Discover Sustainability

RESEARCH Open Access

Economic narratives of the energy transition in university–industry learning spaces

Ann-Katrin Voit[1] and Imke Rhoden[2,3*]

*Correspondence:
Imke Rhoden
i.rhoden@fz-juelich.de
[1]FOM Hochschule für Oekonomie und Management, Leimkugelstraße 6, 45141 Essen, Germany
[2]Jülich Systems Analysis, Institute of Climate and Energy Systems, Forschungszentrum Jülich GmbH, Wilhelm-Johnen-Str., 52425 Jülich, Germany
[3]Chair of Environmental and Resource Economics, TU Bergakademie Freiberg, Schloßplatz 1, 09596 Freiberg, Germany

Abstract

Economic narratives are central to how organizations interpret the opportunities, risks, and distributional consequences of the energy transition. While existing research highlights the coordinating and sense-making functions of these narratives, the processes through which they emerge in cross-sectoral settings remain insufficiently understood. This study examines how economic narratives of the energy transition are formed at the intersection of scientific expertise and corporate practice. Interactions between universities and companies constitute distinct interpretive spaces where problem framings, expectations, and evaluative criteria are jointly negotiated. To illustrate this, a corpus of 366 cross-sectoral project objectives using Latent Dirichlet Allocation topic modeling is analyzed. The findings reveal seven distinct narrative clusters that function as a shared interpretive infrastructure. The analysis demonstrates how mechanisms of selective mobilization, causal construction, and agency attribution allow actors to stitch together narrative elements into broader narratives and condensed storylines. These co-created narratives do not merely exchange knowledge; they structure sustainability learning by providing shared cognitive reference points that persist even when interests do not fully align. However, the findings also reveal a semantic capture, where diverse actors borrow transition vocabulary to frame disparate strategic goals. The paper concludes by outlining implications for SDG-oriented collaborative learning formats. It emphasizes that recognizing the constitutive role of narratives and storylines is essential for navigating the complex sociotechnical pathways of the energy transition.

Keywords Sustainability transitions, Co-creation, Economic narratives, Sense-making, University–industry collaboration, Latent Dirichlet allocation, Interpretive infrastructure

1 Introduction

Technological roadmaps, regulatory targets, and discussions about cost curves have long dominated the debate on the energy transition. Yet, when observing how organizations navigate the transition, one encounters something far less linear: a constant struggle to interpret what the shift towards decarbonization means for their business models, routines, and future identities. It is in this interpretive work that economic narratives have become unexpectedly influential. In the terminology used here, narratives are broader economic sense-making structures, while storylines are their condensed and portable

formulations. Such storylines, sometimes hopeful, sometimes defensive, help organizations impose order on an otherwise confusing field. In practice, these narratives often travel more quickly than formal strategies, subtly shaping how managers talk about risks, justify investment decisions, or explain uncertainties to their teams [1].

While literature has made considerable progress in conceptualizing narratives as sense-making devices [2, 3], less attention has been paid to the places in which such narratives take shape. Some transition and management debates implicitly privilege policy targets, market signals, cost curves, or technological roadmaps as the main drivers of organizational interpretation. The argument is that such signals do not automatically generate narratives; rather, they become meaningful through situated interactions and interpretive practices. University–industry collaborations, be they research projects, executive programs, innovation labs, or policy-oriented partnerships, have become particularly interesting in this respect. They bring together people who do not usually share the same language, incentives, or time horizons, and who must nonetheless agree on how to interpret the transition. Conversations in these settings are rarely neat. They involve partial misunderstandings, disciplinary blind spots, strategic positioning, and moments of genuine curiosity. In Hajer's terms, such settings can produce a "communicative miracle": actors may coordinate around shared storylines without necessarily sharing identical assumptions [4]. Precisely because of this heterogeneity, such arenas generate narrative elements, including metaphors, problem framings, causal claims, evaluative criteria, and attributions of agency, that would not emerge within organizations alone [4, 5].

This paper argues that these cross-sectoral encounters function as co-creative interpretive spaces in which economic narratives of the energy transition are assembled, refined, and stabilized. Although co-creation is typically discussed in relation to innovation processes, its narrative dimension, how it facilitates the weaving together of evidence, expectations, and normative commitments, has not been systematically examined. Drawing on interpretive policy analysis, sociotechnical transition studies, and organizational learning theory, a framework will be developed to explain how such spaces shape three aspects of narrative dynamics: formation, stabilization, and integration into sustainability learning. First, it will be shown why economic narratives cannot be understood without examining the interactions through which they are produced. Second, mechanisms that structure the co-creative construction of narratives in university–industry settings will be identified. Third, it will illustrate these dynamics through a brief vignette centered on the widely disseminated narrative of green competitiveness. The goal is not to test hypotheses but to sharpen the conceptual vocabulary needed to analyze narrative processes in sustainability transitions. Ultimately, understanding how organizations jointly craft the stories that orient their actions is essential for designing learning formats that support more ambitious, future-oriented forms of cooperation.

2 Theoretical background

2.1 Economic narratives as sense-making devices create interpretative approaches for sustainability

For analytical clarity, the revised manuscript distinguishes five related but non-identical terms. Following Hajer [4], discourse is understood as an ensemble of ideas, concepts, and categories through which meaning is given to social and physical phenomena and

which is produced and reproduced through identifiable practices. A narrative is used here as the broader economic sense-making structure that links actors, problems, causal assumptions, evaluative criteria, and possible futures. A storyline is a condensed, portable, and politically mobilizable formulation of such a narrative, often supported by metaphors or symbolic expressions. Metaphors are specific linguistic devices that condense meaning. Narrative elements are smaller components from which narratives and storylines are assembled, including metaphors, problem framings, causal claims, evaluative criteria, and attributions of agency.

The recent resurgence of interest in economic narratives is not accidental. The energy transition, like other large-scale transformations, produces uncertainty faster than organizations can process it. In such situations, actors rely on narratives as broader interpretive structures that link problems, causes, actors, and possible futures. Storylines, by contrast, are understood in Hajer's sense as condensed forms of narratives in which metaphors and symbolic expressions allow actors to communicate across differences [4]. The notion of fictional expectations captures that organizations anticipate the future by weaving fragments of data, professional judgment, and normative assumptions into future-oriented narratives [2]. These narratives rarely aim for empirical precision, but they provide coherent plots that render complex dynamics actionable. In the field of energy transition, the viral quality of economic narratives explains why certain storylines achieve dominance well before evidence is conclusive. Narratives are constructed through encounters, not merely aggregated from individual beliefs. This understanding follows a social-constructivist view of discourse: language is not treated as a neutral transmitter of pre-existing meanings, but as constitutive of how transition problems, responsibilities, and future pathways become intelligible. They crystallize in conversations where actors bring different evaluative criteria, different readings of policy signals, and different stakes. In this sense, economic narratives are artifacts shaped by organizational interests, professional cultures, and broader socio-political discourses. Treating them as sense-making devices, therefore, requires an understanding of the social settings in which sense-making takes place [3, 4].

Interpretive work has long played an important, if sometimes underestimated, role in how environmental problems are handled. Analysis of ecological discourse makes this particularly clear: policy debates rarely proceed as neat exchanges of evidence but rely on shared storylines that help actors navigate fragmented knowledge and institutional complexity. Hajer's discourse analysis is central here because it defines discourse as an ensemble of ideas, concepts, and categories through which meaning is given to social and physical phenomena and which is produced and reproduced through identifiable practices [4]. Similar observations on environmental discourses can be found in Dryzek [6]. Fischer [7] highlights that deliberative practices shape not only decisions but the categories through which issues become intelligible. Sustainability debates often stabilize a vocabulary whose meaning appears self-evident only in hindsight. Governance arrangements cannot be understood independently of the discursive frames that sustain them [8].

Transition research arrives at similar conclusions from a different angle. Geels [9] places cultural meaning-making at the center of the multi-level perspective, showing that transitions advance not merely through technological breakthroughs but through institutionalized imaginaries of viable futures, a point elaborated through the concept of

sociotechnical imaginaries [10, 11]. Transitions involve competing discourses that shape regulatory trajectories long before concrete policy decisions are made [12, 13]. Collaborations between universities and companies are not neutral information exchanges. They combine models, routines, and experiences that rarely align, leading to discussions that switch between technical and normative questions. Boundary organizations are institutional arrangements that mediate between science, policy, and practice by creating arenas, tools, or routines for knowledge exchange and translation. They show that hybrid spaces develop unique interpretive practices. The interpretive literature explains why these arenas foster narrative creation: the energy transition is shaped not just by tools and incentives, but by shared narratives and storylines that give those tools meaning [14].

2.2 Co-creation and inter-organizational sustainability learning

University–industry-government relations can be understood as dynamic systems in which expectations are continuously adjusted, and problem definitions are negotiated [15]. Subsequent studies show that these interactions increasingly produce hybrid spaces where actors learn not only from each other but with each other [16, 17]. While the broader co-creation literature extends this to social innovation and public service delivery, the common emphasis remains on shared problem definition and iterative alignment of meaning [18]. This is significant when distinguishing between incremental adjustments and deeper reflection on the assumptions guiding behavior [19]. Co-creative settings, particularly when they involve actors with different vocabularies and professional logics, tend to expose the limits of habitual sense-making. Learning emerges from negotiated meaning rather than from formal instruction, underscoring the centrality of collective sense-making for strategic adaptation [20, 21].

What remains under-theorized is the narrative by-product of co-creation. Studies on collaborative innovation [22] and transdisciplinary sustainability research [23] note that participants often rely on narrative elements such as stories, metaphors, and simplified causal chains to bridge disciplinary boundaries. Some of these elements correspond to Hajer's metaphors, while others include technical terms, project objectives, or evaluative vocabularies that may not function as metaphors in a strict sense. These narrative elements help actors articulate why specific pathways appear promising or risky. Over time, recurring metaphors, shared terms, or implicit assumptions become part of a shared repertoire that orients joint learning. In Hajer's terms, actors may form discourse coalitions when they coordinate around shared storylines without necessarily sharing identical interests, epistemologies, or interpretations [4]. Organizational learning is inseparable from the narratives through which actors make sense of complex environments [24].

From this perspective, narrative formation is a core part of co-creation, not just a by-product. Organizations learn by absorbing information and refining their narratives to interpret and justify actions. Shared narratives in inter-organizational learning networks are essential for coordination and long-term cooperation [25]. Co-creative university–industry arenas therefore have the dual function of generating new knowledge and simultaneously producing narrative structures to integrate this knowledge into broader organizational learning processes.

3 Conceptual framework: the co-creation of energy-transition narratives

3.1 Interaction arenas between universities and companies

The spaces in which universities and companies collaborate tend to be messier and more plural than typologies in policy documents suggest. They range from long-standing strategic partnerships to short-lived pilot projects, from EU-funded research consortia to informal innovation workshops. What makes them analytically interesting is not their formal architecture but the epistemic encounter they enable; an encounter that often exposes and negotiates the differences between scientific reasoning, managerial judgment, and policy expectations. This dynamic is central in the literature on boundary work, which argues that hybrid arenas can generate distinct forms of knowledge that do not neatly belong to either domain [26, 27].

A classic point of reference is the concept of boundary objects, which describes how heterogeneous actors work together by relying on shared artifacts whose interpretive flexibility accommodates divergent perspectives [5]. In university–industry collaborations around the energy transition, such boundary objects may appear in the form of technology roadmaps, scenario frameworks, sustainability metrics, or even experimental prototypes; all artifacts that facilitate cooperation without eliminating deeper epistemic tensions [14].

At the same time, these arenas resonate strongly with Mode 2 contexts in which knowledge becomes socially distributed, application-oriented, and transdisciplinary [28]. Many energy-transition partnerships bear exactly these characteristics: they are problem-driven, embedded in real-world constraints, and require constant translation work between different knowledge cultures. Transdisciplinarity scholars have argued that such spaces often become negotiation zones for problem definitions, where actors attempt to stabilize shared understandings of what the transition requires [23, 29].

A recurring feature of these arenas is the heterogeneity of knowledge inputs. Universities typically contribute long-term analytical models, conceptual frameworks from transition theory [9, 30], or evidence on sociotechnical trends. Companies, in turn, contribute localized operational insights, competitive pressures, financial considerations, and regulatory intelligence. As Carlile [31] notes, knowledge boundaries become productive only when actors are forced to articulate tacit assumptions, something these arenas frequently provoke.

Another characteristic is the future orientation of discussions. Whether participants explicitly refer to sociotechnical imaginaries [11], transition pathways [32], or foresight exercises [33], the shared act of "thinking into the future" creates a discursive space where narrative fragments naturally emerge. Imagined futures, as Beckert [2] argues, do not simply describe possibilities; they coordinate expectations. University–industry settings thus become arenas in which actors test, contest, or refine the expectations that later crystallize into economic narratives.

A third feature concerns the negotiation of evaluative criteria, a point widely emphasized in sustainability transitions governance [12, 34, 35]. Deciding what constitutes a "promising" sustainability solution, lower carbon intensity, scalability, social legitimacy, and profitability, is rarely straightforward. These evaluative criteria are not technical givens but negotiated interpretations, often shaped through dialogue rather than data alone. The governance literature suggests that such negotiations are central for understanding why certain narratives later stabilize, and others fade [13].

Taken together, university–industry arenas function as incubators of narrative elements because they bring together epistemically diverse actors, produce future-oriented deliberation, and require interpretive alignment around contested criteria. Importantly, these arenas do not intentionally produce narratives. Instead, narratives form as a pragmatic response to the need for shared orientation in situations where no single actor possesses sufficient knowledge or authority to define the transition on their own. Such narratives can also overlap, contradict, and coexist. Actors may mobilize the same vocabulary, for example, "innovation", "transition", or "competitiveness", while attaching different meanings to it. These overlaps can enable collaboration, while contradictions can generate productive friction and learning.

3.2 Mechanisms of narrative formation

Understanding how narratives take shape in university–industry interactions requires attention to the mundane but consequential interpretive work that happens when heterogeneous actors try to make sense of the energy transition together. While this might sound like a purely discursive task, studies in organizational sense-making [36, 37] and collaborative innovation [22, 38] show that such processes rarely follow linear stages. Instead, they unfold through iterative exchanges, misalignments, and provisional agreements that gradually coalesce into shared storylines. In the context of sustainability transitions, this narrative co-production is amplified by the uncertainty of technological pathways and by the political nature of transition trajectories [12].

Four mechanisms are central here: Problem Framing and Re-Framing, Selective Mobilization of Evidence, Construction of Causal Chains, and Attributions of Agency. These mechanisms are not presented as a closed typology, but as a synthesis of interpretive policy analysis, organizational sense-making, and sustainability transition research [12, 24, 36, 37]. They unfold iteratively and reflexively, producing narrative elements that gradually assemble into broader narratives. Storylines are then the condensed and communicatively portable forms of these narratives. The mechanisms do not follow a predefined order. Their interaction reflects the broader insight that sustainability transitions are not driven by information alone, but by shared interpretive infrastructures [13, 24]. Co-creation arenas function as the spaces where these infrastructures are first articulated.

Problem framing and re-framing

Narrative formation often starts with the struggle over how a situation is framed as a problem in the first place. Research in interpretive policy analysis repeatedly shows that problem definitions reflect underlying values and institutional positions [7, 39]. In collaborative arenas, these definitions often diverge sharply: universities may frame the energy transition as a systemic reconfiguration of sociotechnical regimes [9, 30], whereas companies often articulate the transition in more operational categories: regulatory exposure, technological uncertainty, or capital allocation constraints. As these framings collide, actors are pushed into what Schön and Rein [39] call frame reflection. This process does not dissolve differences but generates hybrid framings that become the seedbed for narrative construction. Transition researchers describe similar dynamics when actors negotiate shared transition pathways [32] or govern expectations around emerging technologies [40].

Selective mobilization of evidence

Narratives are built from evidence, but the meaning and strategic weight of evidence are never fully neutral in collaborative settings. Particularly in sustainability transitions, model projections, carbon budgets, market studies, and regulatory forecasts often point in different directions. The point is not that evidence has no empirical basis, but that its relevance, interpretation, and communicative use are shaped through language, institutional interests, and evaluative criteria. Organizations, therefore, engage in a strategic use of expertise: selecting, emphasizing, or downplaying evidence in ways that support preferred interpretations [8]. In co-creation arenas, this becomes a collective filtering process. Academic participants might bring cost curves, transition scenarios, and sociotechnical analyses. Practitioners contribute internal performance data, investor expectations, or customer insights. As transdisciplinary settings force such divergent evidentiary standards into conversation, a necessary mutual adjustment of validity criteria is created [23, 29]. Narrative formation emerges from this negotiated evidentiary landscape.

Construction of causal chains

Narratives gain persuasive power when they provide a coherent causal explanation of how change unfolds, who or what drives the transition, which policy levers matter, and how technological shifts translate into organizational consequences. In sustainability transitions, causal reasoning is complicated by deep uncertainty and by the intertwining of social, technological and political processes [10, 41]. Co-creative settings bring different causal heuristics into play. Academics tend to rely on conceptual models (e.g., multilevel perspective, innovation diffusion), whereas practitioners mobilize more situational or experiential cause-and-effect logics. When these heuristics interact, causal chains are revised, sometimes subtly, sometimes substantially. This resembles what Weick [36] calls the enactment of meaning: actors discover causal structures through interaction rather than deduction.

Attribution of agency

Attributing agency is a core narrative act. Whether the energy transition is seen as policy-led, market-driven, technology-pushed, or socially contested has significant implications for how organizations position themselves. Research on sociotechnical imaginaries [11], future-oriented governance [42], and sustainability expectations [43] shows that such attributions shape expectations long before concrete decisions are made. In university–industry interactions, agency attribution becomes a negotiated affair. Companies may emphasize market dynamics or regulatory pressures; academics may foreground systemic lock-ins or the enabling role of innovation policy. Through dialogue, these diverging emphases often congeal into a shared sense of who or what constitutes the main driver of change. Such negotiated agency frames later harden into narrative elements that structure organizational decision-making.

3.3 Mechanisms of narrative stabilization

Narratives that arise in co-creative university–industry interactions do not automatically endure; many remain tentative fragments that never travel beyond the meeting room. What distinguishes the narratives that stick is not merely their cognitive appeal but the degree to which they become embedded in organizational routines, tools, and expectations. Research in organizational institutionalism [44], organizational memory [45], and technological governance [46] suggests that stabilization hinges on processes that sediment interpretations into structures that no longer require active negotiation. This

stabilization also corresponds to Hajer's distinction between structuration and institutionalization: structuration occurs when actors increasingly draw on the same storylines to make sense of a field, while institutionalization occurs when these storylines become embedded in organizational routines, tools, and decision rules [4].

Embedding narratives in artifacts, tools, and methods

One of the most powerful ways narratives stabilize is by becoming embedded in artifacts that guide decision-making. The concept of boundary objects helps explain why such embedding matters: artifacts travel across contexts more easily than abstract meanings do [5]. When a narrative becomes inscribed in a scenario methodology, a Key Performance Indicator framework, a technology readiness matrix, or a carbon accounting tool, it gains a form of durability that does not depend on ongoing persuasion. In sustainability transitions, this embedding often occurs through instruments used in joint projects: life-cycle assessments, decarbonization roadmaps, transition scenarios, or scoring models for innovation portfolios. These tools do not simply apply narratives. They codify assumptions about system boundaries, causal importance, and desirable outcomes [47, 48]. Once a narrative is translated into a methodological template, challenging it requires more than a new argument; it requires revising the artifact itself, which is institutionally and politically more difficult.

Social reinforcement and resonance

Narratives stabilize when they resonate with organizational experience or normative expectations. Weick [36] argues that plausibility matters more than accuracy in sensemaking, and this insight carries through strongly in co-creative collaboration. Narrative elements that echo existing organizational stories, about competitiveness, innovation, resilience, or risk, encounter less resistance and are more likely to be repeated. Maitlis and Lawrence [49] show that narratives gain organizational salience when retold by actors with authority: project leads, senior managers, and university researchers with epistemic legitimacy. In university–industry settings, these actors often circulate between workshops, internal presentations, and public events. Through this circulation, a narrative gains layering: it picks up examples, metaphors, and partial justifications that gradually thicken its credibility. Over time, the narrative becomes a "traveling idea": recognizable, adaptable, and increasingly taken for granted [50]. Empirically, this can be observed in how certain energy-transition narratives: green competitiveness, hydrogen as strategic backbone, digitalization-driven efficiency, circular materials as license to operate, echo across sectors, even when the underlying empirical basis remains contested. Resonance, therefore, functions less as a reflection of truth and more as an alignment of institutional experience.

Organizational anchoring and institutionalization

The third stabilization mechanism is organizational anchoring, the integration of narratives into decision rules, strategy documents, roles, and institutional expectations. Institutional theory [44, 51] shows that ideas harden into institutions once they are embedded in formal structures or linked to organizational legitimacy. In the context of sustainability transitions, narratives often transform into strategic priorities ("electrification-first," "hydrogen leadership"), capability frameworks (e.g., "green skills" requirements), governance structures (ESG committees, innovation boards), performance metrics (carbon intensity, circularity scores), and investment criteria (internal carbon pricing, innovation risk weighting). Once a narrative underpins such structures,

it becomes part of organizational memory [45], a background assumption that shapes action even when individuals who co-created it leave the organization. Moreover, when the same narrative becomes anchored on both sides of a collaboration, in a university's research agenda and a company's strategic documents, it gains a cross-institutional stability that is difficult to reverse.

This anchoring can also be read through the lens of transition governance. Expectations solidify when institutionalized in transition management cycles [34]; policy mixes reinforce consistent interpretive frames [13]; sociotechnical regimes stabilize through the alignment of cultural meanings and institutional practices [46]. In the vocabulary of Hajer [4], this movement from repeated use to organizational embedding marks the shift from discourse structuration to discourse institutionalization. Narrative anchoring is thus part of a broader dynamic in which interpretive structures become governance resources.

Figure 1 illustrates the comprehensive framework in which university–industry arenas produce learning outcomes for sustainability. Each step has its own reinforcing setup, and each successively contributes to institutional anchoring.

3.4 Narratives as drivers of sustainability learning

If co-created narratives take shape and stabilize through the mechanisms described above, the next question is what they actually do once they begin circulating within and across organizations. Much of the organizational learning literature, from the classic distinction between single- and double-loop learning [19] to more recent work on interpretive learning [24], suggests that learning is rarely a matter of information transfer alone. Instead, learning depends on the interpretive scaffolding through which actors understand what counts as a problem, which solutions are plausible, and what kinds of organizational adjustments are legitimate. Narratives provide exactly this scaffolding and influence sustainability learning in at least three interconnected ways, though in practice these dimensions tend to blur rather than unfold neatly in sequence.

Narratives direct organizational attention

Attention is not a neutral capacity; it is shaped by the cognitive frames that tell actors what is worth noticing and what can be ignored. An attention-based view argues that

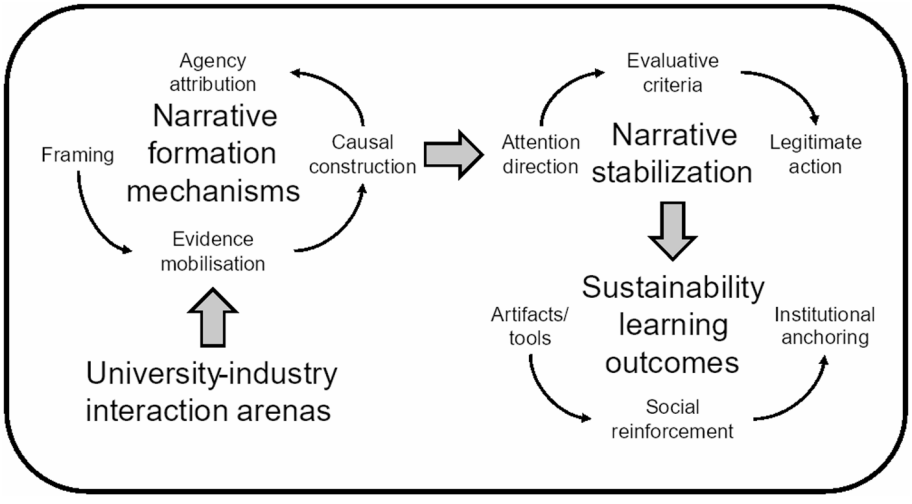

Fig. 1 Overview of narrative formation and anchoring

organizations do not react to the environment per se, but to the environment as they interpret it [52]. In the energy transition, co-created narratives function as selective attention structures. They spotlight certain elements (e.g., innovation opportunities, geopolitical vulnerabilities, supply-chain carbon exposure) while rendering others peripheral. For instance, consider how the story of green competitiveness shifts the view of sustainability from merely a compliance matter to a crucial driver of innovation. Companies exposed to this narrative may prioritize R&D investments, partnerships, and skill development in ways that would be unlikely under a risk-dominant or cost-burden narrative. Likewise, universities that adopt narratives emphasizing societal legitimacy or just transition concerns may shift learning formats toward reflexive, participatory, or problem-based approaches. In this sense, narratives are not passive reflections of reality; they shape the horizon of what organizations pay attention to.

Narratives establish evaluative criteria and learning standards

Learning in sustainability contexts requires evaluation; deciding which ideas, projects, or technologies are promising and which are not. Yet evaluative criteria are highly contested: what counts as "impact," "viability," or "responsibility" can vary widely across actors. Narratives provide a provisional answer by embedding evaluative standards into their causal and normative structure [53, 54].

For instance, if a narrative frames hydrogen as a "strategic industrial backbone," then learning processes will prioritize capability-building, infrastructure readiness, and long-term competitiveness. If a narrative emphasizes social acceptance or justice, organizations integrate considerations of legitimacy, equity, or stakeholder involvement into their learning frameworks. This echoes insights from the policy-learning literature [55], which argues that learning depends on interpretive filters that define what counts as valid evidence or successful adaptation. Narratives thus act as normative engines: they tell organizations not only what is happening but what ought to matter.

Narratives structure legitimate organizational action

While attention and evaluation shape how organizations learn, narratives also define the boundaries of legitimate action. They justify certain strategic moves while rendering alternatives improbable or even unthinkable. This links to research on performativity [47, 48], which shows that ideas can shape markets and organizational practices by prescribing what "makes sense" within a given frame. In sustainability transitions, this often becomes visible in narratives that legitimize early adoption of emerging technologies (first-mover advantages in green markets), justify investments that lack short-term returns (transition leadership), or normalize particular governance structures (cross-sector partnerships as prerequisites for system change). On the flip side, narratives can narrow organizational imagination. A dominant narrative about electrification, for example, can overshadow deliberations about alternative thermal pathways or decentralized models, a dynamic transition scholars frequently warn against [35, 56]. Thus, narratives do not merely reflect organizational learning; they configure the scope of possible learning trajectories.

Narratives as cognitive infrastructures

Taken together, these mechanisms suggest that co-created narratives function as what some authors call cognitive infrastructures [57]. Interpretive structures persist long enough to influence strategies, competencies, and institutional routines. They guide how organizations perceive risks, define responsibilities, and imagine their own role in the

transition. Crucially, these infrastructures are rarely designed intentionally. They emerge, stabilize, and then recede into the background, where they continue to guide action precisely because they are no longer questioned. If sustainability learning is understood in this broader sense, as the reconfiguration of interpretive capacities and organizational practices, then narratives become central. They do not replace technical expertise or formal learning structures, but they condition how such expertise is interpreted and integrated. In cross-sector collaborations, this conditioning can become mutually reinforced when narratives co-created with universities acquire epistemic legitimacy. In contrast, narratives co-created with companies gain practical relevance and strategic depth.

4 Empirical illustration: mapping the green competitiveness narrative

4.1 Data selection and method

To illustrate the framework, a corpus of 366 project objectives from the European CORDIS database is analyzed, selecting collaborations between universities (Higher or Secondary Education Establishments, HES), and private industry (Private for-profit entities (excluding Higher or Secondary Education Establishments), PRC) in the area of "energy transition" from 2021 to 2026. The period corresponds to the first work programme cycle of Horizon Europe. Restricting the corpus to a single framework programme holds the funding architecture, evaluation criteria, and call language constant, so that variation in project objectives reflects narrative work by consortia rather than shifts in the funder's own framing. The period also follows the adoption of the European Green Deal and the European Climate Law, which together establish the policy horizon against which "energy transition" is currently articulated in EU calls [58].

The project objectives, typically ranging from 100 to 300 words, serve as primary artifacts of the initial interpretive alignment between sectors. Compared to complete project reports prepared during or after a project's execution, project objectives represent the initial negotiation of meaning. They capture the exact moment where academic and industry partners co-create a shared narrative to secure funding. Importantly, this focus should not be read as implying that interpretive alignment is completed at the proposal stage. Sense-making is an ongoing negotiation across the whole project cycle where objectives are revisited, reinterpreted, and sometimes quietly abandoned as consortia encounter technical setbacks, regulatory shifts, or changing partner interests. Project objectives are therefore best understood as first formally codified negotiation of meaning rather than its endpoint, and the findings speak to the initial interpretive infrastructure from which later narrative work departs.

The word cloud in Fig. 2 shows the frequency of the terms in all the projects' objectives, with the larger words appearing more often than the smaller words. It provides a descriptive entry point into the corpus rather than a stand-alone analytical result. The terms "energy" and "transition" were excluded, as they form the base of the projects' search query and are included in all of the descriptions. The visualization shows which additional terms, such as "technologies", "building", "solutions", "system/s", and cluster around applications of renewables, sustainability, materials, and climate. Therefore, terms illustrate the crystallization of semantics that anchors the cross-sectoral narratives.

With a 7-topic Latent Dirichlet Allocation (LDA) model, distinct narrative clusters that serve as the shared interpretive infrastructure for these partnerships are identified.

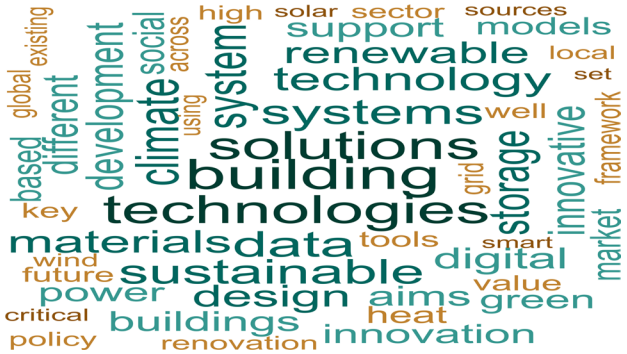

Fig. 2 Word cloud of the Horizon Europe projects with at least one HES and one PRC [58]

The LDA approach identifies recurring semantic patterns across cross-sectoral projects. In this context, "linguistic infrastructure" refers to the shared vocabulary and recurring semantic patterns that make narrative construction possible across heterogeneous actors. It does not replace the concepts of narrative or storyline; rather, it denotes the linguistic material from which narrative elements and storylines are assembled. LDA is based on processing large quantities of documents and generates a probabilistic model, in which each document contains a random assortment of topics [59]. The technique is well established and frequently applied to investigate different types of documents, texts, and images to address various research questions [60, 61]. After basic text processing to clean the text and remove stop words that do not contribute to the selected topics, the dataset is built.

Formally, LDA draws each topic as a distribution over the vocabulary, $\varphi_k \sim Dir\,(\eta)$, and each document as a distribution over topics, $\theta_d \sim Dir(\alpha)$; for each word position, a topic $z_{d,n} \sim Mult(\theta_d)$ and then a term $w_{d,n} \sim Mult(\varphi_{z_{d,n}})$ are drawn. Estimation inverts this generative process, recovering the term-topic probabilities $\beta_{k,v}$, which identify each topic's characteristic vocabulary, and the document-topic probabilities $\gamma_{d,k}$, from which each objective's dominant topic $\widehat{k}_d = argmax_k \gamma_{d,k}$ is taken and its highest-loading objectives is used as example when interpreting that topic. Because θ_d is a mixture rather than a single label, objectives typically load on several topics; this overlap is substantively meaningful, indicating shared semantic material across otherwise distinct narrative clusters. Here, D is the number of documents (project objectives), K the number of topics, V the size of the stemmed vocabulary, and N_d the number of word positions in document d. θ_d is the topic distribution of document d, and φ_k the term distribution of topic k. α and η denote the Dirichlet priors governing, respectively, the expected sparsity of the topic mixture within documents and of the term distribution within topics. $z_{d,n}$ is the topic assigned to the n-th word position of document d, and $w_{d,n}$ the term drawn at that position. $\beta_{k,v}$ is the probability of term v under topic k; $\gamma_{d,k}$ the proportion of document d attributable to topic k; and $\widehat{k}_d$ the dominant topic of document d. $\mathrm{Dir}\,(\cdot)$ and $\mathrm{Mult}\,(\cdot)$ denote the Dirichlet and multinomial distributions [59].

The analysis is conducted in R using the *tm*, *SnowballC*, and *topicmodels* packages [62–65]. Preprocessing comprises conversion to lowercase, removal of punctuation and numerals, removal of English stop words augmented by a corpus-specific list of high-frequency but non-discriminating terms (e.g., "project", "research", "system", "approach", "aim", and the search terms "energy" and "transition" themselves, which appear near-universally and would otherwise dominate every topic), whitespace normalization, and

Porter stemming, so that variant forms of the same word are counted as a single term [66].

To determine the number of topics, the matrix is split into a training set (80%) and a held-out test set (20%). Models are estimated for $k = 2$ to 30 in steps of two using Gibbs sampling (500 iterations) and evaluated by perplexity on the held-out documents [67, 68]. Perplexity declines monotonically without a pronounced elbow, which is a common outcome for short, thematically adjacent documents and indicates that the statistical criterion alone does not identify a unique solution. Therefore, perplexity is treated as a lower bound rather than a selection rule and retains $k = 7$, the point beyond which additional topics no longer produce interpretatively distinct primary themes but instead subdivide existing ones.

Using a lower number of topics results in slight overlap in high-frequency terms across some of the topics (Appendix Table 3). However, this is not to be reported as an error but rather understood as evidence of the semantic focus points mirrored in the framework. A core set of energy transition-related terms, therefore, forms the shared linguistic basis across the diverse project objectives and illustrates narrative stabilization and the background assumptions of the energy transition. The unique terms in the topics define the specific problem framings. The final model is estimated on the full matrix. For the custom stop word list, see Appendix Table 2.

4.2 Findings of a hybridization of language

Applying the LDA algorithm yields the seven topics listed in Table 1. For each topic that includes specific terms, a primary theme and a theoretical alignment can be assigned. Additionally, the validated mechanisms for each topic are listed. The primary theme of the topics is created by accounting for the most frequent words and the general narrative of the project objectives. The theoretical alignment is shaped by the narrative constructed from the most frequent terms and the general notions contained in the project's objectives. The topics can then be related to the mechanisms that are delineated in the previous sections.

For some topics, there is strong hybridization, with several shared terms. This applies, for example, to topics *3: Relational Innovation* and *5: Industrial Energy Management*. The term "technolog" (technology) appears in both topics among the top 5 words, indicating that both projects, with a stakeholder-centered context and a seemingly more technical context of heating and storage systems, place importance on this term.

Table 1 Resulting topics and structural alignment

Topic	Primary theme	Theoretical alignment	Mechanism validated
1	System Dynamics & Power	Contested meanings of "power" and "networks"	Problem framing
2	Digital Interoperability	Digital twins and data as boundary objects	Semantic sedimentation
3	Relational Innovation	Agency attributed to "stakeholders" and "co-creation"	Attribution of agency
4	Decarbonization Pathways	Causal Chains linking hydrogen to industrial products	Causal construction
5	Industrial Energy Management	Selective use of "heat" and "storage" as evidence	Selective mobilization
6	Circular Built Environment	Stabilization of "circularity" in construction	Stabilization through artifacts
7	Normative Governance	The European policy "engine" as a driver	Attribution of agency

Another example is topics *3: Relational Innovation* and *7: Normative Governance*, where the term "European" highlights the relevance of international contexts when applying co-creation frameworks and policy contexts. While the projects share a narrative, they frame it differently.

Table 1 is constructed in three steps. First, the primary theme of each topic is assigned inductively: the top-ranked terms are combined with a close reading of the project objectives showing the highest topic probability for that topic, so that theme labels are grounded in exemplar documents rather than in term lists alone. Second, the theoretical alignment relates each theme to the conceptual vocabulary developed in Sects. 2 and 3. Third, the validated mechanisms are assigned by reading each topic against the four formation mechanisms using theory-derived criteria: problem framing where the topic's terms constitute a distinct and bounded definition of what the transition is a problem of; selective mobilization of evidence where the topic is dominated by terms designating data, models, demonstration, or measurement; construction of causal chains where terms specify a directional pathway from intervention to outcome; and attribution of agency where terms designate actors, mandates, or institutions as the source of change. Topics may satisfy more than one criterion, and the table reports all mechanisms met [68].

This assignment is interpretive rather than algorithmic. The LDA model identifies co-occurrence structure in the corpus; it does not identify narrative mechanisms. The step from topic to mechanism is an analytical reading performed by the authors, in which the model output constrains but does not determine the interpretation. This is consistent with the use of topic modeling as a device for structured reading rather than as a classifier, and it is a reason for validation of the mechanisms in the sense of demonstrating their empirical traceability, rather than of testing them in a confirmatory sense [69].

Regarding topic designation, the assignment is made based on the plain words in the project objectives. It is therefore possible that words with a double meaning (e.g., "power" in the sense of executive strength and in the sense of electricity) are not accounted for. The model occasionally assigned high probabilities to outliers when they used a specific vocabulary in contexts where it was not expected. However, this capturing of semantics illustrates that energy transition narratives function as dominant linguistic tools that even non-technical energy actors adopt to frame their strategies. The recurrence of terms like transit (transition), network, and innov (innovation) across almost all topics proves these are sedimented vocabularies. However, the presence of projects from unrelated sectors (e.g., finance, macroeconomics) indicates that these terms function as narratives that different actor groups can borrow to frame entirely different problems. In practice, the vagueness validates the mechanism of problem framing. It illustrates that the transition narrative is not stable or fixed, but somewhat fragmented and continuously negotiated. The model's stretch to accommodate separate projects more clearly reflects the real-world challenge that organizations are hybridizing their language to align with the dominant, desired European "green" mandate.

4.3 Validation of mechanisms

To interpret and validate the underlying project objectives and the collected topics, the focus is directed on the mechanisms described in the previous sections. The mechanism of problem framing is validated by the distinct thematic boxes observed in the model.

While *topic 1* might frame the transition as a primarily technical challenge of grid stability, *topic 7* frames it normatively, focusing on the policy mandate. The fact that, among the captured projects in *topic 1*, financial and economic topics can also be clustered shows that problem framing can be understood as a competitive process in which actors conform to a dominant (energy) transition narrative.

Furthermore, selective mobilization of evidence is visible in topics such as *topic 4*: Decarbonization Pathways and *topic 5*: Industrial Energy Management, where narrative fragments are selected as technical evidence for why specific pathways are necessary. The interpretation of topics can be selectively mobilized to make complex processes more understandable and to convert them into a persuasive storyline for partners. In *topic 4*, another mechanism to create a causal link is also apparent. The topic clusters the shared logic of the hydrogen-process–product-transit narrative, starting with investment in a specific technological input to achieve an industrial output and a green transition status.

The attribution of agency is evident, especially in *topic 7*, where the terms European, policy, and climate are clustered. The context suggests the change is being initiated by institutional and political mandates rather than solely by individual-firm innovation. Still, in the more technical topics, agency is attributed to material and infrastructure, illustrating that narratives are also distributed across sociotechnical systems where the terms and contexts of technology and society overlap.

All in all, the empirical examples show that shared interpretive narratives are fragmented and contested. The semantic overlap where terms like "transit" (transition) or "materi" (material) appear across multiple topics should not be viewed as a lack of distinctness. Instead, it provides empirical evidence of shared cognitive references and background assumptions that hold these cross-sectoral interpretive spaces together. The demonstrated flexibility in interpreting and crystallizing concepts in the topics defines modern sustainability learning in current European research collaborations.

5 Implications and discussion

5.1 Implications for designing collaborative learning formats

Understanding how narratives emerge and stabilize in university–industry settings has practical consequences for the design of collaborative sustainability learning formats. However, successful learning formats must actively engage with the interpretive work participants perform, rather than treating sense-making as a side effect.

(1) Make interpretive assumptions explicit

Workshops and innovation labs often gloss over the different ways actors frame the transition. Structured reflective activities, such as framing sessions, assumption surfacing, and narrative mapping [70], can help articulate these differences early rather than letting them silently steer interactions.

(2) Design for friction, not just consensus

Collaborative learning often aims for convergence, yet the literature on interorganizational learning suggests that constructive friction is essential for double-loop learning [71]. Formats that legitimize disagreement (e.g., counterfactual scenario

work, role-based deliberation) may enhance the diversity of narrative elements that ultimately stabilize.

(3) Attend to the artifacts that embed narratives.

As the analysis shows, tools and methods can quickly harden narratives. Designing artifacts that are transparent about their underlying assumptions, or offering "plural" tools rather than a single framework, can prevent premature narrative closure.

(4) Allow for iterative and longitudinal engagement.

Narratives stabilize over time through repetition and anchoring. Short-term engagements rarely create sustainable interpretive alignment. Longer formats (fellowships, multi-cycle executive programs, real-world labs) provide the temporal depth in which narrative co-creation becomes meaningful.

5.2 Limitations and outlook

While the mechanisms described are based on well-established literature, the framework has not been empirically tested and is therefore provisional. These limitations indicate areas where empirical refinement and theoretical expansion are needed. Interactions in real collaborative settings may be more complex or politically charged than outlined here, and the focus on university–industry settings necessarily simplifies the diversity of collaboration formats. Co-creation in public-sector, civil-society, or community-led contexts may involve additional dynamics, especially concerning power asymmetries, legitimacy struggles, or contested expertise [72]. Future studies may well identify narrative mechanisms that differ significantly from those discussed here.

While the study emphasizes the productive side of narrative co-creation, narratives can also constrain imagination, reproduce dominant interests, or marginalize dissenting voices [56, 73]. A more critical perspective might examine how narrative stabilization interacts with power, hierarchy, and institutional inertia. Additionally, the conceptual model does not fully address the material aspects of co-creation, including prototypes, infrastructure, and technological artifacts. Material agency plays a vital role in transitions and may shape narrative formation more directly than captured here [74, 75].

A further interpretive caution concerns the attribution of narratives to specific actor types. The selection criterion guarantees the presence of at least one HES and one PRC partner in each consortium, but it does not establish that the objective text is authored by, or reflects the framing of, those partners specifically. European consortia routinely include research and technology organizations, public bodies, municipalities, associations, and SMEs, each of which may contribute to and contest the objective's formulation. Objective descriptions are, moreover, typically drafted and consolidated by the project coordinator, who acts as an intermediary translating heterogeneous partner inputs into a single fundable storyline while anticipating evaluator expectations. The narratives observed are thus better understood as consortium-level interpretive settlements shaped by coordinator brokerage than as direct expressions of university or firm perspectives. Establishing who contributes what to these settlements would require complementary data, such as proposal drafts, coordinator interviews, or partner-level

attribution of text sections, and constitutes a natural extension of this work. Additionally, tracing how initial negotiated framings are sustained, revised, or displaced across deliverables, periodic reports, and final reviews remains an important task for longitudinal designs.

The corpus is defined by the keywords "energy transition" in the CORDIS metadata. This excludes projects addressing the transition without that specific term, even if these keywords already encompass a wide scope. The sample should be seen as purposive, focusing on projects that explicitly identify with the transition narrative, which suits an interest in its discursive construction. However, it likely under-represents technically framed projects using different vocabulary. A broader query or embedding-based retrieval could expand the corpus and affect topic distribution.

Furthermore, several future research directions emerge. These include ethnographic and discourse-analytic studies of co-creative arenas such as living labs [42]. Additionally, comparative studies across sectors and countries can be used to map differences in narrative styles and power dynamics. Furthermore, examining how collaborative arenas enable or restrict narrative diversity could highlight the importance of multiple pathways [56]. Analyzing how narratives influence SDG-related learning and capacity-building, including education, executive programs, and labs, can also reveal how they align with or conflict with sustainability goals. Overall, the future research agenda suggests that narratives are not peripheral to sustainability transitions but central organizing devices that warrant systematic investigation.

6 Conclusion

The conceptual framework developed here suggests that cross-sectoral arenas are not merely channels for exchanging knowledge but sites where knowledge is jointly interpreted and reorganized. The empirical illustration of 366 project objectives supports this, demonstrating how participants stitch together narrative elements that, over time, become sufficiently coherent to guide strategic reasoning. Through mechanisms of problem framing, selective mobilization of evidence, causal construction, and agency attribution, these clusters, ranging from technical grid optimization to policy governance, form a shared interpretive infrastructure. It can be observed that even when these fragments exhibit interpretive flexibility, such as the term “power” spanning both electrical and financial contexts, they provide linguistic anchors necessary for collaboration. Linguistic anchors are recurrent terms or expressions, such as “transition”, “innovation”, “hydrogen”, or “circularity” that stabilize meaning across different project contexts. They are not narratives in themselves, but they help hold together broader narratives and storylines by providing recognizable points of reference.

Stabilization occurs not because narratives win arguments but because they become embedded in tools, routines, and institutional expectations; a process of semantic sedimentation that renders them durable and, after a while, almost invisible. Understanding this narrative dimension is important because it influences how organizations learn, where they focus their attention, and which pathways they see as viable. It also matters because narratives created within a workshop between researchers and managers, such as the identified storylines regarding circularity or hydrogen pathways, can later appear in corporate strategies, policy consultations, or educational formats. In this

Table 2 Custom stop words applying for all the analysis ("custom general stop words"), additional stop words for the word cloud ("word cloud stop words"), and additional stop words for the topic model ("custom analysis-related stop words")

Custom general stop words	Word cloud stop words	Custom analysis-related stop words
will	energy	system
new	Transition	model
project	european	support
research		approach
within		development
also		challenge
can		provide
use		key
		aim

sense, co-created narratives contribute to the cognitive infrastructure of the transition by enabling coordination across sectors even when interests do not fully align.

The central point is that interpretive processes are constitutive elements of the transition, not ancillary to it. Narratives do not necessarily determine the direction of the transition, nor does co-creation always produce progressive or inclusive interpretations. Recognizing this opens space for more deliberate design of collaborative learning formats, more reflexive engagement with underlying assumptions, and more systematic analysis of how narrative plurality or its absence shapes the scope of transformative action. If sustainability transitions require new technological capabilities, new policies, and new forms of coordination, they also need the ability to imagine futures and collectively negotiate their meanings. University–industry arenas offer a vantage point from which to observe how such imaginaries are co-created. Paying closer attention to these processes may not solve the transition, but it can help illuminate why some forms of collective action gain traction while others quietly dissipate.

Appendix

See Tables 2 and 3.

Acknowledgements
During the preparation of this work the authors used DeepL in order to improve readability and the language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Author contributions
A.-K. Voit: Writing—Original Draft, Writing—review & editing, Validation, Investigation, Conceptualization. I. Rhoden: Writing—Original Draft, Writing—Review & Editing, Formal analysis, Data curation, Methodology, Software, Visualization, Validation, Funding acquisition.

Funding
Open Access funding enabled and organized by Projekt DEAL. This work was supported by the Helmholtz Association, Germany, under the program "Energy System Design". Open Access is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation, Grant no. 491111487).

Data availability
The data supporting the empirical illustration of this study are available from the European CORDIS database. All code for processing data and conducting analyses is available from the authors upon reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent publication
Not applicable.

Table 3 Top 5 terms of the selected seven topics. Beta stands for the per-topic-per-word probability. It is the specific weight of a word within a particular topic [58, 59]

Topic	Term	β
1	grid	0.012481
1	transit	0.012034
1	wind	0.011453
1	power	0.009231
1	oper	0.008294
2	build	0.024890
2	data	0.015493
2	solut	0.013001
2	digit	0.008383
2	integr	0.007995
3	innov	0.012526
3	activ	0.009737
3	stakehold	0.009224
3	technolog	0.009072
3	european	0.008637
4	hydrogen	0.011394
4	process	0.010189
4	materi	0.009696
4	product	0.008339
4	transit	0.008273
5	technolog	0.018929
5	heat	0.018647
5	industri	0.015174
5	storag	0.013947
5	materi	0.009646
6	build	0.019863
6	digit	0.010075
6	materi	0.009452
6	circular	0.007368
6	construct	0.007171
7	transit	0.012825
7	polici	0.009382
7	european	0.007759
7	climat	0.007519
7	sustain	0.007459

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Received: 8 April 2026 / Accepted: 23 July 2026

Published online: 10 August 2026

References

1. Rosenbloom D. Framing low-carbon pathways: a discursive analysis of contending storylines surrounding the phase-out of coal-fired power in Ontario. Environ Innov Soc Transit. 2018;27:129–45. https://doi.org/10.1016/j.eist.2017.11.003.
2. Beckert J. Imagined futures: fictional expectations and capitalist dynamics. Harvard University Press; 2016. https://doi.org/10.4159/9780674545878.
3. Shiller RJ. Narrative economics: how stories go viral and drive major economic events. Torrossa; 2020. https://doi.org/10.1515/9780691189994.
4. Hajer MA. The politics of environmental discourse: ecological modernization and the policy process. Clarendon Press; 1995.
5. Star SL, Griesemer JR. Institutional ecology, translations, and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39. Soc Stud Sci. 1989;19(3):387–420. https://doi.org/10.1177/030631289019003001.
6. Dryzek JS. The politics of the earth: environmental discourses. Oxford University Press; 2022.

7. Fischer F. Reframing public policy: discursive politics and deliberative practices. Oxford University Press; 2003. https://doi.org/10.1093/019924264X.001.0001.
8. Boswell C. The political uses of expert knowledge: immigration policy and social research. Cambridge University Press; 2009. https://doi.org/10.1017/CBO9780511596704.
9. Geels FW. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Res Policy. 2002;31(8–9):1257–74. https://doi.org/10.1016/S0048-7333(02)00062-8.
10. Smith A, Stirling A, Berkhout F. The governance of sustainable sociotechnical transitions. Res Policy. 2005;34(10):1491–510. https://doi.org/10.1016/j.respol.2005.07.005.
11. Jasanoff S, Kim SH. Containing the atom: sociotechnical imaginaries and nuclear power in the United States and South Korea. Minerva. 2009;47(2):119–46. https://doi.org/10.1007/s11024-009-9124-4.
12. Meadowcroft J. What about the politics? Sustainable development, transition management, and long term energy transitions. Policy Sci. 2009;42(4):323–40. https://doi.org/10.1007/s11077-009-9097-z.
13. Kern F, Rogge KS. The pace of governed energy transitions: agency, international dynamics and the global Paris agreement accelerating decarbonisation processes? Energy Res Soc Sci. 2016;22:13–7. https://doi.org/10.1016/j.erss.2016.08.016.
14. Guston DH. Boundary organizations in environmental policy and science: an introduction. Sci Technol Hum Values. 2001;26(4):399–408. https://doi.org/10.1177/016224390102600401.
15. Etzkowitz H, Leydesdorff L. The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. Res Policy. 2000;29(2):109–23. https://doi.org/10.1016/S0048-7333(99)00055-4.
16. Carayannis EG, Campbell DF. "Mode 3" and "Quadruple Helix": toward a 21st century fractal innovation ecosystem. Int J Technol Manag. 2009;46(3–4):201–34. https://doi.org/10.1504/IJTM.2009.023374.
17. Ranga M, Etzkowitz H. Triple helix systems: an analytical framework for innovation policy and practice in the knowledge society. Ind Higher Educ. 2013;27(4):237–62. https://doi.org/10.5367/ihe.2013.0165.
18. Voorberg WH, Bekkers VJ, Tummers LG. A systematic review of co-creation and co-production: embarking on the social innovation journey. Public Manag Rev. 2015;17(9):1333–57. https://doi.org/10.1080/14719037.2014.930505.
19. Argyris C, Schön DA. Organizational learning: a theory of action perspective. Reis 1997;(77/78): 345–348. https://doi.org/10.2307/40183920
20. Wenger E. Communities of practice: learning, meaning, and identity. Cambridge University Press; 1999. https://doi.org/10.1017/CBO9780511803932.
21. Senge PM. The fifth discipline, the art and practice of the learning organization. Performance + Instruction. 1991;30(5):37–37. https://doi.org/10.1002/pfi.4170300510.
22. Lusch RF, Nambisan S. Service innovation: a service-dominant logic perspective. MIS Q. 2015;39(1):155–75. https://doi.org/10.25300/MISQ/2015/39.1.07.
23. Lang DJ, Wiek A. Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustain Sci. 2012;7(1):25–43. https://doi.org/10.1007/s11625-011-0149-x.
24. Brown AD, Colville I, Pye A. Making sense of sense-making in organization studies. Organ Stud. 2015;36(2):265–77. https://doi.org/10.1177/0170840614559259.
25. Provan KG, Fish A, Sydow J. Interorganizational networks at the network level: A review of the empirical literature on whole networks. J Manag. 2007;33(3):479–516. https://doi.org/10.1177/0149206307302551.
26. Gieryn TF. Boundary-work and the demarcation of science from non-science: strains and interests in professional ideologies of scientists. Am Sociol Rev. 1983;48(6):781–95. https://doi.org/10.2307/2095325.
27. Jasanoff S. The fifth branch: science advisers as policymakers. Harvard University Press; 1998.
28. Nowotny H, Scott P, Gibbons M. Re-thinking science: knowledge and the public in an age of uncertainty. Polity; 2001.
29. Pohl C, Hirsch Hadorn G. Principles for designing transdisciplinary research. Oekom Verlag; 2007. https://doi.org/10.14512/9783962388638.
30. Markard J, Raven R, Truffer B. Sustainability transitions: an emerging field of research and its prospects. Res Policy. 2012;41(6):955–67. https://doi.org/10.1016/j.respol.2012.02.013.
31. Carlile PR. Transferring, translating, and transforming: an integrative framework for managing knowledge across boundaries. Organ Sci. 2004;15(5):555–68. https://doi.org/10.1287/orsc.1040.0094.
32. Köhler J, Geels FW, Kern F. An agenda for sustainability transitions research. Environ Innov Soc Transit. 2019;31:1–32. https://doi.org/10.1016/j.eist.2019.01.004.
33. Wiek A, Iwaniec D. Quality criteria for visions and visioning in sustainability science. Sustain Sci. 2014;9(4):497–512. https://doi.org/10.1007/s11625-013-0232-4.
34. Loorbach D. Transition management for sustainable development: a prescriptive, complexity-based governance framework. Governance. 2010;23(1):161–83. https://doi.org/10.1111/j.1468-0491.2009.01466.x.
35. Gajjar SP, Singh C, Deshpande T. Tracing back to move ahead: a review of development pathways that constrain adaptation futures. Clim Dev. 2019;11(3):223–37. https://doi.org/10.1080/17565529.2017.1410086.
36. Weick KE. Sense-making in organizations. Sage; 1995. https://doi.org/10.4135/9781452243580.
37. Maitlis S, Christianson M. Sense-making in organizations: taking stock and moving forward. Acad Manag Ann. 2014;8(1):57–125. https://doi.org/10.1080/19416520.2014.873177.
38. Nambisan S, Sawhney M. Orchestration processes in network-centric innovation. Acad Manag Rev. 2011;36(1):195–212. https://doi.org/10.5465/amr.2009.0164.
39. Schön DA, Rein M. Frame reflection: toward the resolution of intractable policy controversies. 1994; Basic Books.
40. Berkhout F, Verbong G, Wieczorek AJ, Raven R, Lebel L, Bai X. Sustainability experiments in Asia: innovations shaping alternative development pathways? Environ Sci Policy. 2010;13(4):261–71. https://doi.org/10.1016/j.envsci.2010.03.010.
41. Grin J, Rotmans J, Schot J. Transitions to sustainable development: new directions in the study of long term transformative change. Routledge; 2010. https://doi.org/10.4324/9780203856598.
42. Kuhlmann S, Rip A. Next-generation innovation policy and grand challenges. Sci Public Policy. 2018;45(4):448–54. https://doi.org/10.1093/scipol/scy011.
43. van Lente H. Promising technology. The dynamics of expectations in technological developments. Delft: Eburon; 1993.
44. Scott WR. Institutions and organizations. Sage; 1995.

45. Walsh JP, Ungson GR. Organizational memory. Acad Manag Rev. 1991;16(1):57–91. https://doi.org/10.5465/amr.1991.4278992.
46. MacKenzie D, Wajcman J. The social shaping of technology. Open University; 1999.
47. MacKenzie D, Millo Y. Constructing a market, performing theory: the historical sociology of a financial derivatives exchange. Am J Sociol. 2003;109(1):107–45. https://doi.org/10.1086/374404.
48. Abolafia M, Callon M. The laws of the markets. Blackwell; 1998.
49. Maitlis S, Lawrence TB. Triggers for sensegiving: Alternative perspectives on sensegiving and sense-making. Acad Manag J. 2007;50(1):57–84. https://doi.org/10.5465/amj.2007.24160823.
50. Czarniawska B. Narratives in social science research. Sage; 2004. https://doi.org/10.4135/9781849209502.
51. Tolbert PS, Zucker LG. Institutional sources of change in the formal structure of organizations. Adm Sci Q. 1983;28(1):22–39. https://doi.org/10.2307/2392383.
52. Ocasio W. Towards an attention-based view of the firm. Strateg Manag J. 1997;18(S1):187–206. https://doi.org/10.1002/(SICI)1097-0266(199707)18:1+%3c187::AID-SMJ917%3e3.0.CO;2-K.
53. Schmidt VA. Discursive institutionalism: the explanatory power of ideas and discourse. Annu Rev Polit Sci. 2008;11:303–26. https://doi.org/10.1146/annurev.polisci.11.060606.135342.
54. Hall PA. Policy paradigms, social learning, and the state: the case of economic policymaking in Britain. Comp Polit. 1993;25(3):275–96. https://doi.org/10.2307/422246.
55. Dunlop CA, Radaelli CM. Systematising policy learning: from monolith to dimensions. Polit Stud. 2013;61(3):599–619. https://doi.org/10.1111/j.1467-9248.2012.00982.x.
56. Stirling A. Keep it complex. Nature. 2010;468(7327):1029–31. https://doi.org/10.1038/4681029a.
57. Keller R. The sociology of knowledge approach to discourse: foundations, concepts and tools for a research programme. Springer Nature; 2024. https://doi.org/10.1007/978-3-658-41710-9.
58. European Commission. Publications office of the European Union. CORDIS: Community Research and Development Information Service. 2026. https://cordis.europa.eu/.
59. Blei DM, Ng AY, Jordan MI. Latent dirichlet allocation. J Mach Learn Res. 2003;3:993–1022.
60. Li L, Lemke F. Shaping the future of business sustainability: LDA topic modeling insights, definitions, and research agenda. J Bus Ethics. 2025;201(2):391–456. https://doi.org/10.1007/s10551-025-05969-z.
61. Antons D, Breidbach CF. Big data, big insights? Advancing service innovation and design with machine learning. J Serv Res. 2017;21(1):17–39. https://doi.org/10.1177/1094670517738373.
62. Feinerer I, Hornik K, Meyer D. Text mining infrastructure in R. J Stat Softw. 2008;25(5):1–54. https://doi.org/10.18637/jss.v025.i05.
63. Grün B, Hornik K. Topicmodels: an R package for fitting topic models. J Stat Softw. 2011;40(13):1–30. https://doi.org/10.18637/jss.v040.i13.
64. Silge J, Robinson D. Tidytext: text mining and analysis using tidy data principles in R. J Open Source Softw. 2016;1(3):37. https://doi.org/10.21105/joss.00037.
65. R Core Team. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing; 2026.
66. Porter MF. An algorithm for suffix stripping. Program Electron Libr Inf Syst. 1980;14(3):130–7. https://doi.org/10.1108/eb046814.
67. Griffiths TL, Steyvers M. Finding scientific topics. Proc Natl Acad Sci U S A. 2004;101(suppl_1):5228–35. https://doi.org/10.1073/pnas.0307752101.
68. Wallach HM, Murray I, Salakhutdinov R, Mimno D. Evaluation methods for topic models. In: Proceedings of the 26th annual international conference on machine learning. Montreal: Association for Computing Machinery; 2009. p. 1105–1112.
69. Chang J, Gerrish S, Wang C, Boyd-Graber J, Blei D. Reading tea leaves: How humans interpret topic models. Adv Neural Inf Process Syst. 2009; 22. https://proceedings.neurips.cc/paper_files/paper/2009/file/f92586a25bb3145facd64ab20fd554ff-Paper.pdf.
70. Roe E. Narrative policy analysis: theory and practice. Duke University Press; 1994. https://doi.org/10.1215/9780822381891.
71. Easterby-Smith M, Lyles MA, Tsang EW. Inter-organizational knowledge transfer: current themes and future prospects. J Manag Stud. 2008;45(4):677–90. https://doi.org/10.1111/j.1467-6486.2008.00773.x.
72. Chilvers J, Kearnes M. Remaking participation: science, environment and emergent publics. Routledge; 2015. https://doi.org/10.4324/9780203066843.
73. Felt U, Wynne B. Taking European knowledge society seriously. European Commission; 2007.
74. Latour B. Reassembling the social: an introduction to actor-network-theory. Oxford University Press; 2005.
75. Suchman LA. Human-machine reconfigurations: plans and situated actions. Cambridge University Press; 2007. https://doi.org/10.1017/CBO9780511808418.

Publisher's Note