EU RESEARCH AND TECHNOLOGICAL CAPABILITIES ANALYSIS

June 2026

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EU Research and Technological Capabilities Analysis

Executive Summary

This report presents a structured mapping and analysis of European research and innovation (R&I) activities related to the Cognitive Computing Continuum, based on a curated dataset of 418 projects funded under Horizon Europe programmes between 2021 and 2025.

The analysis adopts a multi-dimensional approach combining:

- Technological pillars, representing the main layers of the continuum ecosystem
- Strategic destinations, representing the long-term outcomes Europe aims to achieve
- Policy recommendations, representing strategic intervention areas supporting these outcomes

The Cognitive Computing Continuum is approached as a distributed and interoperable ecosystem spanning cloud, edge, AI, data, networking, hardware, software, and operational environments.

The results reveal a strong concentration of European activities in infrastructure-related domains, particularly those associated with cloud-edge integration, distributed computing, interoperability, and scalable infrastructures. **Pillar II – Cognitive Computing Continuum Convergence & Infrastructure achieved the highest weighted score in the analysis (599) and the highest proportion of high-intensity contributions (48%)**, confirming the central role of **D1 – Scalable and energy-efficient AI and data processing** and **D4 – A secure, sovereign European computing continuum infrastructure** within the current European landscape.

At the same time, the analysis identifies significant gaps in:

- AI tooling, orchestration, and developer ecosystems
- Frontier and high-impact AI capabilities
- Emerging disruptive computing paradigms
- Cross-layer integration across the continuum

Pillar IV – AI-tooling for intelligent infrastructure management and developer productivity in the Computing Continuum recorded the lowest weighted score (276) and the lowest proportion of high-intensity contributions (10%), highlighting a potential area for future attention. These findings are reflected in the comparatively weaker positioning of destinations related to open AI stacks, advanced AI ecosystems, and disruptive computing technologies (D2, D3, and D6).

The assessment also shows that Europe is comparatively advanced in deployment-oriented infrastructure domains, while higher-level AI capabilities and enabling layers remain less mature and less industrially consolidated.

The analysis suggests several areas that may require increased attention in future European R&I activities:

- Continue strengthening secure and interoperable infrastructure capabilities
- Further support AI tooling, orchestration, and developer ecosystems
- Further support high-impact and frontier AI research
- Consolidate a sovereign European hardware-software stack
- Accelerate industrial deployment and cross-sector scaling
- Improve integration and interoperability across the continuum

These priorities are aligned with recent European policy developments, including the Data Act[1], the Artificial Intelligence Act[2], the European Chips Act[3], and the EU Cloud and Edge Strategy[4], as well as with the strategic directions identified in the NexusForum roadmap and policy activities.

Achieving a more integrated, interoperable, and innovation-driven Cognitive Computing Continuum will be essential for strengthening Europe's technological sovereignty, industrial competitiveness, and long-term digital resilience.

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Project funded by
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1. Scope, analytical framework and methodology

This analysis is based on a structured dataset of 418 European research and innovation projects funded under Horizon Europe programs.

Projects were selected through a targeted filtering process aimed at identifying activities relevant to the Cognitive Computing Continuum, based on project objectives, keywords, technological focus, and application domains.

The analysis is based on projects funded under Horizon Europe calls available at the time of data collection, covering the period from 2021 to 2025.

1.1 The Cognitive Computing Continuum framework

The Cognitive Computing Continuum represents a European vision for a distributed, interoperable, and intelligent digital ecosystem spanning cloud, edge, IoT, AI, data, networking, hardware, software, and operational environments.

Rather than a single technology or infrastructure, the continuum should be understood as a multi-layered system-of-systems ecosystem where different technological layers, deployment models, and governance approaches coexist and interact.

To support the analysis of European R&I activities, the framework is organised around three complementary dimensions:

- **Technological pillars**, representing the main technological and operational layers of the continuum.
- **Strategic destinations**, representing the long-term outcomes Europe aims to achieve.
- **Policy recommendations**, representing intervention mechanisms supporting these outcomes.

The five technological pillars cover:

1. Foundational AI and ML technologies in the Computing Continuum
2. Cognitive Computing Continuum Convergence & Infrastructure
3. Achieving a European AI stack and global leadership in AI-enabling technologies and infrastructures / An AI-enabling hardware-software stack for the Cognitive Computing Continuum
4. AI-tooling for intelligent infrastructure management and developer productivity in the Computing Continuum
5. Sectoral adoption, testbeds, and deployment environments

In parallel, the analysis is aligned with six strategic destinations addressing areas such as:

- D1 - Scalable and energy-efficient AI and data processing
- D2 - An AI stack built on an open European hardware/computing ecosystem

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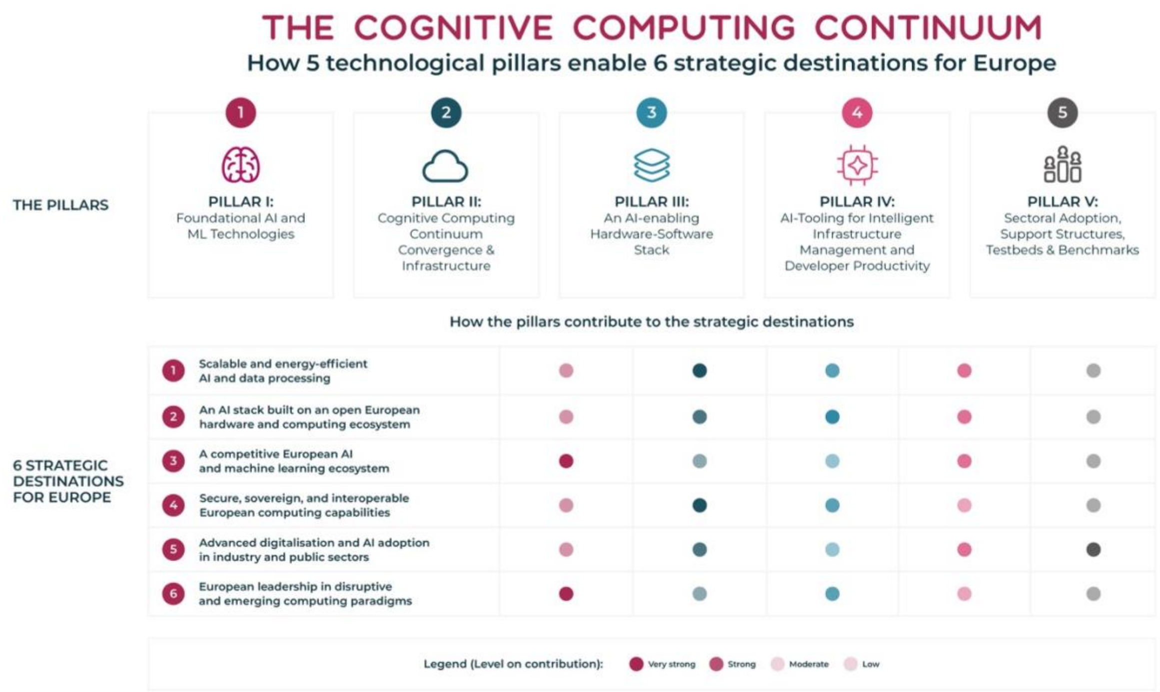
- D3 - A competitive AI and machine learning ecosystem in Europe / Building advanced AI and machine learning capacity in Europe
- D4 - A secure, sovereign European computing continuum infrastructure
- D5 - Advanced digitalisation and AI adoption in industry and public sectors
- D6 - European leadership in emerging disruptive computing paradigms

The destinations represent strategic outcomes enabled through the combined contribution of multiple pillars across the continuum.

Furthermore, the analysis considers seven policy recommendations identified through the NexusForum policy related activities.

- PR1: Unify infrastructure and integrate future technologies
- PR2: Strengthen trust and cross-border data fluidity
- PR3: Reduce vendor lock-in and strengthen strategic autonomy
- PR4: Consolidate governance and coordination
- PR5: Strengthen Open source and standards commons
- PR6: Support SMEs to scale and compete globally
- PR7: Enhance technological sovereignty and adoption capacity



Together, pillars, destinations, and policy recommendations provide the analytical basis for the assessment developed in the following sections. The six strategic destinations are enabled through the combined contribution of multiple technological pillars. Their achievement requires balanced progress across AI, infrastructure, tooling, deployment, environments and computing ecosystems.

1.2 Methodological approach and limitations

The analysis adopts a semi-quantitative and multi-dimensional methodology combining technological, strategic, and policy-oriented perspectives.

Projects were analysed and categorised based on:

- Project objectives and descriptions
- Keywords and thematic tags
- Technological focus and operational scope
- Sectoral use cases and deployment domains

Projects were classified according to their level of contribution to each pillar (high, medium, low). These contribution levels were translated into numerical weights (3, 2, and 1 respectively), enabling the calculation of weighted scores reflecting both the volume and intensity of activities.

The mapping of projects to strategic destinations was based on the primary technological focus of each project and should be interpreted as indicative and multi-dimensional rather than strictly one-to-one.

The assessment of technological readiness and innovation capacity is based on a combination of qualitative and quantitative indicators derived from the project dataset, including contribution intensity, technological maturity (TRL), thematic diversity, and proximity to operational deployment.

Several methodological limitations should be acknowledged:

- The dataset includes only publicly funded projects under Horizon 2020 and Horizon Europe up to the calls available at the time of data collection (up to 2025)
- Private-sector innovation and startup ecosystems are not systematically represented
- Contribution levels are based on qualitative interpretation
- The weighting methodology provides a simplified representation of contribution intensity
- Projects are treated as equivalent analytical units regardless of funding size or impact

Despite these limitations, the methodology is considered sufficiently robust to support a strategic-level assessment of the European Cognitive Computing Continuum.

2. Mapping and characterization of European R&I activities

This section maps European research and innovation activities related to the Cognitive Computing Continuum across both the technological pillars and the strategic destinations defined in the analytical framework.

2.1 Mapping across pillars and strategic destinations

The distribution of projects across the technological pillars reveals a clear imbalance in the current European R&I landscape.

Pillar II – Cognitive Computing Continuum Convergence & Infrastructure, which covers cloud-edge infrastructures, distributed computing, networking, and operational environments, represents the strongest area of concentration, achieving the highest weighted score (599) and the highest proportion of high-intensity contributions (48%).

Pillar III – Achieving a European AI stack and global leadership in AI-enabling technologies and infrastructures / An AI-enabling hardware-software stack for the Cognitive Computing Continuum, also shows significant activity, particularly in hardware, middleware, orchestration frameworks, AI services, and European processor initiatives.

In contrast, activities related to **Pillar I – Foundational AI and ML Technologies in the Computing Continuum,** remain more exploratory and fragmented, particularly in areas such as generative AI, agentic systems, and emerging AI paradigms.

The weakest area of activity is **Pillar IV – AI-tooling for intelligent infrastructure management and developer productivity in the Computing Continuum**, where projects related to orchestration, tooling, automation, and developer ecosystems remain significantly underrepresented. **Pillar IV** achieved the lowest weighted score (276) and the lowest proportion of high-intensity contributions (10%) among all pillars.

Pillar V – Sectoral Adoption, Support Structures, Testbeds & Benchmarks, demonstrates broad sectoral coverage, particularly in manufacturing, energy, mobility, and infrastructure management, although deployment and scaling remain uneven across sectors.

From the perspective of the strategic destinations, the analysis shows the strongest alignment with:

- D1 – Scalable and energy-efficient AI and data processing
- D4 – Secure, sovereign, and interoperable computing capabilities

In contrast, destinations related to advanced AI capabilities, tooling, and disruptive paradigms (D2, D3, and D6) remain comparatively weaker and less mature.

Overall, the mapping highlights a structural imbalance between Europe's strong infrastructure capabilities and the more limited development of higher-level AI, tooling, and disruptive computing ecosystems.

2.2 Sectoral and technological characterization

The analyzed projects cover a broad range of activities across infrastructure, AI, hardware-software integration, and sectoral deployment domains.

A large proportion of projects focus on cloud-edge integration, distributed computing, interoperability,

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and operational infrastructures, while a smaller share addresses orchestration, tooling, and disruptive AI paradigms.

Sectoral activities are concentrated mainly in manufacturing, energy, mobility, and infrastructure management, often supported through pilots, testbeds, digital twins, and experimentation environments.

Overall, the landscape reflects a strong orientation towards infrastructure deployment and operational integration, with more limited activity in enabling tooling and frontier AI ecosystems.

3. Gap analysis and multi-dimensional assessment

The analysis reveals several structural gaps and imbalances that may limit Europe's ability to fully achieve its strategic destinations and long-term digital sovereignty objectives.

3.1 Structural gaps and imbalances

One of the most evident areas receiving comparatively less attention is **Pillar IV (Tooling & Orchestration)**, this is reflected in its weighted score of 276 and the fact that only 10% of its contributions were classified as high intensity, compared with 48% in Pillar II. Despite their strategic importance for scalability and operational deployment, these domains remain comparatively underrepresented and exhibit low levels of technological maturity and innovation capacity.

The analysis also highlights a relative weakness in advanced AI capabilities associated with **Pillar I (AI Paradigms**) and therefore, destinations D3 – A competitive AI and machine learning ecosystem in Europe / Building advanced AI and machine learning capacity in Europe and D6 – European leadership in emerging disruptive computing paradigms. While Pillar I achieved a weighted score of 365, only 23% of its contributions were classified as high intensity, suggesting that many activities remain exploratory, fragmented, and not yet fully translated into industrial impact.

At the same time, the strong concentration of projects in infrastructure-related domains (**Pillar II**) may contribute to an imbalance across the continuum, where infrastructure capabilities advance faster than higher-level AI, orchestration, and operational ecosystems.

The analysis further highlights fragmentation across technological domains, industrial ecosystems, and deployment environments, limiting integration and scalability across the continuum.

Taken together, these findings highlight several interrelated challenges affecting the development of the Cognitive Computing Continuum. These challenges are further synthesized into strategic priorities in the subsequent sections and conclusions.

3.2 Technological readiness and innovation capacity

The assessment of technological readiness and innovation capacity reveals a heterogeneous and structurally imbalanced landscape across the Cognitive Computing Continuum.

Infrastructure-related domains (**Pillar II**), particularly those contributing to D1 – Scalable and energy-efficient AI and data processing and D4 – A secure, sovereign European computing continuum infrastructure, exhibit the highest levels of technological maturity and deployment readiness.

In contrast, activities related to **Pillar I (AI Paradigms)** and destinations D3 – A competitive AI and machine learning ecosystem in Europe / Building advanced AI and machine learning capacity in Europe and D6 – European leadership in emerging disruptive computing paradigms, remain relatively exploratory, suggesting opportunities to strengthen the transition from research excellence to industrial impact.

Pillar III (Computing Stack) shows a moderate but growing level of maturity and innovation capacity, contributing primarily to D2 – An AI stack built on an open European hardware/computing ecosystem, through the development of Europe's computing ecosystem.

Meanwhile, **Pillar IV (Tooling & Orchestration)** appears less mature and less developed than other areas of the continuum, which may limit scalability and operational integration if not further developed.

Projects related to **Pillar V (Applications & Deployment)** contribute mainly to D5 – Advanced digitalisation and AI adoption in industry and public sectors and demonstrate variable maturity depending on the sector and deployment environment.

Overall, the analysis suggests a difference in maturity between infrastructure-related capabilities and higher-level AI and orchestration layers.

Figure below summarizes the multi-dimensional assessment across the five pillars, combining their technological maturity, innovation capacity, and contribution to the strategic destinations.

Multi-dimensional Assessment of Technological Pillars

Pillar	Technological Readiness (TRL)	Innovation Capacity	Overall Assessment
Pillar I: AI PARADIGMS	LOW-MEDIUM Early research phase to pilot testing	MEDIUM Strong research foundation but fragmented impact	Robust research base with limited breakthrough impact.
Pillar II: INFRASTRUCTURE	HIGH Fully operational and mature systems	HIGH Focused on incremental and system-level gains	Core European strength with risks of overconcentration.
Pillar III: STACK (HW-SW-AI)	MEDIUM-HIGH Advanced development and initial deployment	MEDIUM-HIGH Ecosystem is maturing and becoming stable	Strategic consolidating layer with growing importance.
Pillar IV: TOOLING & ORCHESTRATION	LOW Conceptual stages and early prototypes	LOW Limited development of integrated frameworks	Critical adoption bottleneck due to scalability gaps.
Pillar V: APPLICATIONS & SECTORS	MEDIUM-HIGH Performance depends heavily on the specific sector	MEDIUM Progress is uneven across different industries	Solid deployment base with limited cross-sector scaling.

4. Conclusions

The analysis confirms that Europe has established a strong infrastructure base across the Cognitive Computing Continuum, particularly in areas related to cloud-edge integration, interoperability, and secure distributed computing capabilities.

The strongest alignment is observed in destinations related to scalable AI infrastructures and sovereign computing capabilities (D1 and D4), reflecting Europe's strategic focus on resilience, federation, and operational deployment.

At the same time, some areas appear comparatively less developed such as AI tooling, orchestration, advanced AI ecosystems, and disruptive computing paradigms. Destinations related to frontier AI and enabling layers (D2, D3, and D6) remain comparatively fragmented, less mature, and less industrially consolidated.

These findings reflect a set of interrelated gaps identified across the ecosystem, including limitations in tooling and orchestration, frontier AI capabilities, cross-layer integration, ecosystem coordination, sectoral scaling, and emerging computing paradigms. For strategic planning, these gaps can be grouped into a smaller number of priority areas requiring future attention. Addressing these challenges will require:

- Continue strengthening AI tooling and orchestration ecosystems
- Further support high-impact and frontier AI research
- Consolidating a sovereign European hardware-software stack
- Accelerating industrial deployment and cross-sector interoperability
- Promoting stronger integration across the continuum ecosystem

Overall, Europe's future competitiveness may increasingly depend on maintaining strong infrastructure capabilities, but also on improving integration, scalability, and innovation across higher-level AI and enabling ecosystems.

The identified gaps and priorities are broadly consistent with the seven Policy recommendations identified in the project activities and that are included in the Digital Policy Report, particularly those addressing infrastructure integration, interoperability, open standards, governance, SME participation, and technological sovereignty. This alignment reinforces the relevance of the proposed policy directions as mechanisms for advancing Europe's strategic destinations across the Cognitive Computing Continuum.

Progress towards this transition could play an important role for positioning Europe as a globally competitive, sovereign, and resilient leader in the next generation of distributed AI and computing ecosystems.

Key Gaps, Policy Recommendations and Implications for the Cognitive Computing Continuum

IDENTIFIED GAP / CHALLENGE	RELATED PILLARS AND DESTINATIONS	KEY FINDINGS FROM ANALYSIS	RELEVANT POLICY RECOMMENDATIONS	IMPLICATIONS FOR EU R&I POLICY
1 Underdeveloped AI tooling and orchestration	Pillar IV D1 D2	• Limited maturity • Low innovation capacity • Lack of developer ecosystems, orchestration, and operational AI tooling	PR1 Unify infrastructure and integrate future technologies PR5 Strengthen Open source and standards commons	Increase support for AI tooling, orchestration, automation, and developer ecosystems to enable scalability and operational deployment
2 Limited high-impact and frontier AI capabilities	Pillar I D3 D6	• Strong research base but fragmented efforts • Limited industrial scaling • Low breakthrough impact in advanced AI paradigms	PR6 Support SMEs to scale and compete globally PR7 Enhance technological sovereignty and adoption capacity	Reinforce frontier AI research, support scaling from research to deployment, and strengthen Europe's AI competitiveness
3 Overconcentration in infrastructure-related activities	Pillar II D1 D4	• Strong focus on infrastructure deployment and federation • Comparatively weaker development of AI and enabling layers	PR1 Unify infrastructure and integrate future technologies PR4 Consolidate governance and coordination	Rebalance investments to ensure full-spectrum innovation across infrastructure, AI, tooling, and applications
4 Fragmentation across technological layers	Cross-pillar D1 D2 D3 D4 D5 D6	• Weak integration between infrastructure, AI paradigms, tooling, stack components, and applications	PR1 Unify infrastructure and integrate future technologies PR3 Reduce vendor lock-in and strengthen strategic autonomy PR5 Strengthen Open source and standards commons	Promote interoperability, federation, open standards, and system-level integration across European initiatives and ecosystems
5 Limited sectoral scaling and interoperability	Pillar V D5	• Uneven adoption across sectors • Limited cross-sector replication • Fragmented deployment environments	PR6 Support SMEs to scale and compete globally PR7 Enhance technological sovereignty and adoption capacity	Support industrial deployment, cross-sector scaling, and operational adoption across public and industrial domains
6 Weak integration of research, industry, and operational ecosystems	Cross-pillar D2 D5 D6	• Limited coordination between research activities, industrial uptake, and operational deployment ecosystems	PR4 Consolidate governance and coordination PR6 Support SMEs to scale and compete globally	Foster ecosystem integration, value chain coordination, and stronger links between research and deployment
7 Limited support for disruptive and emerging paradigms	Pillars I & III D6	• Fragmented and early-stage activity in neuromorphic computing, quantum technologies, novel accelerators, and non-conventional architectures	PR1 Unify infrastructure and integrate future technologies PR7 Enhance technological sovereignty and adoption capacity	Strengthen long-term investment in disruptive computing paradigms and future European technological leadership

OVERALL MESSAGE | Europe has solid strengths in infrastructure and a broad research base, but key gaps in tooling, advanced AI capabilities, integration and sectoral scaling limit its ability to fully leverage the Cognitive Computing Continuum.

Quantitative references throughout the report are derived from the weighted aggregation analysis presented in Annex 1.

Annex 1 – Methodological aggregation and weighted contribution analysis

A.1 Purpose of the aggregation analysis

To support a structured interpretation of the European R&I landscape related to the Cognitive Computing Continuum, a semi-quantitative aggregation methodology was applied to assess the relative contribution of projects across the technological pillars.

The objective of this aggregation was to:

- Identify the relative concentration of activities across pillars
- Assess the intensity of project contributions
- Support the identification of strengths, gaps, and structural imbalances
- Provide a comparable basis for the multi-dimensional assessment presented in the report

The aggregation complements the qualitative analysis by providing a simplified but transparent indicator of activity distribution and contribution intensity.

A.2 Contribution levels and weighting scheme

Projects were classified according to their level of contribution to each technological pillar using three qualitative categories:

Contribution level	Interpretation	Weight
High	Strong and direct contribution	3
Medium	Relevant but supporting contribution	2
Low	Indirect or limited contribution	1

The weighted score for each pillar was calculated using the following formula:

Weighted Score=(High×3) + (Medium×2) + (Low×1)

This approach combines:

- The **volume of contributions**
- The **intensity of contributions**

allowing for a structured comparison across pillars.

A.3 Aggregated contribution results across pillars

Pillar	High	Medium	Low	Weighted score	% High contributions	Overall interpretation
Pillar I (Foundational AI and ML technologies in the Computing Continuum)	49	55	108	365	23%	Strong research activity but limited high-impact concentration
Pillar II (Cognitive Computing Continuum Convergence & Infrastructure)	130	69	71	599	48%	Core strength of the European ecosystem
Pillar III (Achieving a European AI stack and global leadership in AI-enabling technologies and infrastructures / An AI-enabling hardware-software stack for the Cognitive Computing Continuum)	61	72	105	432	26%	Maturing ecosystem with growing strategic importance
Pillar IV (AI-tooling for intelligent infrastructure management and developer productivity in the Computing Continuum)	21	30	153	276	10%	Critical gap with low maturity and innovation intensity
Pillar V (Sectoral Adoption, Support Structures, Testbeds & Benchmarks)	44	68	92	360	22%	Broad deployment base but uneven sectoral scaling

A.4 Methodological considerations

The aggregation methodology provides a simplified representation of contribution intensity and should therefore be interpreted as indicative rather than absolute.

In particular:

- The weighting scheme does not account for project size, funding volume, or actual market impact
- Contribution levels are based on qualitative interpretation of project descriptions and objectives
- Projects may contribute simultaneously to multiple pillars and destinations

Despite these limitations, the methodology is considered sufficiently robust to support a strategic-level assessment of the Cognitive Computing Continuum and to identify major trends, strengths, and gaps across the European ecosystem.

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