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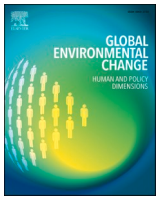

# "These industries have polluted consciences; we are unable to envision change": Sense of place and lock-in mechanisms in Sulcis coal and carbon-intensive region, Italy

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ABSTRACT

European coal and carbon-intensive regions (CCIRs) face the intricate challenge of navigating destabilization-reconfiguration pathways, requiring a nuanced understanding of how phase-out intertwines with innovation and lock-in mechanisms. The success of this transformation depends on a multitude of factors, including socio-political, economic, and material conditions, as well as psychosocial and cultural dimensions of place. This study examines how feedback loops between structural factors (i.e., socio-political, socio-economic, and infra-structural) and sense of place can either disrupt or reinforce lock-in mechanisms and path dependency in CCIRs. The study focuses on Sulcis CCIR (Sardinia, Italy), where extractive and metal industries are deeply ingrained in the region's culture and economy. To reconstruct the trajectory of the CCIR and gain in depth understanding of feedback mechanisms of path dependency across time, we triangulate different data sources including policy documents, newspapers, participatory workshops, and interviews with key stakeholders. The findings reveal the profound influence of a sense of place grounded in a shared industrial myth along with associated place meanings, identities, and memories on lock-in mechanisms. Positive feedback loops between sense of place and structural factors of lock-in have legitimated the dominance of coal and carbon-intensive industries across time, impeding the recognition of the need for change and obscuring windows of opportunity for low-carbon transformation. Following the definite destabilization of coal, dominant place meanings are being actively challenged, while the legacy of sense of place is serving as a guiding frame for shaping the legitimacy and imaginaries of place transformation and defining a just transition pathway. The study discusses the importance of recognizing and addressing the role of sense of place and its interaction with structural factors in perpetuating lock-in to ensure effective deliberate destabilization efforts and navigate a just reconfiguration of CCIRs.

## 1. Introduction

Despite phase-out commitments and climate goals, coal remains the largest source of $CO_2$ emissions in Europe (IEA, 2022). Indeed, transitioning away from coal entails more than a technological and resource substitution, it involves systemic changes that can potentially create or exacerbate social injustices, resistance to innovations, and economic and political struggles (Rinscheid et al., 2021; Köhler et al., 2019; Lockwood, 2018; Markard, 2018). These challenges are particularly acute in coal and carbon-intensive regions (CCIRs), that is, subnational territories heavily dependent on fossil fuel extraction or carbon-intensive industries.

In CCIRs, transition involves navigating a complex pathway of destabilization and reconfiguration that often meets the resistance of regional stakeholders (Johnstone and Hielscher, 2017; Turnheim and Geels, 2012), especially due to socio-economic concerns related to job losses, uncertainties over energy security and industrial competitiveness associated with low-carbon transformations (Skoczkowski et al., 2020). Beyond mere economic considerations, research suggests that resistance to coal phase-out in CCIRs can stem from the entrenched role of extractive industry in place, culture, and politics (Duffy and Whyte, 2017). For this reason, recent scholarship (e.g., Mohr and Smits, 2022;

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Della Bosca and Gillespie, 2018) emphasizes the significance of psychosocial and cultural dimensions of places in comprehending transitions.

However, limited attention has been devoted to comprehending the interplay of psychosocial processes related to place (i.e., place-based identities, memories, meanings, and imaginaries), which provide the socio-cultural context in which socio-technical regimes operate and socially reproduce, along with the structural drivers of change (i.e., socio-economic, political, environmental), and their significance across destabilization-reconfiguration pathways (Biddau, Brondi, and Cottone, 2022; Creutzig et al., 2022; Herrfahrdt-Pähle et al., 2020).

To address these conceptual and empirical gaps, this paper draws on Sulcis CCIR in South Sardinia (Italy) to examine how feedback loops between structural and place-based psychosocial factors shaped the pathway of coal destabilization and sustainable reconfiguration. Using a case study approach to analyze the complex interactions among these elements across time, we seek to shed light on the processes that can enable or hinder low-carbon transitions in CCIRs.

## 2. Theoretical background

### 2.1. Transitions, transformations, and path dependencies in socio-technical and social-ecological systems

The relationship between systems' change and stability is a central issue in sustainability transition research, with socio-technical and social-ecological approaches to sustainability emerging as prominent paradigms. The socio-technical transition perspective emphasizes technological innovation as the primary driver of sustainable change (Geels & Schot, 2007) focusing on the co-evolution of society and technology in the transition of specific sectors like water, energy, and food (referred as socio-technical systems, STS). From an initial focus on innovation uptake, recent attention has been placed on phase-out processes to create space and momentum for innovations and accelerating transition (Rogge & Johnstone, 2017; Turnheim & Geels, 2012; Trencher et al., 2023). This shift emphasizes the significance of considering the development and stabilization of innovations alongside the destabilization and decline of existing practices and structures to understand and navigate low-carbon transitions (Hebinck et al., 2022; Mangalagiu et al., 2024; Biddau et al., 2024). In contrast, the resilience perspective examines the transformations of human-environment coupled systems (referred as social-ecological systems, SES) (Folke, 2006; Olsson et al., 2014; Moore et al., 2014) as systemic changes that involve creating new development pathways when ecological, economic, or social conditions make the existing system untenable (Folke et al., 2010). SES perspective considers the environment, society, and economies as fundamental parts of the system, and views transition as a subset of a larger transformation (Herrfahrdt-Pähle et al., 2020). Transformations involve the reconfiguration and reconnection of these elements in a way that is deeply connected to ecological systems across scales (Moore et al., 2023). To exemplify the distinction, the transition from fossil fuels to biofuels may slow down climate change and offer economic benefit, but could also lead to detrimental land use changes, biodiversity loss, and social injustices (e.g., land grabbing and using land for cultivating fuels instead of food), highlighting the interplay between technological change and broader social-ecological considerations (Grau and Aide, 2008; Borras Jr and Franco, 2010).

Compared to transitions, transformations entail profound structural changes, altering key relationships and feedbacks between the economic systems and society-nature relationship. This includes the distribution of authority, power and resources, changes in practices and processes as well as underlying norms, values and beliefs that underpin existing structures (Gantioler et al., 2023; Moore et al., 2014; 2023).

Despite the differences, however, STS and SES perspectives recognize that change happens at dominant system configurations, defined regimes, and identify general patterns emphasizing the feedback dynamics between levels, actors and sectors across phases (cf. Loorbach et al., 2017; Geels, 2019).

Accordingly, change typically begins with disruptions to dominant states providing opportunities for transformation. However, sustainable innovations face entrenched systems and established patterns of production and consumption (Köhler et al., 2019). Historical developments create feedback loops that stabilize systems locking them into a particular trajectory with a limited corridor of possibilities for change, i.e., path dependency (Krasner, 1988). This condition of entrapment, which must be addressed to enable sustainable change, has been addressed through concepts of lock-in in STS and social-ecological trap in SES (Goldstein et al., 2023).

***Socio-technical transitions and lock-in***. The Multi-Level Perspective (MLP) on socio-technical transitions conceive transitions as involving the interactions between three levels: landscape, regime, and niche (Geels, 2010). The landscape represents the broader context made up of social and physical elements like macroeconomics, deep cultural patterns, macro-political developments and environmental conditions. The regime refers to a dominant and stable societal configuration that encompasses dominant actors, practices, technologies, norms, and institutions. Niches are protected spaces where innovations are developed and tested (Geels & Schot, 2007). The concept of regime is fundamental in transition dynamics, explaining path dependency and lock-in of existing STSs around specific technologies. It assumes that transitions occur via regime destabilization opening a window of opportunity for niche innovations to diffuse and transform the regime (Avelino and Rotmans, 2009; Geels, 2005; e.g., Sarrica et al., 2020).

Initially anchored on the concept of technological regime, the notion has evolved to include institutional, economic policy, and sociological perspectives and describing regimes in terms of materiality, their constituent actors and the relationships among them.

Unruh (2000) introduced the concept of carbon lock-in to describe how industrial economies become trapped into fossil fuel-based energy systems, due to the co-evolution of technologies and institutions. Seto et al. (2016), highlighted that lock-in of technologies and associated infrastructures is reinforced by institutional lock-in (regulations, policies, subsidies), and behavioural lock-in factors (user behaviour, habits, and culture). Path dependency is thus reinforced by high exit costs, learning effects, coordination effects, and self-fulfilling expectations (Pierson, 2000). While lock-in and path dependency are often seen as obstacle to sustainability progress, their dynamics could contribute to stabilizing sustainable policies and practices (Seto et al., 2016; Yona et al., 2019).

Regimes are not static entities, but semi-coherent sets of rules, underpinned by institutional and cultural-cognitive aspects stabilizing existing trajectories and multiple voices contributing to their construction and reproduction (Geels, 2014; Fuenfschilling and Binz, 2018). Power dynamics and multiple rationalities at times aligned, competing or coexisting influence regime dynamics, with changes originating internally as well as in response to landscape pressures (Runhaar et al., 2020).Therefore, to understand regime dynamics, it is essential to consider their local embeddedness in space and time, delimiting the analysis to socially and geographically-based systems along with transition governance and management (Fuenfschilling and Binz, 2018; Lawhon & Murphy, 2012; Geels, 2019; Coenen, Benneworth and Truffer, 2012).

***Social-ecological transformations and traps***. Early resilience-based frameworks draw on the concept of multiple basins of attraction and view social-ecological transformations as regime shifts between stable states (Folke et al., 2005). Regime shifts involve the dissolution of attractors of a dominant state and emergence of new ones along with relationships and feedback loops in alternative basins – thus unmaking and making sets of relationships making up the system (Feola et al., 2021) and calling for "a fundamental shift in perspectives, worldviews, and institutions" (Folke et al., 2011, p. 719). Such attractors encompass newly articulated visions, narratives, and imagined futures that attract

behaviours and institutions to organize around them (van der Leeuw and Folke, 2021).

Integrating MLP and resilience theory, sustainability transformations have been recently conceptualized to unfold via the interplay of landscape, regime, and niche dynamics and progressing through three distinct phases: preparation, navigation, and stabilization (Herrfahrdt-Pähle et al., 2020; Moore et al., 2014). In SES frameworks transitions are located in the navigation phase, a period of uncertainty between systems' basin of attraction shaped by what happens during preparation and institutionalization (Olsson and Moore, 2024).

The preparation phase typically begins with a perturbation and includes sense-making of the situation and vulnerability elements in the trajectory, envisioning alternative futures encompassing what needs to be changed and how, gathering momentum through self-organization, experimentation, and mobilization around new ideas and innovations (Moore et al., 2012).

The navigation phase involves selecting, learning, and adopting envisioned alternatives and pathways. Ideally, dialogue and learning guide these processes, however, powerful actors often dominate this phase and orient the selection and adoption of alternatives serving their interests (Stirling, 2014; Smith and Raven, 2012).

Finally, stabilization involves consolidating the new direction and institutionalizing the emerging regime through routinization (e.g., dedicating funds, personnel, and laws), addressing resistance and unanticipated perturbations (Moore et al., 2014). Similarly to lock-in, resilience can have both positive and negative implications. As "the ability of groups or communities to cope with external stresses and disturbances'' (Adger 2000, p. 347), community resilience can hinder transition to alternative states (Olsson, Galaz and Boonstra, 2014) to the point that an unsustainable trajectory is maintained, suppressing innovations, and reinforcing an undesirable and unsustainable state (Tidball, Frantzeskaki and Elmqvist, 2016; Gunderson and Holling, 2002; Carpenter and Brock, 2008). This condition, known as a social-ecological trap, denotes maladaptation resulting from resilience processes (Marschke and Berkes, 2006; Bailey et al., 2010; Gunderson and Holling, 2002).

For this reason, resilience scholars are increasingly interested in understanding how traps are created, maintained, and escaped (Steneck et al., 2011; Boonstra and de Boer, 2014).

To conclude, the feedback loops between variables making up a system can entrench specific technologies, local economies, and natural resource management practices. Therefore, we argue that sense of place (SoP) offers a human-centered perspective capable of bridging SES and STS perspectives and examine the interplay between socio-technical change and broader social-ecological considerations.

### 2.2. The role of psychosocial sense of place in lock-in, entrapment, path dependency

Place is a significant concept in sustainability transitions literature, yet primarily considered as the physical container or the context in which material means of socio-technical change are located.

However, place can also serve as a guiding cognitive and cultural frame for transitions (Biddau, Brondi, & Cottone, 2022; Binz et al., 2020; Mohr and Smits, 2022). Drawing upon interdisciplinary scholarship, in this paper we consider SoP as a concept to bridge SES and STS perspective of low-carbon transformations and add a psychosocial and cultural perspective to change and stability (Frantzeskaki et al., 2018; Masterson et al., 2017), beyond processes of technology adoption, acceptance, and diffusion (Bögel and Upham, 2018; Sarrica et al., 2016).

SoP is a multidimensional construct encompassing the emotional and cognitive aspects of place experience, including meanings, attachments, beliefs, and identities that individuals and groups associate with specific localities (Tuan, 1977). It serves as both a driver and outcome of social-ecological processes (Masterson et al., 2017) and is widely acknowledged in social psychology and human geography for examining place awareness, memory, identity, and representations of SESs (Stedman, 2008; 2016) and understand what people value and want to preserve or enhance (Brehm et al., 2013), and the role of people–place relationships in sustainability challenges (Masterson et al., 2019; Peng, Strijker and Wu, 2020). SoP is thus relevant to many psychosocial processes relevant in STS and SES literature. For example, place awareness is crucial for preparing and initiating transformations, aiding in identifying windows of opportunity, available resources, enablers and constraints (Folke et al., 2010; Nelson, Adger and Brown, 2007). Place memory contributes to coping with and making sense of change and uncertainty inherent in sustainability transformations (Folke et al., 2005; Herrfahrdt-Pähle et al., 2020). Yet, psychosocial factors anchored to place memory, like conservative norms, belief systems, and identities, can sometimes reflect cultural resistance and make it challenging to envision and embrace alternative pathways, ultimately undermining the community's capacity to respond to new challenges and opportunities (Wilson, 2014). On the contrary, gradual changes in place perception and values can break path dependencies by re-framing place problems (Parsons et al., 2019).

Given the subjective nature of place meanings, multiple interpretations and conflicts between place readings may emerge, varying in the degree of sharedness and dominance. Such symbolic understanding influences how individuals interpret place changes induced by transitions and promotes specific imaginaries for transformation aligned with place meanings (Frantzeskaki et al., 2018).

Moreover, dominant place meanings may shape social-ecological processes over time, obscuring alternative meanings and identities, hindering the recognition of place potential and reinforcing traps that can be escaped only by questioning such meanings (Masterson, 2016; Enqvist, Tengö and Boonstra, 2016; Murphy, Enqvist and Tengö, 2019). In this sense, SoP connects collective memories and future visions with place-making processes, linking individual experiences with historical dynamics and societal struggles (Feola et al., 2023; Batel and Devine-Wright, 2017). In CCIRs, SoP can embody a deep cultural connection with coal and industrial activities, with the transformation of related places and traditions perceived as potentially disruptive and leading to the loss of place histories and memories (Duffy and Whyte, 2017; Della Bosca and Gillespie, 2018).

Therefore, it is paramount to understand the influence of dominant meanings and underlying power dynamics (Masterson et al., 2019) and the role that place idealization and imaginaries can have in shaping (the legitimacy of) sustainability transformations (Watkins, 2015; Crowe and Li, 2020; Chateau, Devine-Wright and Wills, 2021).

### 2.3. Integrative analytical framework for examining phases and feedback dynamics of regime shifts

Building on this comprehensive theoretical framework, this study seeks to bridge the gap between SES and STS perspectives by integrating elements from both streams and focusing on a situated regional system enabling concrete empirical analyses and conceptualisation.

Particularly, it adopts an integrative approach inspired by Moore et al. (2014) and Herrfahrdt-Pähle et al. (2020). This combines the resilience-based transformation phases and the interaction between levels from the MLP (cf. Geels, 2019) to analyze the interplay between social, technological, and ecological processes and explore the dynamics of stability and transformation in the Sulcis CCIR (see Fig. 1).

The framework presented in Fig. 1 illustrates the multi-level and multi-phase dynamics of regional transformation starting from a stable state. It emphasizes the alignment/positive feedback among components of the coal and carbon-intensive regional configuration and the interplay with landscape pressures, which either stabilize or destabilize the regional system. The coal and carbon-intensive regime is conceptualized as a co-evolution of six components that must remain aligned to maintain its dominance and function. Similar to the operationalization of the socio-technical regime (see Geels, 2004), it encompasses "technology and infrastructure", "industrial and economic sectors",

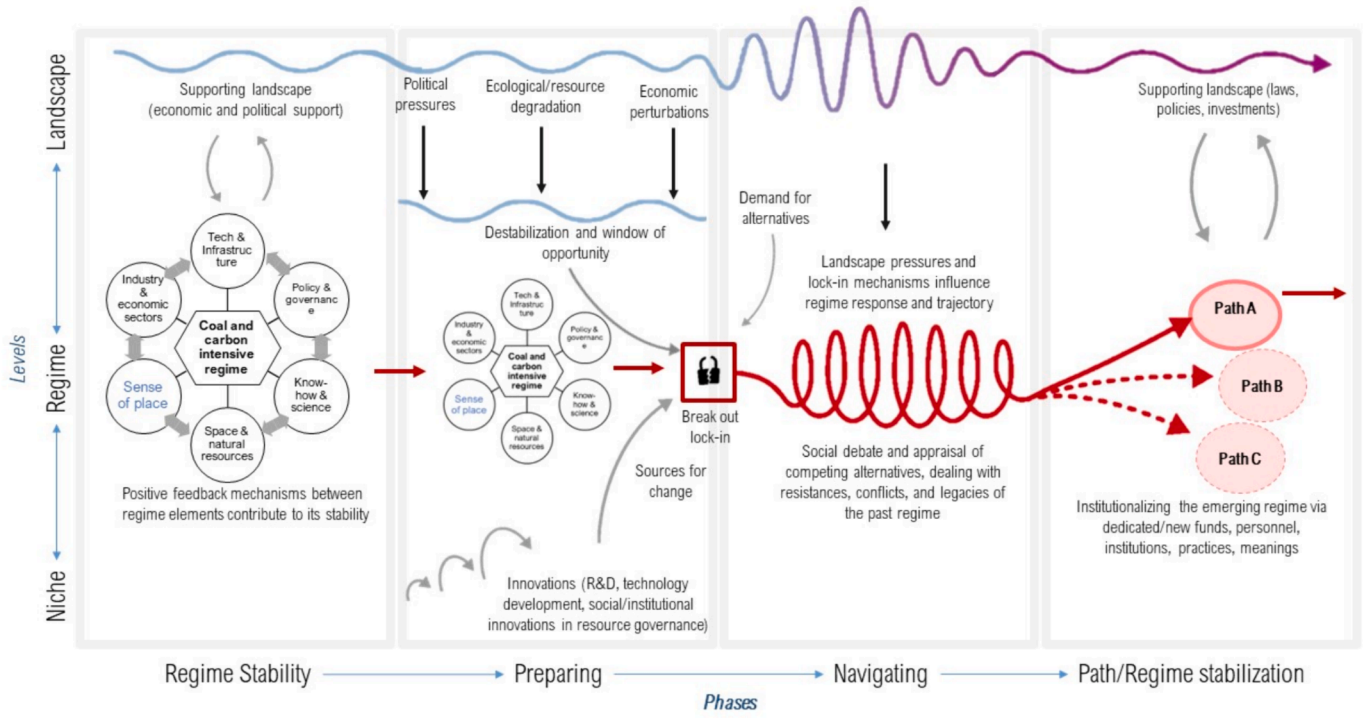


**Fig. 1.** Comprehensive integrative framework based on Herrfahrdt-Pähle et al. (2020).

"know-how and science/innovation", and "policy and governance". Additionally, considering the CCIR a geographically grounded system we operationalize the "culture" dimension of the MLP with the "SoP", which serves to bridge and incorporate the spatial and ecological aspects of natural capital and resources often overlooked or neglected in the analysis of STS.

To understand path dependency, various sources and mechanisms have been examined in the literature, including material, socio-economic, socio-political, and psychosocial ones. Table 1 provides an overview of such sources and mechanisms derived from literature on resilience, lock-in, and path dependency within in STS and SES (see Trencher et al., 2020; Herrfahrdt-Pähle et al., 2020; Moore et al., 2014; Seto et al., 2016; Goldstein et al., 2023). Importantly, these factors can exert influence across all phases of transformations and their interaction can explain both the onset and the success or failure of sustainable transformations (Herrfahrdt-Pähle et al., 2020; Parsons et al., 2019; Wilson, 2014).

Our objective is to analyze how these factors interact to influence the Sulcis CCIR trajectory with a focus on understanding their role in enabling or hindering the regional pathway of destabilization and sustainable reconfiguration. Specifically, we examine how SoP interacts with socio-structural factors – including socio-political, socio-economic, and infrastructural elements – across different phases.

## 3. Methods

To ensure a comprehensive analysis of feedback mechanisms across time and multiple levels, we employed a triangulation approach combining various data sources (Flick, 2009). This included secondary data such as policy and public documents, as well as primary data collected through narrative episodic interviews and workshops engaging diverse regional stakeholders.

First, preliminary desk research was conducted to create a chronology of events, capturing changes at the landscape level, regime responses, and niche innovations. We surveyed public documents with a key focus on the energy and environment domain – such as newspaper articles (n = 965) over a ten-year period from 2011 to 2021 (see Biddau et al., 2024; Rizzoli et al., 2024), policy and planning documents from different levels of governance, assessment reports, studies, dossiers, or advocacy briefs by different groups (n = 19); (see Appendix B). This further enhanced our understanding of the underlying structural factors (see Appendix A for a detailed overview). Second, starting from the same data, following Hajer (1995) and Sarrica et al. (2018), we examined the discursive dynamics playing a role in reproducing the dominance of coal and carbon-intensive industries along with their technologies, institutions and practices and mapped actors involved in the discoursive struggle (Simoens, Fuenfschilling and Leipold, 2022; cf. Biddau et al., 2024). Third, we conducted twenty-six narrative episodic interviews (see Mueller, 2019) with key regional informants and stakeholders selected via purposive sampling to represent heterogeneous perspectives in the region (Table 2). The interviews aimed to investigate how the subjectivity involved in SoP – including place-related meanings, identities, awareness, memories, and imaginaries – interacted with the structural factors in the context of regional events and trajectory providing deeper insights into how individuals perceive and respond to these events.

After signing an informed consent, interviewees were asked to narrate the regional trajectory. The interview guide included discussion prompts about the perceived identity and current state of the social-ecological system, the most salient events in recent history, including the decline and rise of industrial and energy sectors, and imaginaries of transformation (see Appendix C for interview questions, informed consent, and coding process).

After transcription, interviews were thematically coded using an inductive-deductive approach to data (Braun & Clarke, 2006; Taylor & Ussher, 2001) that used the key features of lock-in and transformation (cf. Table 1) as a set of sensitizing concepts, and generating codes grounded on data, i.e., code labels summarizing the patterns of meaning (see Appendix C). The initial coding step was conducted by the first author and subsequently reviewed and discussed among the other authors until a consensus was reached.

Finally, in February and October 2022, preliminary results were shared and discussed with 13 participants from the pool of interview participants. The aim was to share and discuss insights and

**Table 1**
Sources and dimensions/mechanisms of lock-in in STS and SES.

| Source | Dimension/ mechanism | Examples | Illustrative references | Approach |
|---|---|---|---|---|
| **Psychosocial/ sense of place** | Social/place memory | Accumulated knowledge and experience influence learning, adjustment, and the direction of future pathways | Wilson (2012); Folke et al. (2005) | SES |
| | Problem awareness | Awareness of place conditions/environmental problems influence coping | Parsons et al. (2019) | SES |
| | Place meanings | Meanings influence the type of relationship with the environment (e.g., exploitation vs stewardship) and coping response to sustainability challenges | Masterson et al. (2019); Murphy et al. (2019); Mohr and Smits (2022) | SES & STS |
| | Place identity | The relationship between sense of collective self and the perceived identity of a place influences the awareness about place potential and the corridor of possibility | Enqvist et al. (2016) Cowell (2020) | SES & STS |
| **Socio-political** | institutionalized discourses/ policy arrangements | Institutionalized discourse and policy arrangements affect radical innovation and the implementation of alternatives | Pierson (2000); Simoens et al. (2022) | STS & SES |
| | Interdependence of interests | Elite mutual dependencies create powerful alliances that perpetuate system inertia and exclude alternative frames and pathways | Seto et al. (2016); Simoens et al. (2022); Trencher et al. (2020) | STS |
| | Leadership | Leaders promote a sectorial transformation rather than structural change | Scheffer et al. (2003); Stirling (2014) | SES & STS |
| | Bridging organizations and niches | Presence/absence of grassroots/intermediary organizations providing spaces for experimentation, collaboration, knowledge exchange, integration, and learning | Olsson et al. (2006); Folke et al. (2005); Smith and Raven (2012) | SES & STS |
| | Information and knowledge integration | Institutional arrangements that provide access to information, expertise, and decision-making arenas | Stirling (2014); Olsson et al. (2004) | SES & STS |
| **Socio-economic** | Trade flows | Embeddedness within/dependence on globalized trade flows determines vulnerability | Mansfield (2007) | SES |
| | Poverty and income | Poverty and debt constrain the focus of economic activities toward basic 'survival' | Parnwell (2007) | SES |
| | Economic diversification | Dependency of communities upon one economic sector shapes wage-labor relationships and power asymmetries | Wilson (2007); Fernández-Vázquez (2022) | SES & STS |
| | Access to Capital | Business-as-usual access to capital prevents investments and adoption of alternatives | Casper and Whitley (2004); Berti and Levidow (2014) | SES & STS |
| | Sunk costs | Established investment return implies high exit costs | Janipour et al. (2020); Van Staveren and van Tatenhove (2016) | STS & SES |
| **Material (Geographical, technological)** | Technological interrelatedness/ compatibility | Entrenched technologies and infrastructures (e.g., power grid and fueling stations) affect the adoption of alternatives due to compatibility | Seto et al. (2016); Trencher et al. (2020) | STS |
| | Technology competitiveness and operational life | Alternative technologies are expensive and established infrastructures live until sunk costs are recovered | Seto et al. (2016); Van Staveren and van Tatenhove (2016) | STS & SES |
| | Location and environmental state | Embeddedness of community within a (centralized) STS and environmental conditions influence economic development opportunities | Wilson (2007); Bulkeley (2006) | SES & STS |

interpretative claims derived from the analytical process. Workshops provided the opportunity for ensuring research validity by determining whether participants recognized the findings as accurate and meaningful, and gathering additional input and feedback (Tracy, 2010).

## 4. Case study context: The Sulcis coal carbon-intensive region, Italy

Sulcis was selected as a significant case due to its historical foundation as a coal region and its unique combination of extractive and carbon-intensive industries making it an ideal case for examining the role of SoP in the regional development pathway. Fig. 2 illustrates a timeline of the key historical events and projects that shaped the CCIR, providing an overview of its major milestones and initiatives (see also Appendix A for a detailed review[1]).

Sulcis is a subregion located in the southwest of Sardinia, an Italian administrative region with special autonomy and a longstanding movement advocating for independence. The region has a long mining history – particularly coal, lead, and zinc. The extractive industry profoundly shaped regional identity, economy, territory, and infrastructure, especially in the 20th century. In 1937, the fascist regime established the urban center Carbonia (literally "coal city") as the national energy capital due to its coal reserves. The regional population increased from 78,000 to 137,000 residents between 1937 and 1951. Afterward, mining declined due to competition with minerals from international markets (Sabattini & Moro, 1975).

During the post-war period, state investments aimed to create industrial development areas nationwide. Investment policies such as

[1] For more detailed information, Appendix A provides a comprehensive historical overview focusing on: (a) policy, financial, and R&D support for the coalfield (1965-today); (b) initiatives for energy diversification and affordability (gas pipeline project in early 2000s, and wind farms close to the industrial cluster in 2011); (c) investments and plans addressing socio-economic and environmental crises, including the Sulcis Plan (2012) and Just Transition Fund (2022); (d) the current competing pathways for energy transition in the region (green electrification project with utility-scale renewables, and distributed generation with renewable energy communities).

**Table 2**
Overview of interview respondents.

| ID | Type of organization | Sector | Role | Date |
|---|---|---|---|---|
| 1 | Regional Environmental NGO | Environmentalism | Scientific representative | 21/12/2020 |
| 2 | Regional newspaper | Journalism | Journalist (Sulcis reporter) | 24/03/2021 |
| 3 | Youth political organization | Local politics | Representative | 11/05/2021 |
| 4 | Youth political organization | Local politics | Representative | 04/06/2021 |
| 5 | Municipality | Local politics | Municipality councilor | 01/09/2021 |
| 6 | Municipality | Local politics | Municipality councilor | 23/04/2021 |
| 7 | Regional Environmental NGO | Environmentalism | President | 25/06/2021 |
| 8 | Local movement | Activism | Representative | 22/06/2021 |
| 9 | Local movement | Activism | Representative | 23/06/2021 |
| 10 | Forum of local movements | Activism | Coordinator | 27/07/2021 |
| 11 | Coal industry | Industry | Worker and trade unionist | 18/06/2021 |
| 12 | University | Science | Sociologist | 27/05/2021 |
| 13 | Environmental health organization | Science | Representative (Medical Doctor) | 29/09/2021 |
| 14 | Regional political authority | Regional politics | Public office manager | 30/09/2011 |
| 15 | Mining institution | Industry | President | 04/10/2021 |
| 16 | Non-ferrous-metal company | Industry | Former worker | 05/10/2021 |
| 17 | Energy R&D firm | Science | Research manager | 08/10/2021 |
| 18 | Local trade union | Union | Representative | 14/10/2021 |
| 19 | Non-ferrous-metal company | Industry | Worker (x2) | 13/10/2021 |
| 20 | Local environmental association | Environmentalism | Representative | 14/10/2021 |
| 21 | Regional radio and press | Journalism | Journalist | 18/10/2021 |
| 22 | Municipality | Local politics | Municipality mayor | 21/10/2021 |
| 23 | Provincial political authority | Provincial politics | Province representative | 24/10/2021 |
| 24 | Regional Authority | Science | Energy planner | 26/10/2021 |
| 25 | Coal industry | Industry | Manager | 02/11/2021 |
| 26 | Regional Government | Regional politics | Regional councilor | 03/11/2021 |

*Cassa per il Mezzogiorno* and *Piano di Rinascita* led to the reconversion of the mining sector. In 1972, the Portovesme industrial cluster – an energy-metallurgy supply chain was established becoming the nation's primary nonferrous metals site (Sanna, 2015). Additionally, in 1973 a 590 MW coal-fired power plant was constructed to support local coal mining and meet the needs of energy-intensive industries (see Fig. 3 for an overview of the spatial-economic organization).

In the 1990s, the extractive and manufacturing-metallurgical sectors employed 32.5 % of Sulcis workforce (Saba, 2003). However, between the 1990s and early 2000s, the region encountered challenges in maintaining coal mining and competitive industrial activity due to cyclical fluctuations in raw materials, logistical inefficiencies, and the lack of competitively priced electricity. These difficulties intensified after the 2008 global crisis, leading to a severe industrial decline. From 2012 to 2018, the manufacturing sector experienced a 28 % decrease in employment, with unemployment reaching 20.6 % doubling national average of 10.3 % (Regione Autonoma della Sardegna, 2019; Istat, 2019).

Additionally, mining, waste and industrial activities caused severe environmental degradation, including air pollution, and soil and water ground contamination acknowledged since the 90s' (Russo et al., 2021; Ausili, Bergamin and Romano, 2020). Despite benefitting from dedicated investments and plans, like the extraordinary plan for the development of Sulcis Iglesiente *(Piano Sulcis*, 2012, 1.243 million Euros), the region has seen limited visible impact. Indicators suggest that previous perturbations and windows of opportunity have been followed by inadequate adjustment and reconfiguration leaving Sulcis highly vulnerable and subject to path dependency (cf. European Commission, 2020). Regarding energy supply, multiple initiatives overlapped to sustain the coal and metal industries while reducing environmental impacts through carbon capture and storage (CCS). Following the mine closure decision in 2014 and the 2017 national energy strategy declaring the phase-out of coal-fired power, Sulcis is undergoing a coal phase-out. This has raised concerns about energy security and socio-economic stability due to Sardinia's reliance on coal for electricity (around 33 %) and the lack of natural gas infrastructure (Regione Autonoma della Sardegna, 2023). Mining activity ceased in 2018, and Sardinia is expected to phase out coal-fired generation by 2025 according to national commitments. Sardinia is increasingly attracting renewable energy investments and projects due to its favorable location and abundance of renewable sources. ENEL, Italy's leading energy company, has decided to decommission the Sulcis coal-fired power plant and proposed a green electrification initiative in 2021, as part of the UN's Multi-Stakeholders Energy Compact, to replace coal with renewable energy, positioning the island as Italy's energy hub and green laboratory for transition. Moreover, Sulcis benefits from the EU's Cohesion Policy framework Just Transition Fund (JTF) to mitigate the social, economic, and environmental impact of decarbonization. Despite this window of opportunity, phase-out and renewable energy transition face significant opposition and the interaction between structural factors and psychosocial processes can perpetuate the region's lock-in, posing challenges for its transition.

## 5. Results

By combining newspaper article analysis (Biddau et al., 2024; Rizzoli

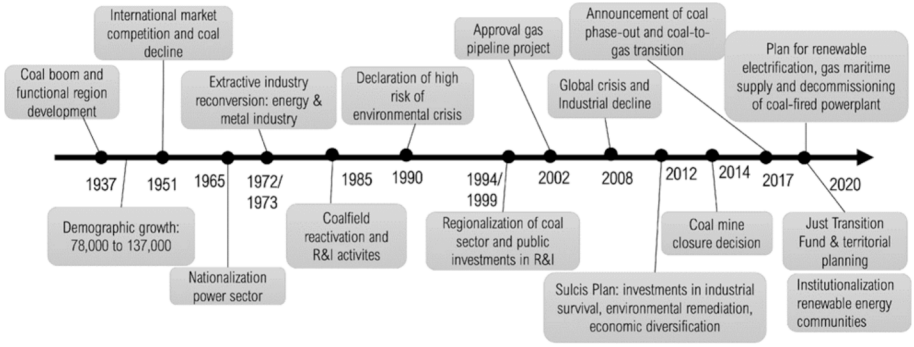


**Fig. 2.** Timeline of the Sulcis CCIR trajectory. Key historical events and projects starting from the emergence of the coal functional region up to today.

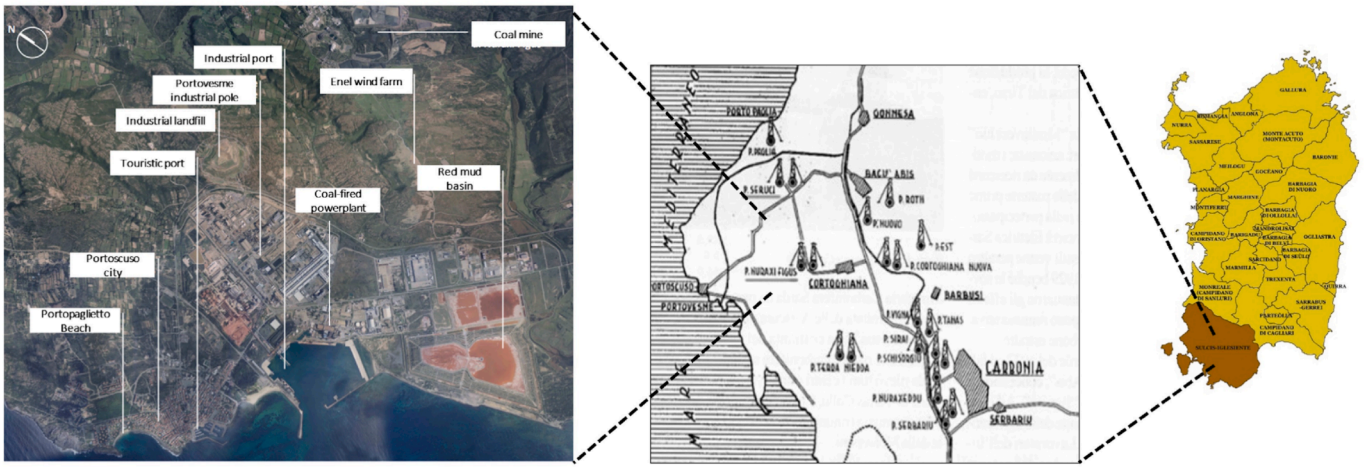


**Fig. 3.** From right to left: Localization of Sulcis territory in Sardinia, the Sulcis coal basin (Museo del carbone) and Portovesme industrial cluster. (adapted from Pessina, 2018)

et al., 2024) and policy and planning documents scanning (see Appendix B) we have delineated the four phases of the regional trajectory pinpointing critical events that demarcate the transition between these phases. (Fig. 4). For example, the cumulation of multiple forces in the 90 s', such as the declaration of a high-risk environmental crisis in 1990, alongside the outflow of investors from the coal sector and its regionalization between 1994 and 1998, compounded by union conflicts and worker protests stemming from socio-economic insecurities, destabilized the CCIR. This prompted a preparation phase to ensure energy security, protecting jobs and safeguarding the local environment (405 million euros in state aid were provided between 1998 and 2010 to support these efforts). Moreover, triangulating interviews and workshops with this data provided insights into the feedback mechanisms between regime components and the patterns of cross-level interaction between the regime and the landscape. In the following sections, we elaborate the outcomes of each identified phase, with a particular focus on the role of SoP and its interaction with structural factors in facilitating or impeding regime transformations, such as adapting to landscape perturbations (see also Appendix A).

### *5.1. Path stabilization (1972–2000): Rise of the coal and carbon-intensive regime and constitution of SoP between pride and stigma*

> "Sulcis, and its history, can be summed up in the rise and decline of the mining sector. The story can be retraced by following the trajectory of this industrial sector: there is an ascent, a peak, and a decline up to 1960–70" (I_23).

The interview excerpt vividly illustrates the profound entanglement of SoP with the extractive industry. Interviewees recalled shared memories depicting the mining period as "mythical" and integral to the place essence, serving as a transformative force that drove industrialization and development in Sardinia. Sulcis is proudly recognized as the birthplace of modernization, where class struggles and dedicated educational initiatives empowered individuals to transcend marginalization and subordination. As the following quotes illustrate, the mining era instilled a sense of pride into the SoP, symbolizing social and economic redemption in the region:

> "Sulcis is the center from which the industrialization of the region started through the mines. Historically, the struggles of trade unions contributed to building the myth" (I_14).
> "The mining period is linked with the memory of the arrival of wages. A mirage for those who lived the rhythms of the countryside, mythical for the Sardinian popular classes because it made them less marginal" (I_12).
> "The technicians came from outside until the opening of the mining school of Iglesias, whose goal was to make the miners' children also become managers. So, from being the son of a miner, I became a manager" (I_15).

Nostalgic memories of the golden and mythized period are followed by accounts of a steady decline and reconversion, that, using the interviewees' words, was initially based on a:

> "territorial fertilization design, first and foremost based on people, using technical managers trained in the coal industry" (I_24).

Existing mining and logistic infrastructure were utilized to integrate industrial and energy facilities, resulting in the spatial concentration of

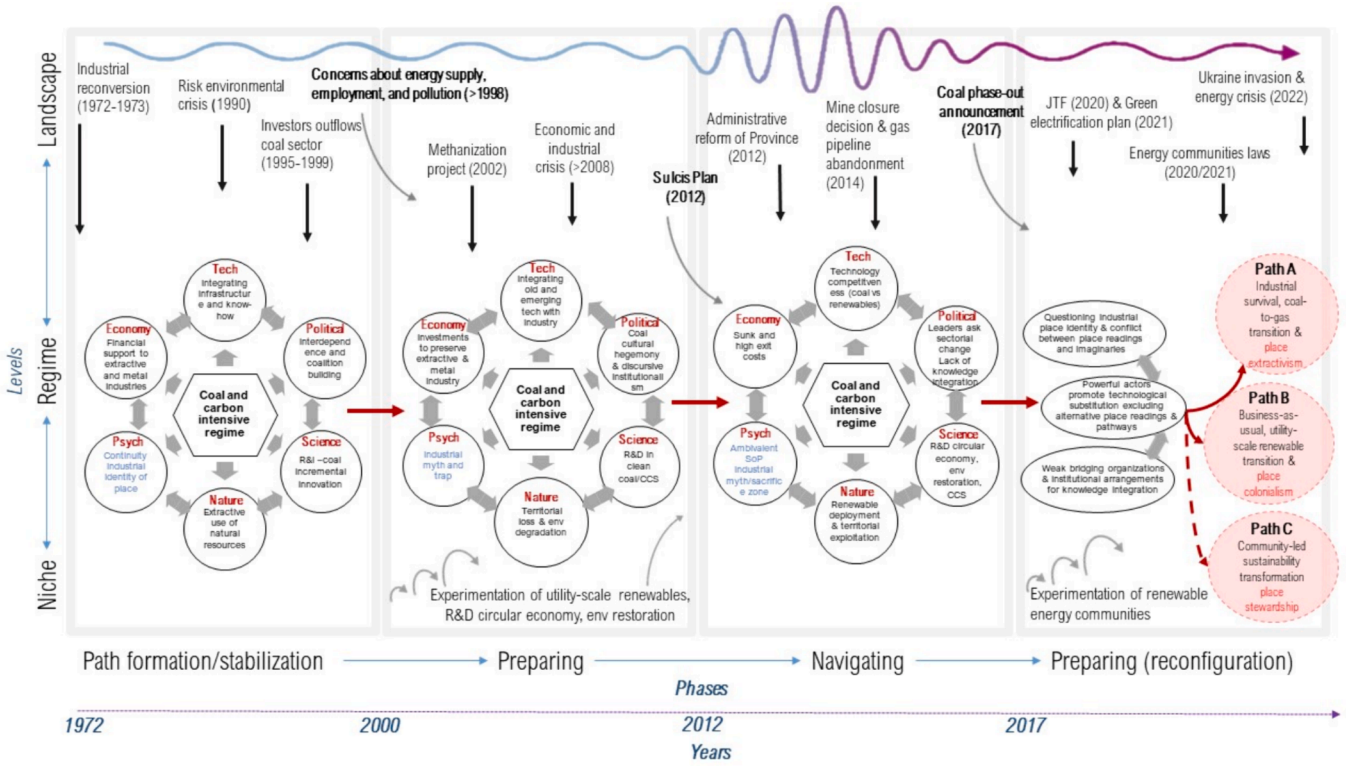


**Fig. 4.** Multi-level and multi-phase representation of Sulcis regime trajectory.
adapted from Herrfahrdt-Pähle et al. (2020). Landscape arrows represent landscape pressures, perturbations or windows of opportunity, when curved turning points or moments of rupture/passage between phases. At the regime level we highlight the interaction between regime factors for each phase. At the niche level, alternative innovations. The factors related to the SoP are highlighted in blue (for interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

energy-intensive industries and energy infrastructures shaping the energy system. As a result, the economy of Sulcis became heavily dependent on the interconnected operations of extractive, energy, and metal industries, while industrial reconversion preserved the dominant meaning and identity of the region as an "industrial-laborer place" (see Fig. 5).

This transformation significantly impacted the social and economic fabric, leading to reliance on exports and increased vulnerability to external forces. This period is depicted by multiple interviewees as a pivotal turning point that undermined the region's endogenous capacities, assets, and traditional economic sectors while "corrupting" people–place relationships:

> "The industry opposed primary activities. Prices adapted to industrial salaries making the farmer's activity no longer liveable. Industry failed miserably after a few years, leaving us with polluted land and without jobs because we learned to be more workers than farmers" (I_7).
>
> "Everything was bartered for a couple of industries, which employed many people, but was the first form of corruption. Meantime you lose the territory, you lose above all your professionalism and knowledge, and you have whole communities completely dependent on these dynamics" (I_10).

In summary, the place reading turned into that of a "sacrifice zone" – an economically exploited, culturally marginalized, and undervalued territory in the name of economic development (cf. De Souza, 2021; Biddau, D'Oria and Brondi, 2023). Participants reported capitalist and neo-colonialist logics as the main drivers of extractivist people–place relationships, conceiving such transformation as "passive modernization" (I_12) or "innovation without development" (I_18). This is illustrated in the following quote:

> "They stuffed everything into a small piece of land: lead, zinc, arsenic, cadmium, aluminium factory, power plants and other heavy processes. Here is the description of Sulcis: a place of industrial servitude, a small piece of land that is not possible to regenerate" (I_8).

Limited economic diversification led to heavy reliance on the metal industry and coal power generation, prompting governments to intervene and support coal mining to preserve employment (see Appendix A).

### 5.2. *Preparing (2000–2012): Fixing socio-technical configuration for fixed place meanings and identities*

Since the early 2000s, several projects and public funding initiatives have emerged to revive coal exploitation, provide affordable electricity to energy-intensive industries, and mitigate environmental impacts (cf. Appendix A; see Fig. 6). The industrial decline, migration, and high unemployment in the region following the 2008 global crisis prompted the State, Sardinia Region, and local authorities to sign the Sulcis Plan in 2012, allocating 1,243 million euros for developing an integrated development strategy (see Appendix A).

However, interviews support our document analysis indicating that the vision and strategy behind these plans reflect an overarching intention to preserve a place identity rooted in industrial heritage. As illustrated in the following quotes, interviewees acknowledge the difficulty of abandoning the "industrial(ization) myth and identity" and imagining alternative pathways.

> "The myth of industrialization it is good that it is abandoned [..] We have lost half a century defending the indefensible without building a vision for the future. This is a collective mea culpa of the territory" (I_15).

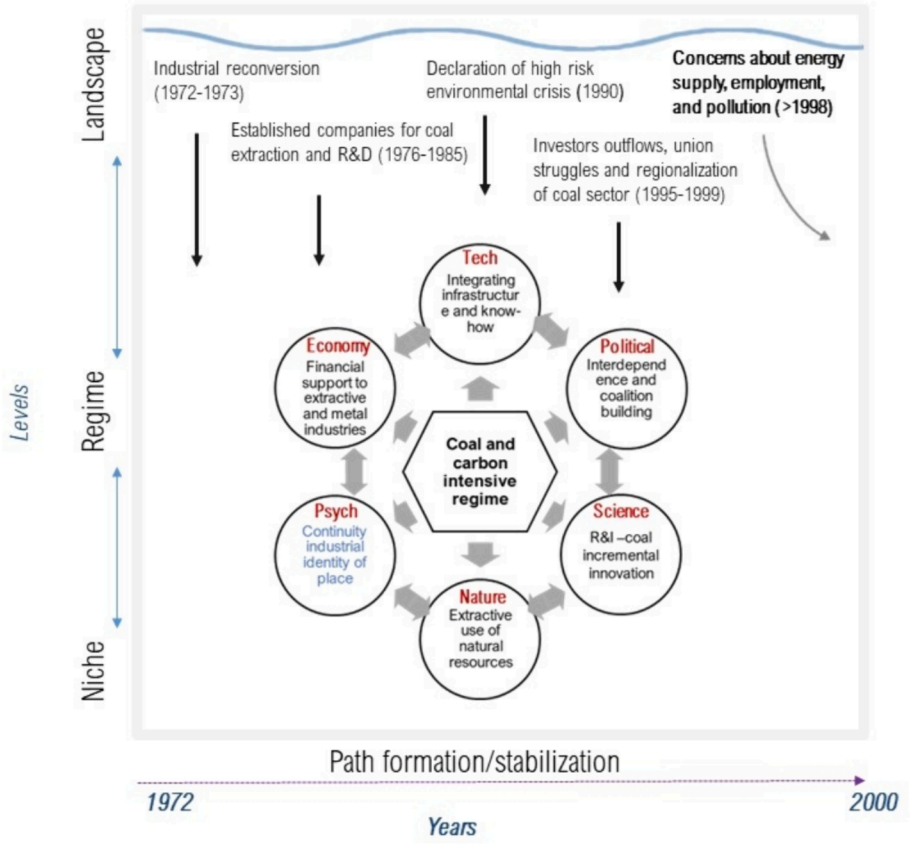


**Fig. 5.** Zoom of the first phase presented in Fig. 4: Path stabilization (1972–2000).

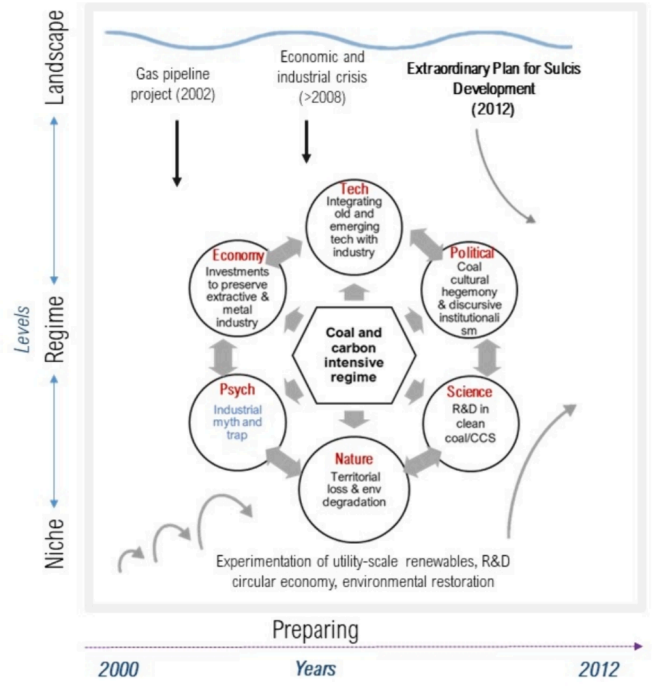


**Fig. 6.** Zoom of the second phase presented in Fig. 4: Preparing (2000–2012).

By referring to the territory and the community as the primary collective agents, the interviewee highlighted a cultural hegemony of the "industrial reading of place", its influence and maladaptation outcomes. As the following statement illustrates, dominant place meanings promoted by interdependent actors and community leaders led to a "therapeutic persistence" toward industrial survival and sectorial change, suppressing the emerging awareness of the need for alternative pathways.

> "There is an inability to see a different future beyond the large metal or extractive industry. The Sulcis plan reflects this industrial vision. We had to take responsibility for a paradigm shift, but you had to convince the whole community – workers, politicians, unions – that building a new vision and dismantling the old was essential" (I_14).

Multiple stakeholders actively contributed to preserving industrial heritage and the employment basin due to their interdependence and shared interests. Investments in R&D, payroll, and business subsidies influenced the preparation phase by constraining imagination, creating expectations, and dispersing efforts and resources needed for envisioning and planning alternatives (See Fig. 6 and Appendix A).

### *5.3. Navigating (2012–2017): Sailing by sight through a stormy sea. Navigating transition without a strategic long-term vision*

The recent navigation phase was characterized by significant landscape perturbations with different and sometimes conflicting projects and intricate relationships between EU, national and local plans. These included the decisions to halt mining and phase out coal-fired power, disrupting R&D and policy initiatives for coalfield exploitation and industrial protection at the regime level (see see Fig. 7 and Appendix A).

Consistent with the results from the analysis of polices and newspaper articles (Biddau et al., 2024), interviewees, confirm that key actors involved in the coal and carbon-intensive cycle strategically mobilized place meanings to resist or delay coal destabilization and phase-out as illustrated in the following excerpt:

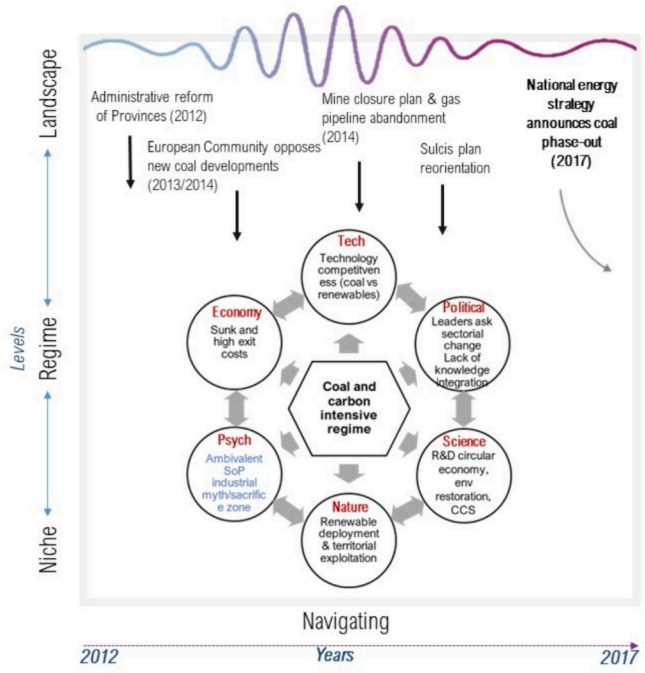


**Fig. 7.** Zoom of the third phase presented in Fig. 4: Navigating (2012–2017).

> "We keep proposing the same model to save the existing. The trade union press releases resemble those from twenty years ago. The basic project is industrial and social conservation, without renewal. Everything revolves around this necessity, which is an industrial, union, and political necessity at the same time" (I_21).

Due to the phase-out decision, planned investments and projects for reviving the energy-metallurgical sector have been redirected, producing significant delays in environmental reclamation and economic diversification initiatives (see Appendix A).

Interviewees describe the CCIR as a place that, in the absence of its industrial-political regime and structure, exhibits a lack of coordination, collaboration, and knowledge integration:

> "There has always been a lack of good coordination. Many projects have been proposed but all very heterogeneous concerning each other. In fact, what was missing was a coordinated 360-degree plan" (I_17).

This portrayal of Sulcis resembles a photographic negative, confirming its state of entrapment and stagnation due to lacking bridging organizations and effective leadership:

> "Many resources have arrived but the deficit of this place has been the ability to implement a program. The intermediary body, which is the province has been lame. Municipal unions don't work. These structures are extremely fragile and absent." (I_5).

As testified by interviewees this condition was further impacted by administrative reforms undermining the potential for a rapid reorganization and governance response.

### *5.4. Preparing (2017-ongoing): Preparing for the great reconfiguration. Redefining social-ecological relationships or adapting the socio-technical regime?*

Following the coal phase-out announcement, the absence of a clear energy-industrial plan for Sulcis raised concerns about the energy security, industrial investments, and related employment. Such situation led to the failure of the navigation phase and triggered a new preparation phase. Consequently, two co-existing pathways for energy system change have emerged: a virtual gas pipeline with maritime supply, coastal deposits and floating storage units, and ENEL's "Green Electrification" project aiming to replace coal with renewable energy, positioning the island as Italy's energy hub (see Fig. 8 and Appendix A).

In response to these developments, we observed the coexistence of two negative readings of place. The diffusion of utility-scale renewable energy projects, such as solar and wind farms (onshore and offshore), has raised concerns and led the perception of the clean energy transition as another extractive agenda offering limited local benefits as illustrated by a political leader:

> "Sardinia as a gigantic platform for renewables. In the past they were massive mineral resources, today the sun and the wind are the resources of the future. Sardinia is uninhabited, so we make this mega cable [to export electricity]. The concept is neo-colonial" (I_23).

Simultaneously, the siting of gas facilities is perceived as exacerbating spatial injustices in an already heavily contaminated region. This sense-making is shared among interviewees, who express a collective awareness and place meaning stressing the intensive exploitation, pollution, and depletion of natural resources:

> "In the context of ecological transition, they [national government] propose regasification, replace one fossil with another fossil…public money to restart polluting factories. Using European funds for the transition, for the new, to revitalize the old. It's a sort of exploiting the territory, the desperation of the people" (I_8).

Such views influence the transition narrative, framing Sardinia as a "subordinate colony" and Sulcis as a "sacrifice zone". Nonetheless, Sulcis was designated as a beneficiary of the EU Just Transition Fund in 2021 to address the social and economic impacts of the energy transition. However, the related territorial planning for preparing the reconfiguration appears to lack dialogue and learning necessary for developing an integrated transformative vision for the region. As the following quote shows, stakeholders expressed concerns over the institutional failure to incorporate local knowledge and the potential risk of losing the window of opportunity and momentum for reconfiguration.

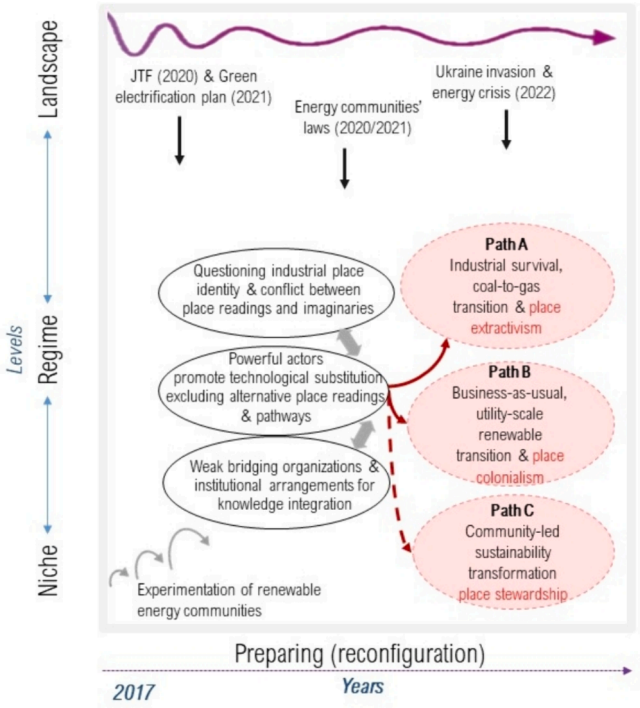


**Fig. 8.** Zoom of the fourth phase presented in Fig. 4: Preparing (2017-ongoing).

> "The Region should help coordinate but is totally absent. Projects have been presented, but without any logic, without any plan, without any dialogue. We allocate funds without a project, an integrated vision for the territory" (I_5).

Nevertheless, there is a consensus on actionable meanings and imaginaries for place transformation. Emerging visions focus on the circular economy and waste-to-resource principles emphasizing the economic and cultural potential of environmental restoration and countering the stigma associated with the region as a sacrifice zone:

> "A change in the development model cannot ignore remediation because nothing can be born on polluted land. So, reclamation, the re-naturalization of those territories and then the promotion of a circular economy" (I_13).

Interviewees stressed the significance of aligning socio-technical transition with social-ecological considerations, and advocating a shift from an extractive economy characterized by place exploitation towards a regenerative economy based on responsible place stewardship, as the following quote testifies:

> "So where is the problem? That there is no land to use because it needs remediation. The "decarbonization" in a Sulcis perspective means the decontamination of the sites and their reconversion in a productive key" (I_6).

In line with this place awareness and imaginary, interviewees perceive the transition to utility-scale renewables as a recurring pattern of place exploitation that threatens the remaining natural resources, jeopardizing alternative pathways for economic development and diversification. Accordingly, this perspective advocates for repurposing brownfields for the deployment of utility-scale facilities:

> "We need to invest in the beauties of Sulcis: agri-food, tourism, and culture. There are no other viable options. These are projects of speculation and devastation of the territory. Because renewables consume soil, and we should try to minimize land consumption, using the covered surfaces and the already degraded areas such as quarries, and industrial areas" (I_3).

In contrast, regional community stakeholders advocate an alternative pathway for energy transition with energy communities as a model for community ownership and responsibility in place transformation and resource governance. The following excerpts illustrate our claim:

> "The principles of renewables must be decentralization, community involvement, self-production, and self-consumption, minimizing impacts through energy communities" (I_10).

It is noteworthy that this imaginary aligns with the growing idealization of renewable energy communities (RECs) at the national level, which has recently resulted in policy and legislative changes (see Appendix A) aimed at institutionalizing and promoting the widespread development of RECs across the country (cf. De Vidovich et al., 2023).

## 6. Discussion

This study combined social-ecological and socio-technical approaches to sustainability to examine how feedback mechanisms between structural and psychosocial factors can either support or hinder sustainability transformations in CCIRs. Using the Sulcis region (Sardinia, Italy) as a case study, the research identified key factors of lock-in shaping path-dependent patterns (cf. Table 3).

By using a case study approach and integrative framework that accounts for the different phases and levels of transformations (cf. Herrfahrdt-Pähle et al., 2020), we explored how psychosocial factors related to SoP interplay with structural factors shaping the dynamics between landscape pressures, regime responses and niche innovations in the regional pathway (see Fig. 4).

**Table 3**
Factors of lock-in identified and their functioning in Sulcis CCIR.

| Source | Factors | Lock-in functioning |
|---|---|---|
| Psychosocial(Sense of Place) | Social/place memory | Memories of emancipation and pride stemming from the mining period and memories of social-ecological exploitation/ disruption from the metal industry influenced visions, industrial legitimacy and coping to windows of opportunity |
| | Place awareness | Past limited awareness/interest in environmental degradation hindered sustainability transformation pathways<br>Current awareness of irremediable pollution and territorial loss influences decarbonization imaginaries |
| | Place meanings | Dominant place meanings ('industrial birthplace', 'sacrifice zone') shape the relationship with the environment (exploitation or stewardship) and affect coping response to transformations/ decarbonization |
| | Place identity | The mythized industrial-labourer identity of the place limited awareness about its potential/ alternatives, constraining the corridor of possibilities |
| Socio-political | Discourse institutionalism | Institutionalized discourse and arrangements perpetuated the survival of coal stifling radical innovation and the implementation of alternatives |
| | Interdependence of interests | Elite mutual dependence underlies powerful coalitions perpetuating system inertia and excluding alternative frames and pathways |
| | Leadership | Decision-makers and unions prioritized a sectorial change (technological substitution and ecological modernization) rather than structural change |
| | Bridging organizations and niches | Weak intermediary organizations and grassroots movements offer limited spaces for experimentation, collaboration, knowledge exchange/integration, and learning |
| | Information and knowledge integration | Institutional arrangements offer inadequate access to information, expertise, and participatory arenas foridentifying, elaborating, and monitoring measures for change |
| Socio-economic | Trade flows | Industrial vocation to export created vulnerability and dependence on the international market for raw materials (coal, metals) |
| | Poverty and low income | Income loss and unemployment oriented investments and policy efforts toward 'industrial survival' overshadowing environmental conservation and radical innovation |
| | Monofunctional economy | Reliance on a single economic sector created precarious labour relationships limiting the ability to explore new paths or pursue change due to a sense of obligation towards community's survival |

(*continued on next page*)

**Table 3** (*continued*)

| Source | Factors | Lock-in functioning |
|---|---|---|
| | Sunk costs | Past investments in coal and metal industry imply high exit costs and stakeholders' resistance to radical change |
| Material (Biophysical, technological) | Technological interrelatedness/ compatibility | Interdependencies among industry, technologies and infrastructures hinder the deployment of alternatives due to competing technologies/needs (e.g., renewables competes with coal due to grid limited capacity) |
| | Technology competitiveness and operational life | Attempt to maintain old infrastructures until sunk costs are recovered delayed the deployment of alternative sources/technologies |
| | Location and environmental state | Environmental conditions constrain economic development opportunities, e.g., lacking infrastructure for tourism and limited available land for agriculture |

Our findings indicate that the extractive industry has played a pivotal role in shaping the identity of Sulcis as a pioneering industrial region, representing a symbol of progress and emancipation. This has fostered a collective sense of pride and distinctiveness within the community, rooted in an industrial-labor collective identity. The reconversion of mining and the development of the metal industry further consolidated this identity but rendered the community vulnerable, reinforcing path dependency and introducing additional lock-in factors stabilizing the coal and carbon-intensive regime (cf. Table 3 and Fig. 4). The community's dependence on a single economic sector reliant on coal power entrenched extractive and metal industries with local technologies and infrastructures, while exacerbating environmental degradation. This fostered an interdependence of interests and a cross-sector coalition advocating for investments, policies, and innovations supporting coal, perpetuating institutional discourse and reinforcing dominant place meanings.

These factors influenced how the region accommodated perturbations, like economic crisis and industrial decline, and reinforced its path-dependent trajectory, with SoP undermining the development of alternative visions, identities, and innovation pathways.

Despite growing environmental and economic concerns and increasing ambivalence of identity marked by a blend of pride and stigma, during the 2000–2012 preparation phase the region struggled to abandon its industrial identity to avoid identity loss and heritage disruption. The industrial decline led to a "poverty trap" and "technosalvation bias" (cf. Carpenter and Brock, 2008; Simon, 1981 cited in Gifford, 2011), prompting policymakers and community leaders to advocate for policy efforts and investments toward incremental technological innovation (e.g., coal co-generation and CCS) and ecological modernization to ensure the industrial regime survival. This approach reinforced infrastructural and economic lock-ins by increasing the integration of technological innovations with outdated infrastructures, thereby escalating exit costs.

The navigation phase is characterized by incremental disorientation and instability driven by socio-political pressures originating at the landscape level. The initially envisioned pathway faced disruptions due to administrative reforms weakening the institutional capacity to coordinate, navigate and reorient the trajectory, consequently losing momentum for change. Political decisions to cease coal mining and phase out coal-fired power generated resistance from regime actors that attempted to re-legitimate coal by emphasizing concerns about community collapse due to the high exit costs, the absence of viable energy supply alternatives, and the loss of heritage.

The definite end of coal marked a significant rupture with the past, intensifying the sense of loss and disorientation regarding the identity and future of Sulcis, returning the region again to the preparation phase. The period is marked by unprecedented uncertainties and shocks (i.e., covid, war, and energy crisis) but also windows of opportunity (e.g., JTF, recovery funds, community energy laws) for a sustainable reconfiguration. Nevertheless, our findings suggest that concerns about energy security might overshadow considerations over existing and emerging drivers of injustice in accelerating decarbonization (cf. also Newell, Geels and Sovacool, 2022).

Our study identifies three competing pathways corresponding to diverse imaginaries of socio-technical and social-ecological reconfiguration[2] (cf. pathways in Fig. 4, see also Biddau et al., 2024). Nowadays, the regional community seems finally challenging dominant meanings and identities associated with extractive and carbon-intensive industries, envisioning a new pathway and identity that embraces a regenerative economy and people–place relationship based on place stewardship. However, inadequate bridging organizations and institutional arrangements are limiting dialogue and knowledge integration, leading to the exclusion, marginalization, and co-optation of this vision in favor of pathways promoted by incumbents. Despite initial resistance to phase-out and attempts to prolong the lifespan of existing infrastructure to recover sunk costs (e.g., converting coal power plant to natural gas), influential actors have begun promoting competing pathways focused on rapid technological substitution with natural gas or utility-scale renewables (Biddau et al., 2024).

In this context, SoP plays a pivotal role in shaping the perceived legitimacy of these pathways and serves as a guiding frame for defining what a just transition entails. Sense-making of these transition pathways is informed by memories of social-ecological exploitation, leading to reading Sulcis as a sacrifice zone and Sardinia as a colony. Moreover, heightened awareness of territorial loss and contamination has led to idealizing of remaining spaces and resources contributing to specific spatial imaginaries for transformation based on place restoration. From being sources of degradation and stigma, brownfields, polluted sites, and wastes are now seen as opportunities for sustainable diversification based on principles of circular economy and energy transition by siting utility-scale renewables. According to interviewees, this approach can be harmoniously combined with the growth of alternative sectors like tourism and agri-food. On the other hand, community energy, circular economy, and cultural tourism can contribute to addressing issues related to industrial identity/heritage, ownership, and injustice, while also fostering a shift in the people–place relationship from extractive to regenerative.

However, these elements still fail to gain momentum and activate a navigation phase, necessitating political action to open up discursive space for deliberation over competing pathways, address uncertainties, and foster mutual understanding and learning essential to inform the pathway selection and adoption (Moore et al., 2014).

To ensure the effective implementation of circular economy, green electrification, and decarbonization pathways, it is essential to avoid ambiguity and critically examine how these actionable meanings align or diverge from the emerging changes in the SoP and windows of opportunity (Rizzoli, Norton, and Sarrica, 2021). This can be achieved by engaging the community in a way that fosters co-responsibility while also assessing and orienting the benefits of transformation, which requires coordinating collaboration for identifying leverage points and linking them to the specific window of opportunity for gaining momentum (Olsson, Galaz and Boonstra, 2014). Failure to prioritize these

[2] This segmentation is purely artificial and should be considered an analytical plot and narrative tool as we acknowledge the intrinsic difficulty of drawing definite lines/boundaries between competing pathways and the existence of pathways in-between (e.g., combining coal-to-gas transition and utility-scale renewables).

essential elements can amplify resistance, vulnerability, and uncertainty, heighten inequalities and conflicts, and ultimately hinder the development of crucial capacities, impeding progress and momentum for reconfiguration.

## 7. Conclusions

The success and pace of coal phase-out and the establishment of low-carbon alternatives are intricately linked to regime stability and actors' response to regime destabilization, which is influenced by the interplay of existing cultural, socio-political, material, and economic factors (Markard et al., 2023; Seto et al., 2016; Herrfahrdt-Pähle et al., 2020).

Our study adopted an integrative framework of social-ecological and socio-technical approaches to elucidate how feedback mechanisms historically stabilized the Sulcis CCIR and shaped its destabilization and reconfiguration pathway. Our research provides valuable insights into the feedback dynamics that can characterize coal-dependent regions in transition, shedding light on the complexities of disentangling the cultural and socio-economic and political interdependencies linked to extractive economy and the emergence of new people–place relationships. Our findings align with a growing body of research emphasizing the socially constructed nature of coal hegemony, highlighted by its historical significance for community well-being and identity (see, e.g., Wright et al., 2022; Markard et al., 2023). We emphasize that cultural values and place meanings can be slow to evolve and hinder timely action, especially when they threaten dominant place identities or meanings. The reluctance to embrace structural change in Sulcis CCIR stems from various lock-in mechanisms, including a psychosocial lock-in grounded in the SoP associated with the coal and carbon-intensive industrial sectors. CCIRs facing gradual destabilization of the regional industrial heritage may opt for incremental actions to adapt and preserve related place meanings and identities. However, this can obscure the necessity for radical change and lead to slowly emerging conflicts over meanings and associated actions (Wilson, 2014; Masterson et al., 2017). SoP offers an overarching analytical lens to examine how human subjectivity (e.g., place values, identities, and meanings) may influence coping responses and transformations in geographically based systems. Integrating SoP into systemic frameworks that account for the nature and sequence of transformations can enhance our understanding of feedback loops that reinforce path-dependent patterns in social-ecological and socio-technical systems. In this context, the proposed integrative framework can serve as a valuable tool for analyzing transitions in CCIR with a nuanced sensitivity on people–place relationships. This approach can bridge socio-technical change with broader social-ecological considerations providing insights into potential strategies to escape or disrupt entrenched patterns and facilitate progress in low-carbon transformations.

## Ethics statement

The manuscript adheres to ethical guidelines specified in the APA Code of Conduct and authors' national ethics guidelines.

## CRediT authorship contribution statement

**Fulvio Biddau:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Valentina Rizzoli:** Methodology, Visualization, Writing – review & editing. **Paolo Cottone:** Writing – review & editing, Project administration, Funding acquisition. **Mauro Sarrica:** Conceptualization, Funding acquisition, Project administration, Supervision, Writing – review & editing.

## 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

Data will be made available on request.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gloenvcha.2024.102850.

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## Further reading

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