I4-GREEN

(Priority Sector Report for the Raw Materials Sector in I4-GREEN Regions) D6.4

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TABLE OF CONTENTS

EXECUTIVE SUMMARY 6
1. INTRODUCTION 8
2. REGIONAL PROFILES 8
2.1. Extremadura (Spain) 9
2.2 Andalucía (Spain) 11
2.3 Alentejo (Portugal) 13
2.4 Castilla y León (Spain) 15
3. CROSS-REGIONAL ANALYSIS AND BENCHMARKING 17
3.1 Comparative SWOT Analysis 17
3.2 Shared Strengths and Gaps 18
3.3 Maturity Mapping of Regional Ecosystems 19
3.4 Synergies and Complementary Capacities 19
4. STRATEGIC RECOMMENDATIONS 20
4.1 Priority Areas for Cross-Regional Cooperation 20
4.2 Opportunities for Joint Cluster Development or EU Project Proposals 20
4.3 Recommendations for Regional Policymakers 21
4.4 Suggestions for Attracting Private Investment or Public Funding 21
5. CONTRIBUTION TO THE REGIONAL ECOSYSTEM SCOREBOARD 22
5.1 Alignment with European Commission Tools 22
5.2 Suggested Indicators for Future Monitoring 23
6. POLICY LEVERAGE POINTS BY REGION 23
6.1 Alentejo (Portugal) 23
6.2 Andalucía (Spain) 23
6.3 Extremadura (Spain) 24
6.4 Castilla y León (Spain) 24
7. CONCLUSION AND OUTLOOK 24

List of Tables		
Table 1	SWOT MATRIX FOR ALL I4-GREEN REGIONS	p. 17
Table 2	MATURE MAPPING IN I4-GREEN REGIONS	p. 18
Table 3	METRICS IDENTIFIED DIN I4-GREEN:.	p. 23
Table 4	FUTURE MONITORING INDICATORS	p. 27

Glossary	
Acronym	Meaning
I4-GREEN	Interregional investment for the sustainable supply of raw materials in the EU Green Energy Transition
WP	Work Package
DoA	Description of Action
ESCP-S3	European Strategic Cluster Partnerships for Smart Specialisation Investments
SME	Small and Medium-sized Enterprises
CRM	Critical Raw Materials
ERDF	European Regional Development Fund
EISMEA	European Innovation Council and SMEs Executive Agency
EIC	European Innovation Council
LIFE	The EU's funding instrument for environment and climate action
S3P	Smart Specialisation Platform
TSSP	Thematic Smart Specialisation Partnerships
EDM	Empresa de Desenvolvimento Mineiro
ISMC	Iberian Sustainable Mining Cluster
IPB	Iberian Pyrite Belt
ETS	Emissions Trading System
ESG	Environmental, Social, and Governance

R&D	Research and Development
CoP	Community of Practice
IHO	Iron Holm Oak
E-LIX	Pilot project of I4Green

EXECUTIVE SUMMARY

This Priority Sector Report provides a strategic analysis of the raw materials sector across four core regions involved in the I4-GREEN project: Andalucía, Extremadura, Alentejo, and Castilla y León. The report aims to assess the strengths, challenges, and opportunities within the raw materials ecosystems, with a focus on their readiness for sustainable and circular mining practices. By benchmarking regional assets and innovation capacities, the report serves as a foundation for strategic alignment and interregional cooperation.

The key findings from the regional analysis highlight both common strengths and unique challenges:

- Andalucía and Extremadura are the most advanced in terms of pilot deployment within the I4-GREEN project, with the E-LIX and Iron Holm Oak pilots leading sustainable mining innovations. Both regions have a strong geological potential for critical and strategical raw materials (e.g., REEs, Cu), supported by robust policy frameworks.
- Alentejo and Castilla y León, while less mature in terms of ecosystem development, offer significant mining potential with the Neves-Corvo, Aljustrel and Barruecopardo sites. Both regions show promise for scaling circular mining solutions, with strategic opportunities to benefit from cross-border synergies and joint replication efforts.
- Common strengths across all four regions include relevant critical and strategical raw materials, active participation in EU platform initiatives (e.g., S3 Thematic Platforms), and regional policy support for sustainable mining.
- Shared gaps include fragmented innovation ecosystems, limited SME integration, and infrastructure constraints. These gaps present barriers to scaling innovations across regions, requiring collaborative solutions to foster sustainable growth.

The findings from this report offer valuable insights for regional policymakers and investors:

- The I4-GREEN model offers a proven pathway for replicating sustainable mining technologies across different EU regions, with the potential for co-investment through EU funding instruments such as ERDF, InvestEU, Horizon Europe, Interreg and LIFE.
- Policy implications suggest that regions should update their Smart Specialisation Strategies (RIS3) to explicitly prioritise sustainable mining, circular economy practices, and interregional collaboration. This would help align investments with the EU's green transition goals and reduce Europe's dependency on critical raw material imports.
- The development of multi-region clusters and innovation hubs in Andalucía, Extremadura, Alentejo, and Castilla y León could unlock substantial cross-border synergies. Regions should leverage their participation in S3P and Interreg programmes to foster joint research initiatives, technology transfer, and co-financed projects. The creation of a Eurocluster involving this and other European regions will be determinant to strength innovative cooperation within and outside EU.
- The findings gathered in this report, could attract private sector participation and public funding for key replication-ready sites, which will catalyse innovation and ensure sustainable mining practices.

This report contributes directly to the Regional Ecosystem Scoreboard, a strategic tool designed to:

- Benchmark regional ecosystems based on indicators such as cluster involvement, innovation readiness, circular mining potential, and policy alignment.
- Track the maturity of each region's ecosystem over time and provide a dynamic framework for cross-regional cooperation and investment mobilisation.
- Inform strategic decision-making for policy-makers, investors, and EU-level stakeholders, enabling more effective alignment of resources and initiatives to foster sustainable raw material value chains.
- Through this, the Regional Ecosystem Scoreboard serves as a critical tool to guide the future direction of the I4-GREEN project, ensuring its sustainability and scalability across the EU.

1. INTRODUCTION

The I4-GREEN project ("Interregional investment for the sustainable supply of raw materials in the EU Green Energy Transition") aims to accelerate the green and circular transformation of Europe's extractive industries by supporting innovative technologies, fostering interregional cooperation, and reducing the EU's dependency on critical raw materials (CRMs). Anchored in two industrial pilots in Spain, and supported by a consortium of actors from Portugal, Spain, and Italy, I4-GREEN is a bold response to the environmental, economic, and geopolitical challenges associated with raw materials supply in the green energy transition.

Within this framework, Work Package 6 (WP6) – Interregional Deployment and Replication to Full EU Scale, plays a pivotal role in ensuring that innovations, investments, and industrial models demonstrated in the project, can be extended and adapted across other EU regions. WP6 focuses on creating the foundations for an EU-wide sustainable mining demonstrator through cross-regional replication strategies, coordinated investment planning, and the development of supporting infrastructure such as strategic databases and joint intelligence tools. By doing so, WP6 contributes directly to the project's mission to build a pan-European innovation ecosystem for sustainable and circular mining.

As part of WP6, Task T6.3 – Clustering within Clusters: Regional Perspective for a Benchmarking Strategy towards Cluster, is designed to foster inter-cluster collaboration, enhance regional ecosystem maturity, and support the strategic alignment of innovation actors across the I4-GREEN regions. Through benchmarking activities, collaborative workshops, and strategic engagement with EU-level cluster initiatives, Task T6.3 promotes the identification of synergies and cooperation opportunities within and between clusters, thereby advancing the project's broader goal of interregional integration and sustainable growth. and building the foundation for a new Eurocluster on Mineral Raw Materials.

This document constitutes Deliverable 6.4 – Priority Sector Report, a key output of Task T6.3. The report provides a targeted analysis of the raw materials sector in the I4-GREEN participating regions, with particular attention to the sector's strengths, challenges, innovation potential, and alignment with regional Smart Specialisation Strategies (RIS3). It also contributes to the development of a Regional Ecosystem Scoreboard, offering an evidence-based reference for policymakers and stakeholders to support strategic alignment and investment planning. By mapping sectoral dynamics and highlighting opportunities for coordinated action, this deliverable supports the replicability of the I4-GREEN model and reinforces the interregional innovation ecosystem that the project seeks to build.

2. REGIONAL PROFILES

The I4-GREEN project involves three EU Member States, encompassing a diverse cross-section of the Union in terms of economic development levels, industrial specialisation, and raw materials potential. This report places particular analytical emphasis on four core territories—Extremadura, Andalucía, Alentejo, Castilla y León. These regions form the foundation for pilot deployment, strategic replication, and the alignment of regional ecosystems within I4-GREEN's interregional innovation framework.

The regional profiles presented here aim to capture the distinct characteristics, strategic assets, and innovation capacities of each territory, with a specific focus on their position within the raw

materials value chain and alignment with Smart Specialisation Strategies (RIS3). By assessing strengths, challenges, and ecosystem maturity levels, this analysis contributes to a deeper understanding of interregional complementarities and cooperation potential. It also informs the development of the Regional Ecosystem Scoreboard, providing a robust evidence base to guide investment planning, policy alignment, and the wider replication of sustainable mining practices across the EU.

2.1. Extremadura (Spain)

Context and Regional Potential

Extremadura is a peripheral Spanish region with a strong natural endowment in raw materials, notably iron, lithium, gold, tungsten, tin, feldspar, and rare earth elements (REEs). It is part of the "Iron District of SW Iberia" and increasingly recognised for its strategic relevance to Europe's Green Transition. As an Emerging Innovator+, Extremadura plays a key demonstrator role in the I4-GREEN project through the Iron Holm Oak pilot, which tests rare earth recovery from mining tailings. The region's Smart Specialisation Strategy (RIS3) prioritises sustainable mining, circular economy, and digital transition, aligning well with EU industrial and environmental policy goals.

Despite structural challenges, Extremadura shows real potential for transformation via targeted innovation policies and interregional cooperation. It is home to approximately 1.06 million people and exhibits one of the lowest population densities in the EU (25 inhabitants per km²). Its economic base remains rooted in traditional sectors, with agriculture and mining accounting for 11.4% of employment—notably higher than the national and EU averages. The GDP per capita (PPS) stands at €20,200, reflecting underdevelopment and limited industrial diversification. Only 6.7% of jobs are in knowledge-intensive activities, and the average enterprise size is 2.8 workers, indicating a fragmented business landscape.

Nevertheless, Extremadura's innovation performance has improved by 8.6% since 2016, supported by above-average public R&D investment and digital skills relative to the EU. Its underexploited CRM potential and participation in EU ecosystems such as I4-GREEN make it a strategic site for testing responsible mining models.

Innovation and Ecosystem Maturity

Extremadura's sustainable mining ecosystem is in a transitional phase, shifting from traditional extractive models toward innovation-driven, environmentally responsible practices. There are currently 178 active mining operations employing around 1,900 workers, alongside several major projects, such as Valdeflores and Cañaveral, which aim to supply lithium for battery production at the European scale.

The region complies with modern EU mining safety and environmental standards (e.g. RD 975/2009) and is adopting automation and low-impact processing technologies. However, legacy environmental impacts, including abandoned sites and contamination, pose both technical and social barriers to modernisation. Community engagement and transparency will be key to ensuring social licence to operate in future projects.

The Iron Holm Oak (IHO) pilot under I4-GREEN reinforces Extremadura's role as a testing ground for novel mine waste valorisation approaches. The pilot focuses on REE recovery from iron ore

tailings, contributing to EU strategic autonomy and advancing green innovation in resource management.

Strategic Gaps and Opportunities

Key Strengths

- Rich endowment of CRMs: Lithium, cobalt, REEs tungsten and associated materials make the region central to the EU's green industrial strategy. 3 projects (for lithium – Las Navas, cobalt – Aguablanca Project and tungsten – P6 Metals) have been recently declared as strategic by the European Commission.
- Sustainability orientation: Public and private stakeholders increasingly integrate circular economy and land rehabilitation principles into mining initiatives.
- Institutional integration: Extremadura participates in interregional platforms such as I4-GREEN, which provides technical and policy alignment.
- Public sector leadership: Innovation improvements are supported by solid public R&D investment and digital upskilling initiatives.

Main Gaps

- Weak private R&D and SME innovation: Business R&D accounts for only 0.19% of GDP, and SME-university collaboration remains limited.
- Low innovation intensity in employment: With only 6.7% of jobs in knowledge-intensive sectors, the local labour market is under-equipped for high-tech transitions.
- Underdeveloped innovation infrastructure: The region lacks a critical mass of dedicated mining innovation centres, clusters, or testbeds.
- Fragmented ecosystem coordination: Greater integration is needed between mining companies, research institutions, and industrial partners to build viable circular supply chains.

Alignment with EU and Project Frameworks (RIS3 & I4-GREEN)

Extremadura's RIS3 is fully aligned with the objectives of the I4-GREEN project. It prioritises:

- Sustainable mining and advanced materials
- Circular economy and clean energy transition
- Digital transformation of industry

Policy delivery is supported by the European Regional Development Fund (ERDF), which helps finance infrastructure, SME support, and technology transfer. Extremadura is also engaged in S3 Thematic Platforms for Mining and Raw Materials, Industrial Transition, and Resource Efficiency, enhancing learning and interregional synergies.

The RIS3 framework explicitly promotes quadruple helix collaboration, encouraging joint initiatives between public institutions, academia, SMEs, and civil society. In the raw materials domain, this policy environment supports the upscaling of pilots like Iron Holm Oak and the integration of circular business models. Extremadura's positioning in I4-GREEN helps

operationalise these strategies and may serve as a template for replication in other underdeveloped EU territories.

Extremadura Policy Leverage Point:

Extremadura's RIS3 includes strategic lines on *"Sustainable Resource Management"* and *"Mining and Georesources"*, reflecting the potential of circular raw materials recovery (more detailed in D6.1. Mirroring Strategy). D6.4 highlights moderate ecosystem capacity, which can be addressed through RIS3-linked ERDF investments in green mining technologies. Pilot replication opportunities identified in D6.2 (Pilots Action Plan & Portfolio of Investment Leads) (e.g. Aguablanca) can anchor proposals for EIC Pathfinder or LIFE co-financing.

D6.7 (Mine waste DDBB and report on interregional mine sites) collects all information for Extremadura regarding regulation, mining industry, employment and safety, main minerals and mining wastes as well as other related information.

2.2 Andalucía (Spain)

Context and Regional Potential

Andalucía is a historically significant mining region located in southern Spain and forms part of the Iberian Pyrite Belt (IPB), one of Europe's most metallogenically prolific zones. The region has a long tradition of mining and metallurgy, stretching back to Roman and Tartessian times, and is currently host to some of Spain's most active polymetallic mining operations, including the Huelva Metallurgical Complex. Andalucía plays a pivotal role in the I4-GREEN project as the host of the E-LIX pilot, which is developing an innovative hydrometallurgical process for the extraction of Cu, Zn, Pb and precious metals from low-grade ores and mining tailings.

- Modern operations include the Sotiel, Aguas Teñidas, and La Magdalena mines operated by Sandfire MATSA, as well as the Aznalcóllar-Los Frailes redevelopment by Minera Los Frailes. Additional strategic projects such as Tharsis and La Zarza also contribute to the region's mining portfolio, with demonstrated resources of copper, zinc, and lead. The Huelva Metallurgical Complex and a project to improve circularity has been recently declared as strategic by the European Commission.

Andalucía is positioning itself as a leader in sustainable mining innovation, underpinned by regional political support. The Junta de Andalucía (regional government and part of I4-GREEN consortium) has formally recognised the E-LIX project as a strategic industrial initiative, granting it fast-track permitting and showcasing its alignment with regional green growth objectives.

Innovation and Ecosystem Maturity

The region demonstrates moderate innovation performance (Regional Innovation Index score of 71.1), classifying it as a Moderate Innovator in the EU's 2023 Regional Innovation Scoreboard. While it has a solid industrial base and several flagship mining operations, Andalucía's innovation ecosystem remains fragmented. Dedicated mining innovation clusters or testbeds are limited,

and coordination between public authorities, research centres, and SMEs could be improved to promote more systemic innovation.

The E-LIX pilot serves as a cornerstone of the regional transition towards low-impact, circular mining. The technology is scalable and replicable, with the potential to revitalise legacy sites across Andalucía, converting environmental liabilities into economic assets. Moreover, its green credentials – including a 40% reduction in CO_2 emissions compared to conventional processes – position it as a key enabler of the EU's Critical Raw Materials and Green Deal strategical objectives.

Strategic Gaps and Opportunities

Key Strengths

- Strategic mining operations: Home to some of Spain's largest and most modern polymetallic mines (e.g. Aguas Teñidas).
- Resource base: Rich in Cu, Zn, Pb, Au, and Ag, with high potential for further tailings valorisation.
- Policy backing: The regional government supports sustainable mining through fast-track measures and interregional collaboration (e.g. with Extremadura and Alentejo).
- Pilot leadership: Host of the E-LIX demonstration pilot, offering a replicable model for other EU mining regions.
- The presence of a competitiveness cluster dedicated to mineral raw materials, Iberian sustainable Mining Cluster (ISMC).
- Rich endowment of CRMs: copper and platinum with Cobre Las Cruces, in Sevilla (First Quantum Minerals) identified as a strategic by the European Commission. In addition, an Atlantic Cooper metal recycling plant in Huelva (Circular) is included in the plan.

Main Gaps

- Ecosystem fragmentation: Weak integration between mining enterprises, R&D bodies, and SMEs.
- Limited R&D intensity: Business R&D and patenting levels remain below national and EU averages.
- Data and infrastructure bottlenecks: Some sites lack adequate exploration and characterisation for pilot deployment.
- Public awareness and social licence: While modern projects meet EU standards, legacy environmental issues require proactive community engagement to build trust.

Alignment with EU and Project Frameworks (RIS3 & I4-GREEN)

Andalucía's Smart Specialisation Strategy emphasises advanced materials, sustainable industrial transformation, and circular economy principles. The region is active in the S3 Partnership on Advanced Materials for Batteries, co-led by the Junta de Andalucía, and participates in thematic platforms linked to mining, industry, and digitalisation.

The I4-GREEN project builds on these priorities by enabling industrial-scale validation of green mining technologies and fostering cross-regional investment frameworks. Andalucía's

involvement in replication studies and its adjacency to Alentejo and Extremadura support its strategic role in scaling circular models across the Iberian Peninsula.

Andalucía Policy Leverage Point:

Andalucía's RIS3 2021–2027 emphasises *"Green and Sustainable Industry"* and the development of circular value chains (more detailed in D6.1. Mirroring Strategy). The region's ERDF programme supports innovation hubs and industrial decarbonisation. Building on the Sotiel site identified in D6.2 (Pilots Action Plan & Portfolio of Investment Leads), Andalucía can promote low-impact mineral processing by integrating D6.4 findings into future RIS3 action plans and Interreg Euro-MED partnerships.

D6.7 (Mine waste DDBB and report on interregional mine sites) collects all information for Andalucía regarding regulation, mining industry, employment and safety, main minerals and mining wastes as well as other related information.

2.3 Alentejo (Portugal)

Context and Regional Potential

Alentejo is a large, sparsely populated region in southern Portugal with a long-standing mining tradition. It is part of the Iberian Pyrite Belt (IPB)—one of Europe's richest metallogenic zones—hosting significant deposits of copper, zinc, lead, and precious metals. The region combines legacy mining operations with modernised extractive infrastructure, playing a critical role in the national raw materials sector. Alentejo is Moderate Innovator and the performance has increased over time (7.5%).

Economically, Alentejo faces structural challenges common to peripheral regions. While it contributes to Portugal's mining exports (valued at €1.229 billion in 2023), it exhibits lower GDP per capita, high unemployment in some subregions, and limited economic diversification. Nonetheless, mining and natural stone extraction remain key drivers of employment. The Neves-Corvo mine near Castro Verde—Europe's sixth-largest copper producer—is a flagship operation, employing over 2,600 direct workers and supporting around 5,000 indirect jobs. Recently, the European Commission recognized 2 extraction and 1 processing projects, within this mine, as strategic ones (3RD SILO, LOMBADOR, Semblana).

The region's marble sector in Estremoz, Vila Viçosa, and Borba (the "Marble Triangle") is globally renowned, reflecting a broader endowment of dimension stones. Alentejo's potential in sustainable mining and green value chains positions it strategically within EU policies on raw material security and regional cohesion.

Innovation and Ecosystem Maturity

Alentejo's mining innovation ecosystem is still emerging, with strong industrial assets but relatively weak knowledge-based infrastructure. While major mines (e.g. Neves-Corvo, Aljustrel) operate with high environmental and safety standards, research, development, and SME integration are less visible compared to more central regions.

The region benefits from the presence of Empresa de Desenvolvimento Mineiro (EDM), which manages environmental rehabilitation and sustainable waste management under Portugal's Decreto-Lei nº 198-A/2001. EDM plays a central role in transforming mining liabilities into opportunities, including plans for valorising mining waste as secondary raw material sources.

Alentejo is also home to several closed mine sites (e.g. Cercal, Alvito, Monges-Nogueirinha), identified in I4-GREEN as replication candidates for Iron Holm Oak-type pilots focused on mining waste recovery. These sites have been geologically assessed and show promise for REE, Fe-Mn, and polymetallic recovery, but require further investment in data collection , exploration and infrastructure.

Strategic Gaps and Opportunities

Key Strengths

- Industrial mining capacity: Alentejo hosts two of Portugal's most advanced mines (Neves-Corvo, Aljustrel), operating under EU-aligned environmental standards.
- Strong CRM and base/precious metals potential: Rich in Cu, Zn, Fe, Mn, Au.
- Rehabilitation and sustainability frameworks: EDM offers an institutional anchor for green transition in the mining sector.
- Internationally recognised stone industry: The marble dimension stone sector contributes significantly to exports and skilled employment.
- The presence of a competitiveness cluster dedicated to mineral raw materials, Cluster Portugal Mineral Resources.

Main Gaps

- Limited regional R&D and SME integration: Few mining-specific innovation centres are located in Alentejo.
- Data and infrastructure gaps: Some legacy sites require further exploration, characterisation, and processing capacity.
- Underutilised pilot potential: Although rich in candidate sites, pilot deployment and interregional integration remain at a preparatory stage.
- Need for innovation ecosystem coordination: Better linkage between large industrial operators, SMEs, universities, and public authorities is needed to scale circular economy models.

Alignment with EU and Project Frameworks (RIS3 & I4-GREEN)

Alentejo's strategic alignment with the I4-GREEN project is reinforced by its geological importance and cross-border position adjacent to Extremadura and Andalucía. It is classified as an "underdeveloped region" within I4-GREEN's interregional framework, contributing to a shared ecosystem for sustainable raw materials supply in Southern Europe.

Although Portugal's RIS3 is national in scope, Alentejo benefits from thematic priorities such as:

- Sustainable exploitation of endogenous resources

- Energy transition and circular economy
- Smart specialisation in natural and geological resources

Policy implementation is supported by Portugal 2030 and ERDF investments, including support for mining modernisation, waste recovery, and SME competitiveness. Alentejo's RIS3 execution is reinforced through national actors like EDM, Cluster Portugal Mineral Resources and research institutions involved in mining and environmental technology.

In the I4-GREEN context, Alentejo serves both as a pilot-adjacent partner and as a replication region, particularly for mining waste valorisation and resource recovery demonstrations. Through cross-border learning and technical alignment, the region is poised to benefit from technology transfer and regional upgrading.

Alentejo Policy Leverage Point:

Alentejo's RIS3 targets *"Efficient Use of Resources and Environmental Sustainability"*, making it an ideal setting for smart investments in raw materials valorisation (more detailed in D6.1. Mirroring Strategy).. The region can use findings from D6.4 and pilot data (e.g. Aljustrel, Neves Corvo) to activate ERDF support for cross-border green mining demonstration projects with neighbouring Extremadura and Andalucía. This aligns with the goals of the I3 Instrument Strand 2a and the Advanced Materials for Batteries TSSP.

D6.7 (Mine waste DDBB and report on interregional mine sites) collects all information for Alentejo regarding regulation, mining industry, employment and safety, main minerals and mining wastes as well as other related information.

2.4 Castilla y León (Spain)

Context and Regional Potential

Castilla y León is one of Spain's largest and most geologically diverse autonomous regions categorised as a Moderate Innovator -. Historically, it has played a prominent role in the mining sector, from Roman gold extraction at Las Médulas to extensive coal production in the 20th century. While coal mining has declined due to the clean energy transition, the region remains an important source of tungsten, slate, feldspar, magnesite, and other industrial minerals.

The Barruecopardo mine in Salamanca province is among the most significant tungsten operations in Europe, supplying strategic inputs to the global industry. Other assets include extensive slate quarries in León and Zamora, which support export-driven value chains, and several active feldspar and magnesite producers. Castilla y León is also rich in polymetallic ores and hosts legacy mine sites with valorisation potential—many of which are catalogued in the I4-GREEN database.

The region is classified as "in transition" in the I4-GREEN ecosystem and participates actively in the interregional cooperation framework. It serves as a replication region for sustainable mining practices and waste valorisation technologies, building on ICAMCYL's involvement and institutional leadership in European innovation platforms.

Innovation and Ecosystem Maturity

While Castilla y León demonstrates notable industrial experience and geological potential, its mining innovation ecosystem remains fragmented. The region lacks a critical mass of dedicated mining R&D centres, and there is limited SME integration in high-tech mining projects.

Nevertheless, Castilla y León is a co-lead in the S3P-Industry Thematic Platform for Mining and Advanced Materials for Batteries, under the leadership of I4-GREEN coordinator ICAMCYL. This provides strategic leverage for future EU project participation, shared pilot deployment, and cross-border investment initiatives.

Efforts are underway to modernise legacy sites and integrate new exploration technologies, such as those tested in the I4-GREEN project. Data from D6.7 (Mine waste Database and report on interregional mine sites) shows that additional sampling, exploration, and reprocessing techniques are needed to unlock the full economic and environmental potential of historical mining waste across the region.

Strategic Gaps and Opportunities

Key Strengths

- Strategic tungsten production: Barruecopardo is a flagship mine with global relevance.
- Industrial mineral base: Strong in slate, feldspar, and magnesite; active export markets.
- Interregional leadership: Co-leads S3P Mining & Advanced Materials platform alongside Andalucía and Lazio.
- Policy alignment: RIS3 priorities include clean energy, circular economy, and industrial modernisation.
- The presence of a competitiveness foundation that promotes innovation and technological development, ICAMCYL.

Main Gaps

- Underdeveloped innovation infrastructure: Few centres specialised in mining technologies or pilot support.
- SME fragmentation: Local SMEs lack coordinated entry points into the green mining value chain.
- Data gaps for valorisation: Some legacy mining waste sites require comprehensive exploration to determine viability.
- Limited public-private synergies: More robust collaboration is needed to integrate industrial actors, universities, and public authorities.

Alignment with EU and Project Frameworks (RIS3 & I4-GREEN)

Castilla y León's Smart Specialisation Strategy (RIS3) prioritises:

- Sustainable mining and advanced materials.
- Circular economy and clean energy transition.
- Digital transformation of industry.

These themes are directly aligned with the I4-GREEN project's mission. The region has also been proactive in attracting ERDF and EIT Raw Materials support to modernise mining-related infrastructure and strengthen SME competitiveness. Castilla y León's participation in S3 platforms creates opportunities for joint pilot development and investment mobilisation across Southwestern Europe.

Castilla y León Policy Leverage Point:

RIS3 Castilla y León prioritises *"Advanced Materials and Industrial Transition"* including mining-related innovation (more detailed in D6.1. Mirroring Strategy). Despite lower cluster maturity, D6.4 identifies strong R&D assets. The region can leverage this by aligning with the EIT RawMaterials network and InvestEU for scale-up support. The regional government can also support ecosystem development by targeting replication sites listed in D6.2 (Pilots Action Plan & Portfolio of Investment Leads) (e.g. La Pedrera) with targeted smart specialisation pilot actions.

D6.7 (Mine waste DDBB and report on interregional mine sites) collects all information for Castilla y León regarding regulation, mining industry, employment and safety, main minerals and mining wastes as well as other related information.

3. CROSS-REGIONAL ANALYSIS AND BENCHMARKING

This section synthesises the findings from the regional analyses of Andalucía, Extremadura, Alentejo, and Castilla y León to provide a comparative overview of ecosystem dynamics in the raw materials sector. It highlights shared characteristics, identifies regional complementarities, and offers a maturity assessment to support cross-regional strategy development and targeted investment planning.

3.1 Comparative SWOT Analysis

A comparative SWOT matrix was developed to summarise key features of each region's raw materials ecosystem, including sectorial assets, institutional configurations, and enabling policy environments.

Region	Strengths	Weaknesses	Opportunities	Threats
Andalucía	Active polymetallic mining; E-LIX pilot; strong policy support	Fragmented innovation ecosystem; limited SME integration	Replication of green technologies; EU-linked investments	Environmental legacy issues; social licence concerns

Extremadura	Potential abundant REE reserves; Iron Holm Oak pilot; involvement in S3 platforms	Infrastructure constraints; modest innovation performance	Positioning in EU Green Deal supply chains; RIS3 alignment	Limited R&I base; regional peripherality
Alentejo	Active polymetallic and dimension stones mining; cross-border cooperation	Lack of coordinated governance	Deployment of green pilot models; RIS3 investment synergies with Spain	Outmigration of skilled labour; regulatory complexity
Castilla y León	Tungsten flagship project (Barruecopardo); co-lead in EU S3P platform	Sparse R&D infrastructure; limited SME engagement	Circular valorisation of industrial minerals and tailings; leadership in EU calls	Under-characterised mining waste sites; insufficient public-private cooperation

TABLE 1: SWOT MATRIX FOR ALL I4-GREEN REGIONS

This matrix reflects a mix of shared capabilities and region-specific limitations, providing a baseline for interregional coordination.

3.2 Shared Strengths and Gaps

Across the four core I4-GREEN regions, several shared strengths and systemic gaps have been identified:

Shared Strengths

- Strong geological potential in critical and industrial raw materials (e.g. REEs, Cu, Zn, Pb, Co, Au, W, feldspar).
- Demonstrator pilots (E-LIX, IHO) located in regions with institutional and political support.
- Engagement in Smart Specialisation Platforms (e.g. Mining Industry, Advanced Materials for Batteries).
- Cross-border cooperation potential through shared mining basins and RIS3 complementarities.

Shared Gaps

- Fragmentation in innovation ecosystems, with limited horizontal integration across sectors.
- Insufficient SME cooperation with academia in mining related activities and technology uptake.
- Gaps in infrastructure and data for legacy mining sites valorisation.
- Limited presence of mining-specific R&D and testing facilities in some regions.

3.3 Maturity Mapping of Regional Ecosystems

A qualitative assessment of ecosystem maturity was conducted to support benchmarking. The mapping considers cluster governance, innovation capacity, and readiness for circular and sustainable mining.

Region	Cluster Coordination	Innovation Capacity	Circular Mining Readiness	Overall Maturity
Andalucía	Moderate	Moderate	High (E-LIX pilot)	Moderate–High
Extremadura	Moderate	Low–Moderate	High (IHO pilot)	Moderate
Alentejo	Moderate	Moderate	Moderate	Moderate
Castilla y León	Low-Moderate	Low–Moderate	Moderate (W mine + S3P)	Low–Moderate

TABLE 2: MATURE MAPPING IN I4-GREEN REGIONS

The table indicates relative strength in Andalucía and Extremadura, anchored by their pilot projects, while Alentejo and Castilla y León display emerging maturity supported by S3P engagement and potential for replication.

3.4 Synergies and Complementary Capacities

The regional ecosystems exhibit both vertical and horizontal complementarities:

- Andalucía–Extremadura–Alentejo form a coherent Iberian pilot corridor, offering geological continuity, joint RIS3 priorities, and active political engagement. Pilot technologies can be adapted and scaled across this area.
- Castilla y León, while less mature, brings strategic mineral specialisation (e.g. tungsten, feldspar) and co-leads the S3P Mining Industry platform. It provides a testing ground for replication models.
- Common participation in EU platforms and funding instruments (I3, Horizon Europe, Interreg) enables coordinated policy alignment and multi-region investment packaging.

The interoperability of regional assets supports the development of a shared Regional Ecosystem Scoreboard and lays the foundation for sustained interregional cooperation beyond the I4-GREEN project lifecycle.

4. STRATEGIC RECOMMENDATIONS

This section outlines actionable recommendations to strengthen cross-regional collaboration, foster joint innovation initiatives, enhance policy alignment, and mobilise public and private investment in support of the raw materials sector within the I4-GREEN territories.

4.1 Priority Areas for Cross-Regional Cooperation

The analysis of regional ecosystems reveals a clear opportunity to develop a joint innovation and investment corridor anchored in sustainable mining practices. The following areas are identified as priorities for interregional collaboration:

- Pilot replication and adaptation: Regions with mature demonstrators (e.g. E-LIX in Andalucía, IHO in Extremadura) should coordinate closely with emerging replication zones (e.g. Castilla y León, Alentejo) to share methodologies, technical guidance, and regulatory experience.
- Mining waste valorisation frameworks: Align efforts across regions to co-develop exploration, classification, and reprocessing techniques for historic mining waste. Harmonised approaches could support EU-level standardisation and facilitate funding access.
- Joint skills development and workforce mobility: Establish interregional training programmes focused on digital, environmental, and processing technologies in the mining sector, with shared curricula linked to the European Skills Agenda.
- Data sharing and infrastructure pooling: Foster open access to geochemical, geophysical and geospatial data across I4-GREEN regions to reduce duplication and accelerate replication planning.

4.2 Opportunities for Joint Cluster Development or EU Project Proposals

To reinforce systemic innovation and competitiveness, the following joint opportunities are proposed:

- Cross-regional cluster formation: Establish a transnational/Eurocluster raw materials cluster, building on existing S3 Thematic Smart Specialisation Partnerships (e.g. Mining Industry, Advanced Materials for Batteries). This cluster could act as an EU-level demonstrator of interregional innovation ecosystems.
- Joint EU project proposals: Develop cooperative proposals under:
    - I3 Instrument – Strand 2a, focusing on the replication of pilots and co-investment planning.
    - Horizon Europe Cluster 4 (Digital, Industry, Space) and Cluster 5 (Climate, Energy, Mobility) for technology transfer, circular economy applications, and sustainability assessment tools.
    - LIFE and Interreg programmes for environment, circular economy, land use planning and cross-border policy experimentation.

- S3 Co-Investment Initiatives: Engage with the S3 Community of Practice and DG REGIO to propose a joint co-investment mechanism targeting green mining value chains in Southwestern Europe.

4.3 Recommendations for Regional Policymakers

To maximise regional impact, policymakers in the participating territories are advised to:

- Update RIS3 strategies to explicitly include sustainable mining, mining waste valorisation, and interregional cooperation as core priorities.
- Designate raw materials innovation as a regional mission, facilitating alignment of ERDF and Just Transition Fund resources with I4-GREEN objectives.
- Streamline permitting for strategic projects sustainable mining technologies, particularly where economic, environmental and social benefits are demonstrable, through the use of project designations or expedited procedures.
- Institutionalise interregional governance, potentially through a formal coordination mechanism or Memorandum of Understanding between regional governments and agencies.
- Establish public-private task forces in each region to support pilot uptake, ensure SME inclusion and their cooperation with academia, and coordinate funding applications.

4.4 Suggestions for Attracting Private Investment or Public Funding

In order to leverage the full investment potential of the regional raw materials sector, the following measures are recommended:

- Promote the joint Investment Prospectus, consolidating pilot replication sites, market assessments, and policy incentives. This can be used to engage the European Investment Bank (EIB), national promotional banks, and private equity partners (done under D7.6. Policy Brief
- Create an interregional pipeline of investment-ready projects, structured around the I4-GREEN replication sites, with technical and financial pre-feasibility documentation (included in D6.1. Mirroring Strategy).
- Leverage the European Raw Materials Alliance (ERMA) and EIT RawMaterials networks to attract industrial co-investment in strategic projects and circular mining ventures.

This strategic roadmap builds on the identified complementarities across the I4-GREEN regions and aims to foster durable transformation in the EU raw materials ecosystem. These recommendations are intended to inform follow-up actions under WP6 and WP7 and support the wider replicability and scalability of I4-GREEN's innovation model.

5. CONTRIBUTION TO THE REGIONAL ECOSYSTEM SCOREBOARD

As part of the cross-regional sector analysis conducted under Task T6.3, the following metrics were identified as central to assessing the maturity, innovation potential, and circularity readiness of regional ecosystems within the raw materials value chain:

Metric	Description	Source
Regional raw materials specialisation	Core mineral resources extracted/processed and value chain position	D6.4 regional profiles
Cluster presence and governance	Presence of formal clusters, S3P participation, coordination mechanisms	Partner reporting, RIS3
Innovation performance (R&D intensity, SME integration)	Based on R&D expenditure, SME engagement, and RIS3 alignment	Regional Innovation Scoreboard (RIS)
Circular mining readiness	Existence of circular projects, regulatory incentives, pilot integration	D6.4, D6.6, D6.7
Pilot replication potential	Number and readiness of sites suitable for demonstration or scale-up	D6.2, D6.7
Policy and administrative alignment	Level of policy coordination, regulatory fast-tracking, and RIS3 adaptation	Regional consultations, D6.4

TABLE 3: METRICS IDENTIFIED DIN I4-GREEN:

These indicators were used to qualitatively map ecosystem maturity across four key dimensions: cluster coordination, innovation capacity, circular economy adoption, and investment-readiness.

5.1 Alignment with European Commission Tools

The metrics and methodologies applied in this deliverable are aligned with key EC tools and platforms relevant to regional innovation and smart specialisation:

- Regional Innovation Scoreboard (RIS): Used to benchmark general innovation performance (e.g. Andalucía: Moderate Innovator, Extremadura: Emerging Innovator+). Where possible, data points from the RIS 2023 report were incorporated into regional profiles.
- Smart Specialisation Platform (S3P): All I4-GREEN regions are engaged in at least one thematic platform, notably:
  - *Mining Industry* (Andalucía, Castilla y León, Extremadura, Alentejo)
  - *Advanced Materials for Batteries (AMBP)* (Andalucía, Castilla y León)
- S3 Community of Practice (CoP): The deliverable's emphasis on interregional complementarities and replication pathways supports S3 CoP objectives on co-investment and thematic synergies.
- EIP on Raw Materials Monitoring & Assessment Framework: Though not directly integrated, several D6.4 indicators correspond with EIP monitoring dimensions (e.g. exploration activities, technology deployment, socio-economic impact).

5.2 Suggested Indicators for Future Monitoring

To enhance the long-term usability of the Regional Ecosystem Scoreboard, the following indicators are proposed for ongoing monitoring:

- Summary of key metrics reported to the scoreboard.
- Alignment with EC tools (e.g. Regional Innovation Scoreboard, Smart Specialisation Platform).

Suggested indicators for future monitoring are outlined below.

Proposed Indicator	Justification	Suggested Source
Number of replication-ready sites (by technology type)	Measures uptake potential and inform cross-regional investment planning	D6.1, D6.2, D6.7
SME involvement in pilot deployment or RIS3 actions	Tracks engagement of local enterprises in innovation ecosystems	D6.1 WP5 surveys, open call participation
Cross-border co-investment initiatives launched	Captures the depth of interregional collaboration	WP6/WP7 reporting
Circular innovation index (mining-specific)	Custom indicator assessing circular economy integration in mining sectors	Aggregated from D6.4/D6.6 metrics
RIS3 policy evolution referencing I4-GREEN	Tracks institutional uptake of I4-GREEN outcomes into regional or national policy frameworks	D6.1 Policy documents, stakeholder input
ESG (Environmental, Social, Governance) alignment score	Proxy indicator for investor readiness and alignment with EU Green Deal principles	D6.2, regional investment analyses

TABLE 4: FUTURE MONITORING INDICATORS.

6. POLICY LEVERAGE POINTS BY REGION

This section provides tailored guidance for policymakers in each I4-GREEN region, highlighting how the findings of this report align with existing regional Smart Specialisation Strategies (RIS3), funding mechanisms, and cluster development policies. It also identifies specific opportunities for investment and cross-regional cooperation.

6.1 Alentejo (Portugal)

RIS3 Priority: *Sustainable use of natural resources and raw materials; low-carbon economy.*

- Policy Leverage: The region can integrate outcomes from I4-GREEN pilot activities into its RIS3 implementation roadmap through co-investment with the ERDF Operational Programme 2021–2027. The Aljustrel and Neves Corvo pilot sites (D6.2) present tangible opportunities for scaling regional innovation via circular mining techniques.
- Action Point: Establish a dedicated S3 working group linking Alentejo's mining clusters with TSSPs on "Advanced Materials for Batteries" and "Efficient Manufacturing."

6.2 Andalucía (Spain)

RIS3 Priority: *Advanced materials, sustainable mining, and circular economy.*

- Policy Leverage: The Andalusian Innovation Strategy includes a regional industrial policy on *"eco-industries"* and resource recovery. The region could lead a cross-regional

investment platform with Extremadura and Alentejo, building on shared geological features and the Iron Holm Oak pilot.

- Action Point: Mobilise instruments from the Innovation and Modernisation Fund (ETS) to support decarbonised processing of secondary raw materials.

6.3 Extremadura (Spain)

RIS3 Priority: *Natural resources and circular economy, including mining and mineral processing.*

- Policy Leverage: As an Emerging Innovator (Regional Innovation Scoreboard 2023), Extremadura could use I4-GREEN findings to justify targeted ERDF+ funding for applied R&D infrastructure and technology uptake in circular mining.
- Action Point: Integrate lessons from E-LIX replication potential into the RIS3 Monitoring Committee for the 2021–2027 period.

6.4 Castilla y León (Spain)

RIS3 Priority: *New materials, industrial transition, and mining valorisation.*

- Policy Leverage: The region has a strong tradition in mining innovation, but lower current cluster density. D6.4's findings on ecosystem maturity gaps can be used to advocate for EIT RawMaterials partnership expansion and reindustrialisation funding via InvestEU.
- Action Point: Connect regional actors to EU cluster alliances using D5.1 stakeholder mapping and explore joint applications to the Horizon Europe "Sustainable Raw Materials" calls (e.g. under Cluster 4).

Cross-Regional Recommendation

All four regions share a common opportunity to:

- Coordinate RIS3 updates and implementation through interregional alignment platforms (e.g. TSSPs).
- Use the Regional Ecosystem Scoreboard (forthcoming) to monitor investment-readiness metrics and inform targeted interventions.
- Leverage joint participation in I4-GREEN to pursue EU co-funded cluster initiatives, such as the Interregional Innovation Investments (I3) programme Strand 2b.

7. CONCLUSION AND OUTLOOK

The I4-GREEN Priority Sector Report has provided a comprehensive, regionally grounded analysis of the raw materials sector across four strategic territories: Andalucía, Extremadura, Alentejo, and Castilla y León. Through this deliverable, we have assessed ecosystem maturity, policy alignment, innovation capacity, and the potential for sustainable transformation and interregional replication.

The findings demonstrate that each region brings distinct assets and challenges to the shared objective of securing a greener, more resilient European mineral raw materials value chain. Pilot

regions like Andalucía and Extremadura are already demonstrating replicable technologies (E-LIX, Iron Holm Oak), while replication-ready regions such as Alentejo and Castilla y León provide fertile ground for scaled innovation deployment.

Despite common gaps—such as fragmented innovation ecosystems, limited SME engagement, and infrastructural constraints—there is substantial cross-regional potential. The emergence of a coherent Iberian corridor for sustainable mining presents a unique opportunity for multi-region investment packaging, cross-border demonstration, and co-development of enabling policy and cluster frameworks.

This report has contributed to the formation of a Regional Ecosystem Scoreboard and proposed a suite of metrics, leverage points, and visual benchmarks that can be used by regional authorities, cluster organisations, and EU platforms to track progress, guide strategic investments, and inform smart specialisation programming.

As I4-GREEN moves toward its final stages, the strategic recommendations outlined herein should inform:

- The activation of targeted public and private investments (via ERDF, InvestEU, LIFE, etc.),
- The creation of cross-regional innovation consortia.
- And the embedding of sustainable mining within updated RIS3 frameworks and EU industrial policy instruments.

Ultimately, this deliverable supports the project's overarching ambition: to establish a durable, EU-aligned ecosystem for sustainable, circular raw materials production that reinforces Europe's green industrial sovereignty and regional cohesion.