


INTRODUCTION

Navigating the future: Strategies for the long-term governance of socio-technical change

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Abstract • Long-term governance (LTG) addresses complex, enduring socio-technical challenges such as climate change and nuclear waste management. It requires framework conditions that go beyond short-term political cycles and promote a culture of foresight and collective stewardship. In an analytical framework developed for LTG, four key elements are identified: reflexivity, anticipation, adaptation, and deliberation. Contributions to this Special topic provide insights into LTG approaches in different contexts, highlighting participatory mechanisms for democratic accountability and ethical decision making. The articles explore the complexity of LTG and the tension between long-term objectives and immediate political pressures, thus contributing to the advancement of LTG theory and knowledge base.

Die Zukunft gestalten: Strategien für die Long-Term-Governance des soziotechnischen Wandels

Zusammenfassung • Long-Term-Governance (LTG) befasst sich mit komplexen, dauerhaften soziotechnischen Herausforderungen wie dem Klimawandel und der nuklearen Entsorgung. Sie erfordert Rahmenbedingungen, die über kurzfristige Politikzyklen hinausgehen und eine Kultur der Vorausschau und kollektiven Verantwortung fördern. In einem für LTG entwickelten Analyserahmen werden vier zentrale Elemente identifiziert: Reflexivität, Antizipation, Anpassung und Deliberation. Die Beiträge zu diesem Special topic geben Einblicke in LTG-Ansätze in verschiedenen Kontexten und beleuchten partizipative Mechanismen für demokratische Verantwortlichkeit und ethische Entscheidungsfindung. Die Arti-

kel untersuchen die Vielschichtigkeit von LTG und das Spannungsverhältnis zwischen langfristigen Zielen und akuten politischen Anforderungen und tragen so zur Weiterentwicklung der LTG-Theorie und -Fallstudienbasis bei.

Keywords • long-term governance, transition, socio-technical problems, temporalities

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Why long-term governance?

Climate change, nuclear waste management, and environmental pollution share a common trait: They are long-term challenges, due to their complex nature, potentially severe consequences, and demanding problem-solving pathways – often intertwined with high hopes for technological developments, which mark them as ‘socio-technical problems’, or, in other words, ‘Grand Challenges’ (Kuhlmann and Rip 2018). Some of them, such as nuclear waste management, require safeguarding toxic substances over extremely longtime scales, raising questions about what future generations must know to fulfil this task. Others, like climate change and environmental pollution, affect our daily lives and demand radical transformations of long-established technological systems, including the social practices associated with them. Such changes do not occur solely as a result of technical innovation; rather, they stem from shifts in social values, political debates, and corresponding policy decisions. As a consequence, effectively addressing these challenges requires a form of governance that transcends short-sighted visions and short-term mechanisms, and instead fosters a culture of foresight, resilience and collective stewardship, capable of tackling deep-

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rooted challenges over time. In short: it requires a long-term governance (LTG) approach¹.

The matter of time...

For such governance, *time* is not merely a contextual factor: It is a fundamental determinant of how decisions are framed, enacted, and sustained. LTG necessitates institutions capable of managing problems that unfold over extended timeframes; nevertheless, governance structures often struggle to fully integrate multiple temporal dimensions into the decision-making process. A significant challenge in LTG arises from the misalignment between short-term political cycles and the extended horizons required to address enduring global challenges. Political leaders are often incentivized to prioritize immediate results, often sidelining policies whose benefits will only materialize decades later. This creates a paradox: while many of the most pressing global issues demand sustained, long-term action, the mechanisms of contemporary governance often prove ill-equipped to support such commitments (Jacobs 2016; Meckling et al. 2022). A case in point is German's Heating Law of 2023, which was passed with watered-down requirements for homeowners following intense disputes over what costs could be fairly imposed on them (Hansen and Alkoussa 2023).

...and uncertainty and path-dependency

To complicate matters further, forward-looking policymaking is inherently fraught with deep uncertainty, given the complex interactions between environmental, technological, and social factors (Boston et al. 2019). Such uncertainty hampers decision-makers' ability to set long-term goals and confidently commit to policies. For instance, while investing in hydrogen energy may appear to be a promising solution to climate change and energy security, the inherent risks associated with technological progress, the construction of new infrastructures, and shifts in global energy demand render such decisions precarious. This reluctance to commit to long-term objectives is further exacerbated by fears that unforeseen societal changes may render policies obsolete or ineffective, particularly given that the creation of entirely new socio-technical systems demands substantial investment.

A related challenge in LTG concerns irreversibility and path dependency (Turnheim and Geels 2013). LTG must grapple with processes that, once set in motion, cannot easily be reversed or mitigated. Early policy decisions therefore carry significant weight, as they lock societies into particular technological, economic, or infrastructural pathways, constraining future choices. Governance frameworks should therefore integrate precautionary principles and preventive strategies, striking a balance be-

Long-term governance operates in a hazy environment characterized by ups and downs of change and stability.

This balancing of benefits between current and future generations intertwines LTG with the principle of *intergenerational justice*—defined as the ethical imperative to ensure that present decisions do not compromise the well-being of future generations (Sovacool and Dworkin 2015; Tremmel 2006). This ethical challenge raises significant concerns regarding the prioritization of interests in policymaking, highlighting the need for explicit deliberation on the moral implications of decision-making processes. While the present-day population wields political influence, it is future generations who will bear the consequences of today's choices – despite having no direct voice in governance processes.

tween the necessity to take decisions and the imperative to avoid that present-day decisions foreclose desirable future options. Nevertheless, path dependency is not always a hindrance; under certain conditions, it can be strategically leveraged to strengthen sustainable development pathways.

Long-term governance, in this sense, pertains to fundamental issues, including the meaning of justice within specific contexts, the core principles of democracy and democratic decision-making processes, and the very practical challenge of implementing new solutions within existing systems without compromising their functioning. Collectively, these challenges call for research that addresses both the practical and theoretical dimensions of LTG.

Orienting long-term governance research

The concept of long-term governance (LTG) was first introduced by Siebenhüner and colleagues (2013; see also Sprinz 2009). However, various strands of research have explored key issues

¹ A long-term governance framework was recently published in collaboration with other researchers (see Scheer et al. 2025). Some sections of this introduction are derived from this publication.

related to LTG from different perspectives, including risk governance (Renn 2008), earth system governance (Biermann 2007), and transition studies (Geels and Schot 2007; Kemp et al. 2007). In addition, specific governance approaches such as reflexive governance (Voß and Kemp 2005), foresight and anticipatory governance (Fuerth 2009), adaptive governance (Folke et al. 2005), and robust governance (Pot et al. 2023) have shed light on critical challenges related to governing over time.

LTG typically encompasses strategies, policies, and practices designed to address persistent, long-term societal challenges. It emphasizes strategic decision-making and future planning across multiple institutional levels. Effective LTG requires integrated, comprehensive, and sustained efforts that combine technical, organizational, social, legal, and economic dimensions, while also addressing questions of equity and intergenerational justice. Ideally, it is anticipatory, flexible, and adaptive, capable of responding to evolving structures and agencies, while maintaining focus on the chosen long-term solutions. A central challenge lies in managing path dependencies, which are both foundational to the emergence of new socio-technical systems and significant obstacles to transformative change.

Against this background, we define LTG as the political handling and policy-making that adequately addresses enduring problems persisting over extended time horizons—as a rule of thumb, at least one generation, or approximately 25 years (Scheer et al. 2025). We use the term *governance* broadly, following Meuleman and in 't Veld (2010), to refer to all interactions among governments, public bodies, the private sector, and civil society across different levels, aimed at solving societal problems or creating opportunities in complex settings.

As an elusive and multifaceted concept, LTG requires interdisciplinary inquiry to fully grasp the diverse dynamics, challenges, and approaches involved. To support scholarly reflection and dialogue, we developed an analytical framework for LTG (Scheer et al. 2025), which identifies four key elements essential for effective long-term governance and its research: (1) *reflexivity*, to identify problems and solution-oriented goals; (2) *anticipation, futuring, and iteration*, to prepare for uncertain futures; (3) *adaptation, flexibility and robustness*, to navigate change; and (4) *deliberation, probing, and learning*, to experiment with and learn from governance interventions. More specifically:

- *Reflexivity toward long-term issues and objectives.* Reflexive governance builds on Beck's concept of the risk society (1992), emphasizing the need for governance systems to respond not only to external changes but also to the unintended consequences of governance itself. In the context of LTG, reflexivity entails a continuous, critical re-examination of goals, assumptions, and strategies. It requires both governing and governed systems to engage in ongoing processes of problem identification and solution development. This may involve mechanisms such as policy feedback loops, evaluative foresight, or institutional self-assessment frameworks that allow for adjustments over time.

- *Preparing for change through anticipation, futuring techniques, and iteration.* Uncertainty presents a significant challenge to LTG. Addressing this requires structured approaches to exploring possible, probable, and desirable futures. Science and society can jointly contribute to imagining alternative pathways and options for long-term governance, including those that are feasible, likely, or socially-acceptable. To support the design and implementation of robust long-term strategies, policymakers benefit from tools that facilitate public debate, informed decision-making, and iterative planning. Techniques such as scenario analysis, foresight exercises, or participatory visioning can help to integrate future-oriented thinking into governance processes. Iterative cycles of anticipation and futuring are crucial for staying responsive to evolving conditions and newly emerging challenges.
- *Navigating change through adaptation, flexibility, and robustness.* LTG operates in a hazy environment characterized by ups and downs of change and stability. A key factor in LTG is to maintain agency, i.e. keep up capacity for action, options for action, and power for action. However, 'agency' should be understood in a broad sense, encompassing both hard and soft steering approaches, and extending beyond state authority to include networks, partnerships, and hybrid modes of governance. Navigating change with agency requires interpreting the changing environment and continuously (re)adjusting decisions in pursuit of long-term goals.
- *Experimenting with change through deliberation, probing, and learning.* In diverse and pluralistic societies, deliberation enhances the legitimacy and quality of governance by incorporating a wide range of perspectives and values. Long-term governance benefits from participatory processes that promote mutual understanding, build trust, and facilitate the co-production of knowledge. Experimental approaches, such as pilot programs, living labs, or policy sandboxes, can be used to test innovative solutions in real-world settings. These experiments create opportunities for structured learning, enabling actors to evaluate what works, for whom, and under what conditions. Such iterative learning processes are fundamental to the development of adaptive and resilient LTG.

Although each of these four areas has been described and analyzed in different research contexts, there is a pressing need for empirical insights into how current practices and practical approaches adopted in specific contexts contribute to a long-term governance, as well as theoretical reflections on the implications of implementing long-term governance approaches.

Contributions in this TATuP Special topic

The contributions in this Special topic explore the tensions, uncertainties and ethical dilemmas that arise when policy decisions are called upon to shape trajectories across generations. A key insight emerging from this Special topic is the growing awareness

of the need for institutional mechanisms that actively govern *time*. While much of the literature on LTG focuses on how governance responds to long-term challenges, recent research highlights how institutions structure temporal dynamics, shaping not only implementation timelines and decision-making rhythms, but also societal expectations and perceptions of the future (Bornemann and Strassheim 2019). This perspective highlights that time is not just a constraint to be managed, but a governance resource in its own right. The articles in this Special topic explore long-term governance from different perspectives, namely philosophy, technology assessment (TA), national policies, and regional and urban contexts. The introductory overview below follows this line from the general to the local.

The articles demonstrate how agency can be preserved over time through stepwise decision-making, institutionalized learning, and the design of governance architectures that remain open to adjustment.

Martin Böhnert's article offers a reconceptualization of reflexivity within LTG, framing it as an inherently epistemic and normative endeavour. The author critically examines how dominant knowledge systems, thought styles, and futuring practices shape which future problems are recognized and who holds authority to define them. The article warns that LTG efforts may unintentionally reproduce epistemic exclusions and reinforce existing power structures. It challenges the assumption of a universal and abstract 'we' in futuring discourse, advocating for approaches that are context-sensitive and structurally pluralistic. The article proposes an ethical and epistemic framework to foster more inclusive, reflexive, and critically self-aware practices of LTG.

Tobias Hainz's article identifies three epistemological challenges for LTG, each with profound ethical implications: 'prognostic uncertainty' about the outcomes of today's decisions, 'moral uncertainty' over which ethical frameworks should guide action, and the risk of 'value lock-in' shaping future societies. The author argues that these challenges complicate efforts to positively influence the distant future and create the risk of far-reaching, irreversible consequences. The article discusses possible avenues for addressing these difficulties, such as shifting accountability from outcomes to normative principles, relying on public justification in decision-making under moral uncertainty, and focusing on clear value-driven goals. Overall, it calls for a deeper engagement with these uncertainties to avoid actions that may unjustly constrain future possibilities.

Jens Schippl's article explores how TA can contribute to LTG in managing sustainable transitions in complex sectors such as mobility. The author introduces a typology of 'modes of directionality', which classifies technologies according to their application scope and the degree of normative consensus surrounding their development. This framework helps identify the types of

knowledge—empirical, normative, prospective, hermeneutic, or instrumental—and TA methods most needed for informed LTG. He argues that, especially when the future scope of a technology is broad and the selection environment is normatively heterogeneous, TA must extend beyond purely technical evaluations, incorporating qualitative and interpretive methods to navigate contested futures and support collective vision-building.

The governance of radioactive waste management is particularly challenging due to the extended timeframes and uncertainties involved. Romy Dekker and Rinie van Est's comparative analysis investigates how ten European countries are addressing this issue, focusing on the governance areas of decision-making, public participation, knowledge, and financing. Their

study delves into the procedures, normative principles, and governance arrangements shaping these dimensions. While no single model can be universally applied due to significant political and cultural differences, the analysis identifies a broad movement toward participatory, flexible, and adaptive strategies. The authors argue that effective LTG in this domain must be experimental, incorporating iterative learning processes and institutional adaptation. They stress the importance of ensuring that long-term solutions remain democratically accountable, socially legitimate, and continuously improved to address emerging challenges.

Cindy Rentrop et al. investigate how two German regions—the Rhenish Region (RR) and Heilbronn-Franconia (HN)—are navigating long-term regional transformation processes. While RR faces a shift from lignite mining to renewable energy, HN confronts digitalization and global competition. The authors leverage the concept of 'regional innovation cultures' to explain how local identity, socio-economic legacies, and governance models shape transformation pathways. They argue for a reflexive approach to governance that balances immediate political needs with long-term impacts, particularly those affecting regional identity. The study highlights the importance of inclusive, place-based governance to support sustainable and identity-conscious regional transitions, able to address emerging challenges and ensure democratic accountability.

Franziska Meinherz's contribution focuses on urban mobility governance in Copenhagen, Lisbon, and Madrid, examining how temporary and adaptable interventions—such as pilot programs, street experiments, and technological trials—function as embedded modes of governing. These experimental approaches help mediate the tensions between long-term decarbonisation goals and the inertia of existing infrastructure, political timeframes, and systemic uncertainties. The article highlights how

external shocks, like the energy crisis, have created ‘windows of opportunity’ for accelerating the implementation of democratically approved yet politically contested interventions. It reveals the strategic and political nature of experimentation, showing how actors leverage time, urgency, and temporariness to advance transformation agendas. However, it points to the fragility of these initiatives, especially without durable institutional support and commitment.

Sadeeb Simon Ottenburger and Ulrich Ufer examine how the design and planning of urban microgrids—a decentralized form of electricity infrastructure—can influence long-term sociotechnical resilience and energy democracy. The authors introduce the concept of ‘energy gerrymandering’ to describe how microgrid boundaries can be deliberately or inadvertently drawn to create injustices, especially if based solely on economic or technical criteria. Instead, they advocate for socio-spatial microgrid planning that involves local communities in energy decisions, ensuring equitable access and representation. Using the historical analogy of 1920s Vienna urban design, they emphasize the importance of continuous adaptation to the evolving nature of urban societies. Ultimately, microgrids should serve not only as technical solutions, but also as democratic, adaptive infrastructures integrated into dynamic urban environments, with up-to-date socio-economic data to support targeted interventions and the inclusion of socially vulnerable groups.

Conclusions

Collectively, the contributions to this Special topic advance and substantiate the four key dimensions of long-term governance outlined above. Several articles offer conceptual refinements to the area of reflexivity, interrogating the cognitive foundations, imaginaries, and limitations that shape LTG, and emphasizing the importance of socio-spatial sensitivity, historical awareness, and democratic inclusion in rendering governance more self-critical and responsive. Contributions to the dimension of anticipation, futuring, and iteration highlight the epistemological challenges of acting under deep uncertainty, underscoring the need for iterative approaches that accommodate emerging knowledge and evolving societal values. In terms of adaptation, flexibility, and robustness, the articles demonstrate how agency can be preserved over time through stepwise decision-making, institutionalized learning, and the design of governance architectures that remain open to adjustment. Finally, the issue expands the role of deliberation, probing, and learning by conceptualizing experimentation not as isolated events, but as embedded practices through which legitimacy is built, futures are tested, and long-term trajectories are shaped. Taken together, the articles also reveal key tensions at the heart of LTG, between long-term commitments and short-term responsiveness, between robustness and openness, and between central steering and democratic

participation. Several articles point to the need for integrative approaches that do not treat the four dimensions in isolation, but rather explore their mutual interdependencies in real-world governance contexts. Therefore, this Special topic not only elaborates on the theoretical contours of LTG, but also offers grounded insights into its practice, contestation, and reconfiguration across diverse environments.

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