that accumulate as buildings and infrastructure. This approach enables to identify intervention points to achieve more "**circularity**" (reuse and recycling of resources) and less waste – with the aim of designing "closed-loop" systems to promote urban sustainability.[43]

Urban nexus governance poses both challenges and opportunities. Fragmented authority within and between municipalities, metropolitan

[42] Kennedy et al. 2011; Castan Broto et al. 2012.

[43] Ferrão and Fernández 2013; Lehmann 2018; Schulterbrandt et al. 2018.

agencies, public utilities, and private infrastructure providers can impede coordination and long-term integration. Urban-regional governance should therefore evolve to reflect the cross-sectoral and multi-scalar nature of resource systems – reframing sustainability as a coordination challenge across infrastructures, institutions, and scales.[44] At the same time, city governments are often more agile than national bodies, making them ideal sites for governance innovation and experimentation. Cities can pilot nexus solutions, such as integrated infrastructure planning, decentralized energy–water systems, food–waste–energy loops, and nature-based solutions that address flooding, heat, and water quality simultaneously. Urban living labs and experimental governance arrangements have become prominent tools for testing such approaches, allowing municipalities to explore innovation while managing political and financial risk. This reflects a transition from nexus-as-modeling toward nexus-as-governance, where learning, co-production, and stakeholder participation become essential mechanisms for sustainable urban transformation.[45]

Importantly, the urban nexus cannot be understood only at the scale of the city but also as a **regional nexus** (or metropolitan nexus). Urban systems are deeply embedded in regional and supra-regional infrastructures and socio-economic networks. Cities rely on hinterlands for water, food, energy generation, labor, and waste disposal, while regional transport, logistics, and energy grids shape urban consumption and production patterns. This regional embeddedness means that urban nexus interventions on their own may shift pressures outward rather than resolve them, for example by externalizing water extraction, land-use change, or pollution to peripheral areas. At this scale, interactions between urban cores, suburban and peri-urban zones, and rural areas become visible, particularly in relation to food systems, watershed governance, energy generation, and labor markets. Metropolitan

[44] Important contributions for urban nexus thinking and governance include Artioli et al. 2017; Monstadt and Coutard 2019; Newell et al. 2019; Ramaswami 2020; Williams et al. 2019.

[45] GIZ and ICLEI 2014; Tye et al. 2022.

regions often encompass multiple jurisdictions with uneven capacities and interests, making coordination both more necessary and more difficult. Regional nexus governance can help align infrastructure investment, land-use planning, and social policy across administrative boundaries.[46]

Socio-economic dynamics are also strongly regionalized. Housing markets, commuting patterns, industrial specialization, and income inequality extend beyond municipal borders and shape access to food, energy, and water. **Regional inequalities** can reinforce urban vulnerability, particularly where marginalized populations are pushed to infrastructure-poor peripheries. Incorporating regional socio-economic analysis into the urban nexus highlights the need to integrate infrastructure planning, social policy, and environmental governance rather than treating them as separate domains.

Crucially, scholars emphasize that the urban and regional nexus is not only a technical framework but also a political one. Progressive nexus approaches therefore should focus on the institutional and social – rather than purely technical – conditions under which more inclusive configurations of infrastructure service can be promoted. This includes institutional reform, participatory governance, and sensitivity to historical and spatial inequalities embedded in infrastructures and regional development trajectories. In global South or post-conflict contexts, integrated provision solutions can significantly reduce costs, especially when supported by participatory governance; but they risk reproducing existing inequalities if they prioritize efficiency over inclusion of marginalized communities (e.g. informal settlements, refugee camps). Researchers and policymakers have also explored the "nexus of urbanization, violence, and conflict", linking SDG 11 (Sustainable Cities and Communities) and SDG 16 (Peace, Justice and Strong Institutions) – a topic addressed next.[47]

[46] Seto et al. 2012, Ramaswami et al. 2017, Monstadt and Coutard 2019.

[47] Global Alliance for Urban Crises 2016; Lehmann 2018; Monstadt and Coutard 2019.

2.5. International and Global Dimensions of the Nexus

Beyond cities and resource systems, nexus thinking has been extended to international and global policy domains where environmental, social, and political dimensions intersect. These nexus frameworks address the mutual impacts and interdependencies between different forms of stresses, shocks, and crises that affect communities – as well as the different efforts and interventions to mitigate them by local, national and international stakeholders. This extension is particularly evident in fragile and conflict-affected contexts, where sectoral interventions often fail to address the structural drivers of vulnerability. International nexus thinking therefore combines humanitarian aid, environmental peacebuilding, international development, and climate policy. It includes several dominant and somewhat overlapping approaches.

The **Humanitarian–Development–Peace (HDP) nexus** emerged from critiques of fragmented international responses to protracted crises. Humanitarian aid is typically short-term, addressing immediate needs, while development focuses on long-term capacity-building and community institutions, and peacebuilding focuses on conflict resolution and political stabilization. The HDP nexus stresses that all three policy domains should be harmonized to ensure that relief efforts contribute to sustainable development and peace; to address the root causes of crises, such as inequality, weak institutions, and environmental stress; and to avoid reinforcing existing tensions. Integrated HDP approaches emphasize local ownership of projects, institutional strengthening, and community resilience. In practice, implementing the HDP nexus is challenging. Humanitarian principles of neutrality and independence may conflict with state-led development or peacebuilding agendas, while funding mechanisms and organizational mandates remain siloed. Nonetheless, the HDP nexus has become influential in UN and donor policy, particularly in contexts characterized by chronic instability rather than discrete emergencies.[48]

[48] OECD 2019; Fanning and Fullwood-Thomas 2019; Barakat and Milton 2020; Joireman and Haddad 2023; Brown et al. 2024; Levy 2024.

Closely related is the **Peace–Sustainability nexus**, which frames peace and sustainable development as mutually reinforcing processes. From this perspective, peace is not merely the absence of violence but depends on equitable access to resources, inclusive institutions, and environmental sustainability. Conversely, unsustainable resource use, environmental degradation, and socio-economic exclusion can undermine peace by intensifying grievances and competition. The Peace–Sustainability nexus therefore advocates for peacebuilding and sustainable development policies to be designed in tandem, especially in contexts of conflict prevention or post-conflict recovery. It has gained prominence in both policy and academic debates.[49]

The **Climate–Conflict nexus** (or Climate-Security nexus) further extends this logic by examining how climate change acts as a threat multiplier. Rather than assuming deterministic links between climate change and violent conflict, this literature emphasizes context-specific pathways through which climatic stresses interact with political, economic, and social conditions. Droughts, floods, and heatwaves can undermine livelihoods, increase displacement and forced migration, strain state capacity, and exacerbate existing tensions. Regions with fragile political institutions, including the Middle East, are particularly exposed to climate-induced instability. At the same time, climate adaptation, risk reduction, and resilience-building are increasingly framed as forms of conflict prevention and security policy, and climate diplomacy can become a critical tool to promote regional cooperation and peace. Thus, the Climate–Conflict nexus reframes security as a developmental and environmental challenge, calling for coordinated strategies that address both human security and ecological risk.[50]

Together, these international nexus formulations highlight that the FEW nexus and related sustainability challenges cannot be separated from questions of social development, governance, security, and peace.

[49] Sharifi et al. 2021a; 2021b; Amadei 2021; Fisher et al. 2021; Simangan et al. 2025.

[50] Evans 2010; Scheffran et al. 2012; Ide et al. 2016; Daher et al, 2017; Behnassi 2021; Daoudy 2021; Britchenko 2025; Rapaport 2023.

They also underscore the importance of aligning short-term (e.g. humanitarian aid) and long-term (e.g. climate change) interventions; and of multi-level coordination, linking local and regional dynamics to national and international policy frameworks, such as the SDGs.

2.6. Towards an Expanded Nexus Approach

As this overview demonstrates, nexus thinking has evolved from a resource-management concept into a broader analytical and policy framework, extending into societal, political, and international domains, and addressing urban environments, contexts of conflict, and issues related to sustainability, governance, equity, and peace. While the FEW nexus remains central, it is increasingly complemented by new nexuses, urban, climate, health, biodiversity, and peace-related nexuses.

Recent reviews document a rapid expansion in the number and complexity of nexus formulations (i.e. from nexuses with two or three "nodes" to nexuses with four, five, or even six-nodes"). This is closely linked to the SDG agenda, the planetary boundaries framework, and debates on global risk. New nexus components that are currently being given particular attention in the literature include health, biodiversity, ecosystems, land, materials, and specific natural resources. This expansion enhances analytical realism by "capturing" more components involved in a nexus (i.e. causes, effects, conditions, context, etc.), but it also raises concerns about conceptual coherence and governance capacity. Scholars argue that the nexus approach should be used not only as a tool for systems integration – but also as an open-ended method for exploring development pathways, and as a platform for engagement with stakeholders of diverse concerns and competences. Nexus thinking should include more and different sectors beyond FEW; it should consider geographical scales, bridge nexuses from the local to the planetary scales, and integrate both top-down and bottom-up interactions; and it should simultaneously address nexuses in multiple places, including distant localities and regions, to address the increasing spatial separation between resource production and consumption,

as well as geopolitical tensions, wars, and other impacts of distant processes. Overall, nexus frameworks should be problem-driven, context-sensitive, and participatory rather than become ever more abstract or technical.[51]

In conclusion of Chapter 3, nexus thinking is increasingly applied to compound global challenges, including climate change, ecological degradation, economic instability, and violent conflict. By fostering holistic understanding and integrated action across sectors and socio-technical systems, it offers a powerful approach for addressing 21st-century challenges. In this sense, nexus thinking complements sustainability transitions by clarifying what systems must be transformed together to address contemporary polycrises.

As the interrelated climate, ecological, economic, and political crises seem to escalate across the planet and feed off each other – captured by the notion of the "**polycrisis**" – the next generation of nexus thinking should expand accordingly to incorporate several pillars. It should incorporate a comprehensive outlook of environmental and ecological concerns aligned with living within planetary boundaries and planetary health; it should address increasing economic instability and transform existing economic models fixated on growth through ideas such as sufficiency and wellbeing; and it should strive to end current regional wars and conflicts (in Ukraine, Gaza, and elsewhere) that risk multiplying and escalating into a global crisis.

Emerging work on planetary health and global existential risks underscores the need for integrative approaches that link planetary boundaries, human well-being, and peace. It posits that the health of our planet's ecosystems is intrinsically linked to the stability and peace of human societies, and vice versa. [52] This work can inform a new notion of a **Planet-Peace-Prosperity Nexus** as a method to address the current polycrisis – by exploring and specifying the multifaceted

[51] Estoque 2023; Liu et al. 2018.

[52] Smith 2022; Nurse 2023; Tschudin 2024; Scheffran 2025.

relationships between planetary health, global peace, and a coupled flourishing of economic and ecological systems. This PLENTY nexus – to use a shorthand – is part of the conceptual framework outlined in the next section.

3. A Conceptual Framework for Nexus Transformations

After introducing the two essential frameworks for sustainability thinking and policymaking – sustainability transitions and the nexus – and their key concepts and vocabulary, this chapter seeks to interconnect them into one practical (rather than theoretical) framework. The objective is to offer a useful way to combine both nexus thinking and ST insights and apply them to processes that seek to simultaneously transform multiple **sectors**, at different **levels** (niche, regime, landscape) and across geographical and governance **scales** (from local to planetary). Such an approach could make an important contribution to sustainable development, generally, and to post-conflict reconstruction, especially. This framework is named in this paper **Nexus Transformations** as it aims to highlight the transformative potential of thinking across and interconnecting multiple systems.

3.1. Integrating Sustainability Transitions and Nexus Thinking

As discussed earlier, ST researchers focus on several key transitions in energy, mobility, and agri-food systems. However, these socio-technical systems are mostly studied separately from each other. While there is some acknowledgment in the ST literature of how different socio-technical systems might impact each other (e.g. niches that create innovations for more than one system, or regimes that come under similar pressures from the landscape level), they are seldom considered as inherently interconnected. Currently, there is limited research on "multi-sector transitions" and on the interactions between different systems [53].

This is where the nexus approach adds valuable insights and contribute to the analysis of ST, as it sees the sustainability of any single system not in an isolated manner but as intricately interconnected with other systems. This offers a clear advantage from a sustainable development perspective, especially in contexts where several systems are lacking

[53] Köhler et al. 2019.

or deficient all at once, exacerbating unsustainable conditions; and, conversely, where approaches at integrated planning and governance of infrastructures may enable positive synergies or "leapfrogging" directly towards more sustainable systems. Moreover, the nexus approach is highly relevant for interventions in areas of conflict and processes of post-conflict reconstruction, because often the challenge is not only that separate systems and infrastructures come under extreme stress or are destroyed – but also that their simultaneous collapse can have aggravated effects that must be addressed in tandem.

The ongoing focus of ST analysis on single socio-technical systems is certainly limiting at this point; as is the fact that nexus research does not engage with ST ideas to understand the interactions between systems in a more holistic and institutional way. Currently, there is very little academic or policy literature that engages these two major approaches systematically, although some recent examples have referred to both.[54]

To simplify these two heterogeneous fields of study, we could say that ST is oriented towards **interconnected processes** through which different systems (separately) can be managed and changed over time to achieve more sustainability; while nexus research is oriented towards the physical and technical attributes of interconnected systems, comprising of infrastructures and the resources that flow through them, and how they can be designed in an integrated manner to reduce negative externalities and achieve positive synergies.

Therefore, much could be gained from combining the two approaches within a framework of Nexus Transformations, as tentatively outlined here. Rather than attempting to integrate ST and nexus thinking, this paper simply suggests that their key ideas and their complementary advantages should be used to frame analysis and planning for systemic transformations for sustainability. For example, it would be valuable if policymakers and practitioners of sustainable development were

[54] Schwanen 2018; Bortoleto et al. 2021; Soares Dal Poz et al. 2022; Helerea et al. 2023; Varga et al. 2023; Zellner et al. 2023; Zahedi et al. 2024.

adequately versed in both approaches and could combine or switch between them at different stages of the process – from analysis and conceptualization, through planning, to implementation and monitoring.

This combined approach could be especially useful in situations of **post-conflict reconstruction**, which necessitate the interconnected transformation of inadequate or destroyed infrastructural and socio-technical systems to support more stable and peaceful conditions on the ground. A framework of Nexus Transformations – that advances from local infrastructures, through regional social-economic and ecological systems, to international political conjunctures – would allow to radically rethink conventional ideas and practices of post-war reconstruction. This means, in the first place, not to limit the scope of reconstruction to the physical dimensions of the built environment (i.e. to the construction of new buildings, facilities, and basic infrastructures), nor to conventional community and economic development projects.

Nexus Transformations entails much more than "building back" to the previous situation, or to one slightly improved through a sprinkling of sustainability jargon. Nor should it stop at "building better" by deploying standard, standalone sustainable projects (which may not be sustainable if they do not account for nexus impacts). Instead, this combined approach could redefine reconstruction as a process of "building forward better": transitioning towards sustainability through a multi-nexus of systems and societal processes, that could also open up and "lock in" new opportunities for stability, security, and peace.

3.2. Nexus Transformations: From FEW to MORE to PLENTY

The Nexus Transformations framework integrates an expanded notion of the nexus with the multi-level perspective of sustainability transitions to address the following scales and dimensions of sustainable development and reconstruction:

- **FEW Transformations**: Local level actions and initiatives primarily directed at the nexus of infrastructural systems, especially **FEW**

systems: Food, Energy, Water – that directly impact the local environment.

- **MORE Transformations**: Regional level actions and initiatives primarily directed at the economic-ecological nexus, in particular **MORE systems: Mobility, Regional Economy and Ecology** – that are the basis of a well-functioning sustainable region.
- **PLENTY Transformations**: National, international, or global level actions and initiatives aimed at achieving the SDGs and addressing the **PLENTY nexus: Planet Peace and Prosperity** – purposefully connecting local and regional actions to the potential benefits for the planet as a whole.

The following sections give a short description of each level of nexus transformations, the main interrelated systems it includes, and some additional considerations:

- **FEW Transformations: Focus on the local scale and niche level**

FEW Transformations are the "natural" starting point for practitioners of sustainable development and reconstruction. They align with the prevalent policy focus on the food, energy, and water nexus, but should also include closely connected waste and wastewater treatment systems, alongside local planning and community-based projects. Local level initiatives could set up these essential systems where they are missing, deficient, or destroyed, and design them from the outset as an interrelated set of systems; or they could transform existing, inefficient, and unsustainable systems by studying and enhancing their nexus interrelations to minimize trade-offs and enhance synergies. These transformations should focus on the community and urban scales, where FEW systems have a very large impact on everyday life and environmental conditions (including health and wellbeing), but they would necessarily connect also to regional systems. Specifically, local systems include (but are not limited to):

- **Food**: promote local food security, sustainable agriculture and food production, community gardens and urban agriculture; reduce food

waste and promote composting, reuse and recycling facilities; support local and artisanal food businesses; connect to agri-tech and food-tech hubs.

- **Energy**: design and apply community-managed renewable energy systems, including rooftop solar and other local decentralized generation systems; set up microgrids at the scale of communities or city districts; aim at minimizing GHG emissions and achieving net-zero energy; connect to energy-tech hubs.
- **Water**: design and apply micro- and local water generation, collection, and reuse systems (including collection of rain, recycling of gray water, local desalination facilities); allow for wells and aquifer replenishing; use local wastewater treatment to enable reuse for local agriculture; connect to water-tech hubs.
- **Construction materials**: remove, reuse, and recycle construction debris (from war or redevelopment); support urban mining processes; remediate land contamination using biological and ecological solutions; connect to construction-tech hubs.
- **Community**: design and build the above systems with local communities through processes of co-production to support sustainable and socially rich community life; support a continuum of rural and urban lifestyles and local commerce based on small- and medium-sized enterprises (SMEs); develop accessible and lively public spaces.
- **Urban planning**: promote local transit-oriented development (TOD) in connection to regional transit; plan to boost accessible and safe walkability and biking options and enhance street shade; plant locally adapted trees, develop green and blue infrastructures to tackle heat and pollution; integrate planning with the above systems.
- **Local health**: these different systems should contribute to active lifestyles, individual wellbeing, a healthy local environment free from any forms of locally produced pollution, and a public health system integrated at the community level.

The transformation of FEW local systems is centered on the niche level of the MLP framework. This entails designing and implementing them in collaboration with niche institutions and local technological ecosystems, mobilizing a wide range of niche actors and networks including social actors, community NGOs, etc. It requires identifying and promoting actors with transformative potential, including "newcomers" that could bring innovation and motivation, while also bringing on board "incumbents" that are ready to explore new sustainable paths. Practically, this could take the form of Local/Urban Living Labs (LLLs/ULLs) to experiment with technological and social innovations on the ground, get real-world and real-time local feedback, and allow for their rapid and realistic scale-up. Simultaneously, this might require phasing out some incumbent institutions and procedures that have a vested interest in preserving an unsustainable "lock-in". The time scale (temporal dimension) of FEW transformations prioritizes short-to-mid-term initiatives, starting from emergency and rapid interventions, through interim solutions, up to a planning and implementation horizon of five to fifteen years.

◎ **MORE transformations: Expand to the regional scale and the regime level**

MORE transformations build on FEW nexus transformations and expand their scope and ambition to enhance sustainable regional mobility and economic systems, and to preserve and responsibly benefit from regional natural systems and their ecological services. These economical-ecological ("eco-eco") systems should be highlighted and prioritized as the backbone of a well-functioning sustainable region: where people, materials, and products move with ease, speed, and minimal emissions; where jobs and services are nearby and accessible; where regional education systems and labor markets create knowledge and equal opportunities; and were all these systems help protect and benefit from thriving natural ecosystems. MORE transformations will often require developing and governing transboundary interconnections, especially in regions where existing municipal, administrative, and even national borders do not align with the extent of economic interactions

(e.g. energy dependencies, labor migration), geographical settings (e.g. river basins, coastal planes, mountain ranges), environmental conditions (e.g. cross-border pollution), and ecological systems (e.g. biodiversity). These transboundary interconnections could be strategically developed to overcome political obstacles and create new incentives for cooperation and regional stability. Regional systems include (but are not limited to):

- **Food**: expand and connect local food initiatives to regional agricultural hinterlands (rural communities beyond the urban core) and sustainable food import and export systems, minimizing "food miles" while creating a distinct regional food culture and "brand" (e.g. protected designation of origin, PDO).
- **Energy**: expand and connect local energy initiatives to regional renewable energy systems such as solar fields combined with agriculture, green hydrogen projects (in connection to renewable energy generation and storage); connect region to existing natural gas and electricity grids as a temporary bridge to full transition to renewables.
- **Water**: expand and connect local water initiatives to regional water systems such as larger scale "green" desalination plants (in connection to renewable energy generation and storage); align water and wastewater systems with sustainable river basin and aquifer management; plan for regional water resilience, flood and sea level rise preparedness.
- **Materials**: expand and connect local material initiatives (including construction debris) into a regional circular economy for different material flows and stocks; convert global supply chains and waste flows into sustainable regional loops that minimize carbon, material, and ecological footprints.
- **Mobility**: expand and connect local urban planning initiatives to a regional mobility plan, including regional-scale TOD; develop an electric bus rapid transit system (BRT) as a priority and affordable option (or a "metro" train system if physical and financial conditions

allow); promote cross-border connectivity and open movement (contingent on political and security considerations).

- **Regional Economy**: plan for a circular and decarbonized economy; promote "smart specialization" and distinct regional value chains; support regional R&D clusters, universities, and technological ecosystems; develop data and management systems for "smart regions"; support regional cooperatives and "solidarity economy"; create cross-border free trade zones and integrated labor markets (contingent on political and security considerations).
- **Regional Ecology**: promote land and marine conservation and sustainable river basin management; protect the integrity of regional ecosystems (e.g. through ecological corridors), biodiversity hotspots, and nature reserves; recognize and sustainably draw on ecological services; eliminate regional and cross-border pollution; enable abundant access to nature to all communities in the region.
- **Regional health**: develop an extended network of hospitals and health facilities that are fairly distributed across the region (avoiding "medical deserts") and embedded in the regional economy (e.g. supporting health-tech and biotech R&D); connect healthy living environments and healthy ecosystems to enhance overall wellbeing.

The transformation of MORE regional systems is centered on the socio-technical **regime level** of the MLP framework. This entails developing strategies to transform existing (often large scale and powerful) institutions, industries, and infrastructure providers, both public utilities and private corporations. It also requires that regional strategies pay close attention to issues of regulation, industrial standards, social values, and cultural norms. This is not a simple task, but a nexus approach could prove advantageous; because although such incumbent actors can dominate a single system or sector, it is unlikely that they can dominate several sectors at once. Therefore, a nexus approach – backed by political will and economic viability – could open new pathways for collaboration and transformation that would not exist if tackling each of these systems separately.

Practically, this could take the form of larger Regional Living Labs and innovation hubs that scale up the experiments and lessons learned at the local/urban level. Politically, it could advance through a collaborative forum that brings all the relevant stakeholders (including local communities) to the table to openly deliberate and jointly determine transformation pathways. Government (national or regional) should ensure the democratic functioning and fair play of such a regional transformation forum. The **time scale** of MORE transformations should prioritize **mid-to-long-term initiatives**, based on strategic planning and an implementation horizon of ten to twenty-five years.

- **PLENTY Transformations: Connect to the global scale and the landscape level**

The novel concept of the PLENTY Nexus highlights the intersections between the wellbeing of planetary systems (as defined and evaluated by the Planetary Boundaries (PB) or Earth Systems Boundaries (ESB) scientific framework)[55] and political-economic processes that can support peace and prosperity, regionally and globally. It posits that the health of our planet's ecosystems is intrinsically linked to the stability and peace of human societies – and that both are the foundations of human and natural prosperity and flourishing. A PLENTY approach stresses that security, peace, and prosperity cannot be achieved in a world that is ecologically unsustainable, as environmental degradation and the collapse of ecosystems would lead to conflict and destabilize societies.

Peace on earth is contingent upon the ability to live within the Earth's ecological limits. Overuse and depletion of natural resources including land and water, climate change and global warming, biodiversity loss and

[55] The planetary boundaries framework highlights the rising risks from human pressure on nine critical global processes that regulate the stability and resilience of the Earth. These nine boundaries are climate change, biosphere integrity, biogeochemical flows (nitrogen and phosphorus cycles), land system change, freshwater change, ocean acidification, novel synthetic chemical pollution (such as microplastics), atmospheric aerosol loading, and stratospheric ozone depletion. The 2023 update concluded that six of the nine boundaries are currently transgressed. See: https://www.stockholmresilience.org/research/planetary-boundaries.html

collapse of ecosystems, the severe disturbance of biogeochemical cycles, environmental contamination – these unchecked processes do not only threaten ecological integrity but pose existential threats to human security and peace. The PLENTY nexus therefore calls for a global approach to peace that includes urgent action to remain within planetary boundaries, to ensure that future generations and other species can thrive in a peaceful world. This requires global political commitments that go beyond the current sustainable development agenda.

PLENTY Transformations thus offer policymakers and practitioners an aspirational outlook for the future of the region in its interrelations with the world at large – from international development agendas (notably the SDGs), thorough global economic and societal trends, to the planet itself and its different systems. They draw stronger links between environmental nexus thinking (FEW) and political nexus thinking (e.g. Peace–Sustainability or Climate–Conflict) and apply them in tandem to situations of conflict and to processes of peacebuilding. More specifically, PLENTY Transformations concern:

- **International roadmaps**: align and purposely connect the FEW+MORE transformations with the SDGs and with relevant international agreements (e.g. the Paris Agreement on climate change, The Kunming-Montreal Global Biodiversity Framework (GBF), The UN Convention to Combat Desertification (UNCCD)) – as well as with the post-2030 agenda that is currently debated.
- **Planetary Boundaries**: align and purposely connect the FEW+MORE transformations to the PB framework; examine potential impacts on different earth systems under stress according to the region's specific impacts on different PBs; ensure in a scientifically verifiable way that local and regional transformations do not add to the transgression of PBs and even contribute to retreating from dangerous thresholds and tipping points.
- **Ecologies of Peace**: consider pathways to transform the climate and ecological crisis from a security risk enhancer to an opportunity for regional (Middle East) and international cooperation and

peacebuilding; promote regional climate and biodiversity initiatives (mitigation, adaptation, resilience, ecological wellbeing) as a connector between national plans (e.g. NDCs) and international agreements; work towards integrated peace-climate-ecological protection agreements in the region.

- **Prosperity**: align the FEW+MORE transformations with economic thinking that recognizes the physical finiteness and ecological limits of the planet; shift from economic models obsessed with growth (GDP) to new economic frameworks (e.g. steady-state, post-growth, degrowth, sufficiency), societal arrangements, and indices that emphasize non-material prosperity, wellbeing, and happiness (e.g. Sustainable Development Index, Happy Planet Index, World Happiness Report); create long term conditions for humans and nature to flourish together.
- **Planetary health**: align PLENTY transformations with the One Health and Planetary Health frameworks as unifying approaches that aim to sustainably balance and optimize the health of people, animals, plants, ecosystems, and the planet.

The transformation of PLENTY global-planetary systems engages with the socio-technical **landscape level** of the MLP framework. While landscape dynamics cannot be willfully transformed or even wholly predicted (even by powerful governments or corporations), they are critical for framing any transformational process. Technological revolutions, geopolitical tensions, wars and conflicts, global economic fluctuations, trade agreements and tariffs, international conventions, climate change and planetary ecological stressors – should be considered and analyzed for their potential impact on local and regional level transformations. Equally, the regional and local levels could be considered as specific "filters" or "lenses" of landscape dynamics, reflecting and refracting their impacts in ways that can be more or less advantageous to the wished-for transformations. For example, while global technological advances (such as the rapid rise of AI) are beyond the direct control of any region, that does not mean that regional-regime

or local-niche actors could not play an important role in applying them according to their specific needs. It is important not to directly adopt generic technologies but to adapt them to the social and technological innovations designed at the Local/FEW and Regional/MORE levels.

The **time scale** of PLENTY transformations aligns with **long-term initiatives** based on a strong visioning (or "futuring") element and with a strategic planning horizon of twenty to forty years and beyond. It should set up principles that are fundamental for human-planet prosperity yet enable flexibility to the inevitably changing circumstances and potentially escalating conditions, such as in the case of crossing Earth system tipping points (e.g. addressing sea-level rise in coastal areas).

3.3. Key stages and considerations in applying Nexus Transformations

In applying the Nexus Transformations framework, it is suggested to start from specific and localized socio-technical systems, notably those that constitute the FEW nexus, and gradually scale up the analysis to examine more wide-ranging and higher-level processes (MORE + PLENTY).

1. **Identify specific systems** that require urgent intervention or hold potential for substantial transformation:

- Different scoping methods could be used to identify and prioritize systems that are under intensifying stress, have suffered from direct shocks, or are clearly unsustainable.
- As a preliminary stage, it might be practical to first consider each system in isolation to gain a quick indication of its conditions (e.g. applying a SWOT analysis of strengths, weaknesses, opportunities, and threats,).
- Even this early evaluation should be done in a collaborative method, paying attention to the needs, wishes, and concerns of a wide range of stakeholders, including systems' users or beneficiaries.

2. **Identify nexus connections between systems** that would produce synergies and minimize tradeoffs:

- Apply conceptual, qualitative, and quantitative analyses to understand different dimensions and dynamics connecting these systems to each other.
- Consider both horizontal interactions between systems at the same scale and vertical interactions across scales.
- Try to identify first the most significant connections between local systems, then move up through regional systems to global and planetary contexts: FEW >> MORE >> PLENTY.
- When scaling up, expand and consider interactions with other systems and processes beyond those that were the focus at the first stages.
- As more systems and dynamics are added, it is important to "revisit" the analysis of the local systems and reframe it accordingly: **PLENTY >> MORE >> FEW.**
- Develop a holistic view of interactions between systems within and across scales, even if some of these interactions could only be addressed at a later stage.

3. **Apply the sustainability transitions framework and the multi-level perspective:**

- Analyze the interrelated socio-technical systems, nexuses, and contextual processes in view of **niche, regime, and landscape dynamics** that impact them.
- It might be practical to identify first the **interactions between "corresponding" nexus scales and transition levels**. There are likely to be important impacts between niche dynamics and localized FEW systems; regime dynamics and regional MORE systems; landscape dynamics and global PLENTY systems.
- However, there are significant **interactions between different transition levels** (i.e. between niches and regimes, regimes and landscape, niches and landscape). Therefore, their combined and cumulative impacts on FEW-MORE-PLENTY systems should be considered.

- Focus the analysis to **identify existing "lock-ins"** within unsustainable systems and nexuses. Are there particular dynamics across the niche, regime, and landscape levels that preserve a detrimental status-quo and prevent a sustainable transformation?
- **Identify specific system elements that should be destabilized** and phased out to support of system transformations. This could include regulations, (dis)incentives, outdated infrastructures and technologies, vested economic or political interests, lack of trust or knowledge, values, norms, etc.
- Correspondingly, **identify existing or imminent innovations** that have potential to be applied, adapted, or scaled up to transform systems. Technological innovations at the niche level could play an important role, but it is just as important to scope for potential social, economic, organizational, and community-based innovations.

4. **Map the key institutions and actors** that manage and impact the different systems across scales and levels:

- Categorize institutions and actors according to their level and scale (e.g. are they niche, regime, or landscape actors; do they operate at a local, regional, global scale?); domains of action (e.g. technology, finance, security, community, environment, politics); and specific socio-technical sectors (e.g. energy, agriculture, mobility).
- Establish principles (and potential metrics) to **distinguish between institutions and actors that enable "lock-in" and those that could contribute to sustainable transformation.**
- This critical distinction is likely to align with the distinction between **newcomers and incumbents** within the systems and nexuses analyzed.
- Such distinctions are not meant to be moralistic or derogatory, nor should they be binary. Rather, they should set up a scale of **transformative potential** and help determine which institutions and actors are positioned to contribute to the envisaged transformation and which are likely to object to it or obstruct it.

- It might also be useful to apply **political power analysis** to understand the relations of power between key institutions and actors. How might they be realigned and what coalitions of actors could be developed in support of transformative change?
- This stage, especially, should be designed in a **collaborative, inclusive, and transparent** way to bring together the views of a wide range of institutions and actors and to counteract potential biases and prejudices.

5. **Identify entry points or impact points** that have the most potential to support sustainable nexus transformations:
- Based on the above stages, identify and prioritize the most strategic components of the systems and nexuses to be transformed, and the levels and institutions that could have the most impact on their transformation.
- Is there a **specific socio-technical system** (or a more limited set of systems) that could start the process of "unlocking" the wider nexus?
- Is there a **specific set of innovations and networks of institutions** applying them that would support a sustainable transformation?
- Are there **specific communities and localities** where experimentation takes place, innovations are applied, and that can create public awareness and political support for transformation?

6. **Set up a temporal vision of sustainable transformation** and a set of accumulative goals across an extended process:
- Envision and plan **how transformation would evolve over time:**
- Develop **short-range (5-15 years) local community-based collaborative plans** focusing on FEW transformations.
- Develop **mid-range (10-25 years) regional outline plans** for MORE transformations.
- Develop **long-range (20-50 years) scenarios and strategic plans** for PLENTY transformations.

- The overlap in time scales is both intentional and practical, as these are not separate stages but rather integrated processes that will inevitably impact each other.
- This is a major difference of the Nexus Transformations framework compared to methods that set up concrete predetermined goals in advance. Rather, the framework should assist to identify **processes and levers for transformation** towards an emerging outcome of a more sustainable nexus of systems.
- As the nexus of systems expands over time, it remains adaptable to changing circumstances and experiences on the ground. It may "contract" in response to changing needs or obstacles, or it may also expand its reach and ambitions building on its success.
- Hence, **regional peace** could be considered both a key facilitator of sustainable nexus transformations – and the hoped outcome of it.

Conclusion: Future Directions for Applying Nexus Transformations for Sustainability and Peace

This paper introduced researchers and policymakers in security and peace studies to two key frameworks of sustainability, Sustainability Transitions and Nexus. It then offered a practical synthesis of the two through the integrated framework of Nexus Transformations. This framework can help policymakers draw critical connections between FEW (Food, Energy, and Water) systems at the local scale, MORE (Mobility, Regional Economic and Ecological) systems at the regional scale, and PLENTY systems for living in security, prosperity, and peace within planetary boundaries. Nexus Transformations is therefore presented as a systematic way to think through and transform complex socio-technical and political systems into much more stable, sustainable, and potentially peaceful constellations. It calls on policymakers to address sustainable development challenges and regional conflicts, including post-conflict reconstruction, as multi-level and multi-scale opportunities for systemic transformation.

While the approach taken in this paper is mostly conceptual, it outlines the key stages and guiding questions for applying the Nexus Transformations framework across diverse domains of sustainable development and post-conflict reconstruction. The framework is open-ended enough to be potentially applied in different parts of the world, in both Global North and Global South contexts, and in different geographical and geopolitical settings. However, it is important to note that the paper was originally written with a specific region and context in mind. Namely, the cross-border Gaza region, encompassing both the Palestinian Gaza Strip and the Israeli Gaza "Envelope", following the shocking October 7th attack by Hamas, the devastating Gaza War that ensued, and currently, the fragile ceasefire, which could hopefully lead to a wider regional process.

There are different reasons why it would be worthwhile to apply the Nexus Transformations framework to the cross-border Gaza region

and its post-war reconstruction. First, it helps us recognize the current situation in Gaza as a culmination of an extremely unstable and unsustainable socio-technical border regime, evolving and hardening for several decades – before collapsing on October 7th and then rehardening during the war.[56] Second, the framework helps identify and analyze the multiple dimensions and complex interdependencies of the existing socio-technical systems along and across the border. It can address together different (severely damaged and constrained) infrastructural systems that are critical for life under extreme conditions in Gaza and highlights their interdependence with each other and with systems on the Israeli side of the border. Finally, it can be applied to open new opportunities for positive interdependencies and synergies for a "sustainable political-ecological reconstruction" between Gaza and the Western Negev.[57]

In this way, the Nexus Transformations framework offers a roadmap for transitioning away from the decades-long harmful and unsustainable border regime between Israel and Gaza, that has been the source of so many causalities and losses on both sides. It can help identify different lock-ins and obstacles to transformation that might not be seen through traditional conflict management frameworks. More importantly, it can also point at potential leverages and effective interventions – between niche innovations, regime destabilization, landscape pressures, across local to planetary scales – towards a more stable, sustainable, and peaceful region. Hence, analyzing the situation in the Gaza region through this framework is not a purely academic exercise. Rather, it opens new perspectives and delivers insights – beyond those more familiarly generated by security and peace studies – to inform and design new pathways of sustainable transformation.

The hope of this paper, therefore, is to introduce Nexus Transformations as a useful framework that could be applied to the Gaza region; the wider region encompassing Israel, the Palestinian territories, and neighboring

[56] Marom 2023.

[57] Rapaport and Kibrik 2024.

states such as Egypt and Jordan as direct partners in the envisaged transformations; and the wider Middle East region, including key partners in the Gulf and the international community. The toolbox and trajectory proposed here – moving from FEW systems through MORE synergies to PLENTY opportunities – match the scale of the regional and global challenges at hand. How can we transform the immense and fraught task of rebuilding a war-devastated Gaza into a launchpad for a regional process of peacemaking? How do we integrate this with multi-scale sustainability and resilience projects to address the climate and ecological crisis? In other words, the Nexus Transformations framework could be used as a method to explore ways to align the Gaza region, Israel, Palestine, and the Middle East with the necessary political and ecological transitions in the years and decades ahead.

The Mitvim Institute is currently leading a project on the post-war reconstruction of the Gaza Region through the "Built Forward Better" approach, together with local, regional, and international partners. The Nexus Transformations framework, as detailed in this paper, will serve as a guiding set of concepts for the project. Follow-up work is expected in the coming year to translate the proposed framework into more detailed policy recommendations.

Appendix:

Automobility as a socio-technical system

The conceptual foundations of the ST and MLP "theory of change" are grounded in detailed empirical studies of historical socio-technical change. As this research demonstrates, a socio-technical system often starts with a revolutionary technological invention, which is then mainstreamed. One paradigmatic example is automobility. Research by Geels and others demonstrates how the private automobile evolved from a technological novelty into one of the most dominant socio-technical systems of the twentieth century. Automobility began with the invention of the internal combustion engine and its incorporation into mass-produced vehicles. Over time, this technology became embedded in extensive infrastructures, including urban road networks and national highway systems, and intertwined with powerful economic actors such as oil companies, automobile manufacturers, and construction firms. Policy support, including zoning regulations and public investment in roads and highways, reinforced this trajectory, while cultural meanings associated with freedom, speed, and individual autonomy further stabilized the system.[58]

During the twentieth century, automobility profoundly reshaped cities, landscapes, and everyday life. It became closely linked to industrial growth, suburbanization, and modernist ideals of progress. It also reshaped modern politics and the contours of the modern state in different, sometimes contradictory, ways.[59] The highway system, for example, allowed for easier and faster physical connections between different regions within and between countries, leading to increased regional integration – but also to the blurring of regional and local differences (economies, languages, cultures, etc.). Modern automobility

[58] Geels 2002; 2005; Marletto, 2012.

[59] Mitchell 2011.

also necessitated the growth of state bureaucracies and monopolies for the construction and maintenance of road infrastructure – while simultaneously concentrating economic and political power at the hands of the fossil fuel and automobile industries, which can lobby and pressure governments, both domestically and internationally.

Yet the very "success" of automobility generated mounting negative externalities, including traffic congestion, road accidents, air pollution, greenhouse gas emissions, and social exclusion. Over time, these costs have increasingly outweighed the benefits, rendering automobility environmentally, socially, and politically unsustainable. We are still "locked-in" within a socio-technical system that was largely beneficial in the first half of the 20th century – but has become highly detrimental in the 21st century.

In recent decades, these contradictions have prompted efforts to transition toward more sustainable mobility systems. Electric vehicles, shared mobility services, cycling and walking infrastructure, public transport innovations, and car-free urban zones have emerged as alternatives to car-centric models. Cities have become especially important sites of experimentation, implementing policies and infrastructures that seek to reduce car dependency, reclaim public space, and improve urban quality of life.[60] However, mobility transitions remain highly contested. Established stakeholders – including automobile manufacturers, fossil fuel industries, and planning institutions – often resist transformative change. Moreover, technological innovation alone does not guarantee sustainable outcomes. Rather, sustainable mobility transitions must deliberately address affordability, accessibility, and social inclusion, particularly for groups historically marginalized by car-centric planning.[61]

The automobility case illustrates the central dynamics of STs: lock-in, resistance, experimentation, and the need to align technology, policy,

[60] Sovacool and Axsen 2018; Sonnberger and Graf 2021.

[61] Ruhrort 2024.

culture, and equity to reshape how societies move in more sustainable and inclusive directions. Moreover, it suggests that not all institutions and actors engaged in socio-technical transitions are directly or fully committed to sustainable goals. Rather, the process is non-linear, involving feedback loops and gradual convergence toward new, more sustainable configurations – and it is inherently fraught with politics and conflicts. The following sections develop these ideas, highlighting specific themes within the ST framework that are pertinent to security and peace studies, including the role of states and other key actors, power dimensions, and situations of conflict and post-conflict reconstruction.

References

Alochet, M., Boxenbaum, E., & Roux, E. (2021). Actors and hybridization in sustainability transitions: The case of autonomous mobility. *Research Policy, 50*(6), 104245.

Amadei, B. (2021). A systems approach to the sustainability–peace nexus. *Sustainability Science,* 16(4), 1111-1124.

Artioli, F., Acuto, M., & McArthur, J. (2017). The water–energy–food nexus: An integration agenda and implications for urban governance. *Political Geography, 61*, 215–223.

Avelino, F., & Rotmans, J. (2009). Power in transition: An interdisciplinary framework to study power in relation to structural change. *European Journal of Social Theory, 12*(4), 543–569.

Barakat, S., & Milton, S. (2020). Localisation across the humanitarian-development-peace nexus. *Journal of Peacebuilding & Development, 15*(2), 147-163.

Beck, M. B., & Villarroel Walker, R. (2013). On water security, sustainability, and the water–food–energy–climate nexus. *Frontiers of Environmental Science & Engineering, 7*(5), 626–639.

Behnassi, M. (2021). The nexus of environment, climate, conflict, and security. In *Climate Security and Justice.* Routledge.

Berkhout, F., Smith, A., & Stirling, A. (2004). Socio-technological regimes and transition contexts. In *System Innovation and the Transition to Sustainability.* Edward Elgar.

Binz, C., Truffer, B., & Coenen, L. (2014). Why space matters in technological innovation systems: Mapping global knowledge dynamics of membrane bioreactor technology. *Research Policy, 43*(1), 138-155.

Borrás, S., & Edler, J. (2020). The roles of the state in the governance of socio-technical systems' transformation. *Research Policy, 49*(5), 103971.

Bortoleto, A.P., Barbosa, P., Maniero, M., Guimarães, J., & Junior, L. (2021). A Water-Energy Nexus analysis to a sustainable transition path for Sao Paulo State, Brazil. *Journal of Cleaner Production, 319*, 128697.

Botai, J.O., Botai, C.M., Ncongwane, K.P., & Mpandeli, S. (2021). A review of the water–energy–food nexus research in Africa. *Sustainability, 13*(4), 1762.

Brenner, N., & Schmid, C. (2014). The 'urban age' in question. *International Journal of Urban and Regional Research, 38*(3), 731–755.

Bridge, G., Bouzarovski, S., Bradshaw, M., & Eyre, N. (2013). Geographies of energy transition: Space, place and the low-carbon economy. *Energy Policy, 53*, 331–340.

Britchenko, I. (2025). Climate change as a threat multiplier: Assessing its impact on resource scarcity, migration, and political instability. *Politics & Security, 12*(2), 41–58.

Brown, S., Mena, R., & Brown, S. (2024). The peace dilemma in the triple nexus: Challenges and opportunities for the humanitarian–development–peace approach. *Development in Practice, 34*(5), 568–584.

Bulkeley, H., & Castán Broto, V. (2013). Government by experiment? Global cities and the governing of climate change. *Transactions of the Institute of British Geographers, 38*(3), 361–375.

Carroli, L. (2018). Planning roles in infrastructure system transitions: A review of research bridging socio-technical transitions and planning. *Environmental Innovation and Societal Transitions, 29*, 81–89.

Carvalho, L., Mingardo, G., & Van Haaren, J. (2012). Green urban transport policies and cleantech innovations: evidence from Curitiba, Göteborg and Hamburg. *European Planning Studies, 20*(3), 375–396.

Castan Broto, V., Allen, A., & Rapoport, E. (2012). Interdisciplinary perspectives on urban metabolism. *Journal of Industrial Ecology, 16*(6), 851–861.

Chaar, A., Khatib, S., & Sakr, N. (2020). Infrastructure reconstruction and governance in post-conflict Lebanon. *Third World Quarterly, 41*(5), 792–810.
Coenen and Truffer 2012

Daher, B., Lee, S., Mohtar, R.H., & Asaka, J.O. (2017). Security, climate change, and the resource nexus. In *The Water–Energy–Food Nexus.* Routledge.

Daoudy, M. (2021). Rethinking the climate–conflict nexus: A human–environmental–climate security approach. *Global Environmental Politics, 21*(3), 4–27.

Evans, A. (2010). *Resource Scarcity, Climate Change and the Risk of Violent Conflict.* World Bank.

Evans, J., Karvonen, A., & Raven, R. (Eds.). (2016). *The Experimental City*. Routledge.

Estoque, R. C. (2023). A systematic review of the nexus approach: Evolution, scope, and future directions. *Sustainable Development, 31*(1), 1–16.

Fanning, E., & Fullwood-Thomas, J. (2019). *The Humanitarian-Development-Peace Nexus: What does it mean for multi-mandated organizations?* Oxfam Discussion Paper.

Fargione, J., Hill, J., Tilman, D., Polasky, S., & Hawthorne, P. (2008). Land clearing and the biofuel carbon debt. *Science, 319*(5867), 1235–1238.

Ferrão, P., & Fernández, J. E. (2013). *Sustainable Urban Metabolism.* MIT Press.

Fisher, J., Arora, P., Chen, S., Rhee, S., Blaine, T., & Simangan, D. (2021). Four propositions on integrated sustainability: Toward a theoretical framework to understand the environment, peace, and sustainability nexus. Sustainability Science, 16, 1125–1145.

Fuenfschilling, L., & Truffer, B. (2016). The interplay of institutions, actors and technologies in socio-technical systems– An analysis of transformations in the Australian urban water sector. *Technological Forecasting and Social Change, 103*, 298–312.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy, 31*(8–9), 1257–1274.

Geels, F. W. (2005). *Technological transitions and system innovations: A Co-Evolutionary and Socio-technical Analysis*. Edward Elgar.

Geels, F. W., Sovacool, B. K., Schwanen, T., & Sorrell, S. (2017). Sociotechnical transitions for deep decarbonization. *Science, 357*(6357), 1242–1244.

Geels, F. W., & Turnheim, B. (2022). *The Great Reconfiguration*. Cambridge University Press.

Giordano, G., & Quagliarotti, D.A. (2020). The Water-Energy-Security Nexus in the Middle East. *IEMed.*, 80.

Global Alliance for Urban Crises (2016). *The Nexus of Urbanization, Violence and Conflict.* UNDP & CUNY.

GIZ & ICLEI. (2014). *Operationalizing the Urban Nexus*. Deutsche Gesellschaft für Internationale Zusammenarbeit.

Graham, S. (2011). *Cities under Siege: The New Military Urbanism*. Verso Books.

Grin, J., Rotmans, J., & Schot, J. (2010). *Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change*. Routledge.

Gürsan, C., De Gooyert, V., De Bruijne, M., & Rouwette, E. A. J. A. (2023). Socio-technical infrastructure interdependencies and their implications for urban sustainability; Recent insights from the Netherlands. *Cities, 140*, 104397.

Hansen, T., & Coenen, L. (2015). The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field. *Environmental Innovation and Societal Transitions, 17*, 92–109.

Hejnowicz, A. P., Ramaswami, A., & Kennedy, C. (2022). Integrated urban systems and SDG interactions. *Nature Sustainability, 5*(7), 585–592.

Helerea, E., Calin, M. D., & Musuroi, C. (2023). Water energy nexus and energy transition – A review. *Energies, 16*(4), 1879.

Hodson, M., & Marvin, S. (2010). Can cities shape socio-technical transitions and how would we know if they were? *Research Policy, 39*(4), 477–485.

Ide, T., Link, P.M., Scheffran, J., & Schilling, J. (2016). The climate-conflict nexus: pathways, regional links, and case studies. In *Handbook on Sustainability Transition and Sustainable Peace.* Cham: Springer.

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2018).

Energy justice: A conceptual review. *Energy Research & Social Science, 11,* 174–182.

Johnstone, P., & McLeish, T. (2020). The role of military R&D in civilian innovation: Lessons from socio-technical transitions. *Science and Public Policy, 47*(5), 640–650.

Joireman, S.F., & Haddad, F. (2023). The humanitarian–development–peace Nexus in practice: Building climate and conflict sensitivity into humanitarian projects. *Current Opinion in Environmental Sustainability, 62*, 101272.

Joly, P. B., Barbier, M., & Turnheim, B. (2023). Governing the discontinuation of large socio-technical systems. In *New Horizons for Innovation Studies*. Edward Elgar.

Kennedy, C., Pincetl, S., & Bunje, P. (2011). The study of urban metabolism and its applications to urban planning and design. *Environmental Pollution, 159*(8–9), 1965–1973.

Köhler, J., Geels, F. W., Kern, F., et al. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions, 31*, 1–32.

Kubitza, C., Krishna, V.V., Alamsyah, Z., & Qaim, M. (2018). The economics behind an ecological crisis: Livelihood effects of oil palm expansion in Sumatra, Indonesia. *Human Ecology*, 46, 107–116.

Laspidou, C.S., Mellios, N.K., & Spyropoulou, A.E. (2020). Systems thinking on the resource nexus. *Science of the Total Environment*, *738*, 139868.

Lawhon, M., & Murphy, J. T. (2012). Socio-technical regimes and sustainability transitions: Insights from political ecology. *Progress in Human Geography, 36*(3), 354–378.

Lehmann, S. (2018). Conceptualizing the urban nexus framework for a circular economy: Linking energy, water, food, and waste (EWFW) in Southeast-Asian cities. In *Urban Sustainability and Circular Economy*. Elsevier.

Levy, E. (2024). *Humanitarian Strategy in the Israel-Hamas War*. Mitvim Institute and SID Israel. *https://mitvim.org.il/wp-content/uploads/2024/08/English-Humanitarian-strategy-2.pdf*

Liu, J., Hull, V., Godfray, H. C. J., et al. (2018). Nexus approaches to global sustainable development. *Nature Sustainability, 1*(9), 466–476.

Maghen, L. (2025). *Lessons for the Sustainable Rehabilitation of Gaza*. Berl Katznelson Foundation and Mitvim Institute. *https://mitvim.org.il/wp-content/uploads/2025/10/Lessons-for-the-sustainable-rehabilitation-of-gaza-liel-maghen.pdf*

Marletto, G. (2014). Car and the city: Socio-technical transition pathways to 2030. *Technological Forecasting and Social Change, 87*, 164-178.

Marom, N. (2023). The collapsed border obstacle in Gaza: A sustainability transitions framework. *Ecology & Environment, 14*(3) (in Hebrew).

Matschoss, K., & Heiskanen, E. (2018). Innovation intermediary challenging the energy incumbent: enactment of local socio-technical transition pathways by destabilisation of regime rules. *Technology Analysis & Strategic Management, 30*(12), 1455-1469.

Marvin, S., Bulkeley, H., Mai, L., McCormick, K., & Palgan, Y. V. (2018). *Urban Living Labs: Experimenting with City Futures*. Routledge.

Mitchell, T. (2011). *Carbon Democracy: Political Power in the Age of Oil*. Verso Books.

Monstadt, J. (2009). Conceptualizing the political ecology of urban infrastructures: insights from technology and urban studies. *Environment and planning A, 41*(8), 1924-1942.

Monstadt, J. (2007). Urban governance and the transition of energy systems: Institutional change and shifting energy and climate policies in Berlin. *International Journal of Urban and Regional Research, 31*(2), 326-343.

Monstadt, J., & Coutard, O. (2019). Cities in an era of interfacing infrastructures. *Urban Studies, 56*(11), 2191–2206.

Moss, T., Becker, S., & Naumann, M. (2015). Whose energy transition is it, anyway? Organisation and ownership of the Energiewende in villages, cities and regions. *Local Environment, 20*(12), 1547-1563.

Murphy, J. (2015). Human geography and socio-technical transition studies: Promising intersections. *Environmental Innovation and Societal Transitions, 17*, 73-91.

Murphy, J., & Smith, A. (2013). Understanding transition—periphery dynamics: Renewable energy in the highlands and islands of Scotland. *Environment and planning A, 45*(3), 691–709.

Newell, J.P., Goldstein, B., & Foster, A. (2019). A 40-year review of food–energy–water nexus literature and its application to the urban scale. *Environmental Research Letters, 14*(7), 073003.

Newell, P., & Mulvaney, D. (2013). The political economy of the 'just transition'. *The Geographical Journal, 179*(2), 132–140.

Nielsen, J., & Farrelly, M.A. (2019). Conceptualising the built environment to inform sustainable urban transitions. *Environmental Innovation and Societal Transitions, 33*, 231–248.

Nilsson, M., Griggs, D., & Visbeck, M. (2016). Policy: Map the interactions between SDGs. *Nature, 534*(7607), 320–322.

Nurse, J. (2023). Human security and existential threats: A governance framework for planet, peace, people & prosperity. *Cadmus*, 192.

Obidzinski, K., Andriani, R., Komarudin, H., & Andrianto, A. (2012). Environmental and social impacts of oil palm plantations and their implications for biofuel production in Indonesia. *Ecology and Society, 17*(1).

OECD (2019) Development Assistance Committee (DAC) Recommendation on the Humanitarian-Development-Peace Nexus. https://legalinstruments.oecd.org/en/instruments/oecd-legal-5019

Ornetzeder, M., & Rohracher, H. (2013). Of solar collectors, wind power, and car sharing: Comparing and understanding successful cases of grassroots innovations. *Global Environmental Change, 23*(5), 856–867.

Özerdem, A. (2015). *Post-war Recovery: Disarmament, Demobilization and Reintegration*. I.B. Tauris.

Ramaswami, A. (2020) Unpacking the urban infrastructure nexus with environment, health, livability, well-being, and equity. *One Earth, 2*(2),120–124.

Ramaswami, A., Boyer, D., Nagpure, A. S.... & Rao-Ghorpade, A. (2017). An urban systems framework to assess the trans-boundary food-energy-water nexus: implementation in Delhi, India. *Environmental Research Letters, 12*(2), 025008.

Rapaport, B. (2023). *Political-Climate Sustainability: The Core of Foreign Policy in the 21st Century*. Mitvim Institute (in Hebrew). *https://mitvim.org.il/wp-content/uploads/2023/03/Hebrew-Bar-Rapaport-sustainble-climate-diplomacy-March-2023-final.docx-2.pdf*

Rapaport, B.& Kibrik, R. (2024). Sustainable Political-Environmental Reconstruction: The Wetern Negev and Gaza Can only Thrive Together. *Ecology and Environment*, 15(1) (in Hebrew).

Rasul, G., & Sharma, B. (2015). The nexus approach to water–energy–food security. *Environmental Science & Policy, 56*, 1–10.

Raven, R., Schot, J., & Berkhout, F. (2012). Space and scale in socio-technical transitions. *Environmental Innovation and Societal Transitions, 4*, 63-78.

Rinscheid, A., & Trencher, G. (2022). Navigating the phase-out of fossil fuel infrastructure: Governance challenges and transition pathways. *Energy Policy, 162*, 112804.

Rinscheid, A., & Wüstenhagen, R. (2018). Divesting, fast and slow: Affective and cognitive drivers of fading voter support for a nuclear phase-out. *Ecological Economics, 152*, 51-61.

Rogge, K. S., & Stadler, K. (2023). Policy mixes for sustainability transitions: A review and research agenda. *Research Policy, 52*(1), 104646.

Roll, K., & Entsminger, J. (2023) *Systems approaches to post-conflict transitions: Potential and practice*. Working Paper Series 2023-03, UCL Institute for Innovation and Public Purpose

Ruhrort, L. (2024). Mobility transitions and social justice: Reframing accessibility and participation. *Transport Reviews, 44*(1), 1–20.

Rutherford, J., & Coutard, O. (2014). Urban energy transitions: Places, processes and politics of socio-technical change. *Urban Studies, 51*(7), 1353-1377.

Scheffran, J. (2025). Planetary boundaries, polycrisis and politics in the anthropocene: Climate pathways, tipping cascades and transition to sustainable peace in integrative geography. In *Towards Rethinking Politics, Policy and Polity in the Anthropocene: Multidisciplinary Perspectives*. Cham: Springer.

Scheffran, J., Brzoska, M., Kominek, J., Link, P. M., & Schilling, J. (2012). Climate change and violent conflict. *Science, 336*(6083), 869–871.

Schulterbrandt Gragg, R., Anandhi, A., & Jiru, M. (2018). A conceptualization of the urban food–energy–water nexus sustainability paradigm: Modeling from theory to practice. *Frontiers in Environmental Science, 6*, 133.

Schwanen, T. (2018). Thinking complex interconnections: Transition, nexus and geography. *Transactions of the Institute of British Geographers, 43*(2), 262–283.

Searchinger, T., et al. (2008). Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science*, 319(5867), 1238–40.

Seto, K.C., Reenberg, A., Boone, C.G., Fragkias, M., Haase, D., Langanke, T., Marcotullio, P., Munroe, D.K., Olah, B. and Simon, D. (2012). Urban land teleconnections and sustainability. *Proceedings of the National Academy of Sciences, 109*(20), 7687–7692.

Sharifi, A., Simangan, D., & Kaneko, S. (2021a). The literature landscape on peace–sustainability nexus: A scientometric analysis. *Ambio, 50,* 661–678.

Sharifi, A., Simangan, D., Kaneko, S., & Virji, H. (2021b). The sustainability–peace nexus: Why is it important? *Sustainability Science, 16*(1), 3–17.

Shove, E., Watson, M., & Pantzar, M. (2012). *The Dynamics of Social Practice: Everyday Life and How It Changes*. Sage.

Simangan, D., Fisher, J., Ide, T., … & Roy, J. (2025). Twelve research agendas for advancing the peace-sustainability nexus. *Peace and Sustainability, 1*(1), e100008.

Smith, A., Stirling, A., & Berkhout, F. (2005). The governance of sustainable socio-technical transitions. *Research Policy, 34*(10), 1491–1510.

Smith, D., Bell, N., Faller, J., … & Queiroz, C. (2022). *Elements of a Planetary Emergency: Environment of Peace*. SIPRI: Stockholm.

Soares Dal Poz, M.E. et al. (2022). Food, energy and water nexus: An urban living laboratory development for sustainable systems transition. *Sustainability, 14*(12), 7163.

Sonnberger, M., & Graf, A. (2021). Electric mobility as a socio-technical transition: Discourses, imaginaries and conflicts. *Energy Research & Social Science, 73*, 101932.

Sovacool, B. K., Heffron, R. J., McCauley, D., & Goldthau, A. (2016). Energy decisions reframed as justice and ethical concerns. Nature Energy, 1(5), 1-6.

Sovacool, B. K., & Axsen, J. (2018). Functional, symbolic and societal frames for automobility: Implications for sustainability transitions. *Transportation Research Part A, 118*, 730–746.

Stegmaier, P., Kuhlmann, S., & Visser, V. R. (2014). The discontinuation of socio-technical systems as a governance problem. In *The Governance of Socio-technical Systems*. Edward Elgar.

Swilling, M., & Annecke, E. (2012). *Just Transitions: Explorations of Sustainability in an Unfair World*. UCT & UNU Press.

Truffer, B., & Coenen, L. (2012). Environmental innovation and sustainability transitions in regional studies. *Regional Studies, 46*(1), 1-21.

Truffer, B., Murphy, J. T., & Raven, R. (2015). The geography of sustainability transitions: Contours of an emerging theme. *Environmental Innovation and Societal Transitions, 17*, 63-72.

Tschudin, A. (2024). The nexus approach to climate action, planetary integrity and sustainable development in Africa. In *Climate Change and Socio-political Violence in Sub-Saharan Africa in the Anthropocene*. Cham, Springer.

Turnheim, B. (2023). The historical dismantling of tramways as a case of destabilisation and phase-out of established system. *Proceedings of the National Academy of Sciences, 120*(47), e2206227120.

Turnheim, B., Kivimaa, P., & Berkhout, F. (Eds.). (2018). *Innovating Climate Governance: Moving Beyond Experiments*. Cambridge University Press.

Turnheim, B., & Geels, F. W. (2012). Regime destabilisation as the flipside of energy transitions. *Energy Policy, 50*, 35–49.

Tye, M. R., Wilhelmi, O. V., Pierce, A. L., et al. (2022). The food water energy nexus in an urban context: Connecting theory and practice for nexus governance. *Earth System Governance*, 12, 100143.

Vargas, D., Hoyos, C., & Hernandez Manrique, O. (2023). The water-energy-food nexus in biodiversity conservation: A systematic review around sustainability transitions of agricultural systems. *Heliyon, 9*(7).

Weinthal, E., & Sowers, J. (2020). The water-energy nexus in the Middle East: Infrastructure, development, and conflict. *Wiley Interdisciplinary Reviews: Water, 7*(4), e1437.

Williams, J., Bouzarovski, S., & Swyngedouw, E. (2019). The urban resource nexus: On the politics of relationality, water–energy infrastructure and the fallacy of integration. *Environment and Planning C: Politics and Space, 37*(4), 652-669.

Wirth, S., Markard, J., Truffer, B., & Rohracher, H. (2013). Informal institutions matter: Professional culture and the development of biogas technology. *Environmental Innovation and Societal Transitions, 8*, 20-41.

Zahedi, R., Yousefi, H., Aslani, A., & Ahmadi, R. (2024). Water, energy, food and environment nexus (WEFEN): Sustainable transition, gaps and Covering approaches. *Energy Strategy Reviews, 54*, 101496.

Zellner, M., Massey, D., Rozhkov, A., & Murphy, J. T. (2023). Exploring the barriers to and potential for sustainable transitions in urban–rural systems through participatory causal loop diagramming of the food–energy–water nexus. *Land, 12*(3), 551.

Zhou, Y., Wei, B., Zhang, R., & Li, H. (2022). Evolution of water–energy–food–climate study: Current status and future prospects. *Journal of Water and Climate Change, 13*(2), 463-481.

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