

Article

Thematic Coherence in Mission-Oriented EU Energy Policy: A Network-Based Analysis of Horizon Europe's Sustainability Funding Calls

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Abstract

While Horizon Europe is expected to turn the European Union's Mission-Oriented Innovation Policy (MOIP) into concrete actions, little is known about how coherently its funding calls translate high-level ambitions into effective guidance. To address this, we move beyond the traditional focus on funded projects and offer the first systematic analysis of Horizon Europe call texts as cognitive artefacts of policy design. Using Textual Network Analysis (TNA) on 188 calls of Cluster 5 ("Climate, Energy and Mobility") in the 2021–2022 Work Programme, we compare Scope and Expected Outcomes texts. We constructed weighted co-occurrence networks and calculated centrality, community structure, and assortativity metrics. Results reveal clear differences between layers: Scope texts show stronger clustering of technical domains (modularity 0.54, assortativity +0.206), while Outcomes present weaker clustering (modularity 0.50, assortativity −0.035), reflecting convergence around high-level impacts. Across both layers, a small set of hubs ("renewable energy", "climate change", "emissions") dominates, with high-betweenness terms bridging siloed domains; peripheral concepts remain weakly linked. The study contributes a novel framework for analysing the architecture of funding calls and demonstrates the utility of centrality metrics for policymakers to identify conceptual gaps and guide future Work Programme design, as well as for applicants optimising their proposal writing.

Keywords: Horizon Europe; MOIP; funding; innovation management; network analysis



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1. Introduction

Horizon Europe is the European Union's flagship research and innovation programme. It implements the key policies of the European Commission (EC), such as the climate ambitions of the European Green Deal, by funding projects through a complex architecture of funding calls. While this diversity encourages innovation through both top-down and bottom-up approaches, it also creates challenges related to thematic coherence, fragmentation and overlap. These funding calls are also helpful to identify research trends and understand policy targets. In addition to guiding and allocating funding, these calls encode priorities, frame problems, and refine the approaches used by applicants to formulate their innovations and ideas. Therefore, understanding Horizon Europe's internal structure and reasoning is needed to assess whether it is delivering on its mission-oriented policy ambitions.

Despite this, the literature has largely focused on analysing funded projects [1], consortia structures, and national participation patterns [2]. Very few studies examine the design phase of funding programmes, and even fewer approach the call texts themselves as cognitive artefacts that can shed light on the European Commission's logic and strategic framing. Unlike prior work, which concentrates on projects after funding, our study shifts attention to the design stage of Horizon Europe by analysing the call texts directly. This provides a novel upstream perspective on how missions are operationalised, capturing the policy logic embedded in funding calls before any project selection occurs. Addressing this is important to comprehend the previous step of how collaboration structures are formed and how research funding shapes the development of emerging technologies. This gap in the literature raises a fundamental challenge: the need for a better understanding of how the Commission structures its thinking and what might potentially constrain the strategic ambitions of mission-oriented policy.

Network science may become the best approach to address this challenge, as it is an accessible tool for identifying, visualising and interpreting connections in varied and complex data. It has long been applied in innovation studies, specifically in the assessment of how network structures relate to European policy objectives [3] and country-level collaborative research [4]. In the context of research funding programmes, network analysis has proven effective in showing patterns of cooperation among institutions [5], creation of innovation systems promoted by funding consortia [6]. Previous studies on EU frameworks have also used it to map collaboration networks and estimate their influence on research outcomes [7], or to track the journey of cities towards decarbonisation [8]. More recently, cognitive network analyses demonstrated that these methods can capture explicit priorities while also showing implicit framing structures in textual and organisational data [9].

While existing research has examined EU research collaboration patterns and analysed organisation-level networks in EU-funded projects [10], these studies focus on institutional collaboration structures derived from project-level data instead of on the thematic architecture of the funding programme itself. To address this limitation, our study introduces a methodologically distinct approach: a dual-layered thematic network analysis applied directly to a set of Horizon Europe call texts disaggregated into their Scopes and Expected Outcomes. This enabled us to map conceptual priorities at the stage of designing the funding calls, and to capture thematic intent before any proposal selection occurs, studying whether early-stage policy framing shapes thematic coherence across the energy Work Programme. This provides a novel perspective to existing project-level approaches and extends the understanding of how EU research priorities are conceptually organised and potentially influence downstream the funded projects.

The analysis of call texts becomes even more relevant when considering the case of energy-related funding, as the energy transition is characterised by fast-moving innovation and deep systemic shifts, which is the type of transformation described in the emerging-technologies literature. According to Rotolo, Hicks and Martin, the key features of emergence (radical novelty, rapid growth, thematic coherence, and impact under uncertainty and ambiguity) [11] can be traced in policy documents. These attributes are aligned closely with the energy-transition domain addressed by Cluster 5 of Horizon Europe, i.e., breakthrough innovative technologies are the radical novelty; growth and coherence are present in the expanding range of renewable energy topics; and impact-under-uncertainty is in the EU's long-term climate and sustainability goals. Therefore, quantifying thematic coherence and highlighting low-centrality niches provide indirect signals about whether Horizon Europe is already supporting technological emergence and where policy focus remains isolated. In this way, linking emergence metrics with call-text networks reinforces our broader thought that semantic structures can serve as tools of policy direction.

Furthermore, this gap is especially noticeable for energy-related calls, where the coordination of technical, environmental, and societal dimensions is of utmost importance. These domains are intrinsically connected in energy systems, where, for instance, technological innovation must align with climate goals, regulatory frameworks, and citizen acceptance. The clean energy transition pushed by the European Commission involves high levels of complexity, cross-sectoral dependencies, and long-term investment strategies, which requires total internal coherence in policy framing. Consequently, any misalignment or fragmentation in the early design of funding calls can lead to inefficiencies, missed synergies, and potentially conflicting priorities downstream in the research and implementation funding process.

This work does not aim to provide an evaluation of the success of the funding programme nor to assess its value as a policy instrument; our objective is to identify thematic clustering, intersecting areas of research and potential gaps in thematic balance and importance. In doing so, this article makes three contributions: conceptually, it reframes Horizon Europe call texts as deliberate policy instruments rather than neutral administrative documents; methodologically, it introduces a dual-layered Textual Network Analysis (TNA) that disaggregates Scope and Outcomes and applies centrality, modularity, and assortativity metrics; practically, it derives lessons for policymakers (to identify gaps and improve Work Programme design) and applicants (to align proposals with the thematic architecture of EU missions).

Building on these foundations, this research applies TNA to all energy-related calls published under Horizon Europe's 2021–2022 Work Programme. Instead of focusing on funded projects and consortia, integrating TNA at the call-design stage supports the theoretical justification for studying the calls themselves, where the main priorities and internal consistency of European policy are first set. The analysis is focused on the mapping of the interconnections between the different calls, breaking it down in their Scope and Outcomes sections, considering these as dual layers of the funding programme's policy logic: the technical context and the impacts expected.

To facilitate clarity and transparency, Figure 1 presents the structure of the research process. It illustrates the sequential stages followed: (i) manual retrieval of Horizon Europe call texts from the Funding & Tenders Portal; (ii) construction of two corpora corresponding to Scope and Expected Outcomes sections; (iii) keyword extraction using KeyBERT; (iv) network construction and computation of centrality and community metrics in R; and (v) interpretation of results in light of Mission-Oriented Innovation Policy (MOIP) theory. The framework is transferable to other Work Programmes, clusters, or even national funding schemes, making it broadly applicable beyond the immediate dataset.

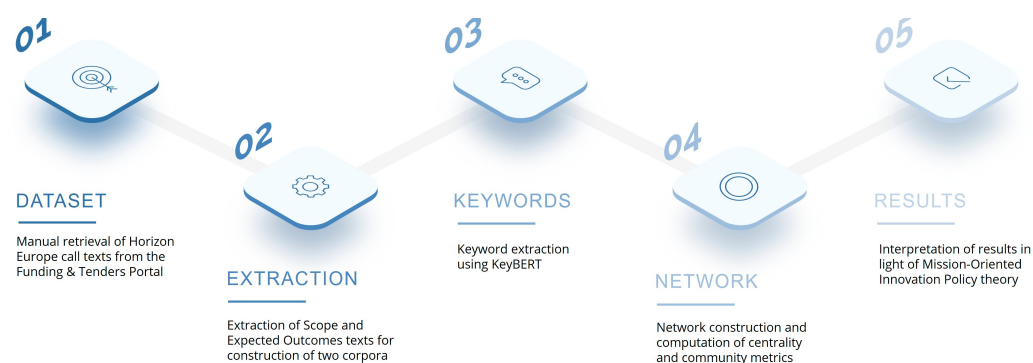


Figure 1. Workflow of the research process of this study.

2. Theoretical Framework

2.1. Mission-Oriented Innovation Policies

The idea that public research funding should actively shape innovation towards societally desirable ends represents a change from earlier models, such as the linear model of innovation or traditional supply-side R&D funding, which followed horizontal structures often anchored in market-failure logics. This new approach was led mostly by Mariana Mazzucato's concept of mission-oriented innovation policies, a new strategy to address complex societal challenges, claiming that states can and should act as market shapers instead of mere "fixers" [12]. Researchers have long been working on both the theoretical and practical dimensions of innovation approaches; for instance, Borrás and Edquist highlighted that the selection of policy instruments intrinsically reflects political priorities [13], while Edler and Georghiou demonstrated the practical use of public procurement as a mechanism to transform policy guidance into demand-driven incentives [14] which can reinforce mission-driven innovation.

More recently, Kattel and Mazzucato described an "epistemic turn" [15], stressing how missions require new public-sector capacities to collectively generate, curate, and interpret knowledge. Their comparative research across various European cases showed that missions face significant challenges when they are implemented through pre-existing, rigid and non-adaptive bureaucratic frameworks.

While MOIP reflects a step forward from traditional siloed programme management, it cannot fit into a one-size-fits-all model or rely on universally applicable policy instruments. If the aim of MOIP is to find effective solutions for ill-defined societal challenges, more dynamic and flexible approaches are needed [16]. Their effectiveness largely depends on the nature and specific characteristics of each mission and their individual contexts, which are shaped by national, regional, sectoral, and technological systems [17]. Their effective implementation demands a coordinated yet flexible approach that goes beyond traditional instruments, using demand-side policies to increase the diffusion of innovations and the creation of markets to achieve objectives specific to their relevant sectors [18].

Horizon Europe represents the European Union's most explicit operationalisation of MOIP to date. Its foundational and preparatory documents, such as the Orientations to the first Strategic Plan for Horizon Europe [19], put high emphasis on directionality, impact pathways, and cross-cutting integration as their structuring principles. As a result, five distinct EU Missions were incorporated into the Horizon Europe Work Programme, addressing different broad topics, namely, climate adaptation, cancer, oceans and waters, soil health, and climate-neutral smart cities. Each of them featured dedicated funding calls and is backed by inter-directorate governance structures to achieve bold and time-bound targets such as "100 climate-neutral cities by 2030" or "improving the lives of more than 3 million people by 2030" [20].

Recent strategic assessments for the European Parliament confirmed that Horizon Europe calls have evolved since previous frameworks like Horizon 2020 (FP7) with thematic portfolios now centred around MOIP. Additionally, calls now often integrate citizen engagement requirements, and use 'Key Impact Pathways' to align the expected outputs of each call to higher-level EU objectives. Nevertheless, funding stakeholders continue to report some persistent challenges. Many researchers struggle to translate these high-level strategic plans into concrete proposal language [21], which directly compromises the effectiveness of MOIP, and suggests potential misalignments between the strategic intent of the approach and the design of funding calls, ultimately leading to proposals that fall short of mission goals.

Additionally, several broader structural challenges affect the implementation of MOIP. The complexity and scale of the European funding programmes often result in overlaps

or thematically similar calls published under different initiatives; this was particularly evident in Horizon 2020, with close to 120 partnerships running [22], which led to confusion among applicants and failure to contribute to related policies at Union and national levels. Although progress has been made compared to earlier programmes, recent studies by the European Commission still highlight these issues [23]. These include overlapping issues between instruments, insufficient guidance on impact performance indicators, and the need for continuous alignment with EU-wide and local policy objectives.

Further analyses note that Horizon Europe's governance model is hybrid and potentially fragmented: for instance, the EU's Missions coexist with Pillar I's bottom-up funding, public-private partnerships, and the European Innovation Council, generating an amalgam of instruments which is at times confusing and risks dilution without explicit coordination. And while some efforts, such as European Commission's own Evidence Framework, aim to address the coherence of the overall funding programme, they do not explore the semantic architecture of individual calls, which is precisely where applicants and evaluators engage with MOIP in practice. This is the focus of our study: we extend MOIP scholarship from programme governance to the elemental wording of calls themselves, providing a new way to evaluate whether mission goals are consistently encoded at the operational level.

2.2. Cognitive Networks

Innovation experts are increasingly aware that research funding calls are not neutral administrative instruments: their specific wording predefines applicants' behaviour, shapes their own perceptions of eligibility, and influences evaluative processes. For instance, Husiev demonstrated that the choice of keywords affected consortia composition in Horizon 2020 energy projects [24], while Smith, Sarabi and Christopoulos showed how thematic directives rooted in funding calls influenced collaboration across research-councils in the United Kingdom [25]. Related studies further corroborate the importance of language in funding, finding that the percentage of promotional words in a grant correlates statistically with the grant's intrinsic level of innovativeness [26].

While existing studies have contributed to better understanding collaboration patterns and broad thematic trends in European funding programmes, there are substantial gaps in our knowledge about the actual wording and semantic structure of their elemental units. Systematic and comparative analyses of Horizon Europe calls remain limited and largely unexplored, which is particularly critical given that these texts shape how MOIPs are interpreted and enacted by applicant researchers and evaluators. Existing studies tend to follow one of two broad approaches: collaboration network studies that consider projects or organisations as nodes, ignoring the semantic content of the calls; or evaluation and monitoring reports that aggregate calls into broader thematic destinations or clusters, consequently obscuring the specificity and nuance present in the individual calls.

In this context, the recent years have seen a noteworthy "text-analytic turn" in policy studies, driven by developments in natural language processing (NLP) and network science methodologies. Among these, textual network analysis, supervised annotation datasets, and case-specific text-mining techniques have emerged as particularly noteworthy: TNA uses keyword co-occurrence graph modelling to reveal underlying thematic structures such as conceptual hubs, bridges, and peripheral areas in policy documents. For instance, the Joint Research Centre mapped thematic coherence across EU legislative documents and identified policy connection using automated analysis [27], while the POLIANNA corpus, with its extensive annotated dataset of EU climate policy directives, explored cognitive networks underlying EU policy design elements [28] and provided benchmarks for training machine learning algorithms in policy analysis.

Our work is conceptually grounded in the principles of Textual Network Analysis, an analytical framework drawn from the broader field of network science and increasingly applied to policy studies and knowledge studies [29,30]. TNA can systematically identify, analyse, and visualise relationships among concepts in text, typically using co-occurrence graphs that may expose patterns of thematic clustering and hierarchy, and it can expose implicit and explicit priorities in the structure of textual content [31]. In contrast to prior uses of TNA in legislative or organisational contexts, we apply it to Horizon Europe call texts, thereby introducing a methodological innovation that allows the design stage of funding programmes to be studied with the same rigour usually reserved for project outcomes or collaboration networks.

Mapping and analysing these aspects at the level of Scope and Outcomes can identify invisible thematic hubs (core policy priorities), bridging connectors (cross-domain integration points), and peripheral terms (neglected niches of research). Since the collective combination of individual funding calls operationalises MOIP, exposing the conceptual architecture embedded in their wording tests whether mission-oriented objectives are consistently present at the operational level where applicants engage with the programme. In this scenario, cognitive network science complements policy and governance-oriented efforts and supports the iterative refinement of MOIP design and implementation, providing a systematic and scalable way to analyse the internal coherence and structure of funding calls, which is the precise point where researchers engage with policy language. Our study combines MOIP theory with cognitive network science, bridging two branches of literature that rarely intersect and offering both a conceptual advance and a practical diagnostic tool for policy design.

2.3. Research Objectives and Hypotheses

Building on this theoretical framework, our study sets out four specific objectives to be achieved:

- O1: Map the thematic architecture of Horizon Europe's Cluster 5 (Climate, Energy and Mobility) calls using textual network analysis of their Scope and Expected Outcomes sections.
- O2: Quantify conceptual hubs, bridges and peripheries through centrality and community metrics.
- O3: Compare the Scope and Expected Outcomes layers to evaluate coordination between the technical framing of the funding calls and their specific impact orientation.
- O4: Derive practical and transferable lessons for both policymakers (in terms of programme design and coherence) and applicants (aiming to enhance proposal writing and thematic positioning).

To fulfil these objectives, and guided by MOIP theory and former work on cognitive networks, we formulated four research hypotheses to be empirically tested with our network analysis:

- H1 (Layer asymmetry): The Outcomes layer will display stronger concentration around a small set of programme-level terms and lower (potentially negative) degree assortativity than the Scope layer, reflecting top-down convergence.
- H2 (Bridging concentration): A small subset of cross-cutting terms will show disproportionately high betweenness, and they will act as thematic integrators across siloed clusters.
- H3 (Hub continuity with policy inflexion): The two layers will share core hubs centred on the energy transition (e.g., renewable energy), while Outcomes will additionally foreground policy-proximate anchors (e.g., project results).

- H4 (Peripheral niches): Both layers will contain low-centrality, weakly integrated concepts (e.g., environmental or territorial qualifiers) that indicate potential policy gaps and innovation niches.

The verification of these hypotheses is carried out by applying centrality metrics and community detection algorithms to the co-occurrence networks derived from the calls' textual content.

3. Materials and Methods

3.1. Data

Our study focuses on the “Climate, Energy and Mobility” Work Programme under Cluster 5 of Horizon Europe for 2021–2022. We manually retrieved the full set of calls, sourced directly from the European Commission's Funding & Tenders Portal [32], which provides official and publicly accessible versions of all Horizon Europe calls.

A total of 188 calls were identified under HORIZON-CL5-2021 and HORIZON-CL5-2022, covering the actions defined by the European Commission on Climate, Energy, and Mobility in those years. For each of these calls, we extracted two key textual sections:

- Scope: describing the expected technical and scientific focus of the call.
- Expected Outcomes: intended results, benefits, or impacts as defined by the European Commission.

These sections were processed and stored as two parallel corpora, which were used as the foundational material for the subsequent semantic and network analyses. This dual structure enabled us to separately explore the alignment between strategic objectives and implementation mechanisms in the design of the calls.

3.2. Text Mining

For keyword extraction, we used KeyBERT [33], a tool based on Bidirectional Encoder Representations from Transformers (BERT) embeddings, to identify semantically representative keywords from unstructured text. KeyBERT generates document embeddings and extracts words or phrases that align closely semantically with the overall content.

The text-mining pipeline followed four steps: (i) manual compilation of Scope and Expected Outcomes texts into an Excel file to create two structured corpora; (ii) application of KeyBERT to each entry in the dataset to extract representative keywords (top ten per section, using unigrams and bigrams); (iii) post-processing of results, which included removing common stop words and manually validating random samples against the original texts; and (iv) export of the cleaned keyword lists into structured files for subsequent network construction.

The extraction process was carried out manually: all Scope and Expected Outcomes texts were copied from the original Work Programme documents into a Microsoft Excel file, which served as the structured dataset. Each text entry was then processed with KeyBERT to extract representative keywords. The model computed BERT embeddings for the entire section and evaluated the semantic similarity of candidate keywords using cosine similarity. The script was configured to automatically remove common English words (e.g., “and”, “the”, “with”) that do not contribute meaningful semantic content. This step ensured that the resulting keywords were conceptually informative.

We also defined the number of keywords to retrieve to control the output size and ensure comparability across calls. For that, we chose an n-gram range of 1 to 2 to capture both unigrams and bigrams. Then, the script extracted the top ten keywords in each call for both their Scope and their Outcomes. The decision to extract the top ten keywords per section was guided by the need for comparability across calls of variable length. While the number is necessarily a simplification, it ensured a manageable, consistent representation

of each call while avoiding dominance of longer calls. To test robustness, we re-ran the extraction at thresholds of 5 and 15 keywords; the relative rankings of centrality measures, as well as the qualitative conclusions, remained stable. This indicates that our results are not sensitive to the exact threshold chosen.

For easier readability and to facilitate manual inspection, results were saved in a structured format using separation with semicolons. To ensure the integrity and accuracy of the extracted terms, we validated the method by manually cross-checking random keyword samples against the original texts, confirming that extracted terms aligned with the intended meaning of the calls.

We selected KeyBERT for keyword extraction because it leverages transformer-based embeddings (BERT), which have been demonstrated to outperform traditional frequency-based or Term Frequency-Inverse Document Frequency (TF-IDF) methods in capturing semantic similarity [34]. Compared to alternatives such as YAKE, RAKE, or topic modelling with Latent Dirichlet Allocation (LDA), KeyBERT provides a balance of interpretability and contextual sensitivity, making it particularly suitable for short, policy-oriented texts, such as Horizon Europe calls.

3.3. Network Analysis

To construct the cognitive networks used in this study, we developed a custom R script [35] (R version 4.3.2, executed on Windows 10). The extracted keywords were treated as nodes in our co-occurrence networks, with edges formed based on their co-occurrence. The script made use of several packages, notably *igraph* [36] (for graph operations), *dplyr* [37] and *stringr* [38] (for data wrangling), and *readxl* [39] and *readr* [40] (for file input and output).

The first step involved parsing each topic entry to extract all keyword pairs appearing within a single outcome. These pairs were interpreted as undirected edges, and their frequency of co-occurrence across calls was recorded as edge weights, thereby reflecting the strength of thematic association. The aggregated edge list was then used to construct a weighted undirected graph using the *graph_from_data_frame()* function from the *igraph* package.

Once the network was built, we computed standard centrality metrics to quantify the structural role of every keyword. Each of these metrics captures a different facet of conceptual relevance or influence [41], which help identify predominant themes and highlight structurally marginal or disconnected areas in the programme's thematic architecture:

- Degree: direct thematic breadth, which measures the number of direct connections a keyword has with others, indicating how broadly a concept is associated across the corpus.
- Betweenness: bridging potential, identifying nodes that frequently occur on the shortest paths between other nodes, thus highlighting keywords that act as connectors between otherwise distant keywords.
- Closeness: semantic accessibility, calculated as the average length of the shortest paths from a node to all others. This shows how quickly information can spread from a given concept.
- Eigenvector centrality: influence through influential neighbours. This assigns relative scores to all nodes based on the principle that connections to highly connected nodes contribute more to the score of the node itself. In addition to the most frequently co-occurring ones, it identifies those keywords embedded in strategically important clusters.

To assess the structural properties of the network and evaluate the quality of clustering, we also computed assortativity coefficients, which shows the tendency of nodes to connect with others that have similar levels of connectivity, and modularity scores, which quantify

the strength of division of a network into distinct communities (higher values indicating clearer thematic clustering). To identify thematic clusters, we applied the Louvain community detection algorithm (*cluster_louvain()* function in *igraph*), assigning each keyword to its corresponding community.

Finally, a basic network visualisation was generated, using colour coding to highlight low-degree nodes, with edge thickness proportional to co-occurrence weight. All output files, including centrality scores and summary statistics, were exported as CSV files for further inspection and integration into the broader analysis.

Formal definitions of the centrality measures used are provided in Appendix A (Equations (A1)–(A4)). The modularity function used for community detection is given in Equation (A5).

3.4. Hypothesis Verification

We interpreted the defined hypotheses H1–H4 using established network measures computed for both layers.

- For H1, we compared degree assortativity and modularity and examined degree distributions; directional support is reported when Outcomes exhibits lower or negative assortativity and comparable or slightly lower modularity than in the Scope.
- For H2, we inspected the rank distribution of betweenness and identified keywords with betweenness values several orders of magnitude above the median as bridges.
- For H3, we compared top-*k* hubs across layers using overlap in degree/eigenvector rankings and noted layer-specific policy anchors.
- For H4, we flagged keywords with degree and closeness values below the 10th percentile as peripheral and qualitatively assessed their policy relevance.

To ensure robustness of results, we compared outputs across alternative parsing configurations and extraction thresholds. Specifically, we varied the number of keywords per section ($n = 5, 10, 15$) and the *n*-gram range (unigrams only vs. unigrams and bigrams), and in KeyBERT. Across all settings, the identity of top-ranked hubs, the relative ranking of centrality measures, and the qualitative interpretation of bridging and peripheral terms remained stable. This suggests that our results are not artefacts of a specific extraction configuration but instead reflect structural features of the Horizon Europe call texts. While alternative NLP methods (e.g., YAKE, RAKE, LDA topic models) might yield slight variations in keyword selection, the persistence of high-level patterns across robustness checks supports the reliability of our conclusions.

4. Results

This section presents the results of our network analysis across both Scope and Expected Outcomes sections of Horizon Europe energy-related calls. Our analysis focuses on better understanding the functions of specific terms, as well as revealing bridges, clusters, and structurally marginal themes in the architecture of the Work Programme. Instead of treating each layer (Scope and Outcomes) separately, we facilitate comparison of their structures and focus on areas of convergence and divergence, which allows our subsequent discussion on overall thematic orientation and policy coherence. See Appendix A for formal definitions of the centrality measures.

4.1. Structural Features and Network Architecture

The overall topology of the networks offers insights into Horizon Europe's thematic structuring logic. To assess the internal organisation of each layer and facilitate visualisation, we first limited the analysis to the top 30 most connected keywords and applied the Louvain community detection algorithm.

Shown in Figure 2, the Scope network reported a modularity score of 0.54, which indicates substantial semantic clustering with cohesive communities of technical terms. Additionally, the positive assortativity coefficient (0.206) implied preferential attachment between highly connected keywords. This means that central keywords tend to reinforce each other and form stable thematic clusters. This architecture mirrors bottom-up structuring of technical areas, where domain-specific text blends naturally around a set of identified key challenges.

Structure of the Scope Network

Node size = eigenvector centrality

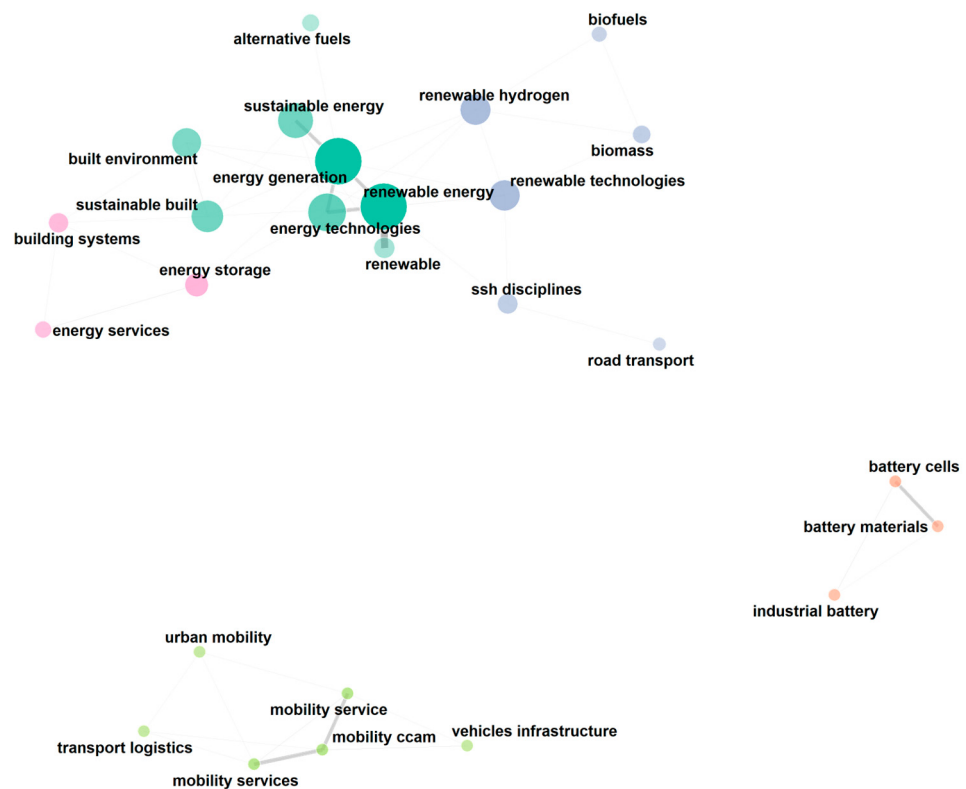


Figure 2. Visualisation of the Scope network using Fruchterman–Reingold layout.

By contrast, the Outcomes network reported a modularity score of 0.50, which was slightly lower but still indicated moderate clustering. In this case, the assortativity coefficient was negative (-0.035) and indicates a weakly disassortative configuration; in other words, highly connected keywords are not more likely to link with each other, and they only connect broadly across the network. This architecture, shown in Figure 3, resembles a hierarchical, policy-oriented structure with a limited number of central and overarching concepts (e.g., “renewable energy”, “climate change”), which are deliberately repeated in the call texts aiming to unify fragmented calls.

The Scope network favours thematic depth and technical cohesion, while the Outcomes network reflects deliberate convergence around impact-oriented goals. This divergence between technical formulation and expected impacts stresses the importance of bridging elements for effective alignment in research proposals.

In the full, unrestricted co-occurrence network derived from the Scope sections, the Louvain algorithm identified 61 communities. Its structure was fragmented with a majority of small clusters consisting of fewer than 10 nodes, alongside a small number of large communities (e.g., 118, 96, and 95 keywords). In contrast, the full network built from the Outcomes produced a modular structure with 43 communities. Most clusters were relatively small, with over 30 of them containing 10 nodes or fewer, but several large

communities were also identified, including one with 140 keywords and others with 110, 97 and 86 nodes, respectively.

Structure of the Outcomes Network

Node size = eigenvector centrality

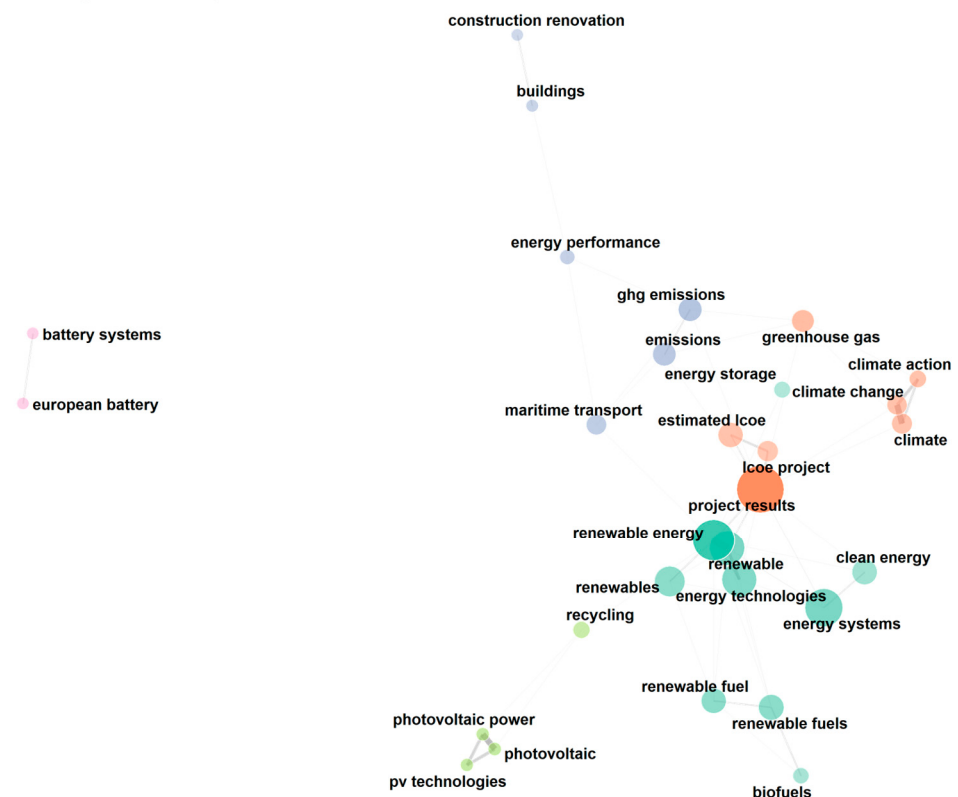


Figure 3. Visualisation of the Outcomes network using Fruchterman–Reingold layout.

4.2. Thematic Anchors and Conceptual Hubs

Degree and eigenvector centrality were used to assess the importance and influence of keywords in the networks. Both Scope and Outcomes layers showed marked asymmetry in the distribution of keyword connectivity and displayed a pronounced long-tail distribution. A small set of hub terms had high connectivity and influence, while the majority of keywords presented minimal links.

In the Scope network, the mean degree across all nodes was 9.0, and the 10th percentile (threshold for low connectivity) was even lower. Similarly, the Outcomes network displayed a median degree of 9, and although its top nodes exhibited approximately double the connections of the Scope network, the long-tail distribution persisted. This suggests that although both layers share structural asymmetry, the Outcomes layer is more concentrated at the upper end of the distribution, reinforcing the assumption that the Work Programme architecture focuses on a compact set of programmatic terms. At the same time, it highlights the asymmetry of the network, where a few terms act as hubs and the majority remain in the periphery.

For instance, in the Scope network (Table 1), “renewable energy” (77 connections), “climate change” (65), “energy storage” (63), and “energy generation” (60) were identified as these thematic anchors. They appeared frequently and also connected across multiple conceptual domains, reflecting the Commission’s emphasis on systemic challenges like the energy transition and climate resilience. The same pattern was mirrored in the Outcomes layer (Table 2), where “renewable energy” (with 142 connections), “project results” (119), and “emissions” (98) dominated. The most notable difference was the presence of “project

results”, absent from the Scope layer, which seems logical considering its role as an impact-oriented focal point. Complementing the technical specifications detailed in the Scope section, this clearly indicates a turn in the emphasis of the text from research orientation to the delivery of tangible impacts.

Table 1. Keywords with the largest degree values in the Scope analysis and in the Outcomes.

Scope Keyword	Degree	Outcomes Keyword	Degree
renewable energy	77	renewable energy	142
climate change	65	project results	119
energy storage	63	emissions	98
energy generation	60	climate change	81
emissions	53	renewable	76
sustainable built	45	climate	65
energy technologies	43	ghg emissions	52
sustainable energy	43	climate action	47
mobility CCAM	43	photovoltaic power	46
battery cells	41	photovoltaic	45

Table 2. Keywords with the largest normalised Eigenvector values in the Scope analysis and in the Outcomes.

Scope Keyword	Normalised Eigenvector	Outcomes Keyword	Normalised Eigenvector
renewable energy	1	renewable energy	1
energy generation	0.822	project results	0.770
sustainable energy	0.611	renewable	0.691
energy technologies	0.579	energy technologies	0.425
sustainable built	0.405	sustainability renewable	0.408
renewable	0.378	energy systems	0.362
energy storage	0.336	goals climate	0.338
renewable hydrogen	0.318	renewables	0.324
planning energy	0.315	enhanced sustainability	0.282
renewable technologies	0.315	European innovative	0.275

Eigenvector centrality confirmed the structural importance of these terms, evaluating their influence by weighting connections according to the centrality of neighbouring nodes, thereby capturing how influential these connections were in our study. “Renewable energy” returned the highest eigenvector score in both networks, which further validated its role as a conceptual nucleus and gravitational centre of the keyword networks. Other influential keywords such as “climate change”, “energy generation”, and “energy storage” also ranked highly and were likely benefiting from their proximity to other well-connected nodes.

4.3. Bridging Concepts and Thematic Integration

Then, we analysed betweenness and closeness centrality, which help identify concepts that link disconnected topics, as well as the overall accessibility of themes in the networks. First, we focused on betweenness (Table 3), since keywords with high values can be considered bridges between otherwise disconnected thematic clusters.

In the Scope network, “energy storage”, “energy generation” and “emissions” show betweenness values several orders of magnitude higher than the average. This high betweenness placed them in structurally strategic positions that connect distinct domains such as renewable technologies, infrastructure, and mobility-related areas. Notably, mobility-related keywords, mostly those concerning transport, infrastructure, and logistics, also showed high centrality values, stressing their importance in the network. “Energy storage”,

for example, was identified as a nexus linking technical generation systems (e.g., solar, wind), grid infrastructure, and application domains like buildings and transport.

Table 3. Keywords with the largest normalised betweenness values in the Scope analysis and in the Outcomes.

Scope Keyword	Normalised Betweenness	Outcomes Keyword	Normalised Betweenness
road transport	0.936	renewable energy	0.919
road infrastructure	0.866	emissions	0.435
mobility CCAM	0.791	climate change	0.420
transport logistics	0.611	ghg emissions	0.361
energy storage	0.583	energy performance	0.335
SSH disciplines	0.560	circular economy	0.332
energy generation	0.511	European research	0.304
infrastructure transport	0.487	maritime transport	0.278
energy climate	0.420	initiatives European	0.248
global warming	0.388	buildings	0.242

In the Outcomes layer, the bridging function was even more concentrated. Most terms displayed zero betweenness, but a handful showed values that were orders of magnitude higher, notably “project results”, “climate change”, and “renewable energy”. These keywords allow cross-sectoral integration and connect areas such as agriculture, urban mobility, and digitalisation. This difference in distribution suggests a tighter concentration of holistic solutions in the Expected Outcomes section; at the same time, this may demonstrate top-down coherence around MOIP objectives rather than sector-specific interventions as the result of the funding calls.

Additionally, closeness centrality was a complementary tool to assess the overall thematic reach and systemic accessibility. In both layers, keywords like “energy generation”, “energy storage”, and “climate change” held central positions with minimal semantic distance from the rest of the network. This clearly highlights their role as the main entry points for navigating the thematic architecture of Horizon Europe. Conversely, peripheral terms with low closeness values, such as “methane”, “materials renovation”, or “aviation research”, were found in both Scope and Outcomes, which indicated areas of limited integration. These may represent both niche opportunities for researchers and neglected policy domains of the European Commission.

Through the analysis of bridging and proximity metrics, we found a dual structure: a consolidated core of cross-cutting themes that reinforce Horizon Europe’s general ambitions, and a periphery of isolated topics that may require deliberate linking strategies to achieve complete policy coherence.

5. Discussion

Building on the structural characteristics identified in our network analysis, we explore the broader implications for programme design, policy coherence, and MOIP. We acknowledge that certain general-purpose terms (e.g., “project results”) may partly reflect drafting conventions of the European Commission rather than thematic strategy. However, their structural prominence in the network is itself meaningful, as it highlights the institutional emphasis consistently encoded in the calls. Such terms may shape applicants’ framing and evaluators’ expectations, thereby carrying policy relevance regardless of their generic nature. This finding supports our central argument that Horizon Europe call texts should be treated not as neutral administrative templates but as cognitive artefacts of policy design,

where textual choices can actively structure the dynamics of both application behaviour and programme coherence.

Assessing the main research hypotheses defined, the results are consistent with H1: compared with Scope, the Outcomes network exhibits a slightly lower modularity (0.50 vs. 0.54) and negative degree assortativity (-0.035 vs. $+0.206$), indicating top-down convergence around impact-level anchors (Section 4.1). H2 is corroborated by the highly skewed betweenness distributions, with a small set of integrators such as “energy storage”, “emissions” and “climate change” in Scope, and “renewable energy”, “emissions” and “climate change” in Outcomes, which show values orders of magnitude above the median. H3 is supported by the continuity of hubs across layers (“renewable energy” ranks first by degree and eigenvector in both networks), with a policy-proximate anchor (“project results”) emerging only in Outcomes. H4 is evidenced by repeated low-degree/low-closeness terms that remain weakly integrated, signalling policy-relevant niches. These results jointly validate our initial expectations while also delineating actionable levers for MOIP-consistent call drafting and proposal design.

For easier readability, we organise our discussion in four pillars: first, the strategic role of bridging concepts for integration; second, the innovation niches identified in the peripheral terms; third, the key features and differences found between Scope and Outcomes as indicators of Horizon Europe’s internal policy logic to be considered in future work programme designs; and fourth, guidance for applicants to increase competitiveness and thematic alignment in their proposal writing.

5.1. Bridging Keywords as Policy Instruments

According to the betweenness centrality analysis, a handful of terms in both the Scope and Outcomes networks act as conceptual bridges and connect loose thematic clusters. Keywords such as “energy storage,” “emissions,” “climate change,” and “construction renovation” occupied structurally strategic positions. These terms are thematically rich and are used to integrate domains that are usually siloed; for instance, coupling renewable generation with urban planning, transport, and digitalisation.

From a policy design perspective, the prominence of these high-betweenness nodes suggests that Horizon Europe deliberately inserts certain cross-domain integrators to enhance its thematic coherence. For example, “energy storage”, a technical enabler, links renewable generation, grid flexibility, and sector coupling with mobility or buildings. Similarly, “digital twin” connects smart infrastructure development with data-driven monitoring and climate adaptation scenarios. Such bridging assumes that they contribute to translating high-level MOIP into implementable research calls. This points to an underlying strategy whereby certain keywords, selected for their thematic relevance and their bridging capacity, are included in call texts to promote integration across different energy and sustainability sectors.

With this approach, the Commission implicitly reinforces the idea that mission-oriented research cannot rely exclusively on disciplinary silos. Rather, it requires the orchestration of conceptual interfaces where distinct themes such as energy, digitalisation, mobility, and climate resilience intersect. This is consistent with the epistemic turn in MOIP described by Kattel and Mazzucato [15] and stresses the European Commission’s intention to develop clear knowledge structures and systems capable of supporting coordination and learning across fragmented innovation ecosystems.

Additionally, a number of key concepts operate as semantic platforms across the Work Programme, in consonance with MOIP’s requirements of multi-sector integration. By facilitating systemic connections, certain bridging terms operationalise the principle of directionality that is central to MOIP. Notably, the case of “energy storage” illustrates

this situation: it connects technological, infrastructural and application layers, while also reinforcing the priorities set out in the EU's energy storage roadmap. In this sense, specific bridging keywords in funding calls are more than semantic artefacts; they function as instruments of policy coherence. Our results therefore show that bridging terms are not incidental but operate as designed connectors, aligning with MOIP's requirement for cross-domain integration. This provides empirical evidence that textual choices in call drafting directly influence the systemic orientation of EU research policy.

5.2. Thematic Silos and Drafting of Funding Calls

In contrast to the strategic centrality of bridging terms, our analysis also identified a long tail of structurally marginal concepts and keywords. These low-degree, low-closeness, and low-eigenvector keywords (e.g., “rural transport”, “forest disturbance”, “drought events”, “ecological compensation”) were isolated across both networks.

At first glance, their marginality might suggest low thematic relevance and low priority to the EU Research Agenda. However, many of these concepts are tightly linked to recent policy efforts as well as to the five EU Missions, such as the Adaptation to Climate Change and the 100 Climate-Neutral and Smart Cities by 2030. Consequently, their structural isolation may point to a disconnection between the objectives of Horizon Europe and their operational implementation using funding calls. This is of utmost importance in mission-oriented research approaches, which heavily depend on a continuous coordination between high-level goals and programme design, and therefore it raises concerns about the extent of MOIP integration in Horizon Europe's call architecture.

From the perspective of researchers, the transformation of these peripheral terms into meaningful components of their proposals can augment the depth and uniqueness of their proposed research. The inclusion of these keywords and concepts would demonstrate a sensitivity to underrepresented EU policy areas and introduce less explored problem-solution pairings that differentiate their proposal from the rest. As an example, researchers framing “drought resilience” in the “water-energy nexus”, or explicitly embedding “rural innovation” in calls addressing smart energy autonomy systems can reposition these concepts from the thematic peripheries to use them as hinges of their projects, which will help researchers stand out by proactively addressing thematic gaps in the programme.

In practical terms and in line with recent discussions advancing FP10, the drafting of funding calls should consider repositioning marginal keywords to strengthen the European research agenda and its MOIP approach. These isolated terms may become opportunities to better maximise EU funding; their inclusion through deliberate language choices in the funding calls would create a more conceptually inclusive innovation ecosystem. For instance, considering peripheral terms related to ecology and land use, this could be achieved by rephrasing funding calls to require applicants to consider territorial cohesion explicitly (e.g., project outcomes must include benefits for remote, rural or ecologically sensitive areas), or call for proposals that integrate these peripheral concepts through nexus framings (e.g., water–energy–biodiversity).

Consequently, while network metrics are mostly used for retrospective diagnostics, our study encourages policymakers to consider cognitive science as a tool for preparation of funding calls and Missions. In the design and preparation of upcoming Work Programmes, keyword metrics can help by early identifying thematic gaps, redundancies, and under-integrated terms. Incorporating these considerations into the drafting process of each individual call would allow for proactive alignment with mission objectives and would ensure that dominant and policy-relevant peripheral concepts are appropriately positioned to support the implementation of MOIP approaches.

Table 4 provides illustrative examples of extracts of call texts being adjusted to reposition peripheral keywords and encourage their integration with central terms. These examples were derived through a comparative analysis of the most typical Scope and Outcome phrasings used in Cluster 5 calls and modified using the conceptual logic derived from the centrality metrics in our study. The goal is to illustrate that simple yet deliberate changes in phrasing can break thematic silos, increase the centrality of marginalised terms, and align them with key central concepts to reduce policy fragmentation. In methodological terms, this illustrates how Textual Network Analysis can move beyond retrospective diagnostics and serve as a forward-looking design tool. The framework is transferable to other Work Programmes, clusters, or even national funding schemes, making it broadly applicable beyond the immediate dataset.

Table 4. Examples of call text rephrasing and adjustments to integrate peripheral terms.

Original Phrasing	Reformulated Scope or Outcome	Peripheral Terms Activated	Central Terms Reinforced
“The proposal should advance battery storage technologies and improve grid flexibility in urban contexts.”	“The proposal should advance battery storage technologies and improve grid flexibility, including innovative deployment in rural or remote regions, with attention to local environmental resilience and drought risk.”	rural, drought, resilience	battery storage
“Expected outcomes include improved logistics efficiency and reduced emissions in freight transport.”	“Expected outcomes include improved logistics efficiency and reduced emissions in freight transport, particularly in ways that enhance connectivity in low-density rural areas or promote nature-based logistics hubs.”	rural transport, nature-based	emissions, logistics efficiency
“Projects should contribute to the EU’s decarbonisation targets through innovative energy-efficiency solutions.”	“Projects should contribute to the EU’s decarbonisation targets through innovative energy-efficiency solutions that explicitly address biodiversity co-benefits, ecological compensation, or synergies with land restoration efforts.”	biodiversity, ecological compensation, land use	decarbonisation, energy solutions

5.3. Implications for Future Work Programmes Design

Our analysis of the Scope and Outcomes networks and their comparison showed an evident asymmetry in their structures. The Scope network displayed higher assortativity and modularity, which indicated stronger thematic clustering and greater attachment among highly connected technical keywords. This reflects a bottom-up logic with the technical prospects coming together around shared research themes. In contrast, the Outcomes network displayed negative assortativity and concentrated density at the top of the distribution. A small group of keywords dominated the network structure, reflecting deliberate top-down coherence around impact-oriented objectives defined by the European Commission.

This dual architecture captures the hybrid nature of Horizon Europe and its attempt to reconcile the diversity and specialisation of bottom-up research with the coordinated efforts of mission-driven approaches. In MOIP terms, this reflects the balance between exploration and exploitation, between the technological specificity to be developed and the policy relevance to be achieved. The Scope is the exploratory layer, more diverse and decentralised, while the Outcome is focused on exploitation and their coordinated efforts with European policy agendas.

For programme designers, centrality metrics offer a useful tool for governance diagnostics. Additionally, cognitive science approaches can be used to monitor thematic coherence and to detect neglected areas in funding structures, which is of particular interest for their future iterations of the programmes. Policy-relevant terms that are currently under-integrated can be deliberately activated using minor adjustments with the aim of connecting marginal topics with central ones. Even subtle changes, such as pairing peripheral terms with commonly used flagship terms in phrasing, can increase their centrality. For example, our analysis shows that keywords such as “energy storage” act as high-betweenness bridges across renewable generation, grid infrastructure, and mobility. Policymakers could use this insight to deliberately frame future Work Programme calls around “energy storage” as a cross-sectoral enabler, thereby fostering proposals that integrate technical, infrastructural, and societal dimensions rather than treating them in silos.

These results make a case for the institutionalisation of network-informed diagnostics as part of the development of Funding and Work Programmes. The stratified nature of keyword centrality gives a better understanding of the conceptual structure of any funding scheme, from their overall objectives to their individual elements. Using network science to provide evidence of the coordination of technical innovations (Scope) with measurable contributions to wider policy objectives (Outcomes) would strengthen the upcoming internal coherence in FP10, as well as enhance its capacity to fulfil the ambitions of MOIP approaches. Based on our analysis, Table 5 provides policy recommendations for future Work Programmes design. By institutionalising such network-informed diagnostics, EU policy actors could establish a systematic mechanism to test the coherence of funding calls before publication.

Table 5. Policy design recommendations derived from Textual Network Analysis.

Observation Found in the Analysis	Implication	Policy Design Recommendation
Asymmetry between clustered Scope and centralised Outcomes	Risks of misalignment between technical diversity and narrow impact anchors	Confirm call drafting explicitly links diverse technical directions with shared policy impacts; introduce bridging language in Scope sections.
High-betweenness bridging keywords	Certain terms integrate siloed domains	Use bridging keywords intentionally in call texts to promote cross-sectoral proposals and systemic solutions.
Peripheral, low-centrality terms	Policy-relevant but under-integrated topics remain marginal	Reposition peripheral terms by pairing them with central keywords to activate neglected areas.
Dominance of generic anchors in Outcomes	Repetition may obscure specific policy objectives	Complement generic anchors with thematic qualifiers
Scope layer as bottom-up, Outcomes as top-down logic	Reflects hybrid mission design, but risks incoherence	Use semantic diagnostics to balance exploration (Scope) with exploitation (Outcomes) when drafting calls to ensure coherence across layers.

Finally, while our analysis is limited to the semantic architecture of Horizon Europe calls at the pre-implementation stage, the structural asymmetries we identified between Scope and Outcomes also raise questions regarding potential coordination challenges during policy implementation. The coexistence of a technically clustered Scope layer and a more centralised Outcomes layer may imply risks in lack of coordination when proposals are executed, particularly if the thematic diversity of technical research directions is not fully reconciled with the narrower set of impact anchors. This echoes broader concerns

in the MOIP literature, in which implementation difficulties often arise from the need to coordinate heterogeneous actors and objectives under rigid programme structures [13,17].

Although assessing actual implementation outcomes requires project-level data and evaluative evidence that fall beyond the scope of this article, our findings suggest that such asymmetries could create frictions in translating research activities into policy impacts. Future research could therefore examine whether the semantic structures identified here correlate with coordination difficulties during project execution, which would offer a complementary line of analysis that bridges call design with policy implementation dynamics.

5.4. Guidance for Applicants and Proposal Writers

For researchers and applicants to Horizon Europe funding, our analysis highlights the value of explicitly integrating high-betweenness connectors into their proposal writing. If their research concepts build on these bridging terms, they can demonstrate cross-cutting relevance and improve the competitiveness of their proposals in the eyes of the evaluators of the European Commission. In the same way, this insight is also relevant for policymakers, who can consider the deliberate insertion of certain terms, as well as their omission, as a tool to shape EU research agendas and their consistency with MOIP principles.

Understanding the different roles of the Scope and Outcomes layers allows for better strategies in proposal writing: use hubs for credibility, bridges for integration, and peripheries for novelty. For grant writers and their consortia, this differentiation offers a data-driven roadmap for structuring proposal narratives and task distribution. Hubs (i.e., high-degree, high-eigenvector keywords) should guide the project idea in well-established and programmatically validated concepts, which increase the perceived legitimacy of the proposal. Bridging terms, typically with high betweenness centrality, are ideal for demonstrating interdisciplinary ambition and wider policy integration, potentially acting as pillars for the proposed work packages and complementary consortium roles that span different sectors and applications. Meanwhile, deliberate engagement with peripheral terms offers a controlled risk–reward opportunity: when smartly framed in the proposal idea and connected to central themes, these marginal concepts can demonstrate innovation, originality, and alignment with neglected or emerging EU priorities.

In addition to thematic convergence, proposal writers should also be aware that the conceptual architecture revealed by our analysis may influence evaluators' mental models. The repeated presence of certain terms in funding calls contributes to shaping what is subconsciously perceived as credible, policy-relevant, or innovative in scope. Consequently, using central or bridging keywords may not only improve semantic coherence with the programme, but also echo the implicit expectations evaluators bring to the review process. This strengthens the value of such terms as structural connectors in the network and as rhetorical anchors during evaluation.

While central and bridging keywords can guide proposal structure and improve evaluation, they should not be used as a substitute for conceptual originality. Without a clearly innovative framing, proposals that rely too heavily on highly central keywords risk blending into a crowded field of superficially similar submissions. Therefore, applicants should aim to match semantic proximity with narrative uniqueness, employing central terms as the structural framework but ensuring their proposal offers a distinct and genuinely innovative contribution to the field. Achieving this balance, however, is rarely straightforward. Our analysis provides a roadmap for applicants: use hubs for legitimacy, bridges for integration, and peripheries for novelty. This actionable guidance exemplifies how methodological advances in TNA can be translated into practical benefits for research communities engaging with mission-oriented policy frameworks.

6. Conclusions

Our study has presented a comprehensive textual network analysis of the “Climate, Energy and Mobility” calls in Horizon Europe’s 2021–2022 Work Programme, focusing specifically on their Scope and Expected Outcomes descriptions. Extracting and analysing keyword co-occurrences, we mapped the conceptual architecture inherent to the programme and assessed the internal coherence of their thematic structure. The results provide a novel, data-driven approach to better understand how research priorities are framed at call-design stage, before any funding is allocated. Our analysis of the wording of calls as cognitive artefacts, rather than of projects or consortia, offers an upstream perspective that extends existing evaluations of EU funding.

At the same time, our research provides evidence that Textual Network Analysis serves as a powerful diagnostic tool for assessing the internal logic of mission-oriented funding frameworks. Centrality metrics, traditionally used in scientometrics, can effectively identify the roles that different concepts play in the programme’s policy narrative. High-degree and high-eigenvector keywords represent consolidated, programmatically endorsed themes, and high-betweenness terms reveal bridging concepts that support cross-domain integration. On the other hand, keywords with low centrality scores point out thematic blind spots and areas of potential innovation that remain under-integrated or underdeveloped. This demonstrates the methodological value of applying TNA to policy design, providing replicable and scalable tools for both scholars and practitioners.

The network structure we uncovered reflects Horizon Europe’s hybrid design. The Scope layer reveals a modular, technically oriented structure mirroring bottom-up research development, while the Outcomes layer displays a more centralised, impact-driven logic consistent with top-down mission framing. This asymmetry highlights the dual challenge faced by researchers and grant applicants, who need to balance the exploratory diversity of emerging and innovative technologies with the priorities of EU policy objectives.

Taken together, the results support our initial hypothesis H1 and confirm that Scope sections exhibit modular and assortative clustering while Outcomes sections are more centralised and policy-driven. The analysis also validates H2 and H3, as keywords such as “energy storage” and “emissions” play a bridging role across otherwise disconnected communities. Finally, H4 is corroborated through the identification of structurally marginal terms that correspond to policy-relevant but under-integrated themes. These outcomes collectively reinforce our main hypothesis that Horizon Europe’s Work Programme embodies a hybrid architecture, which aims to balance exploratory research diversity with mission-driven directionality.

Using centrality metrics, we provide policymakers and applicants with a framework to refine their future programme design and proposal writing strategies. For policymakers, network-based analysis may help identify neglected areas and strengthen semantic consistency in funding call design. Concretely, our results suggest that policymakers drafting future Horizon Europe or FP10 calls could increase coherence by pairing under-integrated concepts (e.g., drought resilience, rural transport) with central hubs such as “renewable energy” or “emissions”. This would prevent thematic blind spots while encouraging projects that align technical innovation with wider territorial and social priorities of the EU. For applicants, purposefully incorporating bridging concepts and peripheral elements can increase thematic coherence and improve the competitiveness of their proposals. Together, these practical implications show how our approach generates direct value for both programme designers and the research community.

Future work could build on this framework by treating entire calls as nodes within the network to trace how thematic clusters evolve across Work Programmes. Extending the analysis to other clusters and subsequent Work Programmes (e.g., 2023–2025) would

also provide a clearer view of thematic trajectories in European research funding over time. Additionally, incorporating post-funding data, such as project abstracts available in CORDIS or impact evaluations, would offer a longitudinal perspective on how semantic design decisions influence actual funding outcomes. Furthermore, cross-referencing call texts with national energy strategies could yield insights into how EU-level framing interacts with member state contexts. These potential extensions, although beyond the scope of the present article, underscore the value of combining textual network analysis with complementary perspectives in future research.

Table 6 summarises the conceptual, methodological, and practical contributions of this research, highlighting how our work extends existing studies while generating direct value for both policy and practice. Ultimately, our study contributes to a growing body of work that views funding calls not merely as administrative instruments, but as deliberate textual elements that shape the future research and innovation landscape. Conceptually, we reframe calls as artefacts of mission-oriented policy design; methodologically, we demonstrate the utility of textual network analysis for diagnosing policy coherence; and practically, we derive actionable lessons for both policymakers and applicants. Through this deeper examination of Horizon Europe’s conceptual infrastructure, we provide a methodological and data-driven foundation for improving funding programme governance and guiding researchers within MOIP frameworks.

Table 6. Summary of the study’s contributions.

Contribution Type	Novelty Introduced in This Study	Distinction from Prior Work	Main Beneficiaries
Conceptual	Frames Horizon Europe call texts as cognitive artefacts of policy design rather than neutral administrative templates.	Previous research focused mainly on funded projects, consortia structures, or participation patterns.	Scholars of mission-oriented innovation policy; policy analysts.
Methodological	Introduces a dual-layer Textual Network Analysis (Scope vs. Outcomes) with centrality, modularity, and assortativity metrics.	Earlier applications of TNA examined legislative texts or collaboration networks, but not funding calls at the design stage.	Researchers in scientometrics, innovation studies, and research policy.
Practical	Provides diagnostic tools for policymakers (to identify thematic gaps and improve call design) and guidance for applicants (to align proposals with hubs, bridges, and peripheral terms).	Most evaluations are qualitative and retrospective; our framework is quantitative, replicable, and forward-looking.	Policymakers drafting Work Programmes; researchers and consortia preparing proposals.

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Abbreviations

The following abbreviations are used in this manuscript:

BERT	Bidirectional Encoder Representations from Transformers
EC	European Commission
EU	European Union
FP	Framework Programme
LDA	Latent Dirichlet Allocation
MOIP	Mission-Oriented Innovation Policies
R&D	Research and Development
TF-IDF	Term Frequency–Inverse Document Frequency
TNA	Textual Network Analysis
WP	Work Programme

Appendix A

Mathematical Definitions of Network Measures

The following standard definitions were used for the centrality and modularity measures:

Degree centrality of node i :

$$C_D(i) = k_i \quad (\text{A1})$$

where k_i is the number of edges incident to node i .

Betweenness centrality:

$$C_B(i) = \sum_{s \neq i \neq t} \frac{\sigma_{st}(i)}{\sigma_{st}} \quad (\text{A2})$$

where σ_{st} is the total number of shortest paths from s to t , and $\sigma_{st}(i)$ is the number of those paths passing through i .

Closeness centrality:

$$C_C(i) = \frac{1}{\sum_j d(i, j)} \quad (\text{A3})$$

where $d(i, j)$ represents the shortest path length between i and j .

Eigenvector centrality:

$$C_E(i) = \frac{1}{\lambda} \sum_j A_{ij} C_E(j) \quad (\text{A4})$$

where A is the adjacency matrix and λ its largest eigenvalue.

Modularity for community detection:

$$Q = \frac{1}{2m} \sum_{i,j} \left(A_{ij} - \frac{k_i k_j}{2m} \right) \delta(c_i, c_j) \quad (\text{A5})$$

where m is the total number of edges, k_i is the degree of node i , and $\delta(c_i, c_j)$ equals 1 if nodes i and j are in the same community and 0 otherwise.

References

1. Benissa, T.; Patil, A. Drivers for Clustering and Inter-Project Collaboration—A Case of Horizon Europe Projects. *Adm. Sci.* **2024**, *14*, 104. [CrossRef]
2. Bralić, A. Social Network Analysis of Country Participation in Horizon 2020 Programme. In Proceedings of the Central European Conference on Information and Intelligent SystemAt, Varaždin, Croatia, 19–21 September 2018.

3. Breschi, S.; Cusmano, L. Unveiling the Texture of a European Research Area: Emergence of Oligarchic Networks under EU Framework Programmes. In *Knowledge Flows in European Industry*; Routledge: Abingdon, UK, 2006; pp. 294–324.
4. Balland, P.A.; Boschma, R.; Ravet, J. Network Dynamics in Collaborative Research in the EU 2003–2017. *Eur. Plan. Stud.* **2019**, *27*, 1811–1837. [\[CrossRef\]](#)
5. Calvo-Gallardo, E.; Arranz, N.; Fernández de Arroyabe, J.C. Analysis of the European Energy Innovation System: Contribution of the Framework Programmes to the EU Policy Objectives. *J. Clean. Prod.* **2021**, *298*, 126690. [\[CrossRef\]](#)
6. Fernández de Arroyabe, J.C.; Schumann, M.; Sena, V.; Lucas, P. Understanding the Network Structure of Agri-Food FP7 Projects: An Approach to the Effectiveness of Innovation Systems. *Technol. Forecast. Soc. Change* **2021**, *162*, 120372. [\[CrossRef\]](#)
7. Hoekman, J.; Frenken, K.; Tijssen, R.J.W. Research Collaboration at a Distance: Changing Spatial Patterns of Scientific Collaboration within Europe. *Res. Policy* **2010**, *39*, 662–673. [\[CrossRef\]](#)
8. Rodríguez Ochoa, D.; Arranz, N.; Fernández de Arroyabe, J.C. The Role of Horizon 2020 in Achieving Climate-Neutral Urban Objectives: A Study of 14 Spanish Cities Innovation Networks. *J. Clean. Prod.* **2023**, *432*, 139820. [\[CrossRef\]](#)
9. Siew, C.S.Q.; Wulff, D.U.; Beckage, N.M.; Kenett, Y.N. Cognitive Network Science: A Review of Research on Cognition through the Lens of Network Representations, Processes, and Dynamics. *Complexity* **2019**, *2019*, 2108423. [\[CrossRef\]](#)
10. Morea, F.; Soraci, A.; De Stefano, D. Mapping Leadership and Communities in EU-Funded Research through Network Analysis. *Open Res. Eur.* **2024**, *4*, 268. [\[CrossRef\]](#)
11. Rotolo, D.; Hicks, D.; Martin, B.R. What Is an Emerging Technology? *Res. Policy* **2015**, *44*, 1827–1843. [\[CrossRef\]](#)
12. Mazzucato, M. Mission-Oriented Innovation Policies: Challenges and Opportunities. *Ind. Corp. Change* **2018**, *27*, 803–815. [\[CrossRef\]](#)
13. Borrás, S.; Edquist, C. The Choice of Innovation Policy Instruments. *Res. Policy* **2013**, *42*, 1513–1522. [\[CrossRef\]](#)
14. Edler, J.; Georghiou, L. Public Procurement and Innovation. *Res. Policy* **2007**, *36*, 949–963. [\[CrossRef\]](#)
15. Kattel, R.; Mazzucato, M. *Mission-Oriented Innovation Policies in Europe: From Normative to Epistemic Turn?* UCL Institute for Innovation and Public Purpose, Working Paper Series (IIPP WP 2023-09); University College London: London, UK, 2023; Available online: <https://www.ucl.ac.uk/bartlett/public-purpose/wp2023-09> (accessed on 10 August 2025).
16. Wanzenböck, I.; Wesseling, J.H.; Frenken, K.; Hekkert, M.P.; Weber, K.M. A Framework for Mission-Oriented Innovation Policy: Alternative Pathways through the Problem–Solution Space. *Sci. Public Policy* **2020**, *47*, 474–489. [\[CrossRef\]](#)
17. Lindner, R.; Edler, J.; Hufnagl, M.; Kimpeler, S.; Kroll, H.; Roth, F.; Wittmann, F.; Yorulmaz, M. *Mission-Oriented Innovation Policy: From Ambition to Successful Implementation*. Policy Brief 02-2021; Fraunhofer Institute for Systems and Innovation Research ISI: Karlsruhe, Germany, 2021.
18. Wittmann, F.; Hufnagl, M.; Lindner, R.; Roth, F.; Edler, J. Governing Varieties of Mission-Oriented Innovation Policies: A New Typology. *Sci. Public Policy* **2021**, *48*, 727–738. [\[CrossRef\]](#)
19. European Commission. *Orientations towards the First Strategic Plan for Horizon Europe*; Publications Office of the European Union: Luxembourg, 2019.
20. European Commission. EU Missions in Horizon Europe. Available online: https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe_en (accessed on 10 August 2025).
21. European Parliamentary Research Service. *The Horizon Europe Programme: A Strategic Assessment of Selected Items*; Scientific Foresight Unit (STOA) Study PE 757.813; European Parliamentary Research Service: Brussels, Belgium, 2024.
22. Council Regulation (EU) 2021/2085 Establishing the Joint Undertakings under Horizon Europe, Recital (4). Council Regulation (EU) 2021/2085 of 19 November 2021 establishing the Joint Undertakings under Horizon Europe. *Off. J. Eur. Union* **2021**, *L 427*, 17–119. Available online: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32021R2085> (accessed on 1 August 2025).
23. European Commission. *Commission Staff Working Document: Interim Evaluation of the Horizon Europe Framework Programme for Research and Innovation (2021–2024)*; SWD(2025) 110 Final; Publications Office of the European Union: Brussels, Belgium, 2025.
24. Husiev, O.; Ukar Arrien, O.; Enciso-Santocildes, M. What Does Horizon 2020 Contribute to? Analysing and Visualising the Community Practices of Europe’s Largest Research and Innovation Programme. *Energy Res. Soc. Sci.* **2023**, *95*, 102879. [\[CrossRef\]](#)
25. Smith, M.; Sarabi, Y.; Christopoulos, D. Understanding Collaboration Patterns on Funded Research Projects: A Network Analysis. *Netw. Sci.* **2023**, *11*, 143–173. [\[CrossRef\]](#)
26. Peng, H.; Qiu, H.S.; Fosse, H.B.; Uzzi, B. Promotional Language and the Adoption of Innovative Ideas in Science. *Proc. Natl. Acad. Sci. USA* **2024**, *121*, e2320066121. [\[CrossRef\]](#)
27. Borchardt, S.; Barbero Vignola, G.; Buscaglia, D.; Maroni, M.; Marelli, L. *Mapping EU Policies with the 2030 Agenda and SDGs*; EUR 31347 EN; Publications Office of the European Union: Luxembourg, 2022; JRC130904; ISBN 978-92-76-60475-4. [\[CrossRef\]](#)
28. Sewerin, S.; Kaack, L.H.; Küttel, J.; Sigurdsson, F.; Martikainen, O.; Eshshaki, A.; Hafner, F. Towards Understanding Policy Design through Text-as-Data Approaches: The Policy Design Annotations (POLIANNA) Dataset. *Sci. Data* **2023**, *10*, 896. [\[CrossRef\]](#)
29. Attride-Stirling, J. Thematic Networks: An Analytic Tool for Qualitative Research. *Qual. Res.* **2001**, *1*, 385–405. [\[CrossRef\]](#)

30. Börner, K.; Chen, C.; Boyack, K.W. Visualizing Knowledge Domains. *Annu. Rev. Inf. Sci. Technol.* **2003**, *37*, 179–255. [CrossRef]
31. Leydesdorff, L.; Nerges, A. Co-Word Maps and Topic Modeling: A Comparison Using Small and Medium-Sized Corpora ($N < 1000$). *J. Assoc. Inf. Sci. Technol.* **2017**, *68*, 1024–1035.
32. European Commission. Funding & Tenders Portal. Available online: <https://ec.europa.eu/info/funding-tenders/opportunities/portal/> (accessed on 10 August 2025).
33. Grootendorst, M. KeyBERT: Minimal Keyword Extraction with BERT. GitHub. 2020. Available online: <https://github.com/MaartenGr/KeyBERT> (accessed on 10 August 2025).
34. Amur, Z.H.; Hooi, Y.K.; Soomro, G.M.; Bhanbhro, H.; Karyem, S.; Sohu, N. Unlocking the Potential of Keyword Extraction: The Need for Access to High-Quality Datasets. *Appl. Sci.* **2023**, *13*, 7228. [CrossRef]
35. R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2023. Available online: <https://www.R-project.org/> (accessed on 10 August 2025).
36. Csardi, G.; Nepusz, T. The igraph Software Package for Complex Network Research. *Interf. Complex Syst.* **2006**, 1695. Available online: <https://igraph.org> (accessed on 10 August 2025).
37. Wickham, H. dplyr: A Grammar of Data Manipulation; R Package Version 1.1.2. 2023. Available online: <https://CRAN.R-project.org/package=dplyr> (accessed on 10 August 2025).
38. Wickham, H. stringr: Simple, Consistent Wrappers for Common String Operations; R Package Version 1.5.0. 2023. Available online: <https://CRAN.R-project.org/package=stringr> (accessed on 10 August 2025).
39. Wickham, H.; Bryan, J. readxl: Read Excel Files; R Package Version 1.4.2. 2023. Available online: <https://CRAN.R-project.org/package=readxl> (accessed on 10 August 2025).
40. Wickham, H.; Hester, J.; Bryan, J. readr: Read Rectangular Text Data; R Package Version 2.1.4. 2023. Available online: <https://CRAN.R-project.org/package=readr> (accessed on 10 August 2025).
41. Newman, M.E.J. *Networks: An Introduction*; Oxford University Press: Oxford, UK, 2010.

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