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Code ecologies: Integrating cultural legitimacy analysis in sustainability transitions

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ABSTRACT

A persistent challenge in sustainability transitions is the uneven uptake of interventions such as renewable energy projects, conservation measures and rewilding initiatives. These often encounter resistance that cannot be explained by economics, technical feasibility or governance arrangements alone. Instead, they hinge on questions of legitimacy and cultural alignment. Existing frameworks, including socio-ecological systems (SES) and cultural ecosystem services (CES), recognise human dimensions yet miss the symbolic dynamics through which interventions are interpreted, accepted or contested. Symbolic codes are patterned systems of meaning expressed through aesthetics, aspirational values and common practices in a particular context, which influence whether interventions are embraced, negotiated or resisted. This paper advances the Symbolic Ecology Framework (SEF), a conceptual framework for integrating symbolic codes as cultural variables in socio-ecological analysis. This conceptual contribution: (1) establishes theoretical premises for treating symbolic codes as cultural variables in socio-ecological analysis; (2) specifies six attributes (salience, valence, resonance, legitimacy, diachronic status, place-binding) drawn from cultural analysis and environmental research for systematic code assessment; and (3) proposes their aggregation into a Symbolic Alignment Index (SAI) for legitimacy alignment diagnostic purposes. An illustrative case study application to renewable energy siting demonstrates the framework's analytical logic. Finally, the empirical research agenda required to operationalise SEF is outlined, including protocol standardisation, validation studies and cross-context calibration.

1. Introduction

Despite decades of innovation, the uptake of sustainability interventions – from renewable energy and conservation to rewilding and circular practices – remains uneven and contested. While frameworks such as social-ecological systems (SES) and cultural ecosystem services (CES) have broadened analysis beyond the biophysical (Ostrom, 2009; Daniel et al., 2012; Fish et al., 2016), persistent difficulties in uptake reveal a critical blind spot: how symbolic systems influence cognitive legitimacy – the taken-for-granted assumptions about what appears appropriate in particular contexts (Devine-Wright, 2009; Batel and Devine-Wright, 2015).

An important factor in whether interventions succeed is the extent to which they fit the socio-symbolic logics of the communities in which they are introduced. When the symbolic framing of an intervention clashes with local codes of meaning, legitimacy is withheld and uptake falters. Renewable energy projects, for example, are often delayed not by technical design or cost, but by disputes over how turbines alter valued landscapes and identities (Devine-Wright, 2009). Similarly, rewilding initiatives can provoke contestation when they disrupt established narratives of belonging and stewardship (Lorimer et al., 2015).

These symbolic dimensions are not always visible. Unlike conscious preferences (stated choices), norms (observed behaviours) and values (what people care about) (Schwartz et al., 2012), they consist largely of unspoken beliefs, assumptions and shared understandings that bind people together and define identity and belonging (Barthes, 1972; Nöth, 1990). For outsiders – whether policymakers, scientists or developers – these symbolic codes are therefore difficult to detect and easy to overlook. A community might value environmental protection and prefer renewable energy, yet resist a specific project because turbines violate symbolic codes of landscape heritage or local sovereignty (Wolsink, 2007; Walker and Devine-Wright, 2008). This explains persistent adoption failures: interventions align with conscious values but clash with unconscious codes (Kollmuss and Agyeman, 2002). The challenge is how to systematically identify such tacit, context-specific codes and account for them in the design of sustainability interventions.

Addressing this blind spot requires interdisciplinary approaches that can integrate symbolic code analysis into environmental science.

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Semiotics, as the study of codes and meaning systems, provides a powerful basis for this integration. Building on previous methodological work on semiotics analysis in the context of sustainable innovation (Santamaria, Escobar-Tello and Ross, 2016; Santamaria, 2023), this paper extends the approach into environmental science by establishing the foundations for the Symbolic Ecology Framework (SEF), a conceptual framework for diagnosing symbolic alignment between interventions and contextual codes.

1.1. Scope and contribution

The contribution is fourfold: (1) establishing the theoretical case for treating symbolic codes as cultural variables in socio-ecological analysis; (2) specifying six attributes through which codes can be assessed; (3) proposing an aggregation logic (Symbolic Alignment Index) for diagnostic purposes; (4) outlining the empirical research agenda required to operationalise the conceptual framework into validated protocols, including standardised procedures for code identification, validation studies correlating SAI with uptake outcomes, and cross-context calibration.

Section 2 reviews the legitimacy gap and introduces core concepts on semiotics and symbolic codes. Section 3 presents SEF's premises, attributes and aggregation logic. Section 4 illustrates application to renewable energy siting. Section 5 discusses implications and outlines the operationalisation agenda.

2. Literature review

This section reviews how environmental science has addressed human dimensions of ecological systems, what remains under-theorised, and what semiotic analysis can offer to fill this gap.

2.1. Environmental science approaches to human dimensions, and the cultural blind spot

Legitimacy has become central to explaining the success or failure of sustainability transitions (Fuenfschilling, 2019). Suchman (1995, p. 574) defines legitimacy as 'a generalised perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs and definitions.' Scott's (2014) well-adopted framework distinguishes between *regulative*, *normative* and *cultural-cognitive* dimensions. *Regulative* legitimacy concerns conformity with formal rules and laws; *normative* legitimacy relates to alignment with values and social expectations; *cultural-cognitive* legitimacy reflects taken-for-granted assumptions about what is appropriate (Scott, 2014; Deephouse and Suchman, 2008). While transitions research has examined regulative and normative dimensions (Fuenfschilling, 2019), what remains under-explored is the symbolic systems (taken-for-granted assumptions) that affect cultural-cognitive legitimacy. Crucially, in transitions, legitimacy itself becomes contested rather than granted. Institutional structures (regulative, normative, cultural-cognitive) are in flux as actors engage in creating, maintaining and disrupting institutions (Fuenfschilling and Truffer, 2016). Cultural legitimacy involves 'framing struggles' where various groups contest evolving discourses and perform on public stages to influence legitimacy judgments (Geels and Verhees, 2011). The question is not merely whether interventions achieve legitimacy but whose symbolic codes, whose taken-for-granted assumptions and whose institutional logics prevail.

While SES and CES keep expanding the scope of socio-ecological modelling (Manyani et al., 2024), they assume stable institutional contexts and overlook the symbolic systems through which intervention legitimacy and meaning are constructed – a gap noted in earlier reviews (Fish et al., 2016; Schäfer and O'Neill, 2017; Partelow, 2018). SES integrates culture through norms, shared strategies, trust and institutional arrangements embedded in governance structures (Ostrom, 2009; McGinnis and Ostrom, 2014). These variables address normative legitimacy: what communities expect and value. CES broadens recognition of cultural benefits through heritage, identity and sense of place, operationalising these through deliberative methods that elicit stated preferences (Daniel et al., 2012; Fish et al., 2016). This again addresses normative legitimacy through what people consciously value and can articulate. What neither framework captures is cultural-cognitive legitimacy as a site of contestation: the assumptions that determine whether interventions are read as 'progress' or 'imposition', 'us' or 'them', 'what belongs here' or 'what is alien'. Consequently, the cultural-cognitive dimension of legitimacy, and the power dynamics embedded within it is under-explored in environmental science, and sustainability transitions uptake challenges persist across sectors and geographies. Symbolic codes are not neutral cultural variables but politically loaded systems through which power operates. Such 'ecology of codes' and their dynamics must be understood to diagnose legitimacy challenges.

Emergent evidence points to the decisive role of cultural-cognitive alignment. In Samoa, blending climate forecasts with traditional indicators increased trust by resonating with indigenous symbolic codes (McNamara and Prasad, 2014). In Sardinia, a participatory plan that involved schools, associations and trusted local media succeeded in building legitimacy around environmental health interventions by anchoring them in familiar community practices (De Marchi et al., 2023). In Belgium, retrofit uptake increased when coded along through local norms (Bielig et al., 2024). These cases reveal that interventions gain traction when they resonate with symbolic logics, yet the question of whose symbolic codes and whose cultural-cognitive frameworks are validated remains largely unexamined.

2.2. Semiotics and symbolic codes

Semiotics is the study of sign systems, the patterned conventions through which humans interpret the world and organise collective life (Nöth, 1990). Semiotics originated in linguistics through the foundational work of Ferdinand de Saussure and Charles Sanders Peirce in the early 20th century and became a major approach within cultural studies in the late 1960s with the work of Roland Barthes, who recognised its value for understanding meanings embedded in images, objects, rituals and their complex associations to identity and belonging. Barthes demonstrated how codes construct myths: cultural associations that make dominant meanings appear 'natural' and 'common sense' and operate as 'assumed truth' in a given context (Barthes, 1972). This process of naturalisation is central to cultural-cognitive legitimacy: what appears self-evidently appropriate in one context may be contested or illegitimate in another (Scott, 2014). In Britain, semiotics was advanced in cultural studies by sociologist Stuart Hall, whose work on media and communication studies (encoding/decoding) showed how meanings are strategically produced by cultural intermediaries and legitimised to audiences through rhetorical and institutional processes, whether through media framing, institutional endorsement or symbolic association (Hall, 1980). Beyond cultural critique, contemporary semiotics has been adopted as 'a hybrid of communication science and anthropology' methodology for examining how symbolic codes structure consumer preferences and anticipate social behaviours (Oswald, 2020, p. 1).

The concept of codes is central to semiotics, which defines them as socially agreed conventions linking signs to meanings (Nöth, 1990). Some codes are obvious, such as traffic lights (red = stop; green = go), while others are tacit and deeply embedded in culture, such as colour–gender associations (pink = female; blue = male). Symbolic codes construct social reality by marking class differentiation, identity and belonging (Baudrillard, 1988).

Operating largely at an unconscious level, symbolic codes constitute what Scott (2014) identifies as cultural-cognitive legitimacy: the taken-for-granted assumptions about what appears appropriate, proper and self-evident in particular contexts.

Marketing semiotics has long recognised that symbolic alignment

shapes uptake as powerfully as technical performance (Oswald, 2015, 2020). When Jeep Wrangler sales stalled in the US, cultural analysis revealed square headlights clashed with codes linking the vehicle to freedom and power. Sales surged after redesigning headlights to resemble horses' 'round eyes', which evoked rural familiarity. In Europe, the same vehicle carried different codes, linked to 'liberator' evoking Allied forces, resulting in a different design (Rapaille, 2007).

Semiotics differs fundamentally from, yet complements, participatory methods commonly used in environmental science. Participatory approaches (interviews, workshops, focus groups) elicit what people can *consciously* articulate. Because codes shaping legitimacy judgments are often inaccessible through direct questioning, semiotic methods analyse publicly circulating cultural discourse – media, policy documents, material culture – to identify codes structuring collective meaning-making (Oswald, 2015; Santamaria, 2020).

Codes are dynamic and contested, not static variables. Raymond Williams' (1977) distinction between *residual* (inherited but active), *dominant* (currently prevailing), and *emergent* (new and contested) cultural forms reveals how codes compete for position and legitimacy. The plastics example illustrates this: reuse and thrift re-emerge as residual codes; disposability and convenience remain dominant yet increasingly contested; circularity and closed-loop design struggle as emergent codes. These codes coexist, clash and migrate, reshaping the symbolic terrain of everyday practice. Concerning legitimacy in sustainability transitions, this results in a volatile 'status quo', where the boundaries of what is considered legitimate are continuously challenged and redefined (Haack et al., 2021). Hence, sustainability transitions require co-evolution across socio-technical dimensions: stewardship of natural resources, innovation adoption and cultural-symbolic systems – meanings and values attributed to the natural and man-made spheres (Geels, 2002). Electric vehicles, for instance, mobilise *technological resources* (batteries, charging grids, regulatory legislation), *ecological resources* (reduced emissions, mineral extraction) *and symbolic resources* (whether EVs are coded as luxury commodities, green necessities or transitional technologies). Working with codes is therefore not 'soft communication' but systemic leverage in sustainability transitions.

2.3. The blind spot, clarified

Across SES, CES and adjacent literatures, there is widespread recognition that cultural and symbolic dimensions matter for sustainability transitions. SES research acknowledges norms, trust and institutions; CES highlights heritage, identity and spirituality; adoption studies demonstrate framing effects. Yet symbolic dimensions remain methodologically under-developed. Three persistent limitations prevent systematic integration:

1. **Culture is proxied rather than operationalised.** Culture is recognised but typically reduced to values, attitudes or preferences, constructs that elicit what people consciously care about but not how symbolic codes structure cultural-cognitive legitimacy, compete for dominance or evolve over time.
2. **Lack of temporal and spatial integration.** While ecological and technical variables are modelled diachronically and spatially, symbolic codes are rarely tracked as residual, dominant or emergent, nor mapped to show where cultural alignment supports or undermines interventions.
3. **Absence of ex-ante diagnostic tools.** SES excels at diagnosing governance fit; CES elicits values. Yet approaches document symbolic barriers or successes only after the fact. There is no systematic method to identify, assess and align symbolic codes with interventions *ex-ante*, diagnosing and anticipating cultural-cognitive legitimacy challenges rather than retroactively explain them, reducing costly delays, opposition and trial-error iterations.

Important precedents show code operationalisation is possible. Semiotics has examined differential weight of codes: Kress and van Leeuwen (2001) proposed visual grammars measuring salience in multimodal texts; Hall's (1980) encoding/decoding model classified interpretive positions as dominant, negotiated or oppositional. Communication studies have shown how moral, economic or security frames alter legitimacy of climate messages (Nisbet, 2009; Wolsko et al., 2016). Ecosystem services research has formalised relational values through classification and weighting (Chan et al., 2016; Fish et al., 2016). Marketing semiotics has long implemented symbolic code analysis with measurable effect: products succeed internationally when encoded to fit target cultural logics (Oswald, 2015, 2020). Related work has demonstrated how code mapping can guide sustainable product-service system design by identifying cultural barriers to adoption and aligning innovations with favourable codes (Santamaria et al., 2016).

The challenge is not proving codes matter – evidence is ample – but developing systematic methods to analyse and operationalise them in environmental science. If symbolic codes shape cultural-cognitive legitimacy and vary across contexts, then alignment cannot be left to chance or treated as a communication afterthought. What is missing is a coherent framework integrating symbolic codes as variables in their own right: analysable, comparable and alignable alongside biophysical, governance and behavioural dimensions.

This paper addresses that gap by proposing the Symbolic Ecology Framework (SEF), which specifies how symbolic codes can be systematically integrated into socio-ecological analysis.

3. The symbolic ecology framework: conceptual premises and analytical structure

The following conceptual framework establishes the analytical logic for integrating symbolic codes into socio-ecological analysis. The framework builds on established methods for code mapping in sustainable innovation contexts (Santamaria et al., 2016; Santamaria, 2023), extending these approaches to address the cultural-cognitive dimensions of legitimacy in environmental science. SEF provides a structured pathway through four stages (Fig. 1): Code mapping, attribute assessment, symbolic alignment synthesis (SAI), interpretive alignment strategies.

Building on these stages, the steps below outline a minimum illustrative procedure for applying SEF in analytical contexts. *This procedure is intended to clarify analytical logic rather than to claim empirical validation.*

1. **Define the intervention context**
   Specify the intervention type, spatial scope and stakeholder setting.
2. **Identify symbolic codes**
   Conduct semiotic analysis of relevant discourse and artefacts (e.g.

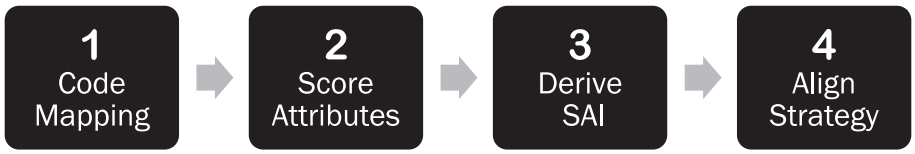

Fig. 1. The analytical stages of the Symbolic Ecology Framework (SEF).

media, policy documents, visual culture) to identify dominant, residual and emergent symbolic codes[1] (see Santamaria et al., 2016).

3. **Classify codes**
   Organise identified codes into aesthetic codes, aspirational values and common practices.
4. **Assess code attributes**
   Analytically assess each code against the six attributes (salience, valence, resonance, legitimacy, diachronic status, place-binding) using an ordinal or qualitative scale.
5. **Derive symbolic alignment**
   Synthesise attribute assessments to derive an indicative Symbolic Alignment Index (SAI) for comparative diagnostic purposes.
6. **Interpret implications**
   Interpret alignment patterns to anticipate legitimacy dynamics and inform reflective intervention design.

3.1. Categories for code mapping

These three categories are derived from applied research in design for sustainability (Santamaria et al., 2016; Santamaria, 2023), where they were developed to map cultural codes shaping sustainable innovation uptake:

- **Aesthetic Codes:** Visual and material signs indicating what is desirable, familiar or modern within a culture (styles of dress, architecture, cars, artefacts). These codes provide cues for how communities perceive harmony, appropriateness or modernity, shaping whether interventions appear legitimate or alien.
- **Aspirational Values:** Collective imaginaries and orientations that motivate what people strive for in life ('my children receive good education,' 'family remains united,' 'we can eat well'). These values anchor long-term visions of the future and condition how sustainability is justified and pursued.
- **Common Practices:** Everyday routines and social rituals embodying belonging – what 'people like us do' (going for a pint after work, rising early for agricultural labour, helping neighbours). These practices reflect collective norms that determine what feels natural, trustworthy and socially legitimate.

These categories provide a comprehensive, structured way to map the cultural-symbolic logics of a given context, highlighting the tacit codes that filter legitimacy and shape whether interventions are resisted, negotiated or embraced. This explains why interventions can align with stated values yet encounter resistance: they overlook the symbolic codes operating below conscious awareness. Once mapped, these codes can be analysed through six attributes (Section 3.2) and aggregated within the Symbolic Alignment Index (Section 3.3).

3.2. Variables and attributes

To integrate symbolic codes within socio-ecological analysis, they must be described and assessed in systematic ways. We propose six core attributes, grounded in cultural analysis and environmental research, that capture how codes shape legitimacy and uptake. This multi-dimensional approach ensures a comprehensive diagnostic of how a code operates in specific contexts, spanning cognitive (salience), affective (valence, resonance), normative (legitimacy), temporal (diachronic status) and spatial (place-binding) dimensions.

1. **Salience** – the frequency and visibility of a code in public discourse, media or practice. In semiotics, salience refers to the degree to which elements attract attention within a composition (Kress and van Leeuwen, 2001). In political science, 'issue salience' captures how strongly a topic features in collective agendas (McCombs and Shaw, 1972).
2. **Valence** – the positive or negative orientation attributed to a code in collective meaning-making, ranging from antagonistic to aspirational. In psychology, affective valence denotes the emotional charge of experiences (Frijda, 1986). In communication studies, valence framing influences whether issues are embraced or resisted (de Vreese and Boomgaarden, 2003).
3. **Resonance** – the depth of alignment between a code and collective identities, values and affective orientations. In social movement theory, resonance explains why some frames mobilise while others fail (Benford and Snow, 2000). In cultural sociology, resonance is the symbolic 'fit' with wider imaginaries (Alexander, 2004).
4. **Legitimacy –** the extent to which a symbolic code is recognised as valid, fair and authoritative within a given context, shaping whether interventions are accepted as just and appropriate. In sustainability research, legitimacy is a key criterion for effective knowledge systems, alongside salience and credibility (Cash et al., 2003).
5. **Diachronic Status** – the temporal positioning of a code (Residual/Dominant/Emergent). Williams (1977) distinguished between residual forms (inherited from the past but still active), dominant forms (prevailing in the present) and emergent forms (new and not yet fully institutionalised). This dimension reflects cultural shifts over time.
6. **Place-binding** – the anchoring of codes to specific landscapes or places. Environmental psychology shows how place attachment and identity shape acceptance (Devine-Wright, 2009; Lewicka, 2011). Cultural ecosystem services research similarly highlights symbolic ties between places and meanings (Chan et al., 2016).

The attributes provide a vocabulary for measuring symbolic dynamics in ways comparable to other socio-ecological variables. They are the building blocks for the Symbolic Alignment Index. Table 1 summarises them for easy access.

[1] **Methodological note on code identification:** Code mapping is an interpretive and semiotic task that requires cultural and symbolic literacy; in applied contexts, it may be undertaken by researchers or practitioners with training in semiotics, cultural analysis, or related interpretive disciplines, drawing on established protocols (Santamaria et al., 2016). Code identification typically involves systematic analysis of publicly circulating discourse (e.g. media coverage, policy documents, visual culture, material artefacts) to identify recurrent symbolic patterns. Participatory workshops and ethnographic observation can provide complementary insight into practices and locally salient codes.

Within the present framework, once symbolic codes are conceptually identified and mapped, the SEF provides a structured analytical lens through which environmental scientists and practitioners may examine patterns of symbolic alignment. This reflects established interdisciplinary practice in environmental research, where interpretive social and cultural analysis informs, rather than replaces, technical and ecological assessment.

Table 1
Attributes for assessing symbolic codes in socio-ecological analysis.

Attribute	Definition (short)	Illustrative example	Reference(s)
Salience	Visibility/ frequency of a code in discourse or practice	Recycling symbol present on packaging and bins	Kress and van Leeuwen (2001); McCombs and Shaw (1972)
Valence	Positive/negative orientation of a code	Wind turbines interpreted as 'green progress' vs 'industrial blight'	Frijda (1986); de Vreese and Boomgaarden (2003)
Resonance	Depth of alignment with identities and values	'Family farming' resonating with rural traditions	Benford and Snow (2000); Alexander (2004)
Legitimacy	Recognition of a code as fair and authoritative	Indigenous stewardship narratives gaining official recognition	Cash et al. (2003)
Diachronic Status	Temporal positioning: residual, dominant, emergent	Revival of residual folk practices in modern rewilding	Williams (1977)
Place-binding	Anchoring of codes to landscapes/ places	Opposition to dams tied to cultural river identity	Devine-Wright (2009); Lewicka (2011); Chan et al. (2016)

3.3. Symbolic Alignment Index (SAI)

The Symbolic Alignment Index (SAI) integrates symbolic codes' attributes into a composite measure of how well an intervention aligns with the codes of a given community. High SAI values indicate strong symbolic legitimacy and smoother uptake, while low or negative values signal symbolic conflict, pointing to likely resistance or contestation.

By spatialising SAI outputs, researchers can generate *Cultural Alignment Maps* that overlay symbolic codes onto ecological and technical data. These maps reveal where interventions are more likely to encounter legitimacy barriers or resonance, offering a diagnostic analysis that complements assessments such as environmental impact studies.

4. Illustrative application: renewable energy siting

The following application shows, step by step, how the Symbolic Ecology Framework (SEF) can be used to analyse cultural–cognitive alignment in sustainability interventions. This is an illustrative application intended to demonstrate the framework's analytical logic. It does not present empirically validated findings.

4.1. Codes as cultural variables

n empirical applications, code data would be derived from systematic code mapping through semiotic analysis of contextual codes, using established protocols (Santamaria et al., 2016, Santamaria, 2020, Santamaria, 2023). It is important to note that symbolic codes are, by definition, context-specific and emerge within particular cultural and spatial settings.

The four concepts presented below are not codes per se. They represent recurring symbolic themes reported across multiple empirical studies on renewable energy siting conflicts and are used here as proxy codes solely to illustrate how the Symbolic Ecology Framework operates:

1. *Industrial imposition* – the reading of wind turbines as intrusion into rural spaces (Jobert et al., 2007)
2. *Sacred skylines* – the cultural-symbolic significance of heritage vistas (Pasqualetti, 2011)
3. *Working land* – stewardship and agricultural legitimacy (Batel and Devine-Wright, 2015)
4. *Local sovereignty* – community ownership and co-benefits as legitimacy anchors (Walker and Devine-Wright, 2008; Bauwens, 2016)

The four themes identified above illustrate recurring empirical dynamics that are widely documented in research on sustainability interventions. For example, in studies of renewable energy siting, the theme of *industrial imposition* appears in descriptions of visual intrusion, externally driven decision-making and perceived loss of rural character. At the level of *regulative legitimacy*, this is reflected in opposition to specific projects, objections to planning decisions and contestation of siting procedures. At the level of *normative legitimacy*, the same theme is articulated through concerns about fairness, consent and respect for rural livelihoods.

SEF does not seek to replace these forms of analysis. Rather, it introduces an additional lens to surface the often implicit contextual logics through which *industrial imposition* is constructed in relation to identity, belonging and power relations. In this sense, communities may share similar stated values yet interpret the same intervention differently because different symbolic codes are activated. This illustrates how a recurring empirical theme can be read across different pillars of legitimacy, with SEF making explicit the cultural–cognitive dimension that is often left implicit.

Within this analytical framing, symbolic codes can be examined across a set of attributes: salience, valence, legitimacy, resonance, diachronic status and place-binding, and, for illustrative purposes, these assessments can be synthesised into an indicative Symbolic Alignment Index (SAI). Tables 2–4 provide schematic illustrations of how such analyses might be used to diagnose cultural–cognitive alignment.

4.2. Illustrative modelling (conceptual)

To illustrate how SEF can be used as an analytical lens, this section presents a conceptual modelling exercise based on a proposed wind farm in Southern Italy. The example is not intended as an empirical case study, but as a schematic illustration of how symbolic codes influence the way an intervention might be interpreted within a specific sociocultural context.

The proposed intervention is technically aligned with European climate and energy objectives. However, in public discourse surrounding similar projects in the region, wind turbines have frequently been associated with 'landscape intrusions' and 'heritage disruption', particularly in areas characterised by olive groves, archaeological sites and traditional *masserie*. The 'sacred skyline' code resonates strongly with established local elites and heritage organisations, while the 'industrial imposition' code carried high salience in regional media and opposition discourse, producing low legitimacy. These dominant readings marginalised alternative interpretations.

Yet the same Cultural Alignment Map contained contested codes operating across different social groups. Youth activists favour the project through 'energy sovereignty' and intergenerational justice codes, while farmers recognised continuities with 'working land' stewardship. This reveals legitimacy as a site of struggle: which codes prevail depends on whose symbolic frameworks gain institutional support, media visibility and authoritative recognition. This shifts attention from whether codes align to whose codes shape the terms of legitimacy.

Interventions may engage this contested terrain in different ways. For example, place-sensitive design elements (such as hedgerow planting or participatory ownership schemes) can be read as activating *working land* codes, potentially strengthening legitimacy among farming communities. Symbolic practices – such as artists reimagining landscapes or schoolchildren narrating turbines as 'new giants'– can be interpreted as introducing emergent codes that challenge heritage-preservation orthodoxies. By making visible these symbolic dynamics and their power dimensions, SEF supports analytical reasoning about

Table 2
Illustrative alignment profiles for proxy symbolic codes (conceptual modelling).

Code	Salience	Valence	Resonance	Diachronic Status	Place-binding	Legitimacy	Indicative alignment profile (A_k)
Working land (stewardship)	High	Positive	High	Dominant	Strong	Moderate	0.6
Sacred skyline (heritage vistas)	Moderate	Negative	Moderate	Residual	Strong	Moderate	0.3
Industrial imposition	High	Negative	High	Dominant	Moderate	Low	0.4
Local sovereignty (co-ownership)	Moderate	Neutral	Moderate	Emergent	Strong	Moderate	0.5

Note: Alignment (A_k) represents an indicative synthesis of attribute assessments (normalised to a 0–1 scale). Values are illustrative and used solely to demonstrate the analytical logic of the Symbolic Ecology Framework; they do not represent empirical measurements, formal calculations or validated scores.

Table 3
Illustrative reconfiguration of symbolic alignment under alternative intervention scenarios.

Scenario	Effect on Codes	Indicative alignment profile
Baseline	–	Low–moderate
Community ownership + Landscape-sensitive siting	↑ Local sovereignty ↓ Industrial imposition	Moderate Moderate–high

Note: Qualitative labels reflect directional shifts in alignment profiles; precise quantification would require empirical calibration.

Table 4
Wind farm intervention: technocratic vs. culturally encoded design.

Category	Before (Technocratic)	After (Culturally encoded)
Aesthetic Codes	Turbines read as *industrial infrastructure*; clash with heritage landscapes.	Turbines embedded in local imagery; artists paint future landscapes; symbols drawn from olive groves, masserie, heritage.
Aspirational Values	Project read as EU policy/ targets, abstract economic efficiency.	Represented as *energy sovereignty* ('keeping wealth local'), *heritage stewardship*, and *for our children's future*. Children build mini-turbines to tell parents the story of the 'new giants.'
Common Practices	Consultation in municipal offices or churches, detached from everyday life.	Engagement in pubs, piazzas, schools, and festivals; codes align with local rituals and daily practices.
Salience	High: dominates local debates and visible in landscape.	High: but reframed positively through participatory art, youth activism and heritage-based symbolism.
Valence	Negative: coded as intrusion, exploitation, aesthetic ruin.	Positive: coded as local pride, empowerment, climate responsibility.
Resonance	Strong, but against the project (landscape beauty, outsider exploitation).	Strong and for the project (heritage stewardship, intergenerational justice).
Legitimacy	Low: decisions seen as top-down, procedural, extractive.	Higher: co-created narratives, participatory processes, reciprocity (local benefits).
Diachronic Status	Residual: stewardship, suspicion of outsiders. Dominant: development/ modernisation. Emergent: youth activism, climate justice.	Residual recoded (stewardship = renewables), emergent codes amplified (justice, sovereignty) to shift dominant codes.
Place-binding	Strong: heritage sites and landscapes used to reject turbines.	Strong: same heritage/landscape recoded as symbols of renewable guardianship.

how legitimacy struggles may unfold, rather than treating resistance as a residual outcome. Shifts in indicative SAI profiles serve to demonstrate diagnostic logic, not to claim empirical effects.

Table 2 illustrates how symbolic codes surrounding a proposed wind project can be systematically described through the attributes of the Symbolic Ecology Framework. At baseline, codes such as 'working land' and 'local sovereignty' offer partial support, while 'sacred skyline' and 'industrial imposition' introduce negative orientations. The resulting illustrative baseline SAI of approximately 0.45 (on a 0–1 scale) signals contested field dynamics: support is partial, but opposition is strong enough to threaten perceived legitimacy. For each code (k), an indicative alignment profile (A_k) is derived by synthesising attribute assessments into a normalised 0–1 score.

Building on the illustrative baseline alignment profile (~0.45), Table 3 schematically illustrates how different intervention strategies may reconfigure symbolic alignment profiles by activating or attenuating specific codes. The table is intended to demonstrate interpretive reasoning within the SEF, not to predict behavioural outcomes or uptake. Community ownership schemes are illustrated as strengthening the positive valence and legitimacy of the *local sovereignty* code, while landscape-sensitive siting and hedgerow planting are shown as attenuating the salience of *industrial imposition* and reinforcing associations with stewardship. The aggregated alignment profile shifts accordingly, indicating a more favourable configuration at the level of cultural–cognitive legitimacy when considered alongside technical and policy variables. While these illustrative profiles demonstrate the framework's analytical logic, empirical validation would require systematic protocols linking symbolic alignment to observed outcomes across multiple cases.

4.3. Designing and framing interventions with the SAI

The value of the Symbolic Ecology Framework lies not only in diagnosing potential legitimacy conflicts but in guiding the design and framing of interventions. By consulting the SAI, planners can identify which symbolic codes carry the greatest weight (positive or negative) in shaping responses to a proposed intervention. For instance, if the index reveals that 'sacred skyline' codes are both salient and negatively valenced, the intervention can be reconfigured through design choices that reduce visual intrusion or foreground heritage-sensitive narratives. Conversely, if 'local sovereignty' is identified as an emergent but underleveraged code, strategies such as community ownership, co-benefit schemes or participatory governance can be prioritised to enhance legitimacy. In this way, the SAI supports reflective intervention design oriented towards cultural alignment with cultural logics, rather than imposed in ways that generate resistance. Over time, repeated application across cases could generate comparative insights into how symbolic codes evolve, enabling adaptive governance that integrates cultural-cognitive legitimacy as a standard component of environmental planning.

Table 4 compares how the intervention looks when configured purely technocratically vs. when it is informed by SAI.

In essence, from a SEF lens, the case study demonstrates how to leverage the cultural-symbolic field through which wind farms are made meaningful: in symbolic narratives, aesthetics, cultural logics and anchors to advance technological change oriented towards ecological balance. The task is not merely to install turbines or justify them with CO_2 savings, but to translate them into the *code ecologies* (the living symbolic systems) of the people who will live with them. Meaning is not imposed from above; it is co-created with communities through symbols and language they already recognise as legitimate. SEF understands sustainability transitions as cultural–ecological translation. This translational function helps explain how a project may be read as shifting

from contested to potentially meaningful within a given cultural–cognitive context.

5. Implications

The Symbolic Ecology Framework (SEF) has implications across science, theory, methodology and practice. By treating symbolic codes as cultural variables, it provides a structured way to consider resonance and legitimacy within sustainability research and governance.

5.1. Implications for environmental science

SES and CES frameworks have expanded the scope of environmental research to include governance, institutions and values. However, symbolic dynamics remain comparatively under-theorised. SEF offers a way to make cultural–cognitive dimensions of meaning analytically explicit within socio-ecological analysis, complementing biophysical and institutional variables. This supports more nuanced interpretation of why interventions may encounter legitimacy challenges, alongside assessments of ecological performance and economic trade-offs.

5.2. Theoretical contribution

SEF bridges semiotic theory and environmental science by bringing cultural meaning-making into socio-ecological analysis as a distinct analytical dimension. It places symbolic codes and contextual logics at the centre of how legitimacy is formed and contested in sustainability transitions, without displacing biophysical, institutional or economic perspectives. By integrating insights from applied semiotics and cultural theory into sustainability science, SEF extends SES and CES frameworks with a code-based vocabulary for analysing cultural–cognitive alignment.

5.3. Methodological contribution

The Symbolic Alignment Index (SAI) and Cultural Alignment Maps are proposed as analytical support tools for diagnosing and comparing symbolic configurations across contexts. These tools build on earlier methodological work (Santamaria et al., 2016, Santamaria, 2023), where cultural codes were incorporated qualitatively in studies of sustainable product–service systems and social innovation uptake. SEF extends this lineage by combining interpretive assessment with indicative synthesis. While the framework enables comparative reasoning across cases, its application remains exploratory, and further research would be required to assess robustness, transferability and empirical calibration.

5.4. Policy and practice

For policymakers and practitioners, SEF offers a structured way to reflect on potential legitimacy dynamics associated with sustainability interventions. By examining symbolic alignment early in planning processes, interventions can be assessed in relation to locally salient codes rather than treated as culturally neutral. This supports more reflexive engagement with the symbolic systems underpinning identity, belonging and place. Incorporating SEF into planning and assessment processes could complement existing policy frameworks, including the Kunming–Montreal Global Biodiversity Framework, by drawing attention to cultural–cognitive dimensions alongside ecological and technological considerations.

5.5. Empirical research agenda

This paper establishes the theoretical foundations and analytical logic of the Symbolic Ecology Framework. Translating SEF into a robust empirical research approach would require a coordinated, multi-stage programme of methodological development and testing. The following priorities outline a prospective research agenda rather than a near-term operational roadmap:

1. **Protocol development and refinement.**
   Develop detailed protocols for code mapping appropriate to SEF application, with explicit guidance on corpus selection, documentation practices and analytical procedures. Building on established semiotic methods (Santamaria et al., 2016), this work would need to clarify how code identification can remain sensitive to local context while maintaining analytical transparency and consistency. This stage would require close collaboration between researchers trained in semiotics and environmental scientists working across diverse intervention contexts.
2. **Inter-analyst consistency.**
   Explore procedures for multiple analysts to independently assess symbolic codes across the proposed attributes, examining the degree of convergence and divergence in scoring. Rather than assuming standardised reliability thresholds, this phase would focus on developing shared interpretive rubrics, illustrative benchmarks and reflexive calibration practices to understand how analyst positionality and expertise shape assessments.
3. **Attribute refinement and extension.**
   Empirically investigate whether the six proposed attributes are sufficient to capture relevant symbolic dynamics, or whether additional dimensions, such as scalar relations, power asymmetries or temporal trajectories are required. Comparative analysis across multiple cases would help identify which attributes appear most salient in different types of interventions and contexts.
4. **Aggregation logic exploration.**
   Experiment with alternative ways of synthesising attribute assessments within the SAI, including equal weighting, differential weighting and non-linear aggregation approaches. Rather than seeking a single optimal formula, this research would examine how different aggregation logics foreground different interpretive emphases and how sensitive alignment profiles are to methodological choices.
5. **Empirical correspondence analysis.**
   Apply SEF retrospectively to interventions with well-documented implementation trajectories to examine how symbolic alignment profiles correspond with observed legitimacy dynamics, contestation patterns and implementation pathways. This work would focus on identifying recurring associations and patterns, rather than establishing predictive thresholds or causal claims.
6. **Comparative and cross-contextual studies.**
   Conduct SEF analyses across varied geographies, intervention types and cultural settings to assess how symbolic codes operate differently across contexts and to refine the framework's cross-cultural applicability. International comparative work would be essential to test the limits of generalisation while preserving contextual sensitivity.

Initial pilot studies in renewable energy siting, rewilding initiatives and circular economy transitions could support early refinement of the framework. Beyond operational considerations, future research should also examine how symbolic codes intersect with questions of resilience, equity and justice, ensuring that cultural–cognitive alignment is analysed alongside broader concerns about power, inclusion and just transitions (IPCC, 2023; IPBES, 2024). Advancing this agenda would require sustained interdisciplinary collaboration and long-term partnerships across academic, policy and practice domains.

5.6. Ethical and governance considerations

The explicit analysis of symbolic codes raises ethical considerations, particularly the risk that cultural insight could be used instrumentally to

engineer legitimacy rather than to support accountable and reflexive intervention design. The Symbolic Ecology Framework is not intended as a tool for persuasion or behavioural manipulation. Rather, it is proposed as a diagnostic and interpretive framework that makes visible the cultural–cognitive dynamics through which legitimacy is constructed, contested and institutionalised. This position builds on earlier work that frames semiotic analysis as a critical practice aimed at revealing power relations, ideological assumptions and exclusions, rather than influencing behaviour or securing compliance (Santamaria, 2023). Ethical concerns around instrumentalisation arise precisely because SEF treats legitimacy as culturally constructed and power-laden, rather than as a neutral outcome of participation or preference aggregation.

To mitigate risks of instrumentalisation, SEF incorporates several methodological safeguards. Code mapping is treated as an interpretive and reflexive process requiring cultural and symbolic literacy, not automated extraction or optimisation. The framework emphasises transparency regarding whose codes are identified, by whom, and for what purpose, foregrounding power asymmetries and analyst positionality. SEF is designed to surface legitimacy tensions rather than resolve them instrumentally, supporting critical reflection on intervention design and governance rather than prescribing acceptance. Any future empirical operationalisation would therefore require ethical oversight and clear governance arrangements to ensure symbolic analysis contributes to more just and accountable sustainability transitions, rather than functioning as legitimacy engineering.

6. Conclusion

Legitimacy remains one of the least predictable dimensions of sustainability transitions. Projects succeed or fail not only on technical, economic or institutional grounds, but on whether they resonate with the symbolic codes through which communities interpret interventions. Recognising these dynamics is not an optional add-on but a central challenge for governing socio-ecological change.

This article has advanced a conceptual pathway for treating symbolic codes as cultural variables within sustainability research. Rather than displacing frameworks such as SES or CES, the Symbolic Ecology Framework extends them by making explicit a dimension that often remains implicit: the cultural–symbolic systems through which interventions are rendered legitimate, contested or resisted.

SEF opens a dialogue between semiotics, environmental science, and policy, building on earlier work in design semiotics and adapting it to environmental research contexts. Without attention to symbolic codes, socio-ecological analyses risk overlooking key dynamics shaping implementation and contestation. Sustainability transitions concern not only flows of energy and matter, but also the circulation and stabilisation of meaning. By formalising this insight, SEF contributes to a more comprehensive understanding of transitions as simultaneously cultural, technical and ecological, and invites greater reflexivity in how interventions are designed, governed and interpreted.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used ChatGPT (OpenAI) to refine language and improve clarity of expression. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

Declaration of competing interest

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.

Data availability

No data was used for the research described in the article.

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