

Justyna Adamska

Innovation Districts in the Transformation of Post-Coal Regions:

From Climate Neutrality to a New
Development Trajectory

**SERIES: GREEN TRANSFORMATION
POLICY IN POLAND**



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PREFACE

It is widely recognised that Poland's green transformation policy is centred on the shift away from fossil fuels, particularly coal, towards renewable energy sources (RES), with the overarching objective of achieving climate neutrality by 2050. This transition is being pursued through the Energy Policy of Poland until 2040 (PEP2040), the National Recovery and Resilience Plan (NRRP) and European Union regulatory frameworks, including the European Green Deal. These measures encompass the development of renewable energy sources, the modernisation of the energy sector, including the development of nuclear power, improvements in the energy efficiency of buildings, the promotion of low-emission transport and support for innovation. Their implementation requires substantial investment, financed, inter alia, through European Union (EU) funding. Research indicates growing optimism among the Polish public

regarding the potential economic and social benefits of the transition. Nevertheless, the process requires significant levels of investment and entails considerable challenges, particularly for coal-mining regions. It also poses important theoretical, descriptive and practical challenges for the academic community.

The present series of publications, devoted to green transformation policy in Poland, provides an in-depth examination of the issues associated with this field of research. Spanning six volumes, the series enables a multifaceted exploration of the subject matter, integrating theoretical perspectives with practical considerations.

The publication series adopts an interdisciplinary approach, with the aforementioned subject matter providing a common thematic framework for the individual monographs. The authors address issues relating to public policy, management, environmental protection, law and public administration. By bringing these studies together within a single series, the research provides a comprehensive and multidimensional perspective on the issues under consideration.

The sixth volume in this series examines the conditions shaping the development of post-coal regions undergoing transition away from coal mining and coal-based energy production. The author critically examines the limitations of approaches that equate regional transformation primarily

with the achievement of climate neutrality. Decarbonisation, while essential to the transition process, does not in itself generate employment, build regional innovation capacity, or establish sustainable and enduring economic functions. The analysis therefore centres on the concept of the innovation district as a place-based mechanism capable of integrating the adaptive reuse of land and infrastructure with institutional collaboration, the development of new economic activities, skills transformation, community participation, and processes of collective learning. Rather than presenting innovation districts as a universal prescription for post-coal transformation, the monograph identifies the institutional, economic, spatial and social conditions under which they can connect decarbonisation with the emergence of a new, socially legitimate and economically sustainable development trajectory for post-coal regions.

CHAPTER I

INTRODUCTION

1.1. Background

Post-coal transformation represents a territorial challenge rather than merely the technical replacement of coal or the administrative closure of mines and power stations. Decades of coal dependence have structurally shaped employment, local public finances, land use, infrastructure, regional identity, and societal expectations regarding the future. Climate neutrality therefore provides a necessary imperative and direction for decarbonisation, but not a complete regional development model: a territory may succeed in reducing emissions yet remain economically vulnerable if the transition is experienced primarily as a loss of employment, public revenue, and future prospects. Sustainable renewal requires systematically linking decarbonisation

to innovation, institutional coordination, spatial re-use, and the establishment of new economic functions.

Poland and Central and Eastern Europe (CEE) provide a critical empirical context for this debate. Many coal-dependent regions across this part of Europe face acute decarbonisation pressures whilst concurrently confronting uneven innovation capacities, institutional constraints, and structural restructuring challenges. The reference territories documented in regional policy analyses include Eastern Wielkopolska and six comparative European regions: Western Macedonia, the Ústí Region, North Rhine–Westphalia, the Irish Midlands, Stara Zagora, and Lusatia. These territories reflect diverse configurations of coal dependence, institutional capability, social vulnerability, policy learning, and potential for innovation-led renewal. In this monograph, they are not treated as exhaustive empirical case studies; rather, they serve as theory-led reference points for a conceptual argument concerning how post-coal regions can transition from a compensatory logic towards one of new path creation¹.

¹ J. Adamska et al., *Raport 1: Identyfikacja. Analiza porównawcza regionów Europy zbliżonych do Wschodniej Wielkopolski, przechodzących proces transformacji energetycznej oraz dobre praktyki w kontekście celów Strategii na rzecz neutralności klimatycznej Wschodniej Wielkopolski*, Poznański Park Naukowo-Technologiczny, Life After Coal PL, Poznań 2024, pp. 13–15, <https://aftercoal.pl/wp-content/uploads/2025/10/>

The central proposition of this study is that innovation districts can provide a robust conceptual and operational bridge between climate neutrality targets and regional renewal. In the mainstream literature, innovation districts have predominantly been associated with metropolitan knowledge economies, dense clusters of anchor institutions, technology firms, start-ups, and highly concentrated urban environments. In post-coal and industrial transition contexts, however, the concept requires substantial reinterpretation. Here, an innovation district must be conceptualised as a place-based mechanism that aligns diverse actors, physical infrastructure, local knowledge, strategic investment, public policy, and brownfield spatial redevelopment. Its strategic value does not reside in the imitation of metropolitan technology enclaves, but in organising a dedicated territorial environment in which alternative developmental trajectories become viable².

Raport-1-2025-02-24.pdf [access: 21.08.2026]; J. Adamska et al., *Raport 2: Analiza. Analiza porównawcza regionów Europy zbliżonych do Wschodniej Wielkopolski, przechodzących proces transformacji energetycznej oraz dobre praktyki w kontekście celów Strategii na rzecz neutralności klimatycznej Wschodniej Wielkopolski*, Poznański Park Naukowo-Technologiczny, Life After Coal PL, Poznań 2025, pp. 12–18, 36–44, <https://aftercoal.pl/wp-content/uploads/2026/02/Raport-2-scalony.pdf> [access: 21.08.2026].

- ² J. Drucker, C.M. Kayanan, *Innovation districts: Assessing their potential as a strategy for urban economic development*, “Urban Affairs Review” 2024, no. 3, vol. 60, pp. 802–834, <https://doi.org/10.1177/10780874231173618>; C.M. Kayanan, *A critique*

1.2. Research Problem

This monograph examines how innovation districts can facilitate the shift in post-coal regions from merely managing structural decline towards generating new developmental pathways. Just transition scholarship has established why decarbonisation policies must explicitly account for uneven socio-economic costs, democratic participation, institutional trust, and territorial vulnerability. Nevertheless, procedural fairness and compensatory funding, although essential, do not in themselves explain how regions can generate new industrial activities, indigenous innovation capacity, and resilient economic functions following the phase-out of coal. The core research problem is therefore developmental as well as distributive: how can a just transition simultaneously establish the foundations for a diversified and durable regional economy?

Research on regional innovation systems (RIS) has addressed this developmental imperative by demonstrating that innovation is territorially embedded within ongoing interactions among firms, universities, public authorities, intermediary organisations, and civil society. The creation

of innovation districts: Entrepreneurial living and the burden of shouldering urban development, “Environment and Planning A: Economy and Space” 2022, no. 1, vol. 54, pp. 50–66, <https://doi.org/10.1177/0308518X211049445>

of new industrial paths relies fundamentally on knowledge circulation, institutional thickness, and regional learning capacities—factors that cannot simply be instituted by administrative decree. What remains insufficiently articulated in the literature is a concrete spatial and institutional mechanism capable of connecting these systemic innovation capacities to the acute social and land-use challenges of coal phase-out. This monograph posits that an appropriately adapted innovation district model can perform this bridging role³.

1.3. Research Gap

The identified research gap is primarily one of theoretical and policy integration rather than an absence of scholarship. Research on innovation districts has remained predominantly focused on dense metropolitan cores; regional innovation studies have rarely engaged in depth with carbon lock-in, legacy assets, and post-mining land remediation;

³ P. Cooke, M.G. Uranga, G. Etxebarria, *Regional innovation systems: Institutional and organisational dimensions*, “Research Policy” 1997, no. 4–5, vol. 26, pp. 475–491, [https://doi.org/10.1016/S0048-7333\(97\)00025-5](https://doi.org/10.1016/S0048-7333(97)00025-5); B.T. Asheim, L. Coenen, *Contextualising regional innovation systems in a globalising learning economy: On knowledge bases and institutional frameworks*, “The Journal of Technology Transfer” 2006, no. 1, vol. 31, pp. 163–173, <https://doi.org/10.1007/s10961-005-5028-0>

just transition literature often lacks a micro-spatial mechanism for industrial path creation; and studies on green innovation and brownfield redevelopment have tended to analyse isolated dimensions of this complex coordination problem. This monograph addresses these limitations by integrating these disparate theoretical streams into a unified, place-based framework that connects climate neutrality mandates, transition justice, territorial innovation capabilities, and regional path creation⁴.

The primary objective is to synthesise existing literature into a coherent conceptual and policy framework capable of informing future empirical investigations, strategic design, and regional policy formulation.

1.4. Aim, Research Questions, and Thesis

The primary aim of this monograph is to develop a conceptual framework explaining how innovation districts

⁴ S. Fastenrath et al., *Mission-oriented innovation districts: Towards challenge-led, place-based urban innovation*, “Journal of Cleaner Production” 2023, vol. 418, art. 138079, pp. 4–5, <https://doi.org/10.1016/j.jclepro.2023.138079>; A. Matern et al., *Strategies for energy transition and regional development in European post-coal mining regions: Ústí Region, Czechia, and Lusatia, Germany*, “Territory, Politics, Governance” 2025, no. 7, vol. 13, pp. 1001–1006, <https://doi.org/10.1080/21622671.2023.2231972>

can support the transformation of post-coal regions by aligning climate-neutrality imperatives, territorial innovation ecosystems, and the generation of new regional development trajectories.

The main research question is formulated as follows:

How can innovation districts function as territorial mechanisms of post-coal regional transformation, linking climate-neutrality objectives with the creation of a new development trajectory?

This central enquiry is addressed through five supporting research questions:

- 1) Which development constraints of post-coal regions are identified within the just transition literature?
- 2) Which elements of regional and territorial innovation systems are most relevant for regions undergoing coal phase-out?
- 3) How can green innovation and post-mining redevelopment be effectively integrated into a new regional development trajectory?
- 4) How should an innovation district be conceptualised in a post-coal context to avoid being reduced to a narrow technological enclave or a speculative real-estate development?
- 5) What strategic and policy implications emerge from treating innovation districts as institutional mechanisms of transformative regional development?

The central thesis of this monograph is conditional: *in post-coal territories characterised by a legitimate strategic mission, an accountable anchor institution, control over suitable brownfield sites, and the organizational capacity to connect enterprises, skills development programmes, and affected local communities, a district-based coordination platform generates more robust portfolio alignment and cumulative learning than disconnected redevelopment and fragmented innovation projects.* Institutional designation alone exerts no such transformative effect. This proposition is empirically testable through comparative, longitudinal research designed to trace whether the identified mechanisms operate as hypothesised and whether alternative governance configurations yield equivalent or superior outcomes under comparable initial conditions.

1.5. Conceptual Framework and Methodological Approach

This monograph synthesises seven foundational concepts: just transition, post-coal regions, climate neutrality, regional innovation systems (RIS), innovation districts, path dependency and path creation, and transformative regional development. The core analytical contribution lies in integrating these disparate concepts into a unified framework. Post-coal transformation is conceptualised as

an inherently territorial process, climate neutrality as an overarching strategic direction, and innovation as structurally embedded in place. Innovation districts are posited as place-based mechanisms through which brownfield spatial re-use, institutional coordination, regional innovation capabilities, and climate-neutral restructuring can be co-ordinated systematically.

The notion of a new regional development trajectory is pivotal. Post-coal territories are profoundly constrained by path dependency, manifested in carbon lock-in, legacy industrial structures, specialised labour skills, dedicated infrastructure, entrenched land-use patterns, and rigid institutional routines. Nevertheless, path dependency does not preclude structural transformation. New regional development pathways can emerge through the novel recombination of knowledge assets, institutional agency, strategic investment, multi-scalar policy coordination, and the purposeful mobilisation of endogenous resources. From this perspective, the innovation district serves as a spatial and institutional vehicle capable of concentrating and interconnecting these transformative elements within a demarcated territory⁵.

⁵ M. Grillitsch, B.T. Asheim, M. Trippl, *Unrelated knowledge combinations: The unexplored potential for regional industrial path development*, “Cambridge Journal of Regions, Economy and Society” 2018, no. 2, vol. 11, pp. 257–274, <https://doi.org/10.1093/cjres/rsy012>; R. Hassink, A. Isaksen, M. Trippl, *Towards*

The methodological approach is grounded in qualitative literature analysis and conceptual synthesis. Rather than conducting a formal bibliometric or mechanical systematic review, this study employs an integrative, purposive review design (e.g. Torraco, 2016). It draws upon a curated corpus of scholarly literature and policy documentation as its primary evidentiary foundation, structured around key thematic streams: just transition, regional innovation systems, innovation districts, green innovation, post-mining redevelopment, stakeholder governance, and regional path creation. The analytical objective is to uncover structural interrelationships among these streams and construct a robust synthetic framework suitable for a research monograph.

To ensure methodological transparency, the investigation is deliberately structured as an integrative, purposive review. Following targeted literature enrichment and bibliographic verification, the final documentary base comprises 51 publications and policy documents published between 1997 and 2026 in English and Polish. This corpus represents the substantive foundation of the conceptual synthesis rather than the exhaustive output of an algorithmic screening protocol.

a comprehensive understanding of new regional industrial path development, “Regional Studies” 2019, no. 11, vol. 53, pp. 1636–1645, <https://doi.org/10.1080/00343404.2019.1566704>

The evidentiary base balances peer-reviewed journal articles, academic monographs, and edited volumes with institutional, strategic, and policy reports. These source categories fulfil distinct epistemological functions: peer-reviewed literature underpins theoretical propositions and validated empirical mechanisms, whereas grey literature is deployed to reconstruct formal policy architectures, institutional arrangements, implementation bottlenecks, and place-specific territorial mechanisms. Grey literature sources were deemed eligible only where institutional responsibility or authorship, publication date, provenance, and direct empirical relevance were rigorously established. Promotional, anonymous, duplicate, or unverified materials were systematically excluded from the analysis.

Because literature retrieval followed an iterative research design, the search process cannot be captured by a single retrospective Boolean string. The conceptual vocabulary deployed to delineate and interrogate the corpus incorporated combinations of terms including ‘just transition’, ‘coal region*’, ‘post-coal region*’, ‘innovation district*’, ‘regional innovation system*’, ‘green innovation’, ‘post-mining redevelopment’, ‘regional path development’, ‘path creation’, ‘territorial transformation’, and ‘climate neutrality’, intersected with geographic qualifiers such as ‘Poland’, ‘Central and Eastern Europe’, and specific reference regions. Inclusion criteria required direct theoretical or empirical

relevance to at least one core thematic stream, alongside an identifiable conceptual, mechanistic, or empirical contribution to territorial restructuring.

A targeted supplementary review incorporated seven additional publications that directly addressed critical theoretical dimensions: mission orientation, policy experimentation, inclusive innovation, strategic spatial planning, policy-instrument evolution, peripheral transformative capacity, and sub-regional spatial metrics. A subsequent theoretical gap analysis integrated five further peer-reviewed studies focused on change agency, the geography of sustainability transitions (GeoST), political-economy perspectives on path creation, and place-based governance mechanisms in Polish coal-mining basins.

All identified sources were systematically coded using a standardised data extraction matrix comprising: publication type; research design and empirical data; geographical scope and spatial scale; actor constellations; core concepts and causal mechanisms; evaluation methodologies; acknowledged limitations; and direct relevance to the five analytical layers of the proposed model. Conceptual and empirical claims selected for synthesis were logged alongside precise page or section identifiers to ensure rigorous source attribution and prevent superficial paraphrasing. The coding framework combined deductive theoretical categories with emergent inductive themes, notably strategic

spatial planning, mission-driven directionality, distributed change agency, multi-scalar governance, brownfield remediation finance, and territorial equity.

Methodological quality appraisal was calibrated to the research design of each source. Empirical studies were evaluated on the basis of procedural transparency regarding case selection, empirical data collection protocols, analytical rigour, and explicit consideration of study limitations. Literature reviews were appraised according to the transparency of their search strategies and synthesis methods, whereas institutional and policy reports were utilised strictly to reconstruct contextual and institutional baselines rather than to substantiate causal claims. For Davidson et al., where only the published abstract and article preview were accessible, evidentiary use was strictly restricted to the findings explicitly documented therein, precluding its deployment for granular mechanistic or causal inferences.

The cross-thematic synthesis was conducted through a concept-to-mechanism comparative mapping. An individual scholarly or policy contribution was incorporated into the framework only where it met at least one of four criteria: clarifying a foundational construct, specifying a causal or institutional mechanism through which that construct operates, providing empirical observations pertinent to that mechanism, or identifying critical boundary conditions. Conceptual convergence across distinct bodies

of literature reinforced the plausibility of the formulated propositions; conversely, theoretical divergence and methodological limitations were explicitly retained as analytical qualifications. In accordance with qualitative synthesis standards, no quantitative effect sizes were pooled, and no deterministic causal inferences were drawn from single-case studies, comparative qualitative designs, or observational predictive models.

The delineation of the integration gap rested on two evaluative criteria. The first was internal: assessing whether the assembled theoretical streams jointly accounted for mission directionality, spatial organisation, actor constellations, implementation pathways, and evaluation metrics within post-coal path creation. The second was external: verifying whether structured literature reviews had previously established direct analytical links between innovation district scholarship and mission-oriented innovation policy. In their systematic assessment, Fastenrath *et al.* observed that a combined search yielded no cross-indexed records, leading them to evaluate the two bodies of literature independently. While their finding substantiates the structural separation of these academic fields up to late 2020, it is utilised here as an initial benchmark rather than as a substitute for this monograph's integrative synthesis⁶.

⁶ S. Fastenrath et al., *Mission-oriented innovation districts...*, op.cit., pp. 4–5.

This methodological design carries two epistemological implications for interpretation:

- 1) The supplementary analytical extensions provide targeted conceptual enrichment rather than exhaustive bibliographic coverage.
- 2) Theoretical propositions and governance models derived from metropolitan or North American contexts are translated into analytical questions, operational criteria, and design requirements for post-coal regions, rather than being treated as empirical baselines directly transferable to Poland or Central and Eastern Europe (CEE).

This strict distinction between empirical source findings, analytical inferences, and proposed territorial applications is maintained across all subsequent chapters.

Such an approach necessitates critical reflexivity. Innovation districts must not be conceptualised as inherently inclusive or automatically successful. Critical urban and geographical scholarship has demonstrated that such initiatives risk exacerbating territorial inequalities, devolving into speculative real-estate branding exercises, or failing to deliver tangible benefits to host communities when divorced from local socio-economic needs. For post-coal territories, this critique is paramount. A post-coal innovation district must therefore be evaluated not merely by start-up incubation rates or inward private investment,

but primarily by its substantive contribution to workforce transitions, brownfield spatial re-use, local institutional capacity building, democratic legitimacy, and long-term socio-ecological resilience⁷.

1.6. Scope and Structure of the Monograph

The geographical scope of this monograph encompasses Poland and Central and Eastern Europe, with Polish post-coal territories serving as primary illustrative reference contexts. Eastern Wielkopolska represents the focal Polish application context due to the availability of empirical documentation on just labour transitions, accelerated lignite phase-out schedules, and multi-level territorial governance arrangements. Additional coal-dependent territories—notably the Upper Silesian Coal Basin, Bełchatów, the Turów–Bogatynia complex, and the legacy mining region of Wałbrzych—are deployed selectively to illustrate sub-national institutional and infrastructural diversity within Poland. Comparative European references (including Lusatia, the Ústí Region, Stara Zagora, the Irish

⁷ C.M. Kayanan, *A critique of innovation districts...*, op.cit., pp. 50–66; A. Morisson, C. Bevilacqua, *Balancing gentrification in the knowledge economy: The case of Chattanooga's innovation district*, “Urban Research & Practice” 2019, no. 4, vol. 12, pp. 472–492, <https://doi.org/10.1080/17535069.2018.1472799>

Midlands, Western Macedonia, and the Gorj region) are integrated strictly where they elucidate specific theoretical mechanisms or policy trade-offs, rather than expanding the inquiry into an exhaustive comparative case-study matrix.

The remainder of the monograph is structured into five core chapters:

Chapter 2 establishes the theoretical and critical foundations of the innovation district model within territorial innovation studies, examining its limitations and adaptation requirements outside metropolitan knowledge hubs.

Chapter 3 connects the imperative of climate neutrality with the geography of sustainability transitions, green technological innovation, and the redevelopment of post-mining assets.

Chapter 4 presents the integrated conceptual model of the post-coal innovation district, specifying its five constituent layers, mechanisms of regional path creation, agency dynamics, and conditional propositions.

Chapter 5 operationalises the conceptual model into actionable territorial strategies, detailing asset-to-function translation, implementation sequencing, governance architectures, and strategic risk management.

Chapter 6 synthesises the primary theoretical, policy, and practical contributions of the study, outlines concrete recommendations for regional actors in Polish and CEE

transition territories, and defines priorities for future empirical research.

The overarching contribution of this monograph is threefold—theoretical, policy-oriented, and applied: it integrates hitherto fragmented bodies of literature and provides regional stakeholders with an analytical framework for co-ordinating land re-use, industrial skills, institutional capabilities, and green innovation around a new regional development trajectory.

CHAPTER II

INNOVATION DISTRICTS AND TERRITORIAL INNOVATION SYSTEMS

2.1. Innovation as a Territorial Process

Innovation is fundamentally a territorial as well as a firm-level process. Novel products, services, and organisational practices do not emerge in an institutional vacuum; rather, they are generated within specific spatial, institutional, and relational settings. In these environments, localized knowledge networks, public institutions, anchor organisations, specialised skills pipelines, financial mechanisms, and social capital collectively determine what can be created, scaled, and territorially embedded. This dynamic is especially acute in post-coal regions, where historically embedded labour markets, dedicated infrastructures, industrial identities, and spatial land-use patterns cannot be restructured through isolated, firm-level capital

investments. Innovation in such settings must therefore be conceptualised as the progressive reorganisation of actors, physical spaces, and institutional routines around new economic and social functions.

Regional innovation system (RIS) scholarship provides the foundational analytical apparatus for this perspective: innovation processes are driven by systemic interactions among firms, higher education and research institutions, public authorities, financial intermediaries, and civil society. Crucially, these capabilities are geographically and structurally unevenly distributed. Consequently, innovation policy in post-coal regions cannot simply replicate national, top-down technology priorities; it must explicitly address regional institutional and organisational thinness, fragmented multi-level governance, and constrained inter-firm learning networks⁸.

Post-coal regional transformation should thus be analysed as a comprehensive territorial reconfiguration rather than a narrow exercise in sectoral decarbonisation. Path dependency remains a defining condition, as decades of coal extraction and combustion have deeply shaped regional topographies, occupational profiles, municipal tax bases, and societal expectations. Nevertheless, path dependency

⁸ P. Cooke, M.G. Uranga, G. Etxebarria, *Regional innovation systems...*, op.cit., pp. 475–491; B.T. Asheim, L. Coenen, *Contextualising regional innovation systems...*, op.cit., pp. 163–173.

does not dictate inevitable decline. New regional development pathways can emerge when inherited industrial and infrastructural assets are creatively recombined with new knowledge, adapted institutional arrangements, emerging clean-technology markets, and mission-oriented policy frameworks. Within this dynamic, innovation districts become analytically relevant insofar as they provide spatial focus, multi-actor coordination, institutional visibility, and an operational platform for such asset recombination—not because post-coal regions ought to uncritically emulate metropolitan high-technology enclaves⁹.

2.2. Regional Innovation Systems and Their Limits in Post-Coal Regions

Regional innovation system theory offers critical insights into why certain territories exhibit a superior capacity to generate, absorb, and diffuse innovations relative to others. It focuses analytical attention on knowledge circulation, institutional architectures, and interactive learning mechanisms. In well-developed regional innovation systems,

⁹ M. Grillitsch, B.T. Asheim, M. Trippl, *Unrelated knowledge combinations...*, op.cit., pp. 257–274; J. Schot, W.E. Steinmueller, *Three frames for innovation policy: R&D, systems of innovation and transformative change*, “Research Policy” 2018, no. 9, vol. 47, pp. 1554–1567, <https://doi.org/10.1016/j.respol.2018.08.011>

dense networks connect enterprises with universities, research organisations, vocational training bodies, public development agencies, and specialised intermediaries. These structural linkages facilitate the early identification of economic opportunities, the mobilisation of regional competences, the rapid prototyping and testing of technological solutions, and the effective transfer of scientific knowledge into industrial practice. Conversely, in weak or fragmented systems, these institutional actors may exist *de jure*, but remain poorly connected, under-resourced, or path-dependently locked into legacy industrial routines.

Post-coal territories frequently typify this latter condition. Their institutional architecture is predominantly configured around incumbent carbon-intensive conglomerates, mono-industrial lock-in, and public-sector routines aligned with fossil-fuel extraction. Local vocational and higher education systems are often closely calibrated to mining, conventional energy generation, heavy manufacturing, and associated maintenance services. Municipal spatial planning is heavily constrained by the extensive physical footprint of deep and open-cast mines, thermal power stations, heavy rail sidings, and contaminated brown-field sites. Furthermore, local small and medium-sized enterprises (SMEs) typically operate as captive subcontractors to dominant mining conglomerates rather than as autonomous, R&D-active innovators. These systemic

features do not imply that innovation is unattainable; rather, they demand that transformative strategies proceed from a rigorous and unvarnished diagnosis of regional structural lock-in.

Across Poland and Central and Eastern Europe, regional innovation capacity is further constrained by fragmented sub-national governance, tenuous science–industry commercialisation interfaces, low levels of private sector research and development expenditure, and uneven administrative implementation capacities. The mere administrative designation of an area as an ‘innovation district’ cannot compensate for these deep-seated systemic deficiencies. While RIS theory effectively identifies key actors and relational networks, it often remains too spatially abstract to guide the concrete, place-based decisions required by coal phase-out: complex land ownership consolidation, environmental remediation, grid connection allocation, spatial zoning, and the infrastructural re-use of energy and transport assets. An innovation district model can operationalise key dimensions of a regional innovation system by concentrating institutional coordination, collaborative experimentation, and physical investment within a defined spatial footprint, while maintaining functional integration with the wider regional economy¹⁰.

¹⁰ E. Dworak, M.M. Grzelak, *The innovation gap of national innovation systems in the European Union*, “Comparative Economic Research.

2.3. The Concept of Innovation Districts

In economic geography and urban planning, innovation districts are broadly defined as compact, geographically concentrated, and amenity-rich areas where research institutions, knowledge-intensive enterprises, technology start-ups, business incubators, public agencies, and investors congregate to foster knowledge creation, collaborative learning, and commercialisation. The concept has been developed primarily in relation to core metropolitan economies, where it is intrinsically associated with spatial proximity, mixed-use urban fabric, knowledge anchor institutions, intensive R&D activity, dense entrepreneurial ecosystems, and the agglomeration of talent and venture capital. In this literature, innovation districts represent distinct territorial environments in which economic, physical, and networking assets are purposefully aligned¹¹.

Central and Eastern Europe” 2023, no. 1, vol. 26, pp. 7–20, <https://doi.org/10.18778/1508-2008.26.01>; A. Matras-Bolibok, P. Bolibok, *Innovation policy and national innovation system: Evidence from Poland*, [w:] *Modeling economic growth in contemporary Poland*, E. Bukalska, T. Kijek, B.S. Sergi (red.), Bingley 2023, pp. 145–160, <https://doi.org/10.1108/978-1-83753-654-220231010>

- ¹¹ T. Yigitcanlar, R. Adu-McVie, I. Erol, *How can contemporary innovation districts be classified? A systematic review of the literature*, “Land Use Policy” 2020, vol. 95, art. 104595, <https://doi.org/10.1016/j.landusepol.2020.104595>; A. Morisson, *Innovation districts: A toolkit for urban leaders*, [b.m.] 2015, ISBN 978-1-51534-062-1

Several fundamental dimensions of this concept offer significant analytical utility for post-coal regional transformation:

- 1) **Spatial Proximity:** Geographic co-location significantly lowers communication and transaction costs, encourages serendipitous informal exchange, and accelerates inter-organisational network formation. In post-coal contexts, intentional spatial proximity can bridge institutional silos that historically operate in isolation—connecting municipal local governments, vocational schools, technical universities, transforming energy utilities, engineering SMEs, regional labour offices, civil society organisations, and land remediation authorities.
- 2) **Anchor Institutions:** Anchor organisations provide proximate environments with operational stability and strategic momentum. Whereas metropolitan districts rely predominantly on research-intensive universities, teaching hospitals, or digital technology multinationals, post-coal anchors frequently encompass technical colleges, municipal utilities, regional development agencies, brownfield asset managers, technology transfer centres, or legacy industrial enterprises undertaking decarbonisation. Their transformative relevance derives from their capacity to commit long-term capital, legitimise collective strategic agendas, and convene regional networks, rather than from academic prestige alone.

- 3) **Physical and Economic Convergence:** The spatial design of the built environment—incorporating specialised laboratories, pilot testing facilities, co-working spaces, advanced vocational workshops, modern digital infrastructure, and quality public spaces—directly structures how actors interact. In post-coal territories, this physical dimension is inseparable from the reclamation and adaptive re-use of post-mining and post-energy real estate. Decommissioned mining complexes, power stations, and associated brownfields can support low-carbon industrial experimentation, technical re-skilling, and green manufacturing only when spatial remediation is directly coupled with viable economic functions.
- 4) **Transformative Transition Narratives:** Where public and political discourse is dominated by themes of industrial decline, employment loss, and socio-economic vulnerability, a tangible innovation district can provide a visible spatial signal that the region is actively cultivating future-oriented industrial capabilities rather than merely managing terminal contraction. However, such signaling retains developmental credibility only when it is underpinned by verifiable job creation, accessible upskilling programmes, modernised infrastructure, and broad civic participation; absent these material founda-

tions, strategic narratives degenerate into superficial place-branding exercises.

For the analytical purposes of this monograph, the innovation district concept is deliberately adapted and contextualised. A **post-coal innovation district** is defined as *a territorially anchored, place-based configuration of re-used industrial land, institutional networks, physical and energy infrastructure, enterprises, and civil society actors, designed to coordinate green technological innovation, workforce upskilling and transition, brownfield site redevelopment, and regional path creation*. This operational definition shifts the construct from an exclusive urban technology enclave to an integrated institutional mechanism for transformative regional development.

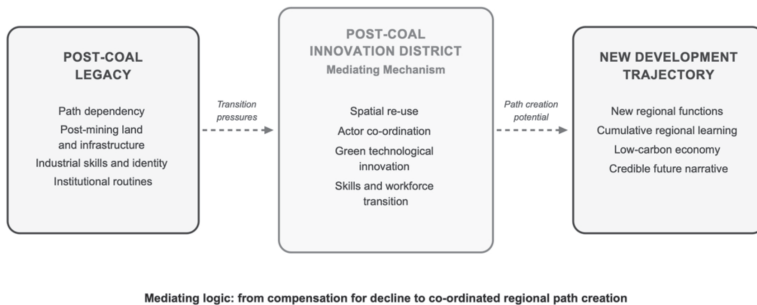


Figure 2.1. The innovation district as a mediating mechanism between post-coal legacy and a new regional development trajectory

Note: Dashed arrows indicate hypothesised relationships for empirical testing rather than verified causal effects.

Source: Own elaboration based on regional innovation systems, innovation district and just transition literature.

This adapted conceptualisation circumvents a prevalent misconception. A post-coal innovation district need not constitute a single, compact urban core modelled on metropolitan archetypes. Instead, it may adopt a polycentric configuration, span multiple non-contiguous sites, or be embedded within smaller, polycentric regional settlement structures. Crucially, analytical and strategic focus must be directed not towards the morphological or architectural form of the district, but towards its territorial and institutional co-ordinating function. Its primary imperative is to systematically connect brownfield spatial re-use with economic renewal, cumulative institutional learning, and climate-neutral structural transformation.

2.4. Critical Perspectives on Innovation Districts

The innovation district concept must be approached with critical circumspection. Critical urban and geographical scholarship has demonstrated that innovation districts can become exclusionary, speculative, and excessively reliant on commercial real-estate development. Such initiatives risk inflating local land values and driving gentrification without yielding substantive socio-economic dividends for established host communities. Furthermore, they frequently attract highly skilled, mobile human capital whilst failing

to generate viable employment pathways or social mobility for resident populations. In many instances, the discursive rhetoric of ‘innovation’ is mobilised to legitimise urban renewal schemes characterised by negligible public value, privileging conspicuous, high-cost physical infrastructure over enduring institutional capacity building¹².

These critical considerations are especially salient in post-coal regions. In these territories, the social legitimacy of the transition trajectory hinges fundamentally upon whether affected communities perceive credible developmental prospects for their own livelihoods and local economies. Should an innovation district be perceived as an exogenous enclave designed predominantly for corporate investors, external consultants, or transient professionals, it risks exacerbating historical distrust and regional alienation. Similarly, redeveloping post-mining land without directly engaging local employment structures, occupational identities, and existing skills capabilities reinforces perceptions of an externally imposed, top-down transition. Consequently, the efficacy and success of a post-coal innovation district cannot be evaluated solely through aggregate investment volumes, start-up incubation counts, or the construction of signature architectural real estate.

¹² C.M. Kayanan, *A critique of innovation districts...*, op.cit.; J. Drucker, C.M. Kayanan, *Innovation districts...*, op.cit., pp. 802–834.

A rigorous critical framework necessitates examining who captures the economic value generated by the district, who participates meaningfully in its governance architectures, and how the district integrates functionally with the broader regional economy. While an innovation district is geographically demarcated, its developmental impacts must not remain spatially enclosed. It must establish robust functional linkages with indigenous enterprises, vocational training systems, municipal authorities, displaced industrial workers, and communities affected by coal phase-out. Moreover, it must be strategically aligned with wider regional innovation and industrial policies rather than operating as an isolated, self-referential flagship project. The fundamental risk is the emergence of a high-profile 'showcase' enclave that masks persistent regional structural crises, including chronic unemployment, low indigenous innovation capacity, and institutional fragmentation.

For this reason, this monograph conceptualises social and territorial inclusion as an intrinsic, constitutive dimension of the post-coal innovation district rather than an optional social add-on. Inclusion does not require every enterprise or facility within the district to absorb former coal workers directly. Rather, it demands deliberate institutional design that establishes accessible pathways through which regional stakeholders can participate in emerging economic opportunities. Such pathways encompass:

- a) Targeted vocational re-skilling and technical qualification programmes;
- b) Local supply-chain development initiatives and local procurement mandates;
- c) Collaborative applied research partnerships connecting regional enterprises and academic bodies;
- d) Institutionalised community consultation and participatory planning mechanisms;
- e) Universal public transport connectivity and affordable enterprise workspaces;
- f) Dedicated institutional interfaces aligning innovation agendas directly with pressing regional needs.

The governance architecture is equally pivotal. Innovation districts are inherently multi-actor, multi-scalar endeavours that demand intensive co-ordination among regional and local public authorities, higher education and research institutions, industrial enterprises, civil society organisations, private investors, and innovation intermediaries. Triple, Quadruple, and Quintuple Helix models are analytically instructive here, demonstrating that systemic innovation emerges from recursive interactions across institutional spheres rather than from unilateral interventions. In post-coal transition contexts, however, helix dynamics must be explicitly coupled with strategic transition governance. Public authorities cannot retreat into passive market facilitation under the assumption that relational

networks will spontaneously self-organise. Instead, the state must actively convene disparate actors, mitigate commercial and technological uncertainty, co-ordinate fragmented funding streams, and establish the institutional conditions necessary for long-term collaboration¹³.

This establishes an essential normative and evaluative benchmark: a post-coal innovation district must be judged by its contribution to regional transformative capacity. This capacity encompasses the ability to nurture green technological innovation, repurpose post-mining land productively, build regional institutional thickness, integrate vulnerable communities, upskill the regional labour force, and open viable developmental pathways beyond fossil fuels. Devoid of these functions, an innovation district remains little more than a spatial branding label; endowed with them, it can serve as a robust institutional mechanism translating climate-neutrality mandates into transformative regional development practice.

¹³ M. Roman et al., *Quadruple Helix models for sustainable regional innovation: Engaging and facilitating civil society participation*, “Economies” 2020, no. 2, vol. 8, art. 48, <https://doi.org/10.3390/economies8020048>; C. Rapetti et al., *Development of innovation districts: A performance assessment*, “Triple Helix” 2023, no. 1, vol. 10, pp. 77–124, <https://doi.org/10.1163/21971927-bja10040>

2.5. Adapting Innovation Districts to Post-Coal Regions

Adapting the innovation district concept to post-coal regions demands a fundamental shift in analytical and operational focus. In metropolitan settings, innovation districts are primarily justified by pre-existing agglomerations of knowledge-intensive firms, highly skilled talent, and elite research institutions. In post-coal environments, the underlying developmental challenge is qualitatively different: the district must serve as a catalytic vehicle enabling a territory to transition from inherited carbon lock-in and mono-industrial dependence towards diversified economic functions. Consequently, it represents less a reflection of pre-existing innovation density and more a strategic instrument for building systemic innovation capabilities over time.

This contextual adaptation operates across several core dimensions:

- 1) **Land Assets and Infrastructure:** Post-coal regions frequently contain extensive tracts of degraded, underutilised, or legally and institutionally complex brownfield land. Decommissioned open-cast and deep mines, spoil heaps, dedicated rail corridors, industrial buildings, high-voltage grid connections, and heavy energy infrastructure present severe structural liabilities as well as unique developmental oppor-

tunities. Strategic spatial re-use must transcend basic environmental remediation or speculative commercial conversion by systematically coupling these legacy assets with renewable energy deployment, circular economy activities, environmental monitoring technologies, advanced industrial modernisation, specialised research and training facilities, digital infrastructure, and pilot-scale experimental production. Scholarship on green innovation and post-mining redevelopment provides the analytical tools required to operationalise this spatial-environmental nexus¹⁴.

- 2) **Human Capital and Industrial Skills:** The translation of human capital requires a similarly tailored approach. Coal-dependent territories possess deeply embedded technical competences, resilient occupational identities, and tacit industrial knowledge that abstract metropolitan innovation frameworks routinely undervalue. Capabilities in precision engineering, industrial maintenance, operational safety, heavy logistics, and automated process management

¹⁴ I. Bashynska et al., *Green innovation in Central and Eastern Europe*, Abingdon–New York 2025, <https://doi.org/10.4324/9781003492771>; S. Greiving, D. Gruehn, C. Reicher, *The Rhenish coal-mining area—Assessing the transformational talents and challenges of a region in fundamental structural change*, “Land” 2022, no. 6, vol. 11, art. 826, <https://doi.org/10.3390/land11060826>

constitute vital transition assets when vocational education providers, applied research centres, industrial enterprises, and regional labour-market agencies deliberately align them with emerging low-carbon sectors. Workforce upskilling and transition thus constitute an integral component of regional innovation capacity rather than an ancillary socio-political afterthought.

- 3) **Multi-Level Institutional Co-ordination:** Supranational (EU), national, regional, and municipal bodies govern disparate funding instruments, decarbonisation mandates, industrial policy programmes, labour-market active measures, and statutory spatial planning frameworks. An adapted innovation district can render this fragmented policy landscape operational by anchoring strategic responsibilities and capital resources in concrete territorial investments, accountable anchor institutions, and bounded spatial sites.
- 4) **Spatial Scale and Polycentricity:** The appropriate spatial scale of a post-coal innovation district cannot be determined *a priori*. A single urban neighbourhood or municipal core is often too constrained for medium-sized or polycentric post-coal basins, where physical assets, labour commuting catchments, and transition burdens span multiple contiguous

municipalities. Instead, the district may function as a networked, polycentric regional platform that links a core strategic site with satellite industrial zones, vocational training hubs, applied research facilities, and affected peripheral settlements. While such a territorial configuration deviates from the hyper-dense, compact morphology of metropolitan models, it achieves far greater systemic embeddedness within the regional economy.

The ultimate developmental test is whether climate-neutrality mandates are systematically coupled with the generation of new indigenous regional capacities. Decarbonisation targets can successfully reduce carbon emissions while regional economic functions and industrial output continue to hollow out. A post-coal innovation district is analytically and practically meaningful only if it helps delineate what economic activities the region can master following coal phase-out, while systematically bridging those emerging specialisations with regional capabilities, supportive institutions, and evolving market demand. In this manner, the construct operates as an essential conceptual and policy bridge between climate mitigation directives and regional economic development policy.

Within the context of Poland and Central and Eastern Europe, this adapted framework serves as an analytical lens and strategic heuristic rather than a universalised, off-the-shelf

blueprint. Polish coal territories—including Eastern Wielkopolska, the Upper Silesian Coal Basin, Bełchatów, Wałbrzych, and the Turów–Bogatynia complex—exhibit markedly diverse configurations of fossil-fuel dependence, institutional thickness, fiscal autonomy, and brownfield redevelopment complexity. Wider European reference contexts, such as Lusatia, the Ústí Region, Stara Zagora, the Irish Midlands, Western Macedonia, and Gorj, further illustrate the profound cross-national diversity in multi-level governance arrangements, labour-market vulnerability, political-economic dynamics, and regional absorptive capacities. While the reviewed academic and policy literature extensively documents these territories, this monograph engages them as theory-led illustrative reference points rather than exhaustive comparative empirical case studies¹⁵.

To prevent conceptual stretching (Sartori, 1970), the proposed post-coal innovation district construct is systematically demarcated from adjacent territorial innovation arrangements. This analytical demarcation pertains directly to the primary unit of analysis, the underlying co-ordinating logic, and the core developmental outcomes to be explained. While an individual regional transformation initiative may hybridise policy instruments across multiple categories, it qualifies analytically as a post-coal innovation district

¹⁵ J. Adamska et al., *Raport 1: Identyfikacja...*, op.cit., pp. 13–15; A. Matern et al., *Strategies for energy transition...*, op.cit., pp. 1001–1022.

only when a territorially anchored, place-based platform systematically integrates all five core dimensions: spatial re-use, transition governance, economic renewal, social access, and cumulative regional learning¹⁶.

This comparative demarcation clarifies the distinct added value of the proposed construct. Whereas a regional innovation system provides the overarching institutional setting, an industrial cluster or technology park contributes economic and organisational assets, a living lab supplies experimental methodologies, and a transition platform facilitates strategic governance. In contrast, the post-coal innovation district represents a more demanding and integrative configuration, in which these complementary capacities are directly anchored in specific spatial sites, aligned with the socio-economic needs of affected communities, and systematically coupled with a testable, reviewable framework of regional path creation.

¹⁶ P. Cooke, M.G. Uranga, G. Etxebarria, *Regional innovation systems...*, op.cit., pp. 475–491; T. Yigitcanlar, R. Adu-McVie, I. Erol, *How can contemporary innovation districts be classified?...*, op.cit.; J.M. Valdaliso, C. Andrés, *Science and technology parks as evolving policy instruments: Challenges when embracing the innovation district model*, “European Planning Studies” 2025, no. 4, vol. 33, pp. 646–664, <https://doi.org/10.1080/09654313.2025.2490119>; S. Fastenrath et al., *Mission-oriented innovation districts...*, op.cit., pp. 4–12; J. Schot, W.E. Steinmueller, *Three frames for innovation policy...*, op.cit., pp. 1554–1567.

Table 2.1. Analytical distinction between a post-coal innovation district and adjacent territorial innovation concepts

Concept	Primary Unit and Spatial Scale	Organising Logic	Principal Developmental Outcome	Relation to the proposed construct
Post-coal innovation district	A defined site or connected network of sites within a post-coal transition territory	Integration of spatial re-use, multi-level governance, enterprises, skills, social inclusion and cumulative learning around a shared mission	A just and cumulative regional development trajectory beyond coal	The proposed construct: a territorially anchored delivery and cumulative learning platform integrating all five analytical layers
Regional innovation system (RIS)	Administrative or functional region (macro or meso-scale)	Systemic relations among enterprises, research and higher education organisations, public authorities and intermediaries	Regional innovation capabilities and absorptive learning capacity	Provides the wider institutional setting; does not require a spatially bounded delivery platform or a dedicated post-coal transition mission
Cluster	Sectoral concentration, specific technology domain or value chain in a territory	Industrial specialisation, agglomeration economies and inter-firm linkages	Competitiveness, productivity and sectoral growth	May constitute the economic layer, but does not inherently integrate spatial remediation, transition justice, public purpose, or cumulative territorial learning
Science or technology park	Demarcated campus, property development, or managed industrial estate	Real-estate management, shared commercial facilities, and spatial research-industry proximity	Technology commercialisation, enterprise support, and inward investment attraction	Can function as an anchor institution or policy instrument; it is not in itself an integrated post-coal transformation mechanism
Living lab	Real-world experimental environment, municipal facility, or user network	User-centred co-creation, socio-technical prototyping, and iterative learning	Prototyping, validation, and user testing of innovative solutions	Provides experimental methodologies and testbeds; does not co-ordinate statutory spatial planning, transition finance, or regional path creation
Transition platform	Multi-actor and multi-scalar policy arena (regional, national, or EU level)	Strategic visioning, stakeholder consultation, and co-ordination of transition policy instruments	Governance of decarbonisation agendas, procedural justice, and policy alignment	Provides strategic governance and institutional dialogue; becomes district-like only when anchored in physical brownfield sites, innovation functions, and cumulative learning

Source: Author's own elaboration based on the literature on regional innovation systems, innovation districts, science and technology parks, living labs, and transformative innovation policy.

2.6. Strategic Spatial Planning and the Evolution of District Policy Instruments

Scholarship on innovation districts frequently takes as its starting point the co-location of economic, physical, and networking assets. While this tripartite formulation helpfully catalogues what a district contains, it does not fully elucidate how statutory land-use decisions, infrastructure phasing, and regional innovation policies become integrated in practice. Kalliomäki, Oinas, and Salo address this lacuna by conceptualising the innovation district as a strategic urban project. They argue that a district's physical built form and its innovation functions must be planned in tandem, necessitating both horizontal integration across sectoral policy domains and vertical integration across tiers of multi-level governance. Strategic spatial planning is therefore not merely an aesthetic or physical supplement to regional economic policy; it constitutes an active co-ordination practice through which disparate sectoral objectives achieve coherent territorial expression¹⁷.

The evidentiary foundation for this argument is derived from a qualitative single-case study of the Turku Science

¹⁷ H. Kalliomäki, P. Oinas, T. Salo, *Innovation districts as strategic urban projects: The emergence of strategic spatial planning for urban innovation*, „European Planning Studies” 2024, no. 1, vol. 32, pp. 89–92, <https://doi.org/10.1080/09654313.2023.2216727>

Park in Finland. The empirical investigation drew upon twelve semi-structured interviews conducted in 2017–2018 with fourteen policy-makers, municipal administrators, and technical experts, triangulated with municipal planning documentation. The empirical material was coded across nine substantive themes—encompassing urban spatial structure, universities, enterprises, relational networks, housing and leisure amenities, historical trajectory, development concepts, implementation challenges, and the *Turku Science Park Masterplan 2050*—before being interpreted through the strategic-urban-project framework. This research design yields granular process knowledge and institutional actor perspectives rather than a counterfactual or quantitative assessment of the master plan’s developmental outcomes¹⁸.

The Turku case is analytically instructive because the science-park precinct did not originate as an empty, branded spatial *tabula rasa*. By the period under examination, the area concentrated approximately 400 enterprises, five higher education institutions, 35,000 students, 17,500 employees, and, by 2019, roughly 8,500 residents. Five distinct sectoral clusters were present, spanning maritime and advanced manufacturing industries, life sciences and health, the bioeconomy and circular economy, cleantech, and digital

¹⁸ Ibidem.

media and tourism. This diversity shifted the strategic spatial planning challenge from supporting a single specialised cluster towards facilitating cross-sectoral synergies among diverse clusters, anchor institutions, local residents, and the wider urban fabric. The case thus demonstrates why a district's transformative innovation function cannot be deduced merely from the sheer aggregate of organisations located within its perimeter¹⁹.

The adoption of the 2017 master plan marked a pivotal juncture, convening actors across multiple policy sectors and administrative tiers, alongside civic groups, within a shared strategic visioning process. However, the institutional preconditions for this integration were constructed incrementally through formal and informal relational networks. Distributed leadership, collaborative deliberative arenas, and administrative restructuring evolved cumulatively over time, while municipal capacities for spatially informed strategic leadership matured alongside the project. In this perspective, institutional co-ordination is fundamentally path-dependent: a strategic master plan can consolidate relational networks and provide spatial directionality, but it cannot instantaneously generate the mutual trust, institutional routines, and administrative competences upon which effective implementation depends²⁰.

¹⁹ Ibidem.

²⁰ Ibidem.

The case also illuminates an underlying legitimacy deficit frequently obscured by celebratory innovation district discourse. While the vision-building process broadened stakeholder participation, strategic rationality channelled deliberations primarily towards the efficient delivery of pre-set municipal objectives, circumscribing debate around conflicting community interests or alternative development priorities. Furthermore, the non-binding visionary master plan required formal translation through statutory spatial planning instruments and detailed regulatory decisions. Consequently, strategic visioning and statutory land-use regulation risked decoupling, requiring distinct administrative departments to actively assume ownership of the collective agenda. This insight is highly pertinent to post-coal territories, where land-use decisions are inherently distributional; here, meaningful procedural inclusion cannot be substituted by tokenistic consultation regarding predetermined investment concepts²¹.

A complementary perspective is provided by Valdaliso and Andrés, who analyse science and technology parks as policy instruments that co-evolve with regional innovation strategies. Their examination of the Basque Country demonstrates an evolutionary trajectory: advancing from initial property-led infrastructure designed to attract

²¹ Ibidem.

manufacturing enterprises, through a technology-park model integrated within the regional innovation system, towards a multi-park, multi-campus network that encompasses the Zorrotzaurre urban innovation district in Bilbao. The analytical value of this perspective is distinctly temporal: the innovation district is conceptualised not as a *de novo* intervention, but as a subsequent developmental stage in the strategic adaptation of an incumbent intermediary, its institutional mission, and its territorial reach²².

Methodologically, their study combines process tracing and sequence analysis of policy programmes, strategic master plans, media reports, and archival documentation with ten semi-structured interviews across the Basque Technology Parks Network, Bilbao City Council, the Zorrotzaurre Management Board, and newly established district tenant organisations. The authors report independent qualitative coding of interview transcripts, inter-coder comparison, and data triangulation across documentary sources and key informants. Nonetheless, they explicitly characterise the Bilbao initiative as an emergent, early-stage project; while the empirical evidence effectively identifies governance friction and implementation bottlenecks, it cannot yet evaluate the district's long-term socio-economic impacts²³.

²² Ibidem.

²³ J.M. Valdaliso, C. Andrés, *Science and technology parks as evolving policy instruments...*, op.cit., pp. 651–652.

Three critical challenges emerge when an incumbent science and technology park transitions towards an urban district model:

- 1) **Governance Complexity:** The entry of municipal authorities, private land developers, and urban planning agencies into a policy domain historically steered by regional industrial and innovation authorities;
- 2) **Brownfield Redevelopment Liabilities:** The structural shift from low-complexity greenfield or suburban campuses to complex brownfield regeneration, which escalates upfront capital expenditure and exposes the initiative to protracted statutory planning and municipal budgetary cycles;
- 3) **Inter-Site Strategic Alignment:** The imperative to ensure that the urban district functions complementarily rather than cannibalising existing technology parks within the wider regional portfolio.

In Bilbao, this alignment process spanned fifteen years from initial exploratory discussions to the formal 2022 partnership agreement, illustrating the profound discrepancy between promotional narratives of rapid district creation and the protracted timeframe required for institutional convergence²⁴.

²⁴ Ibidem.

Taken together, the Turku and Bilbao studies substantiate a more precise conceptualisation of the innovation district as a spatially expressed policy arrangement. Its transformative capacity does not reside solely in physical buildings, enterprise counts, or individual anchor organisations, but in the sustained ability to align land-use planning, economic development functions, long-term financing, and multi-level public authority over time. This interpretation introduces an explicit planning mechanism into regional innovation system theory and a temporal mechanism into the asset-based innovation district literature. It also explains why a post-coal district may fail even when its designated site and technological specialisation appear viable: the statutory planning system and the regional innovation system frequently operate with conflicting mandates, divergent administrative calendars, and competing standards of legitimacy.

For post-coal regions, this evidence must be translated with analytical caution. Neither case involves fossil-fuel phase-out, and both are situated within institutionally robust metropolitan settings. Their transferable value lies not in providing an off-the-shelf blueprint, but in supplying a structured set of diagnostic questions for empirical investigation:

- a) Which institutional actors possess the mandate and legitimacy to integrate spatial planning and regional innovation strategies?
- b) Which relational networks and administrative competences must be established before a strategic district plan becomes operationally implementable?
- c) Through which formal mechanisms will broad strategic objectives be translated into binding statutory land-use decisions?
- d) What financial and land-assembly mechanisms can support substantial brownfield remediation costs without subordinating public purpose to private real-estate value capture?

These questions define essential institutional preconditions for empirical testing in post-coal territories rather than baseline guarantees of project success.

2.7. Chapter Conclusion

Innovation districts are analytically and practically valuable for post-coal regional transformation only when they are fundamentally reinterpreted as territorially embedded, multi-scalar, and socially accountable mechanisms of path creation. Their overarching purpose is to systematically bridge brownfield spatial re-use, multi-level institutional

co-ordination, green technological innovation, and work-force skills transitions—rather than replicating generic, metropolitan high-technology templates.

The empirical evidence on strategic spatial planning and evolving policy instruments establishes a critical design imperative: physical form and regional innovation functions must be harmonised through cumulative institutional capacity building, robust statutory planning alignment, and long-term financing architectures calibrated to brownfield implementation. Within this integrated framework, climate neutrality, environmental remediation, and the creation of new regional economic functions constitute inherently interdependent dimensions of post-coal territorial transformation.

CHAPTER III

CLIMATE NEUTRALITY, GREEN INNOVATION, AND POST-MINING REDEVELOPMENT

3.1. Climate Neutrality as a Territorial Development Challenge

For post-coal regions, achieving climate neutrality constitutes not only a technical emissions reduction target but also a profound territorial development challenge. The decommissioning of mines and thermal power stations fundamentally reshapes regional employment structures, local public finances, land-use patterns, physical infrastructure, and socio-cultural identities. Because decarbonisation and regional development are not intrinsically synonymous, territorial emissions may decline primarily as a consequence of economic contraction and industrial closure, leaving the region structurally fragile and economically vulnerable. Long-term regional renewal becomes attainable

only when decarbonisation is systematically coupled with technological and social innovation, workforce re-skilling, brownfield spatial re-use, and multi-scalar institutional co-ordination.

Scholarship on just transitions has firmly established the necessity of place-based policy support, broad stakeholder participation, and the equitable distribution of transition costs. However, the inherent boundaries of this literature bring the central analytical question of this monograph into sharp relief: while compensatory funding and distributional justice mechanisms can mitigate immediate socio-economic harm, they cannot in themselves determine, generate, or scale the new economic functions required to sustain a diversified regional economy. Climate neutrality is therefore conceptualised as an overarching framework condition; regional strategy must operationalise this mandate through strategic choices concerning re-usable physical and infrastructural assets, redirected industrial competences, co-ordinating governance institutions, and viable green innovation niches²⁵.

²⁵ M. Peretto, W. Eichhammer, D. Süsser, *Just energy transition in coal regions: Innovative framework for assessing territorial just transition plans*, “Renewable and Sustainable Energy Transition” 2025, vol. 7, art. 100101, <https://doi.org/10.1016/j.rset.2024.100101>; A. Schuster et al., *The unjust just transition? Exploring different dimensions of justice in the lignite regions of Lusatia, Eastern Greater*

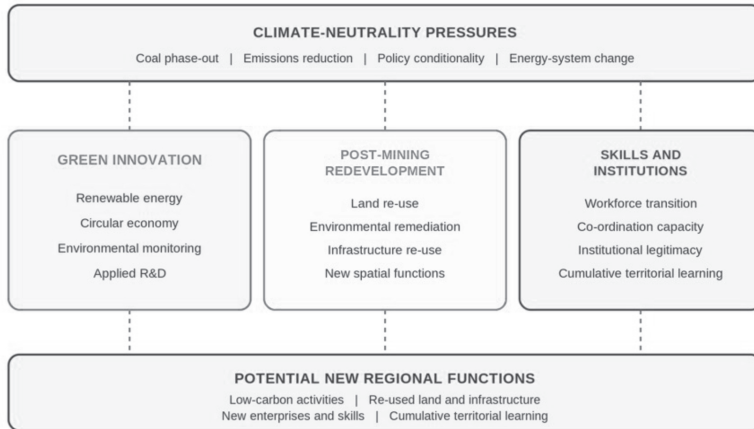


Figure 3.1. Heuristic configuration linking climate-neutrality pressures, transformation domains, and potential new regional functions

Source: Author's own elaboration based on the reviewed literature.

3.2. From Decarbonisation to Green Innovation

Green technological and eco-innovation constitutes the foundational conceptual bridge linking climate-neutrality imperatives with long-term regional renewal. In conventional, narrow formulations, green innovation denotes specific technologies, products, or processes designed to mitigate adverse environmental externalities. Within post-coal transition contexts, however, the construct must

be conceptualised far more broadly. It encompasses an integrated spectrum of technological, organisational, infrastructural, and social transformations that collectively steer regional economies towards low-carbon development pathways whilst simultaneously generating novel economic capabilities and institutional thickness.

Empirical and theoretical scholarship on eco-innovation across Central and Eastern Europe demonstrates that regional green innovation performance must be appraised with analytical caution. While an expanding body of literature investigates green growth and patenting dynamics in the CEE macro-region, these studies consistently highlight acute territorial disparities, deep-seated institutional constraints, and structural misalignments between national policy frameworks and sub-national regional innovation systems. This disparity is critically salient for post-coal territories, which routinely operate from a position of relative structural disadvantage compared to metropolitan knowledge hubs. Although they frequently possess robust engineering competencies and specialised utility infrastructure, they are encumbered by fragile research-commercialisation interfaces, thin entrepreneurial ecosystems, and a scarcity of intermediary institutions capable of orchestrating transition-oriented innovation ecosystems²⁶.

²⁶ Ibidem.

Consequently, green innovation in post-coal territories cannot be conflated with the mere physical deployment of renewable energy installations. Renewable energy infrastructure certainly represents an indispensable pillar of regional restructuring—particularly where post-mining real estate, high-voltage transmission capacities, or industrial heat and power off-take demand can be productively re-used. Nonetheless, establishing a genuine regional development trajectory demands far more than capital-intensive energy hardware installations. It requires deep, systemic linkages to indigenous manufacturing enterprises, workforce qualification pipelines, applied research centres, technical maintenance services, circular economy closed loops, digital environmental monitoring systems, environmental engineering consultancies, and domestic supply chains.

This is precisely where the post-coal innovation district construct established in Chapter 2 provides operational value. An adapted innovation district establishes a coherent spatial and institutional arena in which green innovation activities, rather than remaining fragmented across atomised subsidy projects, are systematically orchestrated around a visible territorial platform. By spatially and relationally converging applied testing laboratories, advanced vocational workshops, industrial enterprises, public development agencies, remediated post-mining

sites, and community amenities, the district functions as an operational mechanism that converts macro-level climate-neutrality pressures into tangible territorial capability-building.

The overarching developmental risk in this domain is policy and funding fragmentation across disparate European transition funds, national operational programmes, and *ad hoc* sectoral grants. Green innovation contributes meaningfully to regional path creation only when it becomes deeply embedded within regional enterprise networks and public institutions, generates positive capability spillovers, and leaves an enduring institutional legacy of technical competences, collaborative networks, and modernised industrial sites. These criteria guard against technological determinism: the decisive analytical question is not whether an individual capital project is environmentally benign in isolation, but whether it is effectively integrated into cumulative, place-based regional learning.

3.3. Post-Mining Land and Infrastructure as Development Assets

Brownfield real estate and post-mining land assets constitute the most conspicuous physical legacy of prolonged coal dependence. Decommissioned open-cast pits, deep mine

shafts, spoil tips, altered hydrological systems, industrial complexes, dedicated freight rail corridors, high-voltage substation interconnectors, and thermal generation facilities fundamentally delineate the spatial development possibilities of post-coal regions. Historically, these legacy assets have been perceived primarily as structural liabilities, encumbered by complex land ownership regimes, prohibitive environmental remediation costs, geotechnical instabilities, statutory planning constraints, and fragmented administrative jurisdictions. Concurrently, however, they represent vital strategic foundations for new economic specialisations if their reclamation is purposefully coupled with regional innovation strategies and industrial renewal.

Scholarship on post-mining and post-industrial redevelopment underscores that brownfield spatial re-use cannot be conceptualised merely as a technical civil-engineering task or an aesthetic landscape remediation exercise; it represents a core strategic development challenge. Decisions regarding geotechnical stabilisation, ecological renaturation, utility-scale renewable installations, advanced industrial re-use, public civic access, or high-value service functions directly shape how a region reconstructs its socio-economic future. While basic ecological restoration enhances environmental baseline quality, a strategically repurposed industrial site serves as a collaborative platform

for technological experimentation, workforce training, and sustainable economic diversification²⁷.

This spatial-functional nexus is especially critical for innovation districts. In core metropolitan economies, innovation districts typically colonise dense inner-city fabrics endowed with established university campuses, knowledge-intensive firms, and vibrant public realms. In post-coal environments, conversely, the district must frequently be forged through the complex physical re-use and semantic reinterpretation of expansive industrial brownfields. This fundamentally alters the logic of spatial agglomeration: the objective is not to manufacture a fashionable urban consumption quarter, but to structurally interlink inherited industrial land and heavy utility infrastructure with high-productivity, low-carbon economic functions.

Post-mining physical infrastructure additionally introduces a severe temporal sequencing challenge. Certain auxiliary assets (such as administrative headquarters or maintenance depots) may become accessible immediately upon operational closure, whereas open-cast voids, heavy processing plants, and contaminated sludge lagoons become developable only following multi-year decommissioning, geotechnical remediation, hydrological re-stabilisation, and land-title consolidation. A robust regional strategy

²⁷ Ibidem.

must therefore implement rigorous spatial and temporal sequencing. It must establish which locations can accommodate rapid-deployment demonstration projects, which sites demand protracted long-term remediation, and which strategic plots can anchor scale-intensive industrial ecosystems in subsequent phases. Absent such deliberate sequencing, post-mining regeneration risks degenerating into isolated symbolic gestures or opportunistic, real-estate-led land speculation.

To operationalise this sequencing, a functional typology comprising three distinct site categories is proposed:

- 1) **Demonstration Sites:** High-visibility, low-complexity plots where targeted early interventions (such as pilot solar-plus-storage demonstrators or circular testbeds) can tangibly demonstrate transition feasibility, build public confidence, and establish early momentum.
- 2) **Platform Sites:** Intermediate-scale brownfield hubs designed to host shared multi-tenant infrastructure, advanced technical training colleges, applied R&D testing facilities, enterprise incubators, and business support intermediaries.
- 3) **Trajectory Sites:** Large-scale, structurally transformative industrial zones capable of accommodating major low-carbon manufacturing clusters, utility-scale circular industrial symbiosis, or clean-technology

gigafactories that alter the region's aggregate economic trajectory over the medium to long term.

While a post-coal innovation district may incorporate and interconnect all three spatial typologies, regional planners must not conflate their distinct developmental functions. Early, high-visibility demonstration projects provide vital symbolic and political value, yet their strategic utility remains contingent on their systematic integration into a broader, enduring architecture of regional capability-building.

This typology further militates against a reductionist brownfield perspective. Conventional urban planning often frames brownfield redevelopment strictly as the technical reclamation of degraded terrain. In coal-dependent regions, however, industrial land carries immense socio-economic, symbolic, and cultural significance. It embodies the historical carbon-intensive development path, yet simultaneously represents the spatial arena wherein alternative developmental trajectories must be materialised. Consequently, post-mining spatial re-use must be conceptualised not merely as a physical engineering intervention, but as a strategic narrative and institutional act: it renders visible and credible what the region aspires to become.

The fundamental conceptual takeaway is that brownfield spatial re-use must be directly coupled with regional path creation. A post-mining site cannot be appraised

solely on physical or fiscal criteria—whether it has been remediated, backfilled, landscaped, or privatised. Rather, it must be evaluated on its substantive contribution to the cultivation of dynamic regional capabilities:

- a) Does the site attract, nurture, and anchor innovative low-carbon enterprises?
- b) Does it supply critical shared infrastructure for applied green technological innovation?
- c) Does it bridge legacy industrial competencies with emerging clean-technology domains?
- d) Does it generate democratic legitimacy, civic pride, and societal trust in the just transition process?

By integrating these evaluative criteria, post-mining land remediation ceases to be an isolated environmental chore and becomes a cornerstone of transformative regional development policy.

3.4. Linking Environmental Repair, Innovation, and New Regional Functions

The structural transformation of post-coal regions necessitates the simultaneous, multi-scalar integration of environmental remediation, economic diversification, social equity, and institutional renewal. Environmental repair is an indispensable prerequisite, yet when conducted

in isolation from economic renewal, it yields ecological restoration without generating viable developmental trajectories. Technological innovation is equally essential, but if detached from physical land assets, local labour markets, and regional institutions, it remains socially thin and structurally footloose. Similarly, regional development policy is vital, but when uncoupled from concrete brown-field sites, targeted capital investments, and realistic spatial sequencing, it remains an abstract strategic aspiration. The central analytical and policy imperative is therefore one of systemic integration.

The theoretical frameworks of transformative innovation policy (TIP) and evolutionary path creation provide the requisite analytical tools to structure this integration. These literatures demonstrate that contemporary innovation policy must explicitly address grand societal challenges, cultivate real-world experimental arenas, mobilise distributed institutional agency, and actively create the market and institutional conditions necessary for path branching and new path creation. This perspective is uniquely suited to post-coal territories, where transition cannot be achieved through spontaneous market adjustments alone. Instead, it demands purposeful public leadership, strategic co-investment, cross-sectoral policy co-ordination, and the

creative recombination of inherited territorial assets with cutting-edge external knowledge²⁸.

In operational terms, post-coal regions can systematically align climate-neutrality mandates with transformative regional renewal across several interconnected functional domains:

- 1) **Ecological Remediation and Ecosystem Services:** Transforming degraded post-mining landscapes into platforms for biodiversity restoration, environmental monitoring testbeds, and ecological tourism assets.
- 2) **Renewable Energy Infrastructure as Strategic Anchors:** Deploying utility-scale solar photovoltaics, wind energy, geothermal extraction from flooded mine shafts, and green hydrogen hubs as foundational power sources that anchor energy-intensive green manufacturing and technical training.
- 3) **Industrial Brownfield Adaptive Re-Use:** Converting decommissioned power stations, workshops, and railheads into shared pilot facilities, circular economy symbiosis hubs, materials-testing laboratories, and low-carbon business incubators.
- 4) **Workforce Capability Re-Alignment:** Synchronising regional vocational curricula, apprenticeship

²⁸ J. Schot, W.E. Steinmueller, *Three frames for innovation policy...*, op.cit., pp. 1554–1567; M. Grillitsch, B.T. Asheim, M. Trippl, *Unrelated knowledge combinations...*, op.cit., pp. 257–274.

schemes, and polytechnic programmes with the technical requirements of expanding clean-technology sectors.

- 5) **Strategic Transition Governance and Procurement:** Mobilising public procurement of innovation (PPI), proactive spatial zoning, and aligned multi-level funding streams to incubate and de-risk emerging regional green specialisations.

The overarching policy logic is inherently integrative: environmental remediation, green technological innovation, workforce capability building, brownfield spatial re-use, and multi-level governance generate substantially greater transformative value when orchestrated collectively rather than pursued in isolation. While compensatory measures for displaced workers, vulnerable municipalities, and host communities remain indispensable, the imperative of regional path creation introduces a forward-looking, generative test: what indigenous competences, relational networks, re-usable physical assets, and strategic future options does a given policy intervention create? For instance, co-locating an advanced technical training facility upon a remediated brownfield site simultaneously mitigates immediate labour-market displacement costs whilst functionally anchoring emerging green economic specialisations.

Table 3.1. Functions of green innovation and post-mining redevelopment in post-coal regional transformation

Transformation Function	Substantive Meaning in a Post-Coal Context	Illustrative Instruments and Strategic Activities	Structural Risk of Narrow Implementation
Environmental repair	Mitigating and eliminating the physical, ecological, and geotechnical liabilities of legacy mining and energy infrastructure.	Contaminated land remediation, ecological restoration, hydrological re-stabilisation, brownfield re-use.	Remediation is managed purely as a regulatory compliance cost rather than a strategic foundation for new regional functions.
Green innovation	Fostering and scaling novel low-carbon products, circular industrial processes, and eco-services aligned with climate neutrality.	Renewable energy generation, circular economy loops, environmental monitoring systems, applied R&D testbeds.	Clean-technology projects remain isolated showcase enclaves, detached from indigenous enterprise networks and local capabilities.
Skills and labour transition	Systematically reconnecting inherited industrial competences and technical know-how with emerging low-carbon economic activities.	Vocational re-skilling, advanced technical qualification programmes, applied demonstration laboratories, supply-chain upgrading.	The territory achieves technical decarbonisation whilst displaced industrial workers and host communities remain economically disenfranchised.
Spatial reconfiguration	Repurposing post-mining land, decommissioned industrial premises, and energy infrastructure into productive developmental assets.	Post-coal innovation districts, mixed-use brownfield regeneration, high-capacity transport and grid interconnections.	Physical sites undergo cosmetic or property-led conversion without altering or upgrading the underlying regional development trajectory.
Institutional coordination	Harmonising multi-level climate mandates, regional economic strategies, statutory spatial planning, and innovation support schemes.	Multi-stakeholder transition platforms, accountable anchor institutions, local-regional governance coalitions, aligned funding packages.	Uncoordinated pilot projects proliferate opportunistically without coalescing into a coherent, place-based territorial strategy.

Source: Author's own elaboration based on the literature reviewed in Chapter 3.

3.5. Geography of Sustainability Transitions

Sustainability transitions are inherently spatially uneven rather than territorially neutral. Institutional settings, natural resource endowments, physical infrastructures, actor networks, and political priorities vary widely across locations, whilst transition processes simultaneously connect local nodes to national and transnational systems. Economic-geographical research therefore posits two critical imperatives for an integrated post-coal framework: sustained attention to the specific territorial embedding of socio-technical change, and an explicitly multi-scalar account of how knowledge, finance, regulation, and markets are mobilised and flow across territories²⁹.

This perspective qualifies the conceptualisation of an innovation district as a purely experimental setting. A re-used mine site, energy campus, or municipal test-bed may provide necessary shelter for experimentation, but it does not automatically function as a transformative transition niche. Its strategic significance remains

²⁹ L. Coenen, P. Benneworth, B. Truffer, *Toward a spatial perspective on sustainability transitions*, „Research Policy” 2012, no. 6, vol. 41, pp. 968–979, <https://doi.org/10.1016/j.respol.2012.02.014>; T. Hansen, L. Coenen, *The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field*, “Environmental Innovation and Societal Transitions” 2015, vol. 17, pp. 92–109, <https://doi.org/10.1016/j.eist.2014.11.001>.

contingent upon the socio-technical regime conditions it confronts, the specific institutions that protect or contest these experiments, and the relational routes through which local learning influences wider infrastructure deployment, public procurement, workforce skills, or industrial practice. The relevant unit of analysis is therefore the systemic relationship between the experimental site and the wider territorial configuration, not the physical site in isolation.

Place specificity additionally raises critical challenges regarding the policy and technological transfer problem. Similar clean technologies can follow widely divergent trajectories where underlying factors such as land ownership structures, labour markets, municipal finance, public trust, or access to external knowledge differ significantly. Conversely, a peripheral region may successfully compensate for limited local organisational density through durable relational links to research, supplier, and policy networks elsewhere. The geography of sustainability transitions consequently directs empirical investigation towards both endogenous local conditions and relations across geographical scales, rather than treating either spatial proximity or external connectivity as sufficient prerequisites³⁰.

For the proposed analytical model, these implications are distinct and operationally concrete. The spatial layer

³⁰ Ibidem.

must record precisely where experiments and environmental liabilities are located; the institutional layer must identify the specific scales at which strategic decisions and financial resources are controlled; and the learning layer must specify how results may diffuse or become territorially embedded. An innovation district claim would be fundamentally weakened if local experimentation remained disconnected from the institutions governing the relevant socio-technical system, or if external connections merely generated ephemeral activity without producing locally retained indigenous competences.

3.6. Governance Conditions for Climate-Neutral Regional Renewal

The multifaceted integration delineated above demands robust governance capacity. Post-coal regional transformation implicates multiple policy domains: climate policy, energy policy, regional economic development, innovation policy, labour-market policy, land-use planning, environmental remediation, and local public service provision. These diverse domains are frequently managed by disparate institutions and financed through distinct instruments. Absent rigorous co-ordination, regions risk facing acute policy overload rather than achieving strategic transformation.

Stakeholder governance mechanisms and helix approaches are pertinent because they emphasise the requisite interaction between public authorities, private firms, universities, civil society, and other critical actors. In post-coal regions, however, these models must be interpreted through the lens of the specific politics of socio-economic transition. The fundamental challenge lies not only in encouraging co-operation in general but in constructing institutional trust around an inherently difficult and spatially uneven process of radical change. Displaced workers, municipalities, and local communities must perceive that new projects are substantively connected to their socio-economic future, not solely to abstract climate targets or external investment narratives³¹.

A resilient governance model for post-coal regional renewal therefore necessitates at least four core capacities. The first is diagnostic capacity: the ability to identify

³¹ E.G. Carayannis, D.F.J. Campbell, *Triple Helix, Quadruple Helix and Quintuple Helix and how do knowledge, innovation and the environment relate to each other? A proposed framework for a trans-disciplinary analysis of sustainable development and social ecology*, “International Journal of Social Ecology and Sustainable Development” 2010, no. 1, vol. 1, pp. 41–69, <https://doi.org/10.4018/jesd.2010010105>; E.G. Carayannis, R. Rakhmatullin, *The Quadruple/Quintuple Innovation Helixes and smart specialisation strategies for sustainable and inclusive growth in Europe and beyond*, “Journal of the Knowledge Economy” 2014, no. 2, vol. 5, pp. 212–239, <https://doi.org/10.1007/s13132-014-0185-8>

territorial assets, specific vulnerabilities, land-use constraints, and innovation potential. The second is convening capacity: the ability to mobilise diverse actors around a shared transition agenda. The third is sequencing capacity: the ability to order projects strategically over time so that early-stage actions systematically create the conditions for later development. The fourth is learning capacity: the ability to rigorously evaluate interventions and dynamically adjust the overarching strategy.

Recent Polish and comparative international studies, alongside key policy reports, are highly instructive in this respect, as they identify concrete regional reference points and acute governance tensions. They demonstrate that post-coal regions diverge significantly in their institutional readiness, social vulnerability, prevailing development narratives, and capacity to effectively utilise transition instruments. In this chapter, these sources are not deployed as comprehensive empirical case studies. Rather, they serve as crucial contextual sources that ensure the conceptual argument remains firmly grounded in the material realities of post-coal territories³².

³² A. Matern et al., *Strategies for energy transition...*, op.cit., pp. 1001–1022; M. Szmytkowska et al., *Top-down policies and bottom-up realities: Governing Europe's just transition in Poland, Bulgaria, and Ireland*, "Energy Research & Social Science" 2025, vol. 130, art. 104429, <https://doi.org/10.1016/j.erss.2025.104429>

This governance perspective also elucidates why innovation districts cannot be conceptualised as purely physical redevelopment projects. A district may physically host buildings, laboratories, and firms, but its transformative potential is entirely contingent upon the governance arrangements that purposefully link those assets to pressing regional needs. The district must function as an institutional platform where climate-neutrality objectives, land redevelopment strategies, innovation support schemes, and social inclusion imperatives can be effectively aligned.

Funding and investment design constitute integral parts of this governance complex. Transition resources frequently arrive through multiple, distinct programmes, each with its own eligibility criteria, temporal horizons, and financial reporting requirements. This fragmentation can inadvertently incentivise regions to assemble disjointed projects around available funding streams rather than pursuing a coherent development sequence. A stronger approach would utilise funding as a strategic co-ordination mechanism: early-phase resources should prepare land, institutions, and skills for subsequent investment, whilst later-phase resources should deepen the capabilities generated in the initial phase. The post-coal innovation district can assist in rendering this necessary sequence visible and credible because it binds specific projects to a concrete territorial platform.

Governance additionally serves a vital communicative function. Post-coal transformation is inherently contested because it fundamentally alters livelihoods, socio-cultural identities, and expectations of fairness and distributional justice. A climate-neutral strategy that is technically robust but socially illegible may utterly fail to mobilise necessary local support. The governance architecture of a post-coal innovation district should therefore incorporate transparent mechanisms through which local actors can understand, influence, and evaluate the transition trajectory. This does not imply that every decision must be consensual. It means that the new regional trajectory must be made credible through authentic participation, procedural transparency, and visible, verifiable links to regional socio-economic needs.

3.7. Transformative Capacity in Rural and Peripheral Transition Regions

The post-coal innovation district construct must also account for non-metropolitan territories characterised by low urban density, sparse research infrastructure, and constrained administrative capacity. The *GreenRuralDeal* policy brief is particularly instructive regarding this operational challenge, documenting implementation-oriented interventions across Western Macedonia in Greece, Kamenica

in Kosovo, and Priboj in Serbia, with Lusatia in Germany serving as a reference region. The project sought to cultivate municipal transformative capacities through bottom-up co-creation and to systematically align structural territorial development with climate, social, and environmental objectives. As a project policy brief, it offers situated implementation lessons, governance architectures, and policy recommendations, rather than an independent, counterfactual impact evaluation³³.

The findings delineate a compound vulnerability profile that diverges substantially from conventional metropolitan innovation district environments. Rural transition territories frequently combine deep structural path-dependence on extractive and heavy industries with demographic ageing, acute youth outmigration, narrow economic diversification, constrained municipal finances, infrastructure deficits, and heightened exposure to climate risks. In Western Macedonia, these socio-economic pressures are exacerbated by accelerated lignite phase-out schedules; in Kamenica and Priboj, high structural unemployment, human-capital flight,

³³ M. Morina, P. Selimi, K. Witte, *Building transformative capacities for a climate-friendly economy in communities of rural regions of the Western Balkans and Western Macedonia: Suitable solutions derived from the GreenRuralDeal project*, Germanwatch, Wuppertal Institute, Berlin–Wuppertal 2023, pp. 3–4, 8–9, https://wupperinst.org/fileadmin/redaktion/downloads/projects/GreenRuralDeal_Policy_Brief.pdf [access: 21.08.2026].

and depleted municipal administrative resources severely impede the capacity to translate high-level climate mandates into bankable, implementable projects. Consequently, transformative capacity in peripheral regions cannot be conceptualised merely in terms of the agglomeration density of technology enterprises or research organisations; it fundamentally encompasses the administrative, institutional, and relational capacities required to design, finance, co-ordinate, and sustain place-based interventions over time³⁴.

To address these vulnerabilities, *GreenRuralDeal* posits that any viable structural intervention must simultaneously advance economic, ecological, and socio-political objectives. While normative in nature, this integrated formulation provides a robust heuristic screening principle for the conceptual model developed in this monograph. An intervention that reduces greenhouse gas emissions whilst failing to establish accessible employment pathways or civic participation mechanisms remains socially fragile; conversely, a job-creation initiative that locks in carbon-intensive or ecologically damaging infrastructure contradicts the core tenets of climate-compatible path creation. This tripartite evaluative filter can therefore serve as an initial portfolio-entry test: proposed transition projects must demonstrate explicit contributions across

³⁴ Ibidem.

the socio-economic, socio-ecological, and socio-political domains, while articulating formal mechanisms to monitor and mitigate emerging trade-offs³⁵.

Furthermore, the policy framework assigns distinct operational functions across tiers of multi-level governance:

- 1) **European and Cross-Border Institutions:** Facilitate accessible knowledge-exchange networks, dedicated capacity-building grants, and platforms for mutual interregional learning.
- 2) **National Government:** Operates concurrently as a statutory rule-maker and enabling public service provider, dismantling regulatory barriers and providing technical assistance to help under-resourced municipalities navigate complex transition funding architectures.
- 3) **Regional and Municipal Authorities:** Convene local stakeholders, establish agile project management structures, and anchor external technological expertise within pressing local development needs.
- 4) **Innovation and Transition Intermediaries:** Act as boundary-spanning translators, decoding complex national/EU operational programmes and reinforcing local implementation capacity.

³⁵ Ibidem.

This vertical division of labour is far more precise than generic appeals for multi-level governance; it directly couples each administrative tier with a specific institutional capability deficit³⁶.

Physical and utility infrastructure is approached through a similarly systemic lens. Rather than pursuing atomised energy-efficiency projects, the framework advocates for integrated infrastructure portfolios that interconnect district heating, building retrofits, renewable power generation, local industrial value chains, and vocational skills development. Initial project stages typically necessitate catalytic public finance, transitioning towards hybrid public–private financing models once operational viability is established. For post-coal innovation districts, this suggests that capital infrastructure investments must be appraised primarily for their functional and developmental connectivity: whether a municipal district-heating upgrade stimulates regional supply-chain demand, whether a technical training programme is synchronized with clean-technology deployment, and whether a utility-scale renewable installation fosters an indigenous base of maintenance and engineering services³⁷.

Crucially, the policy brief directly proposes an innovation district model for Western Macedonia as a strategic

³⁶ Ibidem.

³⁷ Ibidem.

mechanism to attract innovative enterprises, research talent, and skilled workers following the contraction of the lignite industry. This proposition must not be conflated with empirical proof that such a district has already secured these outcomes. Rather, its analytical value lies in demonstrating that the innovation district concept has actively entered the implementation discourse of rural, non-metropolitan coal basins. In this setting, the construct is tasked with socio-economic priorities that differ markedly from inner-city technology precincts: curbing demographic outflow, reconstructing a sustainable regional economic base, and establishing synergies between natural resource endowments, Industry 4.0 applications, and targeted public investments³⁸.

The comparative examples of Priboj and Lusatia further clarify the spatial and structural diversity of district interventions. The decarbonisation of municipal district heating and building retrofits in Priboj hinges upon localized administrative co-ordination and international financial assistance, whereas the Görlitz Innovation Campus in Lusatia brings together municipal authorities, academic institutions, a global technology corporation, and leading research institutes around advanced hydrogen and industrial decarbonisation technologies. While these initiatives

³⁸ Ibidem.

represent fundamentally different project types that cannot be evaluated through direct outcome comparisons, they illustrate opposing ends of a territorial capacity spectrum: basic municipal infrastructure modernisation on the one hand, and a research-intensive industrial innovation platform on the other. Consequently, a peripheral post-coal district strategy must frequently connect such complementary functions across a polycentric network of dispersed sites rather than attempting to artificially concentrate them within a single physical perimeter³⁹.

This empirical reality refines the theoretical conceptualisation of the polycentric post-coal innovation district. Polycentricity in this context is not merely a looser, sub-optimal spatial adaptation of a compact urban quarter. Rather, it represents an intentional structural response to dispersed territorial assets, uneven municipal capabilities, and the imperative to systematically link localised projects with regional, national, and transnational support mechanisms. In such a network, the dedicated co-ordinating body must simultaneously execute **outward-facing functions** (such as funding translation, strategic partnership formation, specialised technical assistance, and interregional policy learning) and **inward-facing functions** (including

³⁹ Ibidem.

brownfield land assembly, community deliberation, and portfolio-level impact monitoring).

Nonetheless, the methodological and evidentiary caveats of these findings must be maintained. The *Green-RuralDeal* initiative covers a discrete project timeframe and reflects programmatic insights articulated by participating consortia. Consequently, it cannot empirically substantiate that establishing a rural innovation district will definitively reverse brain drain, generate durable long-term employment, or enhance macro-regional socio-economic resilience. Evaluating such transformative outcomes demands rigorous, longitudinal comparative research. In this monograph, the brief is utilised instrumentally: to delineate empirical capacity constraints and identify specific governance mechanisms that future investigations should critically test within peripheral and rural coal transitions.

3.8. Limits, Risks, and Evidence Gaps

The analytical framework advanced in this chapter should not be misconstrued as an assertion that green innovation or post-mining brownfield redevelopment will spontaneously or inevitably resolve the structural crises of post-coal

regions. Any such presumption is undermined by three pervasive forms of transition optimism:

- 1) **Technological Optimism:** The uncritical assumption that deploying renewable energy infrastructure, digital monitoring tools, or advanced applied laboratories will automatically generate a dynamic, self-sustaining regional economy.
- 2) **Spatial Optimism:** The belief that the physical remediation, landscaping, or property-led re-use of post-mining brownfields is sufficient in itself to alter a territory's long-term developmental trajectory.
- 3) **Institutional Optimism:** The expectation that meaningful multi-level co-ordination and stakeholder alignment can be instantaneously achieved simply through the formal establishment of new transition platforms, partnership boards, or strategy documents.

Regional innovation systems scholarship provides a vital theoretical corrective to such deterministic simplifications. Territories diverge profoundly in their institutional thickness, absorptive capacities, industrial structures, and collaborative learning cultures. While post-coal regions may possess significant legacy engineering assets and utility infrastructures, they routinely struggle with thin entrepreneurial ecosystems, weak research-commercialisation interfaces, and institutional fragmentation. A climate-neutral development pathway must therefore be rigorously

place-based and context-sensitive, proceeding from granular territorial diagnosis rather than uncritically transposing generic, metropolitan green-growth templates⁴⁰.

Ultimately, empirical evidence addressing the fully integrated research problem remains emergent and fragmented. While the constituent literatures reviewed in this chapter provide robust conceptual foundations, and contemporary policy reports supply traceable institutional context from European coal basins, neither body of work currently offers definitive, longitudinal proof that a post-coal innovation district will fully replace coal-related employment or guarantee new path creation. The central thesis of this chapter is therefore deliberately conceptual and heuristic: macro-level climate targets acquire transformative regional efficacy only when operationalised through the co-ordinated alignment of green technological innovation, strategic brownfield spatial re-use, workforce capability transitions, and cumulative territorial learning—configured around the specific institutional and structural realities of each post-coal territory⁴¹.

⁴⁰ P. Cooke, M.G. Uranga, G. Etzebarria, *Regional innovation systems...*, op.cit., pp. 475–491; B.T. Asheim, L. Coenen, *Contextualising regional innovation systems...*, op.cit., pp. 163–173.

⁴¹ A. Drobniak (red.), *Just transition of coal regions in Poland: Impulses, contexts and strategic recommendations*, Katowice 2023, <https://doi.org/10.22367/uekat.9788378758785>; M. Honorati, A. Banaszczyk, *Options to support workers through a transition away from coal in*

3.9. Chapter Conclusion

Climate neutrality constitutes an indispensable imperative, yet it becomes genuinely developmental only when systematically coupled with green technological innovation, post-mining brownfield spatial re-use, workforce skills transitions, and cross-sectoral, multi-level governance. Empirical and programmatic insights from rural and peripheral transition regions further augment these requirements, underscoring the critical necessity of cultivating municipal administrative capacity, embedding accessible boundary-spanning intermediation, facilitating interregional and cross-border policy learning, and assembling functionally connected infrastructure portfolios.

Within this framework, the post-coal innovation district is conceptualised not merely as an agglomeration of commercial enterprises or academic research organisations; rather, it operates as the institutional and territorial mechanism that bridges environmental remediation with the creation of new, resilient regional economic functions—whether configured around a single brownfield site or orchestrated across a polycentric territorial network. This integrative dynamic establishes the foundational architecture for the comprehensive conceptual model developed in Chapter 4.

CHAPTER IV

AN INTEGRATED CONCEPTUAL MODEL OF THE POST-COAL INNOVATION DISTRICT

4.1. Why an Integrated Model Is Needed

While just transition scholarship primarily addresses distributional fairness, procedural justice, and territorial compensation, the regional innovation systems (RIS) literature elucidates uneven institutional and absorptive capacities across space. Concurrently, innovation district research provides a rich spatial and physical vocabulary, eco-innovation and brownfield redevelopment studies identify viable low-carbon industrial functions, and evolutionary path-creation theory explains the strategic mechanisms required to break free from inherited industrial lock-in. The critical missing link across these disparate traditions is an integrated, place-based delivery mechanism capable

of systematically binding these complementary insights together within coal-dependent territories.

To address this lacuna, the conceptual model advanced in this monograph defines the post-coal innovation district as a territorially anchored co-ordination mechanism that systematically aligns institutional actors, physical brown-field sites, utility infrastructure, workforce skills, multi-level policy instruments, and developmental narratives around an emerging regional path-creation trajectory. Crucially, the model is conceived as context-sensitive and adaptable rather than universally prescriptive, explicitly embedding democratic legitimacy, workforce transition pathways, and civic community access at its core. These structural and normative safeguards directly mitigate the acute risks of superficial place-branding, speculative real-estate capture, and exacerbated socio-spatial inequalities identified across critical urban and regional scholarship⁴².

⁴² J. Drucker, C.M. Kayanan, *Innovation districts...*, op.cit., pp. 802–834; C. Rapetti et al., *Development of innovation districts...*, op.cit., pp. 77–124; A. Morisson, C. Bevilacqua, *Balancing gentrification...*, op.cit., pp. 472–492; C.M. Kayanan, *A critique of innovation districts...*, op.cit., pp. 50–66.

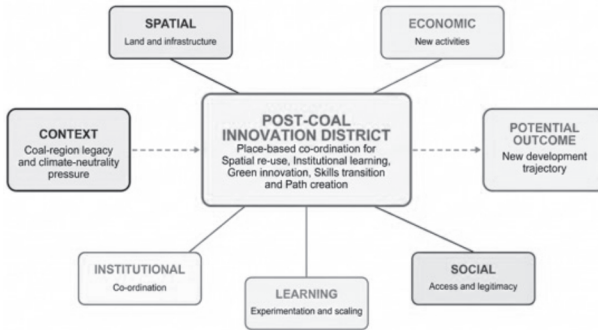


Figure 4.1. Integrated conceptual model of the post-coal innovation district

Note: Lines denote heuristic linkages between the five analytical layers and the district core; directional arrows represent analytical propositions for empirical investigation rather than verified causal relationships.

Source: Author's own elaboration based on the reviewed literature.

4.2. Defining the Post-Coal Innovation District

For the purposes of this monograph, a post-coal innovation district is defined as a territorially anchored configuration of post-mining land, utility infrastructure, public and private institutions, enterprises, workforce capabilities, and civic actors purposefully designed to co-ordinate climate-neutral transformation and foster the creation of a new regional development trajectory. This conceptualisation contains several core attributes that fundamentally distinguish the construct from conventional metropolitan innovation districts.

Four definitive criteria demarcate the analytical boundary of the model:

- 1) **Territorially Anchored:** Grounded in specific legacy brownfield sites, industrial real estate, and heavy utility infrastructure.
- 2) **Institutionally Co-ordinated:** Structured around a shared, mission-oriented transition agenda aligned across multi-level governance tiers.
- 3) **Economically Oriented:** Directed towards cultivating new low-carbon value chains, enterprise formation, and green path branching.
- 4) **Socially Conditioned:** Governed by procedural legitimacy, broad civic access, and distributional equity for structurally affected communities.

Consequently, establishing a post-coal innovation district is substantially more demanding than forming a loose professional network, executing an isolated policy programme, or applying a marketing label to property redevelopment.

This definition builds directly on regional innovation systems (RIS) theory, positing that innovation is inherently territorially embedded and institutionally mediated. A district can spatially concentrate physical and organizational assets, but spatial proximity alone does not automatically generate innovation. The decisive issue is whether proximate co-location effectively facilitates interactive learning,

cross-sectoral co-operation, and the novel recombination of inherited industrial knowledge with emerging technological capabilities. In coal-dependent regions, this distinction is critically salient: regional innovation capacities are frequently uneven, intermediary institutional networks remain thin or fragmented, and legacy industrial routines can constrain technological experimentation⁴³.

Furthermore, this definition establishes clear negative boundary conditions. A re-branded industrial estate, an isolated renewable energy generation array, or an *ad hoc* grant-funding label does not constitute a post-coal innovation district. While an early-stage initiative may be analytically categorized as an emerging district project during initial capability-building phases, robust empirical classification requires a durable, territorially anchored governance arrangement and an operational theory of change spanning all five analytical layers. The fundamental unit of analysis is therefore the relational configuration linking the physical site (or polycentric network of sites), the co-ordinating governance coalition, the wider regional territory, and the intended developmental trajectory—not the physical real estate in isolation.

⁴³ P. Cooke, M.G. Uranga, G. Etxebarria, *Regional innovation systems...*, op.cit., pp. 475–491; B.T. Asheim, L. Coenen, *Contextualising regional innovation systems...*, op.cit., pp. 163–173.

Simultaneously, the model integrates foundational principles from just transition scholarship. A post-coal innovation district functions not merely as an economic modernisation mechanism, but as an explicit socio-ecological transition instrument. It must directly confront the distributive and procedural justice dilemmas precipitated by industrial decarbonisation:

- a) Which socio-economic groups bear the concentrated adjustment costs of structural transition?
- b) What institutional mechanisms ensure authentic civic participation in strategic investment decisions?
- c) Which local workforces, supply chains, and municipalities derive tangible benefits from new clean-technology investments?
- d) How are post-mining land and infrastructure repurposed, and whose long-term developmental interests do these sites serve?

The answers to these questions determine whether a post-coal innovation district emerges as a socially legitimate vehicle for regional renewal or degenerates into a cosmetic symbol of property-led redevelopment⁴⁴.

⁴⁴ M. Peretto, W. Eichhammer, D. Süsser, *Just energy transition in coal regions...*, op.cit.; A. Matern et al., *Strategies for energy transition...*, op.cit., pp. 1001–1022.

4.3. The Five Analytical Layers of the Model

The integrated conceptual model comprises five mutually constitutive analytical layers: **spatial**, **institutional**, **economic**, **social**, and **learning**. These layers represent heuristic distinctions designed for rigorous empirical operationalisation rather than isolated policy silos. In practice, they interact dynamically: an advanced technical training facility operates concurrently as a social, institutional, and economic instrument; a repurposed post-mining site carries spatial, environmental, and symbolic significance; and an applied clean-technology project becomes structurally transformative only when embedded within regional institutions, workforce qualification systems, and local supply chains.

- 1) **The Spatial Layer (Physical Platform and Brownfield Re-use):** Focuses on the physical and infrastructural foundation of transformation. Post-coal regions inherit extensive land portfolios, heavy transport corridors, altered hydrological regimes, and high-capacity electrical grids that can either constrain regional renewal as toxic liabilities or enable it as strategic assets. The analytical focus centres on how these inherited physical assets can be remediated and re-used to anchor productive new functions

rather than merely executing baseline environmental clearance.

- 2) **The Institutional Layer (Multi-Level Governance and Policy Alignment):** Addresses the systemic challenge of strategic co-ordination. Post-coal renewal spans multiple policy domains (energy, climate, industrial policy, spatial planning, higher education, and social services) and multi-level funding instruments (EU Just Transition Fund, national modernisations funds, and municipal budgets). Without dedicated institutional co-ordination, public interventions fragment into disconnected, short-term spending packages.
- 3) **The Economic Layer (Industrial Diversification and Value Creation):** Concerns the emergence of new economic activities, enterprise ecosystems, and industrial value chains. It investigates whether the district platform fosters green technological innovation, circular economy closed loops, applied research commercialisation, indigenous supplier upgrading, and low-carbon entrepreneurship⁴⁵.

⁴⁵ K. Sadowy, *Role of the local government in re-use of post-industrial sites in Poland*, [w:] *Biodiversity and ecosystem services on post-industrial land*, V.C. Pandey (red.), Hoboken, NJ 2025, pp. 263–284, <https://doi.org/10.1002/9781394187416.ch10>; S. Greiving, D. Gruehn, C. Reicher, *The Rhenish coal-mining area...*, op.cit.

- 4) **The Social Layer (Procedural Legitimacy and Workforce Equity):** Governs social inclusion, procedural justice, and public trust. An innovation district that generates high-productivity opportunities solely for imported specialists or footloose external capital risks exacerbating local alienation and regional resentment. Conversely, a district that systematically aligns workforce re-skilling, community amenities, and transparent stakeholder deliberation with innovation activity establishes a socially robust foundation for just transition.
- 5) **The Learning Layer (Experimentation, Feedback, and Temporal Scaling):** Captures the longitudinal, evolutionary dynamics of transformation. Structural regional renewal is never achieved through a single flagship intervention; it materialises through iterative cycles of niche experimentation, institutional feedback, strategic adaptation, and gradual economic scaling. This layer directly couples the conceptual model with evolutionary path-creation theory and transformative innovation policy (TIP)⁴⁶.

⁴⁶ J. Schot, W.E. Steinmueller, *Three frames for innovation policy...*, op.cit., pp. 1554–1567; M. Mazzucato, *Mission-oriented innovation policies: Challenges and opportunities*, “Industrial and Corporate Change” 2018, no. 5, vol. 27, pp. 803–815, <https://doi.org/10.1093/icc/dty034>

Table 4.1. Analytical layers of the integrated post-coal innovation district model

Analytical Layer	Core Diagnostic Question	Key Operational Mechanisms and Instruments	Expected Contribution to Regional Path Creation
Spatial layer	Which brownfield sites and utility infrastructures can be repurposed into strategic platforms for new regional functions?	Post-mining land re-use, environmental remediation, multi-modal transport links, shared testing facilities, clean energy grids, and digital infrastructure.	Reclaims legacy carbon-intensive liabilities as tangible physical platforms for future-oriented, low-carbon industrial development.
Institutional layer	Which governance actors and coalitions can co-ordinate structural transition beyond atomised, short-term subsidy projects?	Dedicated anchor institutions, regional and municipal authorities, boundary-spanning intermediaries, universities, and multi-level policy coalitions.	Cultivates strategic governance capacity, builds institutional thickness, and mitigates fragmentation across disconnected policy domains.
Economic layer	Which low-carbon activities, industrial capabilities, and value chains can become deeply embedded in the indigenous regional economy?	Eco-innovative enterprises, applied clean-tech R&D, circular economy closed loops, local supplier upgrading programmes, and start-up/SME incubation.	Establishes diversified regional value chains and transitions regional policy beyond passive socio-economic compensation towards generative renewal.
Social layer	How can the regional transition achieve procedural legitimacy, civic trust, and inclusive access for structurally affected workforces and communities?	Targeted vocational qualification pathways, workforce transition compacts, community benefit agreements, social procurement, and deliberative civic participation.	Structurally bridges technological innovation with distributinal justice, socio-political trust, and regional belonging.
Learning layer	Through what institutional feedback mechanisms does the territory experiment, evaluate, adapt, and scale novel solutions over time?	Real-world experimental test-beds, rigorous policy evaluation, reflexive institutional learning, strategic project sequencing, and dynamic feedback loops.	Transforms isolated demonstration projects into cumulative territorial learning and enduring regional path creation.

Source: Author’s own elaboration based on the literature reviewed in this chapter.

The five-layer analytical model militates against theoretical and policy reductionism, providing an operational framework that can be applied dynamically across developmental phases. Initial transition phases typically prioritise spatial remediation, institutional governance architecture, and strategic actor alignment; intermediate phases operationalise enterprise incubation, advanced workforce qualification programmes, and community access arenas; and mature phases hinge upon rigorous policy evaluation, institutional adaptation, and economic scaling. Applied diagnostically, the model exposes critical structural disconnects and institutional voids—such as brownfield land reclamation uncoupled from governance capacity, or workforce re-skilling detached from emerging industrial demand. Applied developmentally, it provides a structured roadmap for policy sequencing, guiding regional transitions from baseline environmental remediation and initial skills training towards shared innovation facilities, catalytic private co-investment, and a fully consolidated post-coal innovation district platform.

4.4. Mechanisms of Path Creation

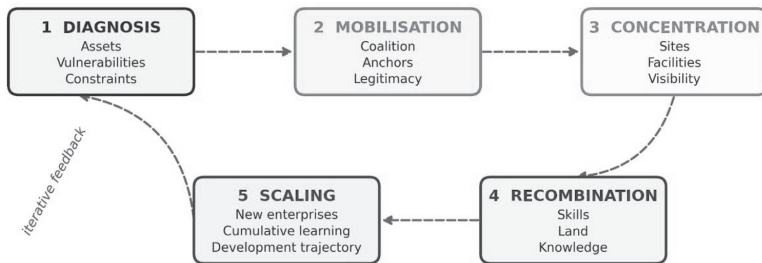
The integrated conceptual model operates through generative mechanisms rather than through an isolated,

monocausal determinant. Five relational and structural mechanisms are decisive in steering regional transformation:

- 1) **Diagnosis:** Systematically identifying endogenous territorial assets, structural vulnerabilities, and institutional constraints.
- 2) **Mobilisation:** Assembling and aligning a broad, multi-actor governance coalition around a shared, mission-oriented transition agenda.
- 3) **Concentration:** Establishing a tangible, high-visibility spatial and institutional platform that prevents project fragmentation across disparate funding streams.
- 4) **Recombination:** Creatively synthesising inherited industrial assets, physical infrastructure, and tacit competencies with emerging technological knowledge and green innovation.
- 5) **Scaling:** Translating localized niche experimentation into enduring, cumulative regional capabilities and market-facing specialisations.

These mechanisms clarify how a post-coal innovation district bridges macro-level decarbonisation mandates with a new regional development trajectory. Whilst climate neutrality exerts exogenous structural pressure to phase out coal dependence, **diagnosis** establishes the empirical baseline of what the territory possesses and what capabilities it lacks. Subsequently, **mobilisation** builds the

requisite institutional coalitions and procedural legitimacy. **Concentration** spatially and strategically anchors disparate investments within a defined brownfield platform or polycentric network. **Recombination** repurposes legacy land, technical skills, and utility infrastructure towards novel low-carbon applications. Finally, **scaling** ensures that successful experimental niches diffuse across the wider regional economy. Absent deliberate scaling, the district remains confined to an isolated demonstration enclave; with scaling, it catalyses genuine, long-term evolutionary path creation.



Learning may trigger renewed diagnosis, remobilisation, or redesign of the district platform.

Figure 4.2. Heuristic and iterative path-creation sequence for a post-coal innovation district

Note: Directional arrows denote analytical propositions for empirical investigation rather than a deterministic causal chain; the iterative feedback loop illustrates how cumulative learning triggers strategic adaptation and institutional realignment

Source: Author's own elaboration based on the reviewed literature.

The sequence should not be interpreted as an invariant, linear blueprint. Post-coal regional restructuring is inherently non-linear, iterative, and politically contested. Regional transition coalitions routinely cycle back to diagnostic reappraisal following project setbacks, reconstruct institutional pacts amidst shifting political cycles, or recalibrate spatial redevelopment priorities as complex brownfield parcels are progressively unbundled. Nonetheless, the sequence articulates the core operational logic of the model: the post-coal innovation district functions not merely as a physical site of localized innovation activity, but as an institutional and territorial mechanism through which a region learns how to pivot from carbon lock-in towards a generative new development trajectory.

Diagnosis degenerates into a structural liability when operationalised as a static, one-off consulting exercise. Within post-coal environments, diagnostic appraisal must be continuously updated as mine closures advance, workforce demographics evolve, brownfield real estate is legally and environmentally remediated, and multi-level funding rules shift. A robust diagnostic capacity must evaluate not only macroeconomic indicators and technical feasibility metrics, but also institutional absorptive capacity, statutory land-use constraints, granular skills profiles, community expectations, and latent eco-innovation niches. An innovation district predicated upon superficial diagnosis risks

transposing generic policy blueprints that fail to engage with endogenous territorial realities.

Mobilisation is equally vital because structural transformation necessitates the alignment of diverse stakeholder groups whose institutional logics, incentives, and temporal horizons routinely diverge or conflict. Extractive corporations, municipal councils, regional authorities, universities, vocational training bodies, trade unions, environmental NGOs, and indigenous SMEs rarely exhibit spontaneous alignment. The post-coal innovation district provides a shared relational platform, but its transformative efficacy remains contingent upon whether its governance architecture establishes compelling institutional incentives for sustained collaboration. Mobilisation therefore demands proactive relational trust-building, transparent mission-oriented agenda-setting, and tangible institutional dividends that justify long-term stakeholder commitment.

Recombination constitutes the primary evolutionary mechanism through which the inherited industrial path is creatively repurposed to seed new developmental trajectories. Tacit engineering and problem-solving competencies rooted in fossil-fuel extraction can be purposefully redirected towards renewable energy systems, environmental engineering, industrial plant remanufacturing, or circular material loops. Concurrently, post-mining land portfolios can be transformed into real-world testing grounds,

vocational training academies, or advanced clean-technology hubs, whilst existing high-capacity electrical grids and heavy rail links dramatically reduce capital expenditure for emerging green sectors. Recombination does not entail an uncritical romanticisation of the extractive past; rather, it represents the strategic identification and intentional redeployment of legacy assets that can be productively modernised rather than discarded.

4.5. Change Agency in Regional Path Creation

The conceptual model demands an explicit account of purposeful human and institutional agency, as inherited territorial assets and exogenous policy windows do not combine automatically. Regional path creation emerges from the dynamic dialectic between underlying structural preconditions and intentional, agentic interventions. Grillitsch and Sotarauta conceptualise this dynamic through the construct of *opportunity spaces*, which are bounded by inherited historical endowments yet actively shaped by perceived future horizons: regional actors interpret latent possibilities, mobilise dispersed resources, and intentionally alter the institutional conditions under which subsequent action unfolds. This theoretical framing elevates the analysis beyond a static inventory of regional capacities towards

an empirical examination of who initiates, legitimises, and sustains transformative asset recombination⁴⁷.

To operationalise this agentic dimension, Grillitsch and Sotarauta formulate a **trinity of change agency**, distinguishing three interdependent modalities:

- 1) **Innovative Entrepreneurship:** Introduces novel products, services, production processes, or business models that deliberately depart from the dominant regional industrial path.
- 2) **Institutional Entrepreneurship:** Actively challenges, reforms, or replaces formal regulatory barriers and informal institutional conventions that obstruct novel economic activity.
- 3) **Place-Based Leadership:** Constructs a compelling collective vision, mobilises shared territorial identity, and aligns fragmented stakeholders across diverse organisational jurisdictions towards a common strategic destination.

These agentic forms are analytically distinct yet functionally complementary: an innovative clean-technology enterprise may unlock a technical niche that remains economically marginal without supportive regulatory

⁴⁷ M. Grillitsch, M. Sotarauta, *Trinity of change agency, regional development paths and opportunity spaces*, “Progress in Human Geography” 2020, no. 4, vol. 44, pp. 704–723, <https://doi.org/10.1177/0309132519853870>.

adjustments, whilst institutional reforms risk becoming empty administrative shells without entrepreneurial experimentation to populate new markets.

Within a post-coal transition context, this analytical distinction prevents the ‘innovation district anchor’ from functioning as a lazy, catch-all explanatory device. Innovative entrepreneurship may be executed not only by private firms, but also by municipal utilities, energy co-operatives, or public-sector service innovators; institutional entrepreneurship may be driven by reform-minded public planners, land reclamation authorities, trade union representatives, or boundary-spanning intermediaries; and place-based leadership may be exercised through distributed governance coalitions rather than relying exclusively on individual political champions. Crucially, agency is frequently distributed across collaborative teams and networks rather than embodied within a single charismatic actor. Empirical investigation must therefore trace concrete actions and observable structural effects—novel asset combinations, modified institutional rules, and sustained collaborative commitments—rather than simply inferring transformative agency from formal hierarchical positions.

A geographical political-economy perspective enriches this framework by explicitly integrating multi-scalar power relations and structural dependencies. As MacKinnon and colleagues emphasise, regional path creation

is fundamentally mediated by strategic interactions across multi-scalar state apparatuses, international market dynamics, and extra-regional corporate hierarchies. Territorial actors diverge profoundly in their structural capacity to frame policy agendas, capture financial flows, and stabilise new industrial pathways; moreover, transnational corporations or central government ministries may enable local transformation, redirect strategic priorities, or extract value without anchoring permanent capabilities locally. Consequently, post-coal path creation cannot be romanticised as an exclusively bottom-up, endogenous process or as the inevitable outcome of local consensus⁴⁸.

Within the integrated model, the mobilisation mechanism is empirically observed through the dynamic interplay of these agency modalities. A robust path-creation sequence demonstrates innovative entrepreneurial experiments, focused institutional work that dismantles regulatory lock-in, and place-based leadership that connects individual investments to a legitimate, long-term territorial mission. This analytical proposition is explicitly conditional: transformative change agency is significantly more likely to alter a regional trajectory where local actors possess meaningful access to capital resources, institutional decision arenas,

⁴⁸ D. MacKinnon et al., *Rethinking path creation: A geographical political economy approach*, "Economic Geography" 2019, no. 2, vol. 95, pp. 113–135, <https://doi.org/10.1080/00130095.2018.1498294>.

and transnational knowledge networks. Conversely, the conceptual framework would be challenged if all three agency modalities were robustly present yet projects remained fragmented, institutional lock-in persisted, and territorial trajectories stagnated—or, conversely, if systemic path creation materialised in the complete absence of deliberate change agency.

4.6. Possible Configurations of Post-Coal Innovation Districts

Given the profound structural heterogeneity across post-coal regions, the innovation district construct cannot be conceptualised as a monolithic or rigid spatial template⁴⁹. Empirical variations between territories such as Eastern Wielkopolska and Turów/Bogatynia illustrate divergent socio-technical transition narratives, differing time horizons for mine closure, and uneven institutional readiness.

⁴⁹ H. Schudy, *Metafory transformacji: analiza dyskursu transformacji energetycznej w regionie Turowa i Wielkopolski Wschodniej*, “Ruch Prawniczy, Ekonomiczny i Socjologiczny” 2025, no. 2, vol. 87, pp. 305–322, <https://doi.org/10.14746/rpeis.2025.87.2.19>; M. Czyżewska, *Start-upy i ekosystem start-upowy w Wielkopolsce jako czynnik rozwoju regionu*, “Rozwój Regionalny i Polityka Regionalna” 2024, no. 72, pp. 53–71, <https://doi.org/10.14746/rrpr.2024.72.04>

Furthermore, the documented start-up ecosystem across the wider Wielkopolska region represents a valuable constituent of the aggregate regional innovation system, rather than empirical proof that its coal-dependent periphery already operates as a consolidated innovation district. Marked disparities in the depth of carbon lock-in, municipal administrative capacities, brownfield land-tenure regimes, labour-market composition, and local political consensus necessitate a differentiated typology of spatial-institutional configurations rather than a one-size-fits-all policy prescription.

To accommodate these territorial specificities, the conceptual model articulates five ideal-typical configurations:

- 1) **Land-Re-use Innovation District:** Primarily driven by large-scale brownfield reclamation, geotechnical stabilisation, and the functional repurposing of decommissioned open-cast mines, spoil heaps, and thermal generation assets into productive economic platforms.
- 2) **Anchor-Led Innovation District:** Catalysed and steered by a prominent institutional champion—such as an applied university campus, research institute, technology park, leading industrial enterprise, or municipal development agency—functioning as the primary institutional entrepreneur.

- 3) **Skills-Transition Innovation District:** Centred on vocational re-skilling infrastructure, technical polytechnics, applied training workshops, and active labour-market adjustment programmes designed to redirect industrial engineering competencies into emerging sectors and curb demographic outmigration.
- 4) **Green-Industry and Eco-Innovation District:** Structurally oriented towards utility-scale renewable energy generation, circular economy closed loops, green hydrogen deployment, clean-technology manufacturing, and industrial symbiosis.
- 5) **Polycentric Innovation Platform:** Configured as a distributed network of spatially dispersed brown-field sites, municipal test-beds, and specialised functional hubs interconnected through a unified regional co-ordination architecture and shared governance framework.

Importantly, these ideal-typical configurations are not mutually exclusive. In empirical practice, post-coal territories frequently develop hybrid configurations that dynamically synthesise brownfield land re-use, workforce skills transitions, and green-industrial diversification. The primary heuristic value of this typology lies in its capacity to systematically calibrate the district model to granular territorial preconditions and institutional endowments.

Table 4.2. Typology and operational characteristics of post-coal innovation district configurations

Configuration Type	Primary Driver	Most Suitable Territorial Conditions	Primary Structural Risk
Land re-use district	Brownfield site redevelopment and post-mining land reclamation.	Substantial available land parcels, geotechnical remediation requirements, and high utility/infrastructure re-use potential.	Degenerating into a speculative real-estate scheme absent indigenous innovation capacity.
Anchor-led district	Applied university campus, technology park, leading energy corporation, or regional development agency.	Presence of an established anchor institution capable of convening diverse stakeholders and mobilising strategic resources.	Institutional overdependence on a single actor and weak social connectivity with affected local communities.
Skills-transition district	Vocational education and training (VET), workforce re-skilling, and active labour-market adjustment programmes.	Concentrated industrial workforce facing impending plant/mine closures and acute structural adjustment pressures.	Qualification programmes outpace local industrial absorption, generating skills without sufficient market demand from new sectors.
Green-industry district	Renewable energy generation, circular economy loops, and clean/environmental technology manufacturing.	Inherited industrial engineering competences with clear potential to pivot into emerging low-carbon supply chains.	Inherited industrial engineering competences with clear potential to pivot into emerging low-carbon supply chains
Polycentric regional platform	Distributed network interconnecting multiple brownfield sites, municipal test-beds, and functional nodes.	Spatially dispersed extractive assets, intermediate polycentric town networks, and multi-municipal transition areas.	Prohibitive inter-municipal co-ordination costs, territorial rivalry, and ambiguous governance accountabilities.

Source: Author's own elaboration based on the literature reviewed in this chapter.

A region endowed with extensive post-mining land holdings but lacking mature anchor institutions necessitates an entirely different strategic entry point compared to a territory hosting an applied technical university constrained by fragmented brownfield land ownership. Similarly, a coal basin confronting acute, near-term workforce displacement must prioritise vocational qualification pipelines and active labour-market intermediation before attempting to cultivate a capital- and research-intensive technology cluster.

Furthermore, the typology provides a robust conceptual safeguard against context-blind, isomorphic policy transfer. Spatial-economic models calibrated for dense metropolitan knowledge economies cannot simply be transposed onto intermediate, non-metropolitan, or peripheral post-coal territories. Likewise, a monocentric brownfield megaproject approach is structurally ill-suited to polycentric regions where the socio-economic fallout of coal decline is dispersed across multiple, administratively fragmented municipalities. The pivotal analytical and policy question is therefore not whether a given territory conforms to conventional, metropolitan definitions of an innovation district, but rather which context-sensitive configuration of district logic can most effectively co-ordinate its structural, climate-neutral transformation.

4.7. Policy Conditions and Governance Requirements

The integrated conceptual model demands sophisticated governance capacities that are rarely spontaneously present in declining industrial regions. It necessitates systematic co-ordination across traditionally decoupled policy domains: climate mitigation, regional economic development, innovation policy, active labour-market policy, statutory land-use planning, and environmental remediation. Furthermore, it requires a resilient coalition of regional stakeholders capable of sustaining a long-term, mission-oriented trajectory beyond the compressed cycles of political administrations or short-term funding programmes. While multi-helix frameworks provide a valuable theoretical foundation by emphasising interactive co-operation among public authorities, enterprises, higher-education institutions, and civil society, in post-coal territories this collaborative architecture must be explicitly anchored in procedural transition justice and territorial legitimacy⁵⁰.

To achieve systemic impact, transition policy design must establish a three-dimensional alignment:

⁵⁰ H. Etzkowitz, L. Leydesdorff, *The dynamics of innovation: From National Systems and 'Mode 2' to a Triple Helix of university-industry-government relations*, "Research Policy" 2000, no. 2, vol. 29, pp. 109–123, [https://doi.org/10.1016/S0048-7333\(99\)00055-4](https://doi.org/10.1016/S0048-7333(99)00055-4); M. Roman et al., *Quadruple Helix models...*, op.cit.

- 1) **Vertical Alignment:** Co-ordinating strategic priorities, statutory powers, and regulatory frameworks across European, national, regional, and municipal governance tiers.
- 2) **Horizontal Alignment:** Dismantling policy silos to connect technological innovation, brownfield land assembly, energy-system modernisation, and work-force skills formation.
- 3) **Territorial Alignment:** Directly coupling investment portfolios with the specific spatial, ecological, and socio-economic vulnerabilities of communities bearing the structural costs of decarbonisation.

The post-coal innovation district functions as an operational mechanism to make these multi-scalar relationships tangible, providing a physical and institutional platform where disparate policies, funding streams, and stakeholder coalitions converge.

Crucially, this does not imply that the innovation district should introduce a superfluous, rigid administrative layer. Its primary value lies in agile territorial co-ordination rather than institutional complexity. A viable governance arrangement must possess the statutory authority to make binding strategic decisions, aggregate capital investment, orchestrate meaningful civic participation, and conduct rigorous progress evaluation. Moreover, governance must maintain transparent communication channels, ensuring

that local workforces and municipal constituents clearly comprehend how district initiatives translate into secure employment, repurposed land assets, modernized public services, and enduring regional resilience.

These governance imperatives are acutely salient across Central and Eastern Europe (CEE), including Poland's transitional coal basins. In these territories, legacy structural weaknesses—uneven indigenous innovation capacities, thin intermediary institutional thickness, municipal fiscal constraints, and politically contested decarbonisation narratives—frequently impede the capacity of regional actors to convert exogenous transition funding into cumulative, durable capabilities. Consequently, the integrated model places equal emphasis on institutional capacity-building and capital investment: the fundamental evaluative question is not merely what volume of funding is absorbed, but whether the territory enhances its long-term institutional capacity to strategically shape its own developmental path.

This analytical premise generates a decisive policy implication: transition funds must not be restricted to financing physical infrastructure or providing passive socio-economic compensation. Rather, public resources must be deployed strategically to build endogenous co-ordination capacity. This encompasses sustained funding for:

- a) Specialized boundary-spanning intermediary organisations;

- Applied industry-academia research partnerships;
- b) Dedicated vocational re-skilling and curriculum-modernisation platforms;
 - c) Indigenous SME supply-chain upgrading initiatives;
 - d) Legally binding community-benefit mechanisms;
 - e) Longitudinal, reflexive policy-evaluation systems.

While such soft institutional investments lack the immediate political visibility of flagship brownfield architecture, they constitute the critical determinants of whether a post-coal innovation district successfully catalyses long-term regional path creation.

Finally, the governance architecture must incorporate robust safeguards against structural capture by narrow interest groups:

- 1) **Real-Estate Capture:** Dominance by speculative property developers risks prioritising land valuation and commercial rents over public-good research, open-access infrastructure, and local workforce integration.
- 2) **Technological Enclave Capture:** Hegemony by elite technology firms or academic consortia risks producing isolated high-tech enclaves detached from displaced industrial workers and broader community needs.
- 3) **Bureaucratic Inertia:** Total administrative control by municipal or regional bureaucracies risks stifling

entrepreneurial agility, resulting in procedural sclerosis and risk-averse programming.

A resilient governance model must therefore construct a dynamic equilibrium, combining strategic public leadership with institutionalised mechanisms for democratic accountability, multi-stakeholder participation, and continuous institutional learning.

4.8. Mission Orientation and Adaptive Experimentation

While the integrated conceptual model identifies climate neutrality as an overarching developmental trajectory, broad directional goals are insufficient to steer operational investment portfolios. Mission-oriented innovation policy (MIP) provides the requisite operational architecture: it establishes rigorous procedures for diagnosing concrete societal challenges, mobilising multi-actor consortia around explicit public objectives, and assessing whether real-world experiments generate verifiable public value. Within a post-coal innovation district, an actionable mission might target the deep decarbonisation of municipal district heating, the ecological and economic repurposing of a complex open-cast mining void, the creation of guaranteed employment pipelines into an emerging clean-technology supply chain, or the comprehensive remediation of disrupted regional

hydrological systems. The core analytical advantage is granular specificity: district interventions are structured around clearly defined socio-technical challenges and identifiable constituencies rather than pursuing innovation promotion in the abstract.

In their comprehensive systematic review, Fastenrath and colleagues provide the definitive analytical synthesis bridging innovation districts with mission-oriented innovation. Conducting a structured Scopus review across an initial corpus of 478 innovation-district and 64 mission-oriented-innovation records, they retained and manually coded 67 and 32 articles respectively across definitions, theoretical frameworks, methodologies, evaluative metrics, and governance models. Significantly, a combined search across both literature streams yielded zero overlapping records, establishing that prior to the end of 2020, these two major paradigms developed in mutual isolation⁵¹.

This systematic review further exposed complementary analytical weaknesses within the two literatures:

- 1) **Innovation District Research:** Approximately three-quarters of empirical studies were case-based, frequently detailing uncritical success stories through descriptive or anecdotal methodologies, while largely

⁵¹ S. Fastenrath et al., *Mission-oriented innovation districts...*, op.cit., pp. 4–5.

omitting systemic directionality and normative public purpose.

- 2) **Mission-Oriented Innovation Research:** Remained predominantly abstract and theoretical, displaying limited spatial sensitivity and offering few operational insights into localized, place-based implementation.

The concept of the **mission-oriented innovation district (MOID)** synthesises the complementary strengths of both paradigms: it provides a situated, territorially bounded spatial platform for intensive collaborative experimentation, while embedding a challenge-led governance framework that infuses innovation activities with explicit directionality and democratic purpose. Fastenrath et al. formulate this construct as an urgent research and policy agenda rather than an established, off-the-shelf governance technology⁵².

When applied to post-coal regional transitions, mission definition must proceed from rigorous territorial diagnosis and specify an unambiguous constituency. Generic proclamations—such as

“establishing a regional green-technology hub”—remain operationally empty signifiers that fail to discipline project selection. A robust, actionable mission framework must explicitly define:

⁵² Ibidem, pp. 10–12.

- a) The specific socio-technical or ecological system targeted for transformation;
- b) The territorial and spatial boundaries of the intervention;
- c) The precise target beneficiaries (e.g. at-risk energy-sector workers, underemployed youth, or energy-poor municipal households);
- d) A realistic temporal horizon;
- e) Verifiable, intermediate performance milestones.

This diagnostic precision prevents the mission construct from degenerating into a rhetorical umbrella used to retrospectively justify disconnected, opportunistic grant-seeking projects. Furthermore, it empowers regional stakeholders to critically contest whether proposed initiatives meaningfully address coal-transition burdens and align with indigenous capabilities.

Directionality must remain fundamentally reflexive. When transition missions are formulated exclusively by central ministries, dominant utility corporations, or academic elites, they tend to prioritise capital-intensive, technically spectacular solutions whilst marginalising the urgent socio-economic priorities of local workforces and municipal communities. Fastenrath et al. therefore stress the imperative of inclusive, reflexive governance, explicitly expanding the conventional Triple Helix model (university–industry–government) to incorporate civil society organisations, labour unions, community grassroots

initiatives, and interdisciplinary expertise across housing, environmental science, public health, and social policy. The primary governance challenge lies not merely in expanding participation, but in cultivating robust intermediary capabilities capable of arbitrating conflicting stakeholder interests without diluting strategic missions into weak, lowest-common-denominator compromises⁵³.

The temporal dynamics and institutional uncertainties inherent in district governance are empirically underscored by Davidson and colleagues in their analysis of the Melbourne Innovation District City North. Drawing upon their published findings, the authors observe an enduring tension within the district's operational mandate, which continuously oscillated between commercial imperatives (tech start-up incubation, corporate spin-offs, and creative-sector agglomeration) and broader socio-ecological mandates. Furthermore, the district's overarching socio-technical imaginary was characterized by persistent ambiguity, requiring ongoing strategic experimentation and contested renegotiation as external systemic crises unfolded, including the Australian 'Black Summer' bushfires and the COVID-19 pandemic⁵⁴.

⁵³ Ibidem.

⁵⁴ K. Davidson et al., *Municipal experimentation in times of crises: (Re-)defining Melbourne's innovation district*, "Cities" 2023, vol. 132, art. 104042, <https://doi.org/10.1016/j.cities.2022.104042>

This empirical observation is directly relevant to post-coal transitions, which will inevitably encounter macroeconomic volatility, national policy shifts, and localised socio-political contestation. In this context, adaptive governance must not be conflated with opportunistic goal displacement—wherein strategic targets are continually downgraded or rewritten whenever individual demonstration projects underperform. Rather, authentic adaptability requires that underlying assumptions, policy instruments, and intermediate milestones are iteratively recalibrated through documented institutional learning, whilst the core public mission remains steadfast.

To institutionalise this discipline, regions should establish a formal **Mission Register** comprising:

- a) An explicit diagnostic problem statement;
- b) Documented stakeholder coalitions and distributional commitments;
- c) Hypothesised causal mechanisms;
- d) Active experimental portfolios;
- e) Verifiable empirical metrics of progress;
- f) Granular evaluations of distributional equity;
- g) Transparent, evidence-based rationales for any strategic modifications.

Such a register transforms experimental trial-and-error into an accountable, cumulative process of territorial learning, preventing the onset of fragmented project cycles.

Crucially, experimental demonstration projects must be governed by an explicit **scaling hypothesis**. Demonstrating that an advanced clean technology or novel governance arrangement operates effectively within a protected test-bed does not constitute systemic path creation. Prior to deploying capital into pilot test-beds, the district governance platform must articulate a clear institutional pathway for scaling and mainstreaming viable solutions. As Fastenrath et al. underline, transformative scaling relies on coordinated policy mixes, including:

- a) Public procurement of innovation (PPI) to create initial guaranteed markets;
- b) Regulatory sandboxes and statutory exemptions to facilitate commercial rollout;
- c) Supply-chain matchmaking programmes linking local SMEs to clean-tech anchors;
- d) Modernised vocational and higher-education curricula;
- e) Inter-municipal technology-transfer compacts.

Treating scaling as an intentional, ex-ante governance mechanism directly counters the structural risk of “pilotitis”—the proliferation of isolated demonstration projects that terminate abruptly once initial grant funding is exhausted⁵⁵.

⁵⁵ S. Fastenrath et al., *Mission-oriented innovation districts...*, op.cit., pp. 10–12.

Ultimately, integrating mission orientation recalibrates the interpretation of the model's five analytical layers:

- 1) **The Spatial Layer** provides the brownfield test-beds, utility networks, and real estate required for physical intervention;
- 2) **The Institutional Layer** establishes multi-level governance coalitions and assigns statutory accountability;
- 3) **The Economic Layer** incubates low-carbon enterprise ecosystems and builds domestic value chains capable of delivering solutions;
- 4) **The Social Layer** ensures procedural legitimacy, equitable community access, and transparent workforce transition pipelines;
- 5) **The Learning Layer** executes real-time evaluation, maintains the mission register, and drives systemic scaling across the territory.

A post-coal innovation district achieves mission orientation only when these five layers are purposefully synchronized around a diagnosed regional transition challenge. The mere presence of environmental branding, a living laboratory label, or a flagship technology pavilion is wholly insufficient.

This theoretical formulation yields a rigorous, empirically testable proposition for evolutionary economic geography and transition studies: post-coal innovation districts that establish explicit, socially legitimate missions

coupled with institutionalised scaling mechanisms will demonstrate significantly stronger functional alignment between project investments and structural territorial vulnerabilities than districts configured around speculative property branding or generic innovation promotion. This proposition does not represent a pre-determined empirical fact; rather, it constitutes an analytical hypothesis derived from the conceptual synthesis of the literature, intended to guide future comparative, longitudinal empirical investigations across European coal basins.

4.9. Inclusive Innovation as an Operational Design Criterion

Within the integrated model, the social layer addresses procedural legitimacy, civic access, and stakeholder participation. Scholarship on inclusive innovation operationalises these normative dimensions by formulating three precise analytical questions: who participates in framing the innovation agenda, who possesses practical access to the resulting socio-economic opportunities, and how are developmental dividends distributed beyond the elite organisations physically co-located within the district perimeter? This tripartite distinction is critical: passive participation in consultative town halls does not guarantee

access to high-quality employment or procurement contracts, and aggregate job creation within a physical precinct does not automatically yield equitable distributional outcomes across the wider post-mining territory.

Morales and colleagues examine this structural dilemma through paired comparative investigations of innovation districts in post-industrial and transitional contexts: Newcastle upon Tyne alongside Pittsburgh, and Medellín alongside Belfast. Their empirical methodology synthesised preparatory documentary analysis and stakeholder mapping with five-to-seven-day intensive field visits, approximately twenty semi-structured key-informant interviews per city, and multi-stakeholder policy roundtables employing rapid appraisal techniques, forensic institutional inquiry, and a pragmatic ‘do-and-don’t’ analytical framework across the 2022–2024 period. While this qualitative research design does not generate population-level counterfactual estimations of social inclusion, it captures institutional sense-making, power asymmetries, and the micro-politics of local policy delivery⁵⁶.

Drawing upon this comparative corpus, the authors define inclusive innovation as the intentional co-creation

⁵⁶ D. Morales et al., *Defining inclusive innovation: Challenges and lessons for innovation districts*, “Regional Studies, Regional Science” 2025, no. 1, vol. 12, pp. 740–743, <https://doi.org/10.1080/021681376.2025.2543915>

of ideas, institutional practices, and technologies with local communities, businesses, and civic organisations to resolve urgent societal challenges, distribute socio-economic benefits equitably, and build enduring community agency. Crucially, they argue that inclusive innovation cannot be applied as a universal, off-the-shelf template; it must be operationalised through place-based diagnostic translation. In a lignite basin, the substantive content of inclusion centres primarily on workforce re-skilling pipelines, municipal fiscal stabilisation, and supply-chain diversification; in an inner-city brownfield quarter, it may focus on affordable housing, mitigating gentrification, and opening non-academic pathways into research-intensive employment⁵⁷.

Across all four international cases, Morales et al. identify a recurring **implementation gap**. While municipal strategies routinely pair science-led growth with urban regeneration rhetoric, operational capital investment and delivery frameworks disproportionately prioritise speculative commercial real estate, high-technology firm incubation, and academic R&D performance. The authors demonstrate that the compressed temporal horizons of property development, venture capital, and commercial patenting inherently clash with social inclusion outcomes,

⁵⁷ Ibidem, pp. 745–750.

which require sustained, multi-decadal institutional investment to mature. Consequently, social inclusion is rarely absent from policy rhetoric; rather, it is structurally relegated to a secondary, 'bolt-on' aspiration within policy instruments calibrated for commercial growth⁵⁸.

To overcome this structural decoupling, the authors isolate three non-negotiable design principles:

- 1) **Identifiable and Accountable Leadership:** District governance must establish visible, collaborative, and locally answerable leadership bodies, ensuring that responsibility for social equity cannot be dissolved across diffuse partnership networks.
- 2) **Intentional Co-Creation and Placemaking:** Community deliberation and participatory placemaking must be systematically linked to binding statutory decisions regarding land allocation, programmatic funding, and spatial programming.
- 3) **Strategic Alignment and Territorial Equity:** Governance compacts must explicitly account for socio-economic impacts beyond the physical boundaries of the district, preventing the extraction of regional resources into an isolated high-value enclave⁵⁹.

⁵⁸ Ibidem.

⁵⁹ Ibidem.

Furthermore, Morales et al. formulate a multi-dimensional evaluative spectrum to assess inclusive innovation, encompassing: economic inactivity and long-term unemployment; physical health and psychological well-being; gender disparities; lifelong educational access from early childhood to technical higher education; the integration of young people, migrant workers, and marginalised groups; intergenerational poverty and regional political resentment; and universal access to affordable decarbonisation solutions (such as clean district heating and public transport). The primary methodological contribution of this framework is the requirement to identify locally material inclusion dimensions *ex ante*, rather than inferring social progress from blunt, aggregate regional employment or GDP metrics⁶⁰.

For post-coal transition regions, inclusive innovation must therefore be operationalised through an integrated **Access-and-Benefit Chain**:

- 1) **Agenda Access**: Structurally affected workforces, local trade unions, and municipal councils possess genuine institutional power to shape the diagnostic challenge and mission agenda.
- 2) **Capability Access**: Dedicated vocational re-skilling academies, transitional stipends, social public pro-

⁶⁰ Ibidem.

curement clauses, and targeted technical assistance empower local actors to participate.

- 3) **Market and Institutional Access:** Indigenous SMEs, local supply chains, and municipal enterprises gain open access to shared research infrastructure, testing grounds, and public procurement frameworks.
- 4) **Benefit Access:** Tangible developmental dividends—high-quality employment, remediated public landscapes, modernised municipal utilities, and community wealth generation—are distributed in a manner directly visible to transition-affected populations.

A systemic fracture at any link along this chain compromises the procedural and distributional legitimacy of the post-coal innovation district.

This focus on territorial equity fundamentally recalibrates the **unit of analysis**. An innovation district may demonstrate impressive output metrics within its legal perimeter whilst surrounding mining municipalities endure fiscal collapse, residual environmental degradation, and deep labour-market scarring. Evaluative frameworks must therefore explicitly disaggregate three spatial scales:

- 1) **Site-Level Outcomes:** Capital investment, firm births, and technology demonstrations within the brown-field perimeter;

- 2) **Host-Neighbourhood Outcomes:** Localised employment absorption, public realm quality, and housing affordability;
- 3) **Wider Regional and Polycentric Outcomes:** Inter-municipal fiscal balance, supply-chain spillovers, cross-border capability diffusion, and regional identity renewal.

This multi-scalar disaggregation is particularly vital in polycentric coal basins, where thermal power plants, open-cast pits, residential mining towns, and applied universities are dispersed across distinct municipal jurisdictions.

Importantly, community agency must not be uncritically romanticised. Local interests are heterogeneous and frequently polarized, participatory processes are vulnerable to capture by vocal interest groups, and technical engineering decisions demand specialized domain expertise. The design challenge lies in establishing transparent protocols that demarcate the relationship between technical authority and democratic governance. Following participatory design theory, district decision-making arenas should explicitly classify whether communities are being **informed, consulted, co-designing, sharing decision-making control, or exercising independent community initiative**. Documenting the exact level of devolved authority for each operational decision provides far greater democratic

accountability than applying generic participatory labels to the entire district.

Ultimately, the comparative empirical evidence demonstrates that no singular governance blueprint guarantees social inclusion. The conceptual implication for this monograph is clear: inclusive innovation becomes an operational, verifiable property of a post-coal innovation district only when explicit equity goals, accountable institutional actors, clear spatial boundaries, concrete access mechanisms, and long-term evaluative timeframes are formally hardwired into its initial governance architecture.

4.10. Evaluation Architecture for Future Empirical Research

A rigorous empirical evaluation of post-coal innovation districts must begin by analytically untangling the **evaluative cascade**:

**Inputs → Activities → Outputs → Outcomes →
Systemic Transformation Effects**

Within this operational continuum:

- 1) **Inputs:** Decontamination capital, public grant allocations, and dedicated brownfield land portfolios;

- 2) **Activities:** Geotechnical remediation works, collaborative industry–academic R&D consortia, and vocational retraining programmes;
- 3) **Outputs:** Newly constructed laboratory floorplates, installed clean-energy capacity, and the gross tally of supported start-up enterprises;
- 4) **Outcomes:** Observable improvements in SME absorptive capacity, structural workforce mobility into green sectors, and reduced municipal carbon emissions;
- 5) **Systemic Transformation Effects:** The cumulative, self-sustaining diversification of the regional economy, the institutionalisation of reflexive governance capabilities, and the permanent uncoupling of regional prosperity from fossil-fuel extraction.

Conflating outputs with transformation effects generates a dangerous evaluative illusion, allowing an active portfolio of subsidised projects to be proclaimed a transformative success before any structural path creation has occurred.

In their evaluation framework for mission-oriented innovation districts, Fastenrath and colleagues insist that assessment metrics must break free from narrow R&D expenditure tallies and start-up formation counts. Instead, evaluation must focus on normative public value, societal and environmental problem-solving, meaningful civic empowerment in problem framing, and long-term

institutional learning. They also mandate systematic vigilance regarding unintended regressive externalities, such as real-estate inflation or spatial displacement. This establishes a **dual evaluative test**:

- 1) Does the district demonstrably generate innovative socio-technical activity?
- 2) Is that activity purposefully directed towards resolving diagnosed transition challenges without shifting financial, social, or environmental burdens onto vulnerable populations?⁶¹

From a quantitative and spatial-econometric perspective, Oikonomaki and Komninos offer an advanced data architecture by constructing a Local Innovation Potential index across US Census ZIP Code Tabulation Areas (ZCTAs). Their analytical framework synthesised thirty-two input variables—spanning socio-economic composition, multi-modal transport accessibility, utility infrastructure, land-use diversity, urban morphology, and environmental quality—to predict granted patent outputs over a ten-year longitudinal lag (2012–2022) utilising multi-variable regression, random forest ensembles, gradient boosting algorithms, and deep neural networks. Their findings demonstrate how open-access administrative data and API-harvested geospatial datasets can successfully capture

⁶¹ Fastenrath et al., *Mission-oriented innovation districts...*, op.cit., p. 11.

fine-grained innovation preconditions at the sub-municipal, neighbourhood scale⁶².

In their empirical models for the New York metropolitan region (which retained robust predictive validity when validated against the Boston urban area), a parsimonious set of spatial and social attributes accounted for a substantial proportion of longitudinal variance in patenting. Highly predictive variables included the density of specialised high-skilled labour, active-mobility commuting shares (walking and cycling), building stock morphology, and the spatial proximity of dedicated innovation spaces. Crucially, however, the authors emphasise that their observational, predictive modelling design does not establish direct causal mechanisms; feature importance metrics indicate statistical association rather than proof that manipulating an individual spatial variable will mechanically yield patent outputs⁶³.

The primary utility of Oikonomaki and Komninos's model for post-coal regional scholarship lies not in importing an off-the-shelf patent index, but in adopting its **geocoded evidence architecture**. It demonstrates that territorial monitoring systems can dynamically integrate

⁶² E. Oikonomaki, N. Komninos, *Predicting local innovation through AI and geospatial models: Revisiting the innovation district theory*, "Technovation" 2026, vol. 156, art. 103544, pp. 5–13, <https://doi.org/10.1016/j.technovation.2026.103544>

⁶³ Ibidem.

social composition, vocational skills, transit connectivity, higher-education assets, enterprise formation, physical innovation spaces, housing markets, and public spaces within a single, spatially disaggregated dataset. This directly operationalises the spatial, institutional, economic, and social layers of the integrated model, exposing acute intra-regional inequalities that are routinely obscured by regional-level averages.

For post-coal European regions, this quantitative architecture can be adapted by integrating context-specific variables:

- a) Brownfield geotechnical remediation progress;
- b) High-voltage electrical grid re-use capacity;
- c) Displaced energy-sector workforce transition flows;
- d) Municipal tax-base exposure;
- e) Sub-regional environmental and hydrological remediation indices.

Nevertheless, methodological caveats must be maintained. Administrative postal boundaries rarely align cleanly with functional industrial ecosystems, open-access and API-harvested datasets display variable longitudinal reliability across European jurisdictions, and patent counts capture only formal technological intellectual property—completely omitting crucial organisational, social, commercial, and non-patented process eco-innovations. Consequently, quantitative neighbourhood-level indices

cannot be uncritically transposed into Central and Eastern European coal basins without rigorous re-specification, empirical ground-truthing, and sensitivity testing⁶⁴.

Furthermore, quantitative spatial modelling must be systematically coupled with the qualitative inclusion dimensions formulated by Morales et al. A territory may display rising patent metrics alongside entrenched economic inactivity, acute energy poverty, and intense socio-political resentment. Conversely, foundational improvements in workforce health, technical qualifications, and civic trust frequently precede formal commercial outputs by several years. A robust, balanced methodology must therefore combine spatial-econometric monitoring with qualitative elite interviews, community oral histories, project-level process tracing, and granular distributional equity audits⁶⁵.

A robust longitudinal research design should integrate:

- 1) **Ex-Ante Baseline Audits:** Comprehensive socio-economic, spatial, and institutional benchmarks established prior to the deployment of major transition capital;
- 2) **Fixed-Interval Panel Measurements:** Longitudinal tracking of intermediate outputs and capability shifts across multi-year intervals;

⁶⁴ Ibidem, pp. 15–20.

⁶⁵ D. Morales et al., *Defining inclusive innovation...*, op.cit., pp. 745–750.

- 3) **Quasi-Experimental Counterfactual Comparisons:** Comparative assessments against matched non-district post-coal territories;
- 4) **Qualitative Process Tracing:** Granular empirical testing to verify whether theorised institutional mechanisms directly linked public inputs to observed systemic outcomes;
- 5) **Contribution Analysis:** Methodical interrogation of rival explanatory factors (e.g. macroeconomic cycles, national currency shifts, or energy price shocks);
- 6) **Participatory Interpretive Panels:** Engaging local stakeholders to evaluate qualitative impacts and unintended consequences undetected by formal administrative indicators.

While no single research design completely eliminates causal uncertainty within complex regional transitions, this plural, staged evaluation architecture offers a vastly more rigorous framework than post-hoc promotional narratives or static indicator dashboards.

Because this monograph is conceptual and synthetic, the integrated model of the post-coal innovation district is presented as an analytical framework for empirical operationalisation rather than a pre-verified causal law. To structure future comparative field research, the model generates five clusters of operational evaluative criteria:

- 1) **Spatial Transformation Criteria:** The extent, speed, and ecological quality of post-mining brownfield remediation; the strategic re-use of legacy grid and transport infrastructure; the spatial integration of district sites with surrounding municipal fabrics; and the prevention of speculative real-estate enclaves.
- 2) **Institutional Capacity Criteria:** The presence of an empowered, boundary-spanning anchor institution; the institutional thickness and collaborative agility of intermediary bodies; the degree of vertical and horizontal policy alignment; and the strategic capacity to blend disparate multi-level funding streams without succumbing to bureaucratic sclerosis.
- 3) **Economic Diversification Criteria:** The empirical formation and survival of eco-innovative enterprises; the depth of applied industry-academia R&D collaborations; the integration of indigenous SME suppliers into emerging clean-technology value chains; and verifiable green path branching.
- 4) **Social Legitimacy and Justice Criteria:** Transparent and accessible vocational re-skilling pipelines for displaced energy workers; the institutionalisation of binding community benefit agreements; documented procedural fairness in strategic challenge definition; and broad public trust in the regional transition trajectory.

- 5) **Cumulative Learning and Scaling Criteria:** The institutionalisation of dynamic feedback loops and mission registers; the systematic scaling and mainstreaming of localised living-lab experiments through public procurement and regulatory adaptation; the regional acquisition of enduring dynamic capabilities; and positive shifts in external territorial reputation.

Finally, the integrated conceptual model establishes clear negative boundaries regarding what cannot be claimed without rigorous empirical substantiation:

- 1) It must not be assumed that establishing a district automatically secures sustainable employment for displaced coal-sector workers;
- 2) It must not be assumed that constructing advanced laboratories automatically attracts mobile high-value enterprises;
- 3) It must not be assumed that brownfield re-use automatically ignites evolutionary regional path creation.

All such transformative effects demand longitudinal, counterfactual empirical verification. The primary contribution of this monograph is therefore heuristic and operational: it provides a rigorous, multi-layered theoretical architecture to investigate whether, how, and under what institutional conditions a post-coal innovation district can

bridge immediate decarbonisation mandates with enduring, just, and generative regional renewal⁶⁶.

Future empirical research can deploy this integrated framework across three decisive analytical frontiers:

- 1) **Comparative Configurational Analysis:** Conducting structured, cross-national comparisons of how diverse post-coal basins across Europe configure district-scale initiatives around their specific structural endowments of land, institutional thickness, workforce skills, and eco-innovation niches.
- 2) **Longitudinal Mechanism Tracing:** Empirically tracing multi-year transition sequences to determine whether early-stage demonstration projects mature into cumulative, scaled regional capabilities or succumb to fragmented “pilotitis”.
- 3) **Distributional and Extra-Territorial Auditing:** Conducting rigorous multi-scalar equity assessments to verify whether the economic, ecological, and social dividends of post-coal innovation districts diffuse across the wider polycentric territory or remain concentrated within privileged industrial enclaves.

⁶⁶ J. Drucker, C.M. Kayanan, *Innovation districts...*, op.cit., pp. 802–834; M. Grillitsch, B.T. Asheim, M. Trippl, *Unrelated knowledge combinations...*, op.cit., pp. 257–274.

4.11. Theoretical Propositions and Boundary Conditions

The conceptual synthesis yields six theoretical propositions that transition the integrated model from a descriptive analytical taxonomy into a conditional, testable research programme. Formulated as deductive-inferential propositions derived from the synthesis of evolutionary economic geography, regional innovation systems, sustainability transitions, and just transition literatures, they do not represent pre-verified empirical laws. Rather, each proposition articulates a hypothesized causal dynamic, specifies the boundary conditions under which it is expected to operate, and delineates explicit empirical observations that would challenge or falsify it.

1) Proposition 1 (P1: Mission–Portfolio Alignment)

- *Theoretical Proposition:* Post-coal innovation districts governed by an explicit, territorially bounded mission, an identified target constituency, and an *ex-ante* scaling pathway will exhibit significantly stronger alignment between their project portfolios and diagnosed structural transition vulnerabilities than initiatives structured around generic innovation promotion or speculative place-branding.
- *Boundary Conditions:* Requires a baseline level of municipal diagnostic and convening capacity, alongside an agile governance mechanism where

the strategic mission remains publicly contestable yet sufficiently stable to discipline project selection.

- *Falsification Criteria:* Observed parity or superiority in problem–portfolio alignment within branding-led initiatives after controlling for baseline institutional endowments, or the empirical absence of any statistically or qualitatively observable relationship between mission specification and portfolio coherence⁶⁷.

2) Proposition 2 (P2: Institutional–Spatial Implementation Coupling)

- *Theoretical Proposition:* A post-coal district portfolio is significantly more likely to transition from strategic design to material execution when brown-field site control, statutory land-use planning powers, a dedicated delivery vehicle, anchor institution maturity, and multi-level blended finance are jointly present.
- *Boundary Conditions:* Bounded by the formal multi-level distribution of spatial planning competences and minimal administrative continuity across electoral cycles.

⁶⁷ S. Fastenrath et al., *Mission-oriented innovation districts...*, op.cit., pp. 10–12.

- *Falsification Criteria:* Transition initiatives lacking these institutional-spatial readiness preconditions achieving comparable implementation rates of integrated portfolios, or formally prepared projects systematically collapsing due to factors entirely decoupled from the proposed coupling⁶⁸.
- 3) Proposition 3 (P3: Polycentric External Linking and Boundary Spanning)
- *Theoretical Proposition:* In non-metropolitan, rural, or spatially dispersed coal basins, a polycentric innovation platform enhances access to knowledge networks, transition capital, and extra-regional markets only when an empowered, boundary-spanning intermediary effectively connects localised projects to multi-scalar networks whilst keeping statutory responsibilities and socio-economic benefits territorially transparent.
 - *Boundary Conditions:* Requires foundational digital and transport infrastructure, a formal mandate for inter-municipal co-operation, and sufficient baseline absorptive capacity within local enterprises and public bodies.

⁶⁸ H. Kalliomäki, P. Oinas, T. Salo, *Innovation districts as strategic urban projects...*, op.cit., pp. 83–92; J.M. Valdaliso, C. Andrés, *Science and technology parks...*, op.cit., pp. 646–660.

- *Falsification Criteria:* Polycentric platforms generating persistently higher administrative co-ordination costs without delivering greater knowledge spillovers, project delivery velocity, or spatial capability diffusion compared to compact single-site models⁶⁹.
- 4) Proposition 4 (P4: The Access-and-Benefit Chain for Inclusive Transition)
- *Theoretical Proposition:* Equitable and inclusive transition outcomes are substantially more pronounced where agenda access, capability access, market/institutional access, and benefit access are systematically interconnected through named institutional accountabilities and enforceable distributional commitments.
 - *Boundary Conditions:* Requires viable economic demand for supported skills and indigenous suppliers, accessible spatial mobility, and robust institutional mechanisms capable of monitoring and enforcing social public procurement clauses.

⁶⁹ M. Morina, P. Selimi, K. Witte, *Building transformative capacities...*, op.cit., pp. 3–16; A. Matern et al., *Strategies for energy transition...*, op.cit., pp. 1001–1022; L. Coenen, P. Benneworth, B. Truffer, *Toward a spatial perspective on sustainability transitions...*, op.cit., pp. 968–979; T. Hansen, L. Coenen, *The geography of sustainability transitions...*, op.cit., pp. 92–109.

- *Falsification Criteria:* Consultation-only or tokenistic participatory models yielding identical distributional equity, or a fully integrated access chain failing to improve workforce transition quality, local SME procurement entry, or tangible community dividends⁷⁰.
- 5) Proposition 5 (P5: Evolutionary Asset Recombination)
- *Theoretical Proposition:* Inherited carbon-intensive assets (brownfield land portfolios, heavy grid infrastructure, and tacit technical competences) contribute to regional path creation only when purposefully recombined with extra-regional knowledge, emerging clean-technology demand, and dynamic organisational capabilities that become structurally embedded within indigenous enterprise ecosystems and training institutions.
 - *Boundary Conditions:* Bounded by the presence of transferable engineering competences, economically manageable environmental remediation liabilities, and clear market or public procurement demand signals.

⁷⁰ D. Morales et al., *Defining inclusive innovation...*, op.cit., pp. 745–750; C.M. Kayanan, *A critique of innovation districts...*, op.cit., pp. 50–66; A. Morisson, C. Bevilacqua, *Balancing gentrification...*, op.cit., pp. 472–492.

- *Falsification Criteria:* Enduring regional path branching emerging exclusively from physical site reclamation and cosmetic landscaping, or the persistent failure of well-capitalised recombination initiatives to generate new technological capabilities, supply-chain linkages, or follow-on investments⁷¹.
- 6) Proposition 6 (P6: Learning-Mediated Path Creation and Dynamic Capabilities)
- *Theoretical Proposition:* Project portfolios underpinned by *ex-ante* baseline audits, mechanism monitoring, granular distributional evidence, and an explicit scaling hypothesis are significantly more likely to generate cumulative regional path-creation trajectories than portfolios appraised solely through capital expenditure, floorplate construction, patent tallies, or start-up counts.
 - *Boundary Conditions:* Requires multi-year time horizons, longitudinal data continuity, and reflexive governance platforms endowed with the political autonomy to terminate underperforming projects or iteratively redesign strategies.

⁷¹ M. Grillitsch, M. Sotarauta, *Trinity of change agency...*, op.cit., pp. 704–723; D. MacKinnon et al., *Rethinking path creation...*, op.cit., pp. 113–135; M. Grillitsch, B.T. Asheim, M. Trippl, *Unrelated knowledge combinations...*, op.cit., pp. 257–274.

- *Falsification Criteria*: Reflexive, learning-oriented portfolios exhibiting no greater adaptive capacity, knowledge diffusion, or capability accumulation than indicator-light initiatives, or where observed regional trajectory shifts are fully accounted for by exogenous macroeconomic cycles or national policy shifts⁷².

4.12. Chapter Conclusion

The integrated conceptual model developed in this chapter operationalises the post-coal innovation district not merely as a physical brownfield intervention, but as a multi-scalar, place-based co-ordination mechanism structured across five interdependent analytical layers: spatial, institutional, economic, social, and learning. Mission orientation provides the requisite strategic directionality, coupling these layers to a diagnosed, socially legitimate public challenge. Concurrently, the inclusive-innovation framework operationalises community agency, procedural legitimacy, and multi-scalar territorial equity across the access-and-benefit chain,

⁷² E. Oikonomaki, N. Komninos, *Predicting local innovation through AI...*, op.cit., pp. 5–20; S. Fastenrath et al., *Mission-oriented innovation districts...*, op.cit., pp. 10–12; D. Morales et al., *Defining inclusive innovation...*, op.cit., pp. 745–750.

whilst the proposed evaluation architecture untangles the evaluative cascade to analytically decouple subsidised project activities and outputs from cumulative, long-term regional transformation effects.

Finally, the six theoretical propositions P_1 - P_6 articulate conditional, testable dynamics linking mission–portfolio alignment, institutional–spatial coupling, polycentric boundary spanning, inclusive access chains, evolutionary asset recombination, and learning-mediated path creation. Formulated not as deterministic assertions of pre-verified causal impact, but as falsifiable, deductive-inferential propositions bounded by explicit institutional, economic, and spatial conditions, they establish an actionable, rigorous analytical agenda for comparative empirical research across European transitional coal regions.

Table 4.3. Empirical evidence matrix, operational indicators, and falsification criteria for theoretical propositions P_1 - P_6

Proposition	Principal Sources	Type of evidence	Empirical Geography	Key Methodological Limitations	Required Empirical Test and Operational Design
P1	Fastenrath et al.	Structured literature review and conceptual synthesis.	International innovation-district and mission-oriented innovation literature.	Absence of post-coal comparative cases; proposed conceptual integration is not an evaluated empirical intervention.	Longitudinal comparative analysis of mission-led versus branding-led initiatives; coding of problem-portfolio alignment and iterative mission revisions.
P2	Kalliomäki et al.; Valdalisio & Andrés	Interview-based qualitative case study; process tracing and key-informant interviews.	Turku; Bilbao.	Focus on institutionally mature, non-coal metropolitan settings; Bilbao case captures early-stage implementation.	Comparative analysis of implementation trajectories and readiness-gate status across post-coal contexts; tracing dependencies across spatial planning, finance, and delivery vehicles.
P3	Morina et al.; Matern et al.; Coenen et al.; Hansen & Coenen	Policy briefs; comparative regional cases; conceptual reviews.	Western Macedonia, Western Balkans, Lusatia, and Ústi Region.	Predominance of policy-partner self-evaluations; absence of district-level econometric or counterfactual impact estimations.	Comparative evaluation of polycentric versus compact single-site models evaluating external network reach, inter-municipal co-ordination costs, delivery velocity, and spatial capability diffusion.
P4	Morales et al.; Kayanan; Morisson & Bewilacqua	Four-city qualitative comparative analysis; critical urban studies and single-site case research.	Newcastle upon Tyne, Pittsburgh, Medelin, Belfast, and Chattanooga	Predominantly metropolitan, non-coal urban environments; brief field visits; lack of population-level distributional estimations.	Tracing the complete access-and-benefit chain and evaluating multi-scalar distributional outcomes (site, host community, and wider region) pre- and post-investment.
P5	Grillitsch & Sotara;ta; MacKinnon et al.; Grillitsch et al.	Conceptual frameworks and geographical political-economy (GPE) empirical research	Broad regional development literature and comparative multi-sectoral cases.	Lack of direct empirical testing within designated post-coal innovation district platforms.	Process tracing of brownfield asset re-use, extra-regional knowledge coupling, enterprise/skills embedding, follow-on investments, and durability against rival structural explanations.
P6	Oikonomaki & Kominos; Fastenrath et al.; Morales et al.	Spatial-econometric observational predictive modelling; structured literature reviews; qualitative comparative analysis.	New York and Boston metropolitan areas; wider international urban district literature.	Patent metrics capture only partial technological outputs; reliance on observational spatial associations in non-CEE metropolitan contexts.	Longitudinal evaluation integrating ex-ante baselines, panel measures, matched comparison regions, qualitative process tracing, contribution analysis, and participatory interpretation panels.

Source: Author's own elaboration based on the studies cited in propositions P1 - P6 evidence types and limitations reflect the methodological designs of the cited research.

CHAPTER V

TERRITORIAL PATHWAYS OF POST-COAL INNOVATION: FROM CONCEPTUAL MODEL TO REGIONAL STRATEGY

This chapter operationalises the integrated conceptual model into an actionable territorial strategy. It conceptualises post-coal innovation not as an episodic project cycle or isolated physical development, but as a strategic evolutionary pathway: a sequenced, dynamic, and reflexive process through which legacy brownfield sites, heavy infrastructure, tacit engineering competences, and institutional architectures are purposefully recombined into new regional functions. Acknowledging profound territorial heterogeneity in fossil-fuel dependence, indigenous innovation capacity, land-tenure constraints, and socio-political expectations, this chapter does not advance a prescriptive, universal blueprint. Rather, it articulates a differentiated

strategic framework for territorial diagnosis, institutional implementation, multi-level governance, and cumulative policy learning tailored specifically to the structural conditions of Polish and Central and Eastern European (CEE) transitional regions⁷³.

5.1. From Conceptual Model to Territorial Strategy

Territorial strategy must structure and discipline public and private decision-making under conditions of acute structural uncertainty—spanning shifting mine-closure timelines, geo-technical land-reclamation complexities, infrastructure re-use parameters, workforce skills mismatches, volatile multi-level public financing, and fragile civic trust. The post-coal innovation district serves as an operational locus for these strategic choices, situated precisely at the territorial nexus where European and national decarbonisation mandates, sectoral

⁷³ P. Cooke, M.G. Uranga, G. Etzebarria, *Regional innovation systems...*, op.cit., pp. 475–491; B.T. Asheim, A. Isaksen, *Regional innovation systems: The integration of local ‘sticky’ and global ‘ubiquitous’ knowledge*, “The Journal of Technology Transfer” 2002, no. 1, vol. 27, pp. 77–86, <https://doi.org/10.1023/A:1013100704794>; R. Hassink, A. Isaksen, M. Trippl, *Towards a comprehensive understanding...*, op.cit., pp. 1636–1645; F. Tödtling, M. Trippl, *One size fits all? Towards a differentiated regional innovation policy approach*, “Research Policy” 2005, no. 8, vol. 34, pp. 1203–1219, <https://doi.org/10.1016/j.respol.2005.01.018>

industrial policies, and Just Transition funding instruments intersect with local enterprises, affected workforces, municipal authorities, higher-education institutions, and civic communities. Its strategic role is to synthesise disparate policy streams into a coherent, implementable architecture for collaborative experimentation, capital co-investment, and reflexive institutional learning⁷⁴.

Achieving this requires a decisive epistemological and practical pivot from fragmented ‘project-based thinking’ towards systemic “pathway thinking”. The piecemeal delivery of an isolated technology park, brownfield remediation scheme, or vocational training programme provides no structural guarantee that these individual interventions will achieve mutual reinforcement or build durable institutional thickness. Territorial strategy must instead be steered by five interconnected diagnostic inquiries that map directly onto the five analytical layers of the integrated model:

- 1) **Spatial Layer (*Spatial & Infrastructural Feasibility*):**
Which legacy industrial sites, transport corridors, and

⁷⁴ B. Katz, J. Wagner, *The rise of innovation districts: A new geography of innovation in America*, Brookings Institution, Washington, DC 2014, <https://www.brookings.edu/wp-content/uploads/2016/07/innovationdistricts1.pdf> [access: 21.08.2026]; J. Wagner, B. Katz, T. Osha, *The evolution of innovation districts: The new geography of global innovation*, The Global Institute on Innovation Districts, New York 2019, <https://giid.org/app/uploads/2019/05/the-evolution-of-innovation-districts.pdf> [access: 21.08.2026].

high-voltage grid connections possess the physical and spatial preconditions to anchor new regional functions?

- 2) **Institutional Layer (*Governance Continuity & Capacity*)**: Which institutional anchors, intermediary bodies, and governance coalitions can sustain strategic co-ordination across fluctuating political and funding cycles?
- 3) **Economic Layer (*Generative Path Creation*)**: Which emerging clean-technology domains, circular economy loops, and indigenous industrial capabilities can generate durable, self-sustaining developmental trajectories?
- 4) **Social Layer (*Procedural & Distributional Justice*)**: Through what institutional mechanisms will displaced industrial workers, local municipalities, and civic communities actively shape, access, and equitably benefit from emerging transition opportunities?
- 5) **Learning Layer (*Reflexive Policy Scaling*)**: Through what empirical feedback loops will localized niche experiments be systematically evaluated, adapted, and scaled across the wider territorial economy?

5.2. Differentiated Starting Points of Post-Coal Regions

Post-coal regions exhibit profound structural divergence in their initial territorial endowments, institutional capacities, and socio-spatial configurations. Whilst this territorial heterogeneity is self-evident, it is frequently obscured when European and national policy instruments are framed around homogenous, aggregated categories such as ,coal basins', ,transition territories', or ,old industrial areas'. Certain regions are densely embedded within diversified metropolitan agglomerations, hosting major research universities, tertiary hospitals, public research laboratories, and advanced corporate R&D clusters. Others are mono-industrial energy basins structured around a single open-cast mine, a thermal power plant, and a specialized, captive supplier network. Furthermore, some territories possess compact, high-value brownfield sites within urban core perimeters, whereas others encompass spatially fragmented mining landscapes, rural municipalities, and peripheral settlements. These divergent starting points dictate the specific configuration, strategic entry point, and governance architecture of the post-coal innovation district⁷⁵.

⁷⁵ J. Adamska et al., *Raport 1: Identyfikacja...*, op.cit., pp. 13–15;
J. Adamska et al., *Raport 2: Analiza...*, op.cit., pp. 12–18.

To operationalise these distinctions, regional strategies must calibrate their interventions across four primary territorial archetypes:

- 1) **Metropolitan-Industrial Coal Regions (*The Challenge of Fragmentation*)**: In metropolitan settings, the primary developmental bottleneck is rarely an absolute deficit of innovation assets, but rather their structural and socio-spatial fragmentation. Advanced higher-education institutions, corporate headquarters, multi-modal logistics corridors, and urban amenities already exist, yet legacy brownfield parcels, displaced industrial workforces, and marginalised local communities remain functionally and socially disconnected from these assets. In these territories, the post-coal innovation district must operate as a mechanism of **concentration and recombination**. Its strategic role is to establish tangible, cross-sectoral linkages among universities, high-tech enterprises, municipal authorities, brownfield redevelopment agencies, vocational training bodies, and civic communities. The objective is not merely to attract exogenous foreign direct investment (FDI), but to systematically recombine existing regional capacities around climate-neutral technologies, circular industrial ecosystems, and socially inclusive urban regeneration.

- 2) **Mono-Functional Energy Basins** (*The Challenge of Monocentric Lock-In*): In mono-industrial lignite or hard-coal basins, the central structural liability is severe economic and institutional path dependency on a dominant extractive utility, a single technology, or captive municipal tax revenues. These regions frequently possess extensive land portfolios, heavy electrical substation connectivity, highly skilled mechanical and engineering labour pools, and resilient technical identities, but operate with institutionally thin Regional Innovation Systems (RIS). A district strategy in this context must actively resist the uncritical imitation of metropolitan start-up quarters. Instead, it must drive structural diversification through challenge-led missions focused on utility-scale renewable energy integration, circular economy loops, environmental remediation engineering, and industrial maintenance services. In terms of spatial morphology, the district is typically **distributed and polycentric** rather than compact, strategically interconnecting decommissioned mining parcels, vocational polytechnics, municipal utility test-beds, and local supply-chain enterprises within a unified regional governance framework.
- 3) **Peripheral Post-Mining Localities** (*The Challenge of Spatial Distance and Thin Density*): Spatially isolated

or non-metropolitan post-mining territories confront acute geographical and institutional disadvantages. While endowed with expansive land holdings and deeply rooted industrial work cultures, they face severe structural deficits in local research infrastructure, risk capital, specialised business services, and dynamic firm formation. In these settings, an innovation district cannot rely on endogenous localised density alone. Rather, it must function as a strategic **boundary-spanning interface** that bridges the peripheral locality with national, macro-regional, and European knowledge and funding circuits. Regional path creation in peripheral basins is fundamentally mediated by **external linking**: orchestrating strategic pipelines for extra-regional academic collaborations, targeted public procurement of innovation (PPI), non-local venture investment, living-lab pilot demonstrations, and multi-scalar value-chain integration into places that would otherwise remain excluded from dominant innovation flows⁷⁶.

- 4) **Central and Eastern European (CEE) Transitional Basins** (*The Challenge of Multi-Level Governance and Institutional Capacity*): A fourth distinctive starting

⁷⁶ A. Drobnik (red.), *Just transition of coal regions in Poland...*, op.cit.; M. Szmytkowska et al., *Top-down policies and bottom-up realities...*, op.cit.

point characterizes CEE post-coal regions, which share deep industrial carbon lock-in while operating within post-socialist administrative frameworks, centralized fiscal regimes, and complex multi-level governance dynamics. Although these territories benefit substantially from the European Union's Just Transition Fund (JTF) and cross-border policy learning platforms, they frequently encounter institutional fragmentation, constrained municipal absorptive capacity, and politically polarized transition narratives between national energy security priorities and local decarbonisation imperatives. Within this context, the post-coal innovation district must function as an institutional **instrument of reflexive policy learning and state capacity-building**. It must serve as a structured platform to test context-appropriate governance models, scale viable pilot demonstrations into enduring industrial capabilities, and overcome the trap of transactional, short-term grant absorption that fails to alter the underlying regional development trajectory.

Table 5.1. Territorial pathways for post-coal innovation districts.

Territorial Starting Point	Typical Endogenous Assets	Primary Structural Bottleneck	Core District Function	Key Strategic Priority
Metropolitan-industrial coal region	Higher-education institutions; established enterprise base, dense labour market, brownfield land portfolios, and multi-modal transport infrastructure.	Institutional and spatial fragmentation; decoupled governance; uneven socio-spatial inclusion.	Concentration and recombination	Reconnect post-industrial land with knowledge institutions; applied R&D platforms, and inclusive local employment pathways.
Mono-functional energy basin	Extensive contiguous land parcels, high-voltage grid infrastructure, specialised engineering skills, and concentrated municipal/corporate assets.	Monocentric lock-in; structural dependence on a single dominant employer, utility, or technological trajectory.	Diversification and mission anchoring	Assemble a coherent portfolio of utility-scale renewable energy, circular economy closed loops, and advanced industrial/technical services.
Peripheral post-mining locality	Available land reserves, deeply rooted industrial identity, high ecological restoration potential, and local SME base	Thin regional innovation system; spatial isolation; weak external connectivity to risk capital and knowledge networks.	External linking and learning	Construct multi-scalar partnerships and institutional bridges that channel academic expertise, transition finance, and external markets into the locality.
Cross-border or CEE transition region	Dedicated European transition funding streams, shared infrastructure challenges, and comparable post-socialist industrial legacies.	Multi-level administrative discontinuity; jurisdictional fragmentation; constrained horizontal policy co-ordination.	Scaling and policy learning	Deploy interregional and cross-border platforms to experimentally test, comparatively evaluate, and mainstream post-coal solutions.

Source: Author’s own elaboration based on the integrated model developed in Chapter 4.

5.3. Translating Regional Assets into District Functions

Operational asset translation constitutes the foundational mechanism through which a post-coal innovation district bridges legacy industrial endowments with emergent economic trajectories. A decommissioned pit head, heavy rail siding, high-voltage substation, vocational polytechnic, or industrial hall does not spontaneously generate a new evolutionary path in its inherited configuration. Rather, these legacy elements become functional components of an innovation district only when purposefully coupled with experimental prototyping, modular vocational training, circular manufacturing loops, renewable-energy integration, environmental monitoring, public-service innovation, and community-centred spatial regeneration.

Land represents the most visible yet institutionally and technically complex legacy asset. Post-mining real estate frequently embodies severe geotechnical liabilities, residual ecological contamination, fragmented or opaque ownership titles, legal safety restrictions, and profound symbolic and cultural attachments. Consequently, a territorial transition strategy must firmly reject treating post-mining land as a passive, speculative real-estate inventory. Instead, it must systematically categorise land parcels according to their strategic transformative potential:

- a) Dedicated demonstration and testing zones for renewable energy generation, large-scale battery storage, geotechnical remediation techniques, and circular construction materials;
- b) Multi-modal logistics hubs, advanced manufacturing platforms, or green industrial symbiosis parks;
- c) Ecological and nature-based restoration corridors, flood-mitigation basins, and public amenity spaces;
- d) Mixed-use civic, educational, and cultural hubs that preserve post-industrial heritage. The fundamental strategic question is not merely what physical assets can be constructed, but what dynamic capabilities, institutional learning, and local absorptive capacity the remediation and redevelopment process itself can generate.

Industrial infrastructure is similarly ambivalent. Coal regions routinely possess dense electrical transmission grids, heavy freight rail networks, industrial water systems, and extensive district-heating networks. These legacy assets offer formidable cost advantages for emerging green sectors, but only if they are deliberately governed as open transition platforms rather than captive corporate assets. For instance, high-voltage grid connections can rapidly accelerate utility-scale renewable deployment, yet become severe structural bottlenecks if grid capacity is monopolised or access rules remain rigid. Similarly, centralized

district-heating grids can serve as experimental platforms for large-scale heat pumps, deep geothermal energy, industrial waste-heat capture, and thermal storage—provided that municipal utilities, innovative engineering firms, and regulatory authorities achieve institutional co-ordination. Legacy infrastructure must therefore be conceptualised not as a neutral, static background condition, but as an active arena of technological and institutional recombination⁷⁷.

Human capital is another inherited asset, though it is often misread. Regional workforce endowments constitute another decisive asset that is frequently mischaracterised in transition policy. Displaced industrial workers do not merely possess narrow, obsolete occupational skills tied to sunset extraction activities; they embody rich, tacit engineering competencies, mechanical problem-solving capabilities, occupational safety cultures, maintenance expertise, complex systems logistics, and deep-seated traditions of collective workplace organisation. A resilient district strategy must actively valorise and redeploy these competencies. Workforce re-skilling and upskilling must not be designed as passive, transactional social-welfare services delivered after mine decommissioning. Rather, vocational qualification pathways should be directly

⁷⁷ J. Adamska et al., *Raport 1: Identyfikacja...*, op.cit., pp. 114–124;
J. Adamska et al., *Raport 2: Analiza...*, op.cit., pp. 109–110, 123–124.

embedded within live capital projects—including ecological remediation works, renewable energy installations, industrial retrofitting, smart-grid monitoring, circular-material processing, and specialised technical-service ventures. This approach provides training with an immediate economic destination, transforming workers from passive subjects of industrial decline into active co-creators of the emerging developmental path.

Knowledge institutions require deliberate institutional translation to become functional drivers of territorial transition. Universities, polytechnics, and research institutes risk remaining ivory-tower enclaves if their engagement is confined to commissioned expert reports or detached academic publishing. Within a post-coal innovation district, knowledge institutions must function as long-term, embedded institutional learning partners. Their operational contribution encompasses applied challenge-led R&D, real-world living laboratories, longitudinal environmental and socio-economic monitoring, student innovation challenges, modular vocational certification, reflexive policy evaluation, and transnational knowledge networking. The decisive factor is not physical proximity to a university campus, but whether academic institutions actively co-produce solutions for concrete territorial transformation challenges and systematically enhance the absorptive capacity of local

firms and public administrations to integrate external knowledge⁷⁸.

5.4. Sequencing the Pathway: Diagnosis, Anchoring, Portfolio, and Scaling

The pathway from conceptual model to regional strategy begins with diagnosis. This must extend beyond a conventional SWOT analysis by mapping land, infrastructure, firms, skills, ownership structures, institutions, community expectations, environmental liabilities, and innovation networks. The central question is frequently not whether assets exist, but why they do not yet operate co-operatively as an integrated development system.

An institutional anchor provides the strategy with continuity. It may be a development agency, university-led partnership, public company, special-purpose vehicle, metropolitan association, or hybrid organisation. Whatever its form, it must convene actors, manage land and projects, align funding, maintain legitimacy, support experimentation, and resist short-term place branding. Absent these functions, the pathway risks dissolving into disconnected investments.

⁷⁸ B.T. Asheim, L. Coenen, *Contextualising regional innovation systems...*, op.cit., pp. 163–173.

A portfolio reduces dependence on a single flagship project. Remediation, skills programmes, demonstrators, enterprise support, university partnerships, public procurement, and community facilities should combine visible early improvements with longer-term capability building. This balance is critical because post-coal transformation must maintain trust whilst altering the regional productive structure⁷⁹.

Scaling links successful experiments to regional strategy, whilst learning permits ineffective projects to be terminated or redesigned. A technical solution may extend to other sites, a training model may enter vocational education, or a demonstrator may become a public procurement standard. Evaluation should begin early enough to demonstrate whether capabilities, worker and community access, firm diversification, and productive environmental repair are accumulating.

5.5. Governance Conditions for Regional Strategy

Governance constitutes the decisive condition for translating an evolutionary pathway into an actionable regional

⁷⁹ M. Mazzucato, R. Kattel, J. Ryan-Collins, *Challenge-driven innovation policy: Towards a new policy toolkit*, “Journal of Industry, Competition and Trade” 2020, no. 2, vol. 20, pp. 421–437, <https://doi.org/10.1007/s10842-019-00329-w>

strategy. Post-coal innovation districts sit at the intersection of disparate policy domains: climate mitigation, energy systems, statutory land-use planning, economic development, research and innovation, education, active labour-market policy, and social welfare. If each policy domain operates in isolation, the district risks being reduced to a conventional brownfield redevelopment site, an opportunistic funding label, or an isolated infrastructure project. Governance must therefore establish horizontal co-ordination across sectoral domains and vertical co-ordination across local, regional, national, and European tiers.

Clarity of mandate determines whether strategic co-ordination can translate into effective project delivery. Stakeholders require unambiguous institutional structures identifying who holds statutory authority to manage land assembly, allocate financial resources, broker partnerships, and steer public communication. An institutional anchor requires sufficient convening and implementation authority, balanced by robust accountability mechanisms that prevent technocratic closure and preserve democratic oversight.

Social legitimacy cannot simply be inferred from the rhetoric of innovation. Given that local workforces and residents may have experienced cycles of unfulfilled promises regarding economic renewal, the district must tangibly demonstrate how individual projects relate to secure

employment, skills development, environmental quality, spatial mobility, housing, public health, the public realm, and local public services. This does not imply that every strategic decision will achieve universal consensus; rather, it renders public purpose and distributional consequences transparent and open to critical scrutiny⁸⁰.

Financial layering responds directly to divergent risk profiles and temporal horizons. Geotechnical remediation, spatial planning, and foundational public infrastructure invariably require direct public funding; demonstration test-beds can blend public grants, competitive research funds, and corporate co-investment; whilst enterprise growth depends on repayable loans, credit guarantees, venture equity, and innovation procurement. Although European Union transition funds provide a critical strategic window of opportunity across Central and Eastern Europe, they cannot compensate for deficits in endogenous institutional capacity or substitute for a self-sustaining operating model.

Finally, open learning extends governance beyond the confines of a formal steering committee. Longitudinal monitoring, transparent public reporting, applied research partnerships, interregional knowledge exchange, and institutionalised arenas where workers and civic communities can interrogate policy assumptions enable knowledge

⁸⁰ J. Adamska et al., *Raport 1: Identyfikacja...*, op.cit., pp. 13–15; J. Adamska et al., *Raport 2: Analiza...*, op.cit., pp. 36–44.

to circulate dynamically. Multi-helix models become operationalised at this juncture: civil society actively generates empirical evidence regarding local needs, transition risks, and territorial legitimacy, rather than functioning merely as a nominal stakeholder category⁸¹.

5.6. Polish and Central and Eastern European Application Contexts

Polish and Central and Eastern European (CEE) post-coal regions provide an empirically demanding testing ground for the proposed conceptual construct. The following contextual applications represent theory-driven analytical hypotheses rather than empirical classifications of the named regions, and they do not constitute evidence that a fully fledged innovation district already exists or is functionally effective in these localities. The cited literature and policy documentation substantiate the diagnosed territorial challenges and comparative contrasts; the proposed district configurations and hypothesised mechanisms remain analytical propositions requiring dedicated, region-level field research⁸².

⁸¹ H. Etzkowitz, L. Leydesdorff, *The dynamics of innovation...*, op.cit., pp. 109–123; M. Roman et al., *Quadruple Helix models...*, op.cit.

⁸² A. Drobnik (red.), *Just transition of coal regions in Poland...*, op.cit.; J. Adamska et al., *Raport 1: Identyfikacja...*, op.cit., pp. 13–15; J. Adamska et al., *Raport 2: Analiza...*, op.cit., pp. 12–18, 36–44;

Upper Silesia provides the most robust empirical foundation for a metropolitan-industrial hypothesis. Nowakowska, Rzeńca, and Sobol's documentary analysis and seventeen key-informant interviews compared Upper Silesia with the Bełchatów Basin, identifying substantial divergences in substantive preparation and the density of stakeholder networks. Their 2021 empirical evidence characterises Upper Silesia as a polycentric, highly urbanised region endowed with extensive restructuring experience and a heterogeneous ecosystem of participating organisations. Drobnia's edited volume similarly conceptualises just transition as a spatially differentiated regional process rather than a uniform national programme⁸³.

Within the framework of the integrated model, these territorial conditions support a metropolitan-industrial configuration strictly as a testable proposition. A networked spatial-institutional arrangement could functionally interconnect selected brownfield sites, higher-education institutions, enterprise networks, labour-market organisations, cultural actors, and municipalities. However, the critical empirical counterfactual is comparison with

A. Matern et al., *Strategies for energy transition...*, op.cit., pp. 1001–1022.

⁸³ A. Nowakowska, A. Rzeńca, A. Sobol, *Place-based policy in the 'just transition' process: The case of Polish coal regions*, "Land" 2021, no. 10, vol. 10, art. 1072, <https://doi.org/10.3390/land10101072>; A. Drobnia (red.), *Just transition of coal regions in Poland...*, op.cit.

fragmented, isolated redevelopment and sectoral projects. Empirical verification would require demonstrating that such a networked platform enhances evolutionary asset recombination, inter-municipal project delivery, and accessibility for affected communities, as institutional density alone is insufficient to guarantee systemic transformation⁸⁴.

Eastern Wielkopolska presents a contrasting evidentiary starting point. Regional strategy documents and empirical research on workforce transitions document a spatially distributed lignite basin in which vocational skills pipelines, multi-municipal co-ordination, land and infrastructure repurposing, and the economic credibility of emerging sectors must be addressed simultaneously. Comparative energy-justice scholarship further demonstrates why labour-market adjustment cannot be analytically separated from procedural participation, social recognition, and the equitable territorial distribution of transition costs⁸⁵.

The model-derived hypothesis posits that a distributed platform systematically linking vocational and higher education, ecological restoration projects, inter-municipal co-operation, enterprise innovation support, and

⁸⁴ A. Drobnik (red.), *Just transition of coal regions in Poland...*, op.cit.; K. Sadowy, *Role of the local government...*, op.cit., pp. 263–284.

⁸⁵ J. Adamska et al., *Raport 1: Identyfikacja...*, op.cit., pp. 13–15; J. Adamska et al., *Raport 2: Analiza...*, op.cit., pp. 12–18, 36–44; M. Honorati, A. Banaszczyk, *Options to support workers...*, op.cit.; A. Schuster et al., *The unjust just transition?...*, op.cit.

new market demand will accumulate greater endogenous regional capability than an uncoordinated portfolio of disparate energy, remediation, and training interventions. A longitudinal empirical test must trace longitudinal work-force trajectories, inter-municipal delivery rates, local SME supply-chain integration, and the extent to which early demonstrator projects catalyse cumulative follow-on investment. At present, no reviewed source empirically validates this district-scale effect.

The Bełchatów Basin must be analytically differentiated from Turów. At the time of the 2021 fieldwork conducted by Nowakowska and colleagues, this lignite region was defined by a dominant state-owned energy conglomerate, a predominantly rural and multi-municipal spatial structure, less advanced transition planning, and a significantly narrower stakeholder network than Upper Silesia. Whilst the study identified an emerging institutional coalition coalescing around the local industrial and technology park, it did not evaluate subsequent operational delivery or broader socio-economic outcomes⁸⁶.

An application to Bełchatów would therefore test an anchor-led, distributed configuration. In this context, the institutional anchor would need to democratise

⁸⁶ A. Nowakowska, A. Rzeńca, A. Sobol, *Place-based policy in the 'just transition' process...*, op.cit; A. Drobniak (red.), *Just transition of coal regions in Poland...*, op.cit.

decision-making beyond the incumbent energy complex, integrate surrounding rural municipalities, and cultivate market demand across multiple complementary green sectors rather than relying on a singular replacement megaproject. Empirical falsification would be evident if formal governance co-ordination left brownfield remediation, skills upgrading, and local supplier programmes functionally decoupled, or merely reproduced structural dependence on a single corporate actor or technological trajectory.

The Turów/Bogatynia basin presents a ‘governance-first’ hypothesis. Schudy’s qualitative discourse analysis compares the Konin and Bogatynia lignite basins, reporting that, as of 2024, no institutionalised transition architecture operated for Turów at municipal, regional, or national tiers. The study further identifies deeply contested public narratives and a persistent deficit of concrete socio-economic expectations. This empirical evidence pertains to discourse and institutional visibility rather than the technical or economic feasibility of a specific investment portfolio⁸⁷.

Under these specific preconditions, the primary empirical inquiry is whether a transparent, accountable institutional arena for collaborative problem diagnosis and civic participation can be established prior to the

⁸⁷ H. Schudy, *Metafory transformacji...*, op.cit., pp. 305–322.

adoption of an innovation-district label or the selection of a technological mix. A viable governance configuration would need to construct institutional bridges between the energy conglomerate, local authorities, trade unions, civil society, and extra-regional research bodies, whilst rendering conflicting interests and alternative developmental pathways openly contestable. The hypothesis would be weakened if such initial governance co-ordination failed to improve project specificity, stakeholder participation, or implementation readiness.

The broader Central and Eastern European comparative horizon is retained strictly as an analytical boundary condition. Extant literature reveals substantial cross-national heterogeneity in regional state capacity, territorial development strategies, and centre–local fiscal relations; consequently, no singular district archetype should be assumed to transfer seamlessly across national borders. Future comparative scholarship should test whether distinct district configurations resolve specific territorial co-ordination bottlenecks and whether transition dividends diffuse beyond physical host sites and lead organisations, rather than reducing additional CEE regions to superficial, descriptive case studies⁸⁸.

⁸⁸ A. Matern et al., *Strategies for energy transition...*, op.cit., pp. 1001–1022; M. Morina, P. Selimi, K. Witte, *Building transformative*

5.7. From Strategic Vision to Brownfield Implementation

A post-coal innovation district strategy achieves operational credibility precisely when it demonstrates the capacity to translate a normative territorial vision into legally secured land, statutory spatial plans, structured multi-layer finance, viable delivery vehicles, and a phased, investable implementation sequence. This implementation threshold is analytically distinct from conceptual coherence. A region may establish broad political consensus regarding the necessity of green innovation and low-carbon diversification, yet remain structurally incapacitated when attempting to assemble fragmented parcels, remediate legacy contamination liabilities, or co-ordinate the disparate public authorities governing environmental reclamation, transport infrastructure, energy transmission, and enterprise support.

The empirical case of Bilbao analysed by Valdaliso and Andrés is particularly instructive, as it examines the urban brownfield extension of the mature Basque network of science and technology parks into a former industrial peninsula (Zorrotzaurre). Whilst this case does not yet demonstrate long-term socio-economic impact, it meticulously documents the institutional and organisational

capacities..., op.cit., pp. 3–16; M. Szymtowska et al., *Top-down policies and bottom-up realities...*, op.cit.

adjustments required when an established regional innovation intermediary transitions into complex urban brownfield development. In this arrangement, the municipal authority maintains strategic oversight over the broader urban regeneration masterplan, whilst the technology-park corporation acts as the developer of the dedicated urban technology campus, requiring continuous alignment with overarching regional industrial priorities and existing suburban science parks⁸⁹.

The brownfield operating model fundamentally recalibrates the economic and financial calculus. Redevelopment expenditures are substantially higher, return on investment is protracted over multi-decadal horizons, and land assembly is strictly mediated by statutory planning procedures and public-ownership structures. In Bilbao, reconciling the market demand for commercial floorplates with private and public capital availability emerged as the primary operational bottleneck, exacerbated by public-sector budgetary constraints that constrained delivery velocity. For post-coal innovation districts, financial exposure is frequently more severe, as complex geotechnical remediation, hydrological management, utility retrofitting, and title restructuring must inevitably precede any revenue-generating economic activities. A rigorous financial framework must therefore

⁸⁹ J.M. Valdaliso, C. Andrés, *Science and technology parks...*, op.cit., pp. 657–660.

decouple non-recoverable, public-good foundational expenditures from commercially viable assets capable of generating recurring operational income⁹⁰.

This analytical distinction underpins a layered capital structure:

- 1) **Public Environmental and Foundational Infrastructure:** Geotechnical decontamination, mine-water management, and trunk transport connectivity necessitate non-repayable public grants or direct state capital expenditure justified by systemic environmental, spatial, and territorial benefits.
- 2) **Shared Innovation and Demonstration Assets:** Applied research laboratories, vocational training centres, and living-lab demonstration test-beds can blend competitive innovation programme funding with capital co-investment from anchor institutions.
- 3) **Commercial and Industrial Premises:** Enterprise incubator spaces, multi-tenant industrial halls, and office floorplates can deploy debt financing, commercial leasing models, or private equity once viable market demand is empirically verified.
- 4) **Civic Amenities and Social Inclusivity Mechanisms:** Community facilities, public spaces, and social access mechanisms require dedicated, sustained public

⁹⁰ Ibidem.

funding streams rather than precarious reliance on residual commercial project surpluses.

The central governance challenge is to establish explicit risk-allocation frameworks, defining which institutional actor bears financial and technical risk at each stage and safeguarding public-interest obligations amidst shifting macroeconomic cycles.

Governance architectures must be sequentially staged. In its initial phase, the Bilbao initiative relied on relatively flexible, relational governance mechanisms among key public authorities, underpinned by decades of inter-institutional trust and political alignment. However, Valdaliso and Andrés caution that a more formalised, comprehensive governance model becomes indispensable as implementation matures, particularly when electoral cycles introduce political discontinuity. This trajectory suggests an analytical distinction between **exploratory governance**—which privileges relational agility, inter-institutional negotiation, and rapid problem-solving—and **operational governance**, which requires codified statutory mandates, transparent resource-allocation protocols, public procurement compliance, and long-term fiduciary stewardship of physical assets⁹¹.

⁹¹ Ibidem.

The case of Turku demonstrates the indispensability of formal planning gates within this implementation sequence. Whilst an overarching strategic vision widened cross-sectoral co-ordination, detailed physical delivery remained contingent upon statutory planning instruments and the administrative internalisation of the vision across municipal departments. For a post-coal innovation district, every strategic project within the portfolio must explicitly identify its authorising statutory instrument, the legal owner of the land or infrastructure parcel, the designated delivery vehicle, and the mandatory formal review points required for municipal or civic approval. A project portfolio lacking this statutory precision represents an aspirational catalogue rather than an actionable implementation pathway⁹².

To enforce implementation discipline, the transition pathway can be operationalised through five progressive **Readiness Gates**:

- 1) **Territorial Mandate Gate:** Formal statutory recognition of the district boundary and governance remit across municipal, regional, and national tiers of government.
- 2) **Site Control and Remediation Gate:** Full legal resolution of land tenure, ownership boundaries,

⁹² H. Kalliomäki, P. Oinas, T. Salo, *Innovation districts as strategic urban projects...*, op.cit., pp. 89–92.

geotechnical risks, environmental liabilities, and physical infrastructure access rights.

- 3) **Planning and Regulatory Compatibility Gate:** Complete statutory alignment between strategic transition objectives, binding municipal masterplans, zoning ordinances, and environmental permits.
- 4) **Delivery and Institutional Capacity Gate:** Formal establishment of an empowered delivery vehicle equipped with dedicated executive personnel, statutory procurement powers, and multi-stakeholder partnership remits.
- 5) **Financial Structuring and Market Demand Gate:** Binding multi-year capital commitments, fully modelled operational expenditure schedules, and documented pre-commitments from credible commercial, academic, or public end-users.

Projects that fail to clear a specific gate must remain strictly within exploratory research or feasibility phases rather than being presented as committed capital investments.

This phased gatekeeper sequence prevents a singular, high-visibility flagship project from dominating the regional transition narrative. A prestige architectural development may satisfy basic construction milestones whilst failing to generate institutional thickness, workforce integration, or technological diversification. Portfolio

governance must therefore track and publish gate status and critical interdependencies separately across all dimensions: brownfield remediation, vocational skills pipelines, enterprise support programmes, applied research infrastructure, civic access mechanisms, and regional connectivity. This disaggregated tracking renders delivery bottlenecks legible, enabling policymakers to distinguish between temporary procedural friction and structural deficits in institutional mandate or market demand.

Whilst incumbent technology-park operators, municipal development agencies, regional utilities, or universities can act as delivery anchors, the Basque evidence illustrates that institutional adaptation inevitably generates organizational frictions. An incumbent anchor may instinctively seek to protect its existing suburban campuses, legacy revenue models, or historical sectoral specialisations. Governance frameworks must transparently disclose these organizational tensions and establish formal mechanisms to ensure that the broader territorial public mission takes precedence over the parochial interests of individual anchor entities. Prior institutional prestige is a strategic asset only when coupled with direct accountability to the post-coal mission.

The protracted developmental horizons documented in both Bilbao and Turku serve as a crucial warning against synchronising district timelines exclusively with short-term political mandates or European funding programmes.

Institutional capability building, statutory spatial planning, and civic trust evolve at structural tempos distinct from capital expenditure deadlines. Interim milestones must demonstrate genuine capability accumulation—such as completed land-transfer covenants, institutionalised procurement protocols, binding user pre-commitments, and functional community-benefit agreements—without prematurely asserting structural regional path creation. While long maturation does not inherently guarantee quality, artificial acceleration risks masking fatal unresolved dependencies.

Each readiness gate must be substantiated by a comprehensive **Evidence Dossier** rather than a superficial binary declaration:

- a) *Territorial Mandate*: The dossier must identify participating jurisdictions, formal inter-municipal compacts, statutory competencies, and dispute-resolution protocols.
- b) *Site Control*: It must document land registers, geotechnical risk assessments, utility servitudes, decontamination obligations, and conditional transfer covenants.
- c) *Planning Compatibility*: It must map strategic objectives to binding statutory spatial plans, infrastructure reservations, and environmental impact approvals.

- d) *Delivery Capacity*: It must provide organisational organigrams, statutory procurement remits, key executive appointments, and a codified responsibility matrix.
- e) *Finance and Demand*: It must provide multi-scenario financial underwriting, operating cost projections, sensitivity analyses, and documented end-user commitments.

Publishing proportionate, transparent summaries of these dossiers empowers regional stakeholders to distinguish verifiable operational readiness from speculative boosterism, creating an empirical baseline for subsequent process evaluation.

The designated institutional anchor should undergo a formal **Maturity Audit**. Whilst Basque technology-park agencies brought decades of experience in brownfield property management, enterprise networking, and innovation-policy intermediation, and Turku built its collaborative capacity through iterative planning cycles, newly designated post-coal anchors frequently possess formal legal remits without equivalent operational or relational capabilities. The maturity audit must critically assess historical project delivery records, balance-sheet resilience, cross-sectoral network centrality, civic accountability mechanisms, and data-monitoring capabilities across municipal and regional scales. Where deficits are identified, the implementation pathway must mandate targeted capacity building, specialised technical

recruitment, or joint-venture delivery structures prior to the procurement of major physical assets⁹³.

Finally, governance architectures must be systematically **stress-tested against foreseeable structural discontinuities**. As Valdaliso and Andrés observe, multi-level governance arrangements remain vulnerable to political turnover across municipal, regional, and national tiers; similarly, the Turku case demonstrates how national infrastructural policy shifts can undermine municipal masterplanning assumptions. A post-coal innovation district must conduct rigorous scenario stress-testing against macro-level shocks: electoral realignments, delayed mine-decommissioning timelines, corporate restructuring or exit of a key anchor tenant, construction cost inflation, or the sudden cessation of European transition subsidies. This stress-testing must delineate which contractual commitments are reversible, which public obligations remain legally protected, who assumes ownership of stranded or partially completed physical assets, and how the overall mission portfolio will be reprioritised under conditions of fiscal contraction. Such institutional stress-testing does not claim to predict exogenous shocks; rather, it verifies whether organisational adaptability is

⁹³ J.M. Valdaliso, C. Andrés, *Science and technology parks...*, op.cit., pp. 657–660; H. Kalliomäki, P. Oinas, T. Salo, *Innovation districts as strategic urban projects...*, op.cit., pp. 89–92.

systematically institutionalised or precariously dependent on transient political goodwill⁹⁴.

These operational readiness gates and governance mechanisms represent analytical inferences derived from Western European urban brownfield cases rather than universally validated empirical laws for coal-dependent regions. Their fundamental utility lies in rendering underlying planning assumptions, resource dependencies, and governance risks explicitly open to scrutiny. Future comparative empirical research must investigate whether post-coal districts that systematically clear these readiness gates demonstrate superior resilience in delivering mission-oriented, inclusive, and spatially integrated portfolios, whilst identifying what supplementary institutional gates are mandated by the distinct administrative, legal, and fiscal architectures of Central and Eastern Europe.

5.8. Risks, Evaluation, and Strategic Learning

The evolutionary pathway approach exposes three primary structural risks that routinely undermine post-industrial regeneration initiatives:

⁹⁴ J.M. Valdaliso, C. Andrés, *Science and technology parks...*, op.cit., pp. 657–660; H. Kalliomäki, P. Oinas, T. Salo, *Innovation districts as strategic urban projects...*, op.cit., pp. 89–92.

- 1) **Symbolic Redevelopment:** The superficial adoption of innovation rhetoric and eco-branding whilst delivering conventional, speculative commercial real estate devoid of indigenous innovation capacity.
- 2) **Technological Narrowing:** The premature tethering of the district to a singular, fashionable socio-technical solution (such as green hydrogen or advanced modular batteries) absent the broader industrial capabilities or diversified supply chains required to sustain it.
- 3) **Social Displacement and Spatial Enclave Formation:** The progressive escalation of land valuations and influx of external capital whilst displaced energy-sector workers and host communities remain socially and economically peripheralised⁹⁵.

These primary risks are compounded by **institutional exhaustion** and **evaluative failure**. Sub-national public bodies are frequently tasked with orchestrating complex, multi-decade transition processes without adequate administrative staffing, analytical data infrastructures, fiscal autonomy, or statutory enforcement powers. Concurrently, conventional evaluation regimes succumb to output bias: gross capital absorption, hectares reclaimed, or promotional

⁹⁵ C.M. Kayanan, *A critique of innovation districts...*, op.cit., pp. 50–66; A. Morisson, C. Bevilacqua, *Balancing gentrification...*, op.cit., pp. 472–492.

media visibility are uncritically equated with structural diversification, procedural justice, or capability accumulation. To counter this distortion, evaluation must systematically span all five analytical layers of the integrated model.

A comprehensive evaluation architecture must combine quantitative spatial-econometric metrics with qualitative institutional evidence across the model's constitutive layers:

- 1) **Spatial Indicators:** Extent and ecological quality of remediated brownfield land; multi-modal transit accessibility and active mobility connectivity; legacy transmission grid and district heating re-use efficiency; and the spatial balance between accessible public amenities and productive research/manufacturing floorplate.
- 2) **Institutional Indicators:** Longitudinal stability of multi-stakeholder governance coalitions; alignment and leverage ratios of multi-level funding streams; statutory decision-making transparency; clarity of executive mandates; and the operational maturity of the boundary-spanning institutional anchor.
- 3) **Economic Indicators:** Net formation and survival rates of eco-innovative enterprises; regional economic diversification indices; depth of applied university-industry R&D collaborations; integration of indigenous SME suppliers into emerging

clean-technology value chains; and verified employment transitions of industrial workers into quality, high-wage occupations.

- 4) **Social Indicators:** Extent of procedural participation by affected labour unions and community groups; completion and absorption rates of vocational re-skilling programmes; delivery of legally binding community-benefit commitments; and multi-scalar assessments of territorial distributional equity.
- 5) **Learning Indicators:** Institutionalisation and active maintenance of a live Mission Register; scaling and regulatory mainstreaming rates of living-lab pilot test-beds; and documented instances where under-performing initiatives are reflexively redesigned or terminated.

This evaluative discipline is paramount because post-coal innovation districts cannot be appraised at the static moment of ribbon-cutting or physical inauguration. Their decisive empirical test lies in whether they permanently enhance the territory's dynamic capacity to act. An effective post-coal innovation district is not merely a spatial parcel containing refurbished heritage architecture or subsidised enterprise tenants; it constitutes an evolving territorial system that empowers a region to diagnose structural bottlenecks, mobilise fragmented actor networks, experimentally test socio-technical solutions, absorb extra-regional

knowledge, and generate durable developmental trajectories. In this vital sense, the post-coal innovation district operates simultaneously as an object of territorial policy and as a generative method of regional learning.

This chapter has extended the integrated conceptual model into an actionable strategic proposition. Post-coal innovation demands evolutionary pathways that are place-sensitive, institutionally anchored, socially legitimate, and capable of reflexive learning. Whilst the imperative of climate neutrality establishes the normative direction of structural transformation, it does not in itself provide the operational governance mechanism. The post-coal innovation district provides precisely this operational mechanism when it systematically binds brownfield land, infrastructure, tacit industrial skills, academic knowledge, enterprise networks, and civic communities into a cumulative, generative process of regional path creation. This synthesis constitutes the practical and theoretical essence of translating a conceptual model into an enduring regional strategy.

5.9. Chapter Conclusion

This chapter has translated the integrated conceptual model into an operational territorial strategy framework. Its analysis demonstrates that post-coal regions cannot adhere

to a uniform, linear developmental trajectory, given profound structural divergences in their inherited asset bases, institutional thickness, spatial morphologies, labour-market vulnerabilities, and connectivity to extra-regional knowledge networks. These territorial disparities dictate both the appropriate configurational archetype of the district and the operational sequencing through which strategic interventions become institutionally feasible. Inherited regional endowments acquire transformative developmental significance only when systematically coupled with identifiable economic and civic functions, capable anchor institutions, and credible market and public-demand signals. Consequently, material implementation requires substantially more than a normative strategic vision: it demands legally secured site control, statutory planning alignment, an accountable and empowered delivery vehicle, a layered capital structure, and verifiable institutional channels ensuring that prospective end-users, displaced workers, and host communities actively participate in the emerging transition pathway.

The regional application contexts examined in Section 5.6 represent theory-driven analytical hypotheses rather than definitive empirical classifications. Their primary methodological function is to illustrate how the integrated framework generates differentiated, testable research questions tailored specifically to metropolitan-industrial,

mono-functional, peripheral, and polycentric post-coal territories across Central and Eastern Europe. The enduring strategic value of a post-coal innovation district resides in its capacity to orchestrate a diversified portfolio of mutually reinforcing interventions, rather than in the promotional visibility of a flagship architectural project or the uncritical adoption of an innovation-district label. Transformative progress must therefore be appraised through verifiable enhancements across implementation readiness, evolutionary asset recombination, multi-level institutional co-ordination, inclusive employment transitions, democratic social access, and reflexive policy learning. Where these systemic linkages remain decoupled, an active portfolio of subsidised projects may merely mask entrenched structural dependence and regional lock-in. Conversely, where these institutional and spatial interdependencies become durably established, the post-coal innovation district provides a generative territorial platform through which localized socio-technical experimentation contributes directly to cumulative regional path creation.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1. Main Conclusions

The primary answer to the overarching research question of this monograph is that whilst climate neutrality establishes a necessary, normative direction for regional transition, it does not in itself determine the economic structures, institutional architectures, or territorial capabilities required to succeed coal. Consequently, the post-coal innovation district is conceptualised as a **conditional territorial co-ordination mechanism**: a place-based platform capable of functionally synchronising brownfield sites, multi-scalar actors, workforce skills, layered investments, and public purpose. Crucially, it must not be treated as an automatic or deterministic generator of employment, technological innovation, or regional renewal.

The principal conceptual contribution of this study resides in synthesising previously decoupled literature streams—spanning just transition and energy justice, Regional Innovation Systems (RIS), urban innovation districts, green technological innovation, brownfield redevelopment, and evolutionary path development—into an integrated **five-layer analytical model** (spatial, institutional, economic, social, and learning). Its distinct theoretical value derives not from any single layer in isolation, but from establishing a territorially anchored, mutually reinforcing, and empirically evaluable architecture that links physical brownfield re-use, multi-level institutional co-ordination, low-carbon economic diversification, procedural and distributional social access, and cumulative policy learning⁹⁶.

The integrated model is deliberately non-universal and context-sensitive. Its five configurational archetypes—**land-re-use**, **anchor-led**, **skills-transition**, **green-industry**, and **polycentric regional platforms**—represent deductive hypotheses to be calibrated against granular territorial preconditions, legacy asset endowments, and institutional thickness. Enduring regional path creation is fundamentally contingent upon:

⁹⁶ S. Fastenrath et al., *Mission-oriented innovation districts...*, op.cit., pp. 4–5; A. Matern et al., *Strategies for energy transition...*, op.cit., pp. 1001–1006; T. Yigitcanlar, R. Adu-McVie, I. Erol, *How can contemporary innovation districts be classified?...*, op.cit.; J. Drucker, C.M. Kayanan, *Innovation districts...*, op.cit., pp. 802–834.

- 1) **Mission–Portfolio Alignment:** Ensuring project selections directly target diagnosed territorial vulnerabilities rather than speculative place branding;
- 2) **Institutional–Spatial Readiness:** Securing statutory planning alignment, site control, dedicated delivery vehicles, and layered capital structures before deployment;
- 3) **The Access-and-Benefit Chain:** Establishing enforceable institutional channels that guarantee procedural participation, capability development, and tangible economic dividends for affected workforces and communities;
- 4) **Evolutionary Asset Recombination:** Purposefully redeploying legacy infrastructure and tacit industrial skills into emerging clean-technology value chains;
- 5) **Reflexive Policy Learning:** Institutionalising dynamic evaluation systems and scaling hypotheses that enable underperforming projects to be redesigned or terminated.

A systemic failure across these core interdependencies leaves regions vulnerable to "pilotitis"—the proliferation of active, subsidised project portfolios that generate short-term activity whilst leaving the underlying trajectory of carbon lock-in and regional dependency fundamentally unchanged⁹⁷.

⁹⁷ J. Adamska et al., *Raport 1: Identyfikacja...*, op.cit., pp. 13–15;
J. Adamska et al., *Raport 2: Analiza...*, op.cit., pp. 12–18, 36–44;

6.2. Theoretical Contribution

This monograph makes a distinct theoretical contribution by bridging three literature streams that have historically developed in mutual isolation: just transition and energy justice studies, territorial and Regional Innovation Systems (RIS) theory, and the urban innovation district literature. By synthesising these disparate fields, the construct of the post-coal innovation district shifts the analytical scope of innovation districts beyond their conventional metropolitan, knowledge-intensive origins, repositioning them as place-based mechanisms of transformative regional path development within carbon-intensive industrial basins confronting structural decarbonisation and deep path dependency.

A second major contribution resides in the **five-layer conceptual model** (spatial, institutional, economic, social, and learning). Rather than reducing regional restructuring to physical brownfield reclamation, technocratic governance, or technological substitution in isolation, the framework conceptualises transformative capacity as an emergent property of dynamic, multi-scalar interactions

M. Grillitsch, B.T. Asheim, M. Trippl, *Unrelated knowledge combinations...*, op.cit., pp. 257–274; R. Hassink, A. Isaksen, M. Trippl, *Towards a comprehensive understanding...*, op.cit., pp. 1636–1645.

across all five layers. This analytical scaffolding provides a robust heuristic to differentiate between an isolated real-estate parcel, an opportunistic funding label, a transactional labour-market programme, and a truly integrated, systemic co-ordination mechanism.

Third, the monograph reframes legacy post-mining endowments through an evolutionary, critical-realist lens. Post-mining land holdings, heavy transmission infrastructure, tacit mechanical and engineering competences, and regional institutional memory are conceptualised neither merely as obsolete structural liabilities of industrial decline nor as spontaneously productive assets. Rather, they constitute the material and institutional substrate for evolutionary asset recombination when purposefully coupled with extra-regional knowledge, low-carbon technologies, dynamic organisational capabilities, and verified market demand—without minimising environmental degradation or uncritically romanticising extractive heritage⁹⁸.

Fourth, the integration of mission-oriented innovation policy infuses the multi-layered architecture with explicit normative directionality. Mission-oriented scholarship establishes that a territorial platform achieves transformative impact only when purposefully organised around

⁹⁸ D. Łowicki, K. Fagiewicz, *A new model of pollination services potential...*, op.cit.; S. Greiving, D. Gruehn, C. Reicher, *The Rhenish coal-mining area...*, op.cit.

a diagnosed, socially legitimate societal challenge. Concurrently, empirical insights from dynamic urban settings (such as the Melbourne Innovation District) demonstrate that innovation imaginaries remain subject to continuous socio-political contestation and external crisis shocks. Consequently, the monograph advances the theoretical proposition that a post-coal innovation district functions not merely as an administrative co-ordination mechanism, but as a **reflexive mission arena**: an institutional setting that governs who defines the transition challenge, where socio-technical experiments are staged, and how iterative policy learning is scaled to the wider regional economy.

Fifth, the study refines the spatial political economy of transitions by clarifying the relationship between spatial form and institutional capability. Insights from strategic spatial planning and policy-instrument evolution demonstrate that physical district formation is strictly contingent upon accumulated institutional competences capable of integrating statutory land-use planning, innovation strategies, blended finance, and multi-level governance. Spatial concentration must therefore be treated neither as an autonomous causal driver of economic diversification nor as a passive, neutral container. Rather, spatial proximity represents an institutional achievement that facilitates collaborative interaction whilst actively structuring the

distribution of authority, capital costs, and socio-economic access.

Finally, the study advances an evaluative contribution by untangling the **evaluative cascade** into fine-grained local innovation potential, subsidised project activities, intermediate outcomes, and long-term trajectory shifts. By coupling geocoded spatial-econometric monitoring with mission-oriented and inclusive-innovation evaluative criteria (spanning public value, distributional justice, and democratic community agency), the proposed evaluation architecture establishes a robust methodological foundation for mixed-methods, longitudinal inquiry. This prevents premature declarations of regional transformation derived from narrow business indices, patent tallies, or static indicator dashboards.

6.3. Policy Recommendations

The overarching policy implication of this research is that post-coal innovation districts must be governed as integrated territorial co-ordination platforms rather than treated as isolated real-estate developments, technological enclaves, or grant-absorption vehicles. A business park, technology campus, brownfield regeneration scheme, or regional branding campaign acquires transformative

developmental relevance only when it systematically synchronises climate mandates, regional economic development, technological innovation, workforce skills, statutory spatial planning, infrastructure adaptation, and social policy around a democratically accountable territorial mission.

A dynamic territorial diagnosis must strictly precede the selection or spatial designation of any district configuration. Sub-national policymakers require a continuously updatable analytical mapping of brownfield land liabilities, high-voltage grid and district-heating capacities, labour-market exposures, institutional thickness, enterprise supply chains, educational assets, civic expectations, and multi-level governance bottlenecks. Static diagnostic documents prepared solely to satisfy ex-ante conditionalities for European or national funding programmes cannot capture how these structural conditions evolve as decommissioning schedules advance, land-tenure rights shift, and industrial workforces transition.

District configurations must then be calibrated against diagnosed territorial preconditions rather than imported as uncritical institutional blueprints:

- a) Spatially extensive brownfield sites situated within institutionally thin innovation systems indicate that environmental remediation, hydrological stabilization, and shared multi-user infrastructure should constitute the primary entry points;

- b) The presence of mature research universities or regional development agencies supports an anchored arrangement;
- c) Acute and immediate workforce vulnerability necessitates placing a dedicated skills-transition platform at the centre of the intervention;
- d) Spatially fragmented mining assets across multi-municipal landscapes demand a distributed, polycentric governance platform rather than a singular flagship campus.

Active labour-market and vocational skills policies must be structurally embedded within the district architecture from the outset. Technical training, vocational education and training (VET) curricula, re-skilling programmes, and lifelong learning frameworks must be organically tied to the concrete economic functions and emerging market demand that the project portfolio is designed to cultivate. Decoupling training from the evolving industrial portfolio risks generating credential inflation—issuing non-portable certificates without establishing viable, high-quality employment pathways for transitioning industrial workers.

Governance architectures must encompass public authorities, private enterprises, higher-education institutions, policy intermediaries, and civil-society organisations; however, passive formal representation is insufficient. Displaced energy-sector workers, host municipal governments,

and local community representatives require legally codified, substantive decision-making roles before strategic, financial, and spatial choices achieve lock-in—particularly where multi-helix arrangements are explicitly tasked with delivering procedural and distributive energy justice⁹⁹.

Policy evaluation must deploy a balanced, multi-dimensional indicator architecture. Conventional economic metrics—such as firm formation, patent registrations, R&D intensity, and private capital leverage—must be critically interpreted alongside spatial remediation indicators, institutional co-ordination stability, workforce transition trajectories, social access mechanisms, public procurement integration, reflexive learning loops, and broader regional economic resilience. The decisive evaluative inquiry is not merely whether the district attracts localized capital investment or promotional visibility, but whether that activity durably enhances endogenous territorial capabilities and who equitably benefits from the resulting transition dividends.

⁹⁹ E.G. Carayannis, D.F.J. Campbell, *Triple Helix, Quadruple Helix and Quintuple Helix...*, op.cit., pp. 41–69; M. Szmytkowska et al., *Top-down policies and bottom-up realities...*, op.cit.

6.4. Practical Recommendations for Polish and CEE Post-Coal Regions

The practical recommendations articulated for Polish and Central and Eastern European (CEE) post-coal regions constitute analytical decision heuristics derived from the conceptual model, rather than prescriptive, pre-validated blueprints for specific administrative jurisdictions. Their operational application must commence with an empirical, evidence-based territorial diagnosis and the critical comparative appraisal of alternative configurational models, actively resisting the premature application of fashionable innovation-district branding to pre-selected brownfield sites¹⁰⁰.

Rather than assigning rigid, deterministic district typologies to specific territories—such as Eastern Wielkopolska, Upper Silesia, the Bełchatów Basin, Lower Silesia (Wałbrzych), or Turów/Bogatynia—regional policymakers and researchers should systematically test competing configurational options against common empirical criteria: societal challenge definition, legally secured site control, anchor institution maturity, workforce and community

¹⁰⁰ A. Drobniak (red.), *Just transition of coal regions in Poland...*, op.cit.; J. Adamska et al., *Raport 1: Identyfikacja...*, op.cit., pp. 13–15; J. Adamska et al., *Raport 2: Analiza...*, op.cit., pp. 12–18, 36–44; H. Schudy, *Metafory transformacji...*, op.cit., pp. 305–322; M. Honorati, A. Banaszczyk, *Options to support workers...*, op.cit.

access mechanisms, verified market and public demand, layered financing structures, and systemic scaling pathways. The contextual applications outlined in Section 5.6 articulate an explicit fieldwork agenda; they do not establish the predetermined operational viability of any specific configuration.

To discipline implementation, regional transition authorities should enforce two foundational integration tests:

- 1) **Strategic Policy Integration Test:** Regional Innovation Strategies for Smart Specialisation (RIS3) and Territorial Just Transition Plans (TJTPs) must be unified around a shared territorial problem definition and an integrated project portfolio, overcoming the pervasive administrative fragmentation wherein they operate as disconnected, competing funding applications.
- 2) **Asset Recombination Integration Test:** Decommissioned mining and energy land holdings must be treated as strategic developmental assets only when physical remediation and infrastructure re-use are functionally coupled with enterprise incubation, vocational re-skilling pipelines, civic access guarantees, and institutional policy learning.

These criteria constitute conditional design propositions; their policy adoption requires rigorous, context-specific empirical verification and continuous reflexive monitoring.

6.5. Limitations and Future Research

The principal methodological limitation of this monograph arises from its conceptual, deductive, and literature-synthesising research design. Whilst the theoretical model is rigorously anchored in the international peer-reviewed literature, official European Union policy documentation, and regional transition reports, it has not yet been subjected to primary empirical testing through extensive field interviews, quantitative enterprise surveys, or in-depth comparative ethnographic case studies. Consequently, the conceptual framework and its associated configurational archetypes must be understood as an analytical heuristic and a system of falsifiable, theory-driven propositions rather than definitive empirical proof of the operational performance or causal efficacy of innovation districts in post-coal territories.

Future academic inquiry must systematically test and refine this conceptual architecture through empirical investigation across multiple operational fronts:

- 1) **Multi-Basin Comparative Fieldwork:** Primary research should conduct comparative empirical analyses across Polish post-coal basins displaying contrasting structural preconditions—including Eastern Wielkopolska, Upper Silesia, the Bełchatów Basin, Lower Silesia (Wałbrzych), and Turów/Bogatynia. This inquiry should examine which configurational archetypes emerge in practice, which institutional actors assume leadership as delivery anchors, how project portfolios are integrated with Territorial Just Transition Plans (TJTTPs), and whether measurable shifts occur across indigenous innovation capacity, high-wage employment trajectories, and brownfield land re-use.
- 2) **Pan-European and CEE Cross-Border Comparisons:** To evaluate the cross-national transferability of the model, comparative research should extend to diverse Central, Eastern, and Southern European transition regions, such as Lusatia and Central Germany, the Ústí and Moravian-Silesian Regions (Czechia), Stara Zagora (Bulgaria), Western Macedonia (Greece), the Jiu Valley and Gorj (Romania), and the Irish Midlands. Such comparative research would illuminate how divergent national administrative traditions, centre–local fiscal architectures, and state-ownership regimes shape the viability of post-coal innovation districts.

- 3) **Development of a Dedicated Evaluative Indicator Suite:** The transition literature currently lacks a dedicated, multi-layered evaluative architecture tailored specifically to post-coal innovation platforms. Methodological scholarship should operationalise composite, longitudinal indicators that synthesise technological innovation metrics, spatial and geotechnical remediation data, governance and institutional thickness indicators, procedural and distributional justice criteria, and evolutionary path-creation indices. Such an evaluative suite is indispensable to distinguish empirically between superficial place branding, transient grant-absorption activity, and genuine, cumulative territorial transformation.

6.6. Final Statement

The post-coal transition fundamentally transforms regional economies, public institutions, territorial landscapes, and civic expectations, extending far beyond the technical decarbonisation of energy systems. Whilst climate neutrality defines the necessary, non-negotiable direction of this structural shift, it does not in itself generate an alternative regional economic future. The post-coal innovation district is proposed neither as an uncritical policy fashion nor as

an immutable, universal blueprint. Rather, it constitutes an adaptable, place-based co-ordination mechanism designed to purposefully bind inherited industrial assets, scarred brownfield landscapes, multi-scalar institutions, enterprise ecosystems, displaced workforces, and host communities into a shared, generative trajectory of regional path creation. Its ultimate developmental value lies in actively organising and governing the institutional conditions for long-term territorial renewal, rather than merely administering the protracted management of industrial decline.

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