MADITRACE

Analysis and roadmap for implementation of a common strategy for the development of material traceability policies within specialisation strategies

Deliverable D5.5

Version N°2

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Summary

Deliverable 5.5, titled "Analysis and Roadmap for Implementation of a Common Strategy for the Development of Material Traceability Policies within Specialization Strategies," stands as the main step for integrating the MaDiTraCe project within the framework of Smart Specialization Strategies and Platforms[1]. Included within Task 5.5 of WP5 "Communication, dissemination, exploitation and business case", its primary aim is to bring together regional, national, and international stakeholders alongside consortium partners, thereby ensuring the sustainable evolution of international ecosystems. This task encompasses not only industrial or scientific dimensions but also institutional ones.

Central to this endeavour is establishing measures to embrace material traceability and formulating a complementary strategy to discern new value chains, the establishment of measures to embrace material traceability and the formulation of a complementary strategy to discern new value chains, thereby fostering innovation and cultivating business opportunities.

This deliverable will take the form of a comprehensive report, incorporating essential data from other critical deliverables developed within WP1 and WP2. Its purpose is to lay down the groundwork for the implementation of forthcoming material traceability policies within the Smart Specialization Strategies and Platforms (S3P).

Keywords

Smart Specialization Strategies (S3P), Material Traceability, Digital Product Passport (DPP), Critical Raw Materials (CRMs),

Abbreviations and acronyms

Acronym	Description
CoP	S3 Community of Practice
CRM	Critical Raw Material
DPP	Digital Product Passport
EO	Earth Observation
EU	European Union
GBA	Global Battery Alliance
ICT	Information & Communication Technology
IoT	Internet of Things
LCA	Life Cycle Assessment
MFP	Material Fingerprint

[1] https://s3platform.jrc.ec.europa.eu/

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OECD	Organisation for Economic Co-operation and Development
REE	Rare Earth Elements
RFID	Radio Frequency Identification
SLO	Social License to Operate
S3	Smart Specialisation Strategies
S3P	Smart Specialisation Strategies Platforms
TSSPs	Thematic Smart Specialisation Partnerships
WP	Work Package

1. Introduction

1.1 MaDiTraCe Context

MaDiTraCe endeavours to expand and integrate a range of technological solutions for enhancing traceability and certification within responsible and sustainable supply chains of critical raw materials (CRMs). This initiative seeks to consolidate these solutions into a Digital Product Passport (DPP) compatible with the EU battery passport. By implementing comprehensive tracking mechanisms, MaDiTraCe aims to enhance the transparency, traceability, and sustainability of complex supply chains involving critical raw materials.

1.2 Deliverable objectives

The primary objective of this deliverable is to produce a comprehensive report analysing the roadmap and the implementation of a strategy concerning traceability policies within the smart specialisation strategies.

This deliverable will serve as a starting point for identifying the connections between industries, research centres and authorities, thereby paving the way for the development of traceability policies. Leveraging the Smart Specialization Strategies (S3) [2]of participating regions will be crucial for integrating key industries and authorities with regional innovation actors. This integration will facilitate business activities both during and after the project, ensuring lasting impact and continuity.

Smart Specialization Strategies (S3) are an innovative approach aimed at driving economic growth and employment by identifying and developing competitive advantages specific to each EU region. These strategies involve the entrepreneurial discovery process (EDP), where stakeholders from policy, business, academia, and civil society collaborate to identify regional strengths and investment priorities. The European Commission supports the development and implementation of these strategies through the Smart Specialisation Platform (S3P), ensuring that regions make effective use of EU funds to support growth and jobs. By focusing on regional strengths and fostering collaboration, S3 aims to integrate key industries and innovation actors, facilitating lasting business activities and regional development

[2] https://joint-research-centre.ec.europa.eu/document/download/dbed87e5-ebfc-4753-9a22-1f9636880e2c_en?filename=RIS3_GUIDE_FINAL.pdf

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2 Theoretical Framework

2.1 Definition of material traceability

Material traceability is the ability to track and trace any movement, origin, processing and distribution of materials throughout their life cycle in a supply chain or a production process. The traceability process will involve the documentation and recording of key information contained in the raw materials, the source, location, transport routes and end user destination, manufacturing processes…

This method will allow to ensure and improve the quality controls, issues in the process, sustainability concerns, regulations…

2.2 Traceability impact on the Raw Material Sector

Traceability plays a crucial role in improving the sustainability of raw materials, with emerging regulations placing greater emphasis on transparency within the raw materials sectors[3]. This regulatory push for increased transparency is particularly significant for technology materials and is poised to set a new precedent in raw material sourcing practices.

Responsible sourcing of raw materials will be key to guaranteeing the mitigation of the risks associated with the environmental impacts of illegal mining. Traceability solutions will enable and ensure responsible sourcing throughout the different stages of the value chain.

Conventional traceability systems within the Raw Material Sector primarily rely on paper or document-based methods, which are susceptible to falsification. To address this challenge, innovative traceability solutions in the mining sector are leveraging digitalization. These emerging solutions aim to connect all relevant data through digital platforms, enhancing accuracy, transparency, and security throughout the supply chain.

2.3 The Smart Specialisation Strategies and the importance of traceability

The S3 concept was introduced by the European Commission as part of the EU Cohesion Policy 2014-2020, with the aim of enabling EU regions to access research and innovation funding through the European Regional Development Fund (ERDF). This policy framework was designed to strengthen regions in their established industrial sectors while also facilitating diversification of their economies in a strategic manner. Additionally, these policies were intended to enhance the capabilities of less advanced regions, addressing common challenges that arise when formulating regional innovation strategies, such as:[4]:

- The picking winner syndrome
- The lack of an international and trans-regional perspective

[3] https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1542

[4] Guzzo. F, Gianelle. C, Mrinelli. E (2018), Smart Specialisation at work: the policy makers' view on strategy design and implementation. JRC Technical Reports, European Commission

- The absence of alignment between territorial innovation strategies and the industrial and economic landscape, marked by a notable presence of public involvement in research and development that lacked adequate business orientation.
- Insufficient examination of the region's resources and strengths.
- The imitation of successful regions without taking into account the unique local circumstances.

Specialization strategies are vital for regional economic development, enabling regions to concentrate on specific industries, such as battery gigafactories or other specialized sectors. This focused approach allows regions to leverage their unique strengths and resources, fostering innovation and competitiveness. Within these strategies, traceability is crucial as it ensures the quality and efficiency of production processes, facilitates effective risk management, and supports sustainability efforts. By meticulously tracking and documenting each step of the production process, regions can enhance transparency, reduce waste, and ensure compliance with regulatory standards.

On an international level, and particularly within the European Union, traceability becomes even more significant, fostering cross-border cooperation and trade. Ensuring traceability in specialized industries allows regions to build trust and reliability in global markets, attract international investments, and participate in multinational supply chains. This comprehensive approach not only maximizes the positive impact of economic initiatives within regions but also strengthens their integration into the global economy, promoting sustainable and inclusive growth across the EU and beyond

2.4 Relevance of traceability policies in the supply chain

Regarding the raw materials supply chain, they play a pivotal role in maintaining integrity, sustainability, and efficiency across all stages of the lifecycle. Equipping companies and stakeholders with essential tools and information is critical to creating a robust system where risk mitigation, meeting consumer expectations, regulatory compliance, and informed decision-making are truly valued. This will ensure that the supply chain operates transparently and responsibly, fostering stakeholders' trust while driving positive environmental and social impacts.

The relevant key aspects of traceability policies within the supply chain could include:

- Transparency: Ensuring that information about the origin, production process and movement is accessible in the supply chain
- Compliance: Helping companies to adhere to the regulatory requirements and industry standards
- Quality assurance: Monitoring and controlling the quality of materials and products reducing the risk to not compliance with the quality standards
- Risk Management: Identifying and addressing issues in materials and products
- Ethical Sourcing: Enabling companies to trace materials from their origins, ensuring the social and environmental standards
- Supply Chain Efficiency: improving inventory management, forecasting and optimization of production
- Sustainability: By providing data on the environmental and social impacts of products.

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- Due Diligence: Facilitating comprehensive assessments of suppliers and production processes to ensure compliance with legal, ethical, and safety standards.

Sufficient supply chain transparency and compliance with legal mandates are essential prerequisites for making credible sustainability assertions. These measures also serve to incentivize further enhancements to sustainability practices throughout the value chain.

Governments are increasingly emphasizing the importance of supply chain traceability to facilitate the transition to a low-carbon economy. In a notable development from 2021, EU lawmakers urged the swift adoption of an EU-wide regulation mandating companies to identify, address, and rectify environmental, social, and governance (ESG) risks within their supply chains[5].

Furthermore, in June 2021, Germany enacted the "Gesetz über die unternehmerischen Sorgfaltspflichten zur Vermeidung von Menschenrechtsverletzungen in Lieferketten" (Supply Chain Act). This legislation imposes substantial obligations on companies sourcing products and services from developing and emerging countries for sale in Germany to ensure compliance with human rights and environmental standards. It also exposes them to potentially severe liability in case of violations[6].

Legislative measures like the US Lacey Act[7] and the EU Renewable Energy Directive[8] serve as examples of how governments can promote certification and sustainability standards alongside regulation, extending the reach of compliance beyond mere procurement.

The abovementioned obligations gain even more strength with the entry into force of the Critical Raw Materials Act on May 23, 2024. The Critical Raw Materials Act represents a significant step forward for the EU, ensuring a secure and sustainable supply of critical raw materials essential to meet its 2030 climate and digital objectives. This Act identifies strategic raw materials crucial for key technologies used in green, digital, defense, and space applications. By embedding both critical and strategic raw materials lists in EU law, the Act sets clear benchmarks for domestic capacities and aims to diversify the EU's supply chain. These measures include achieving at least 10% of the EU's annual consumption from extraction, 40% from processing, and 25% from recycling, while also limiting dependence on any single third country to no more than 65% at any relevant processing stage.

Moreover, the Act emphasizes the importance of traceability in the supply chain, ensuring that critical raw materials are sourced responsibly and sustainably. It aligns with existing supply chain-related legislation such as the Conflict Minerals Regulation, the European

[5] "EU Drives a New Approach to Supply Chain Sustainability." 22 Apr. 2021, https://www.navexglobal.com/blog/article/eu-supply-chain-due-diligence/. Accessed 4 Nov. 2021

[6] "Germany's new Supply Chain Due Diligence Act: What you need to ...." 9 Jul. 2021, https://www.sedex.com/germanys-new-supply-chain-due-diligence-act-what-you-need-to-know/. Accessed 21 Dec. 2021.

[7] "Lacey Act - US Fish and Wildlife Service." https://www.fws.gov/international/laws-treaties-agreements/us-conservation-laws/lacey-act.html. Accessed 3 Nov. 2021.\

[8] "Renewable energy directive - European Commission." 16 Jul. 2014, https://ec.europa.eu/energy/topics/renewable-energy/directive-targets-and-rules/renewable-energy-directive_en. Accessed 3 Nov. 2021.

Partnership for Responsible Minerals (EPRM), and draft legislation on corporate sustainability due diligence, forced labor product bans, and batteries. By doing so, the Act aims to strengthen EU capabilities in this space without introducing regulatory uncertainty, fostering a consistent and transparent approach to supply chain management.

The Call for Evidence supporting this Act also addresses the need for accurate information on the carbon footprint of production processes. Given the challenges of capturing CO2 emissions beyond a manufacturer's direct control, the Act advises alignment with existing EU legislation and internationally recognized industry standards, such as those outlined in the Corporate Sustainable Reporting Directive. This directive includes provisions for delayed implementation of certain reporting requirements for SMEs, ensuring a balanced approach to carbon footprint transparency.

By incorporating these comprehensive traceability measures, the Critical Raw Materials Act not only secures the EU's supply of essential materials but also promotes responsible sourcing, environmental protection, and regulatory consistency across the supply chain.

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3 Methodology for traceability system implementation in S3

3.1 Steps to adopt material traceability.

It is crucial to identify the primary factors that motivate traceability so that decisions can be made about objectives and expected benefits. Some key drivers are presented as follows:

- Assessment of Current Practices: understanding the processes and existing traceability practices will help to identify gaps of improvement
- Set Objectives and Goals: Determine specific information is needed to track and trace
- Research and Select Traceability Solutions: investigate all available traceability solutions in the market.
- Customisation and Integration: Choose the best traceability option and customize it to meet the specific needs.
- Training and Education: Provide the necessary information to all the stakeholders and people involved in the processes.
- Pilot Testing: Conduct the testing of the system chosen in a controlled environment.
- Scale Up: Implement the traceability systems across the entire supply chain.
- Supplier Engagement: Communication and Dissemination of the traceability benefits.
- Continuous improvement: Continuous review and evaluation of the methods.
- Compliance and Certification: Ensure compliance with relevant regulation and standards.

3.2 Strategies for the implementation of traceability policies

Some strategies for the implementation of traceability policies are summarized in the guidance from the Organisation for Economic Co-operation and Development (OECD), providing also best practices for establishing a traceability system[9]. **MaDiTraCe project is committed to bring solutions that prove the traceability of CRMs to comply with existing regulations and future European Union policies.**

Implementing traceability policies requires a comprehensive approach that encompasses various steps. This includes conducting assessments and strategic planning to define objectives and anticipate benefits, as well as adopting suitable technologies and systems. An important part of the strategy, should be focus on the communication and dissemination, to facilitate the stakeholder engagement. Additionally, integrating traceability systems with existing processes is essential for seamless implementation.

[9] OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas: Second Edition, OECD Publishing, http://www.oecd.org/daf/inv/mne/ GuidanceEdition2.pdf.

3.3 Material traceability policies within the smart specialization strategies

Smart Specialization Strategies represent an EU policy framework characterized by three fundamental elements: 1) the establishment of institutional frameworks, 2) the active engagement of stakeholders throughout the processes, and 3) the implementation of information systems enabling the monitoring of policy interventions and assessment of their efficacy. These strategies offer a unique avenue for understanding the role of innovation policies in fostering the prosperity of the regions.

As regions develop specialization strategies, it is essential to implement policies for material traceability within these frameworks. These policies will ensure that the origin, composition, and value chain of materials are effectively tracked at all stages of production and distribution. By adopting material traceability policies within Smart Specialization Strategies, regions can enhance their capacity to optimize resource use, ensure product quality and safety, and promote sustainability practices across industries.

Regions investing in raw materials industries such as mining, recycling, and battery production can foster the emergence of associated businesses, including traceability solutions. To implement effective traceability solutions, an ecosystem of supporting businesses, such as laboratories and blockchain technology providers, is necessary. This integration is driven by the strategic location of the raw materials industry.

Furthermore, this approach aligns with the primary goal of Smart Specialization Strategies (S3) to promote innovation, economic growth, and resilience in regional contexts. By ensuring comprehensive material traceability, regions can build robust and transparent supply chains, attract investment, and integrate more effectively into international markets, contributing to sustainable and inclusive economic development both locally and globally.

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4 Analysis of Current Policies and Development of the Roadmap

4.1 Review of existing material traceability policies in participating regions

MaDiTraCe project deliverable 2.1 *"Review report on existing tracing and 3D printing technologies* "provides a detailed examination of the different traceability systems currently available for CRMs, most of them relying on paper or document-based methods. Efforts are underway to enhance traceability within CRM supply chains through digitalization, leveraging big data, and employing cloud technologies, with many initiatives centering on blockchain solutions. However, these blockchain-based solutions encounter challenges, particularly regarding upstream traceability due to unreliable information.

To address these traceability issues, alternative or complementary approaches are emerging and are being investigated in MaDiTraCe, such as natural fingerprints, which focus on material properties and characteristics to certify origin and ensure traceability.

As highlighted in the **conclusion of D2.1, the viability of any new traceability solution for commercial applications depends on the array of existing solutions and the prospective markets within CRM supply chains.**

Focusing on the Digital Product Passport (DPP) as a solution to address traceability issues, D3.1 "*Draft report supply chain mapping, requirements elicitation, classification* "outlines the current requirements necessary for its successful implementation. These requirements encompass several key aspects:

1. **Compliance with Certification Schemes**: DPP must adhere to standards such as CERA 4in1 to ensure that data attributes and reporting formats align with established requirements.
2. **Adherence to EU Battery Regulation**: It is imperative that DPP complies with and ensures adherence to the EU Battery Regulation, guaranteeing regulatory compliance within the relevant framework.
3. **Data Accuracy**: DPP is committed to maintaining data accuracy through regular updates and validation processes, ensuring that the information contained within it remains reliable and up-to-date.
4. **Interoperability**: DPP should be designed to seamlessly integrate with other systems and databases, facilitating smooth data exchange and interoperability across the supply chain ecosystem.
5. **Accessibility**: Accessibility of DPP to stakeholders throughout the supply chain is essential. Moreover, ensuring data security and privacy measures are in place is paramount to safeguarding sensitive information.

4.2 Identification of best practices and challenges

The analysis of current policies and the development of the roadmap shed light on various best practices and challenges in enhancing material traceability within CRM) supply chains (Figure 1).

Best Practices:

Digitalization and Big Data: Efforts to improve traceability are increasingly leveraging digital technologies and big data analytics to enhance transparency and efficiency in CRM supply chains. MaDiTraCe leverages digital technologies and big data analytics to enhance transparency and efficiency in CRM supply chains, moving beyond traditional paper-based methods.

Material fingerprint and laboratory analysis: a part of the methods developed in MaDiTraCe relies on material fingerprint techniques and raw material analysis in laboratory (geochemistry, mineralogy). This portfolio of solutions allows to validate along the supply chain the provenance of materials. The analytical means for the implementation (chemical laboratories with certain specialized equipment) are essential for the implementation of a such system of analytical traceability.

Blockchain Solutions: Many initiatives are exploring blockchain technology as a means to enhance traceability. Blockchain offers the potential for immutable and transparent record-keeping, which can bolster trust and accountability across the supply chain. MADITRACE integrates blockchain technology to provide immutable and transparent record-keeping, thereby improving trust and accountability across the supply chain.

Compliance with Standards: Compliance with established certification schemes, such as CERA 4in1, ensures that traceability systems meet recognized industry standards, enhancing credibility and interoperability. By adhering to certification schemes such as CERA 4in1, MaDiTraCe ensures that its traceability systems meet recognized industry standards, enhancing credibility and interoperability.

Data Accuracy and Validation: Regular updates and validation processes are essential to maintain the accuracy and reliability of traceability data, ensuring its usefulness for stakeholders. MaDiTraCe maintains high data accuracy through regular updates and validation processes, ensuring that traceability information remains reliable and useful for stakeholders.

Interoperability: Seamless integration with existing systems and databases promotes interoperability, facilitating data exchange and collaboration among stakeholders. MaDiTraCe is designed to seamlessly integrate with other systems and databases, promoting interoperability and facilitating smooth data exchange and collaboration among supply chain stakeholders.

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Figure 1 Best practices in material traceability within CRM supply chains

4.3 Utilisation of Blockchain in Supply Chain Improvement and Traceability

Blockchain is a key technology enhancing advanced traceability systems. Despite progress made with Enterprise Resource Planning (ERP) systems, visibility in complex supply chain remains a challenge. Large organizations often use multiple ERPs that do not easily communicate, and supply chains involving multiple organizations or countries face additional complexities due to lack of standardized data agreement.

Blockchain allows companies to assign unique identifiers (tokens) to assets and digital signatures to participants. Transaction flows (information, financial, and physical) are recorded chronologically on the blockchain, capturing data not typically recorded in traditional ERPs. Encryption and distribution among participants facilitate audits and prevent manipulation, improving traceability and coordination among transaction participants, leading to better business decisions.

Blockchain will complement, not replace, ERPs by enabling interaction and information integration across different systems. It also benefits consumers by providing greater confidence through detailed and reliable product information, enhancing the competitive advantage of companies that can prove sustainability through Blockchain.

Thus, one of the challenges networks will need to overcome is governance mechanisms that determine the rules applied to the system.

Considering the vast amount of data a network intended for sharing supply chain information in a sector must accommodate, a consensus mechanism that enables rapid data handling will be necessary. Proof of Work (PoW) is not suitable for this technology implementation.

Additionally, the quality of the products traded and registered on the network must be ensured. To do so, companies are taking three actions: conducting physical audits of products the first time they enter the production chain to ensure units meet specifications recorded on the Blockchain, developing distributed applications (dApps) to track products throughout the chain, and implementing smart devices using IoT technology and sensors to scan products and record information without human intervention.

Challenges:

Reliability of Information: Blockchain-based solutions encounter challenges, particularly regarding upstream traceability, due to issues with the reliability and accuracy of information.

Scale and Scope: Many traceability methodologies, such as natural fingerprints, are developed at a regional scale and focus solely on upstream segments of value chains, limiting their applicability across broader supply chain networks.

Market Viability: The viability of new traceability solutions depends on existing alternatives and the prospective markets within CRM supply chains. Addressing market demand and ensuring cost-effectiveness are critical considerations.

Regulatory Compliance: Compliance with regulations, such as the EU Battery Regulation, poses challenges for traceability solutions, requiring adherence to complex regulatory frameworks and standards.

Data Security and Privacy: Ensuring the accessibility of traceability data to stakeholders while safeguarding data security and privacy remains a significant challenge. Balancing transparency with the protection of sensitive information is essential for maintaining trust and compliance.

> While advancements in digitalization and technology offer promising opportunities to enhance traceability in CRM supply chains, addressing challenges related to data reliability, scalability, market viability, regulatory compliance, and data security is crucial for the successful implementation and adoption of traceability solutions.Risk identification

Material traceability has emerged as a global practice, that need the adoption of a unified strategy across the regions and countries. The development and implementation of these systems entail several risks that require mitigation. This report categorizes these risks into three segments: stakeholder risks, policy risks, and risks associated with roadmap implementation:

Stakeholder risks

- Lack of industry stakeholder involvement
- The measures developed fail to reach the sectors involved.
- The sector is forced to implement traceability measures

Policy Risks

- Different policy contexts between countries, EU vs. rest of the world

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- Discrepancies or incoherencies between different policies (environment vs. raw materials, regional/national/EU).
- Lack of understanding on the policies applied
- Non-uniformity systems and policies in the regions/countries
- Measures and policies to apply not properly explained

Roadmap development Risks

- Measures identify not properly addressed to accomplish the objectives of traceability
- Issues in compatibility of traceability systems
- Hight technology cost on traceability implementation
- Implementation cost in the field
- Difficulties on tracing the materials with artificial tagging or MFP techniques
- Too high-tech solutions for some actors in the supply chain

4.4 Risk mitigation

To develop measures for implementing the roadmap, it's essential to first elaborate a risk mitigation plan. This plan will enable the prioritization and control of risks, ensuring effective management throughout the implementation process. To mitigate risks effectively, they will be categorized into three distinct categories such as in the identification process:

Stakeholder risks

Several risks have been identified regarding the involvement of stakeholders and related sectors. To mitigate these risks, it will be necessary to have a solid Communication and Dissemination plan aimed at engaging all key stakeholders. This plan will involve conducting various meetings and informative sessions to explain the purpose and benefits of the strategy. Additionally, maintaining an ongoing dialogue with Advisory Board members will be crucial to ensure alignment and address any concerns promptly. Through targeted communication efforts, stakeholders will be informed about the rationale behind the proposed changes and the potential positive impacts on their operations and outcomes. This proactive approach will help build trust, facilitate collaboration, and ensure that all parties are well-informed and supportive of the strategy.

Policy Risks

To mitigate the risk related to the policy it will be necessary a thorough examination of the policies and regulations across the different regions, countries and globally recognized standards such as ISO. This involves conducting deep studies to understand the variations in the existing policies. Additionally, an awareness-raising campaign will be helpful to harmonizing diverse policy systems and ensuring a cohesive understanding of the new measures. This campaign will aim to explain the benefits and advantages of adopting a unified policy context, emphasizing the efficiencies and synergies it can bring to stakeholders across various sectors and regions. By aligning with international standards, the campaign will promote best practices and facilitate smoother integration and cooperation on a global scale

Roadmap development Risks

These risks are related to the implementation phase, so the mitigation measures need to be highly precise. Firstly, a proper analysis ensuring all measures identified are aligned with the objectives must be carried out, with the corresponding review and update of the roadmap. Secondly, the communication with stakeholders needs to be fluid to ensure that all requirements and potential challenges are addressed, and that standards and guidelines are being followed without problems with de data exchange and interoperability. Finally, working with technology providers to explore cost-sharing opportunities and cost-effective solutions will be a key point to ensure the economic feasibility of the implementation.

4.5 Steps for developing the roadmap implementation.

In developing a roadmap, it's essential to first consider the associated risks as a preliminary step. Once all risks and their corresponding mitigation measures have been identified, the roadmap can then be formulated by following these steps:

- Clarification on the object: this will be the initial step of the organizational process, identifying the key requirements for the purpose with the corresponding outputs and profits. This step will help with the detection of the needs and constraints and will support finding the solutions to apply.
- Roadmap designing structure and design of the roadmap, fitting the objectives and requirements identified in the previous step, and assessing cost implication and added value of traceability.
    - MaDiTraCe Project Concept: based on three pillars: MFP techniques, digital traceability systems, and certification standards.
    - Integration of MaDiTraCe in Due Diligence and Sustainable Sourcing Initiatives: explore expectations within international frameworks, EU regulations like the battery passport, and company-level initiatives.
    - Intrinsic or Artificial MFP Challenges: delve into challenges related to intrinsic and artificial MFP, including feasibility, logistics and potential implementation perspectives.
    - Certification Systems: outline ESG certification, CERA 4in1 development, and recommendations for policymakers. Digital Traceability Systems: summarize developed work, integration challenges, and recommendations for policymakers and IT solution developers.
    - Synthetic Case Study and Roadmap Conclusion: explore new business opportunities, potential pitfalls, and general recommendations for future endeavors
- Stakeholder identification: Identify and contact key stakeholders to involve them in the process of developing the roadmap.
- Roadmap implementation: implement the traceability solution after the pilot testing and ensure that all the data from the suppliers is high-quality data.
- Roadmap validation: Update and refine the process in case is needed.
- Lesson learned from the process: this last step will be important to keep improving the method and learn from the mistakes made during the process.

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5 Identification of Relevant Stakeholders

5.1 Mapping of key stakeholders in the field of material traceability in MaDiTraCe

MaDiTraCe has developed a thorough plan for stakeholders mapping (Figure 2), as detailed in D1.1. Stakeholder Engagement Strategy. This document highlighted the importance of implementing a stakeholder engagement plan to identify organizations and entities related with material traceability. Such a plan facilitates garnering valuable contributions from participants.

The stakeholder mapping process will be divided into two sections: Stakeholder Identification, involving the creation of the corresponding database and Stakeholder Analysis and Clustering, which will be focus on the engagement process.

Figure 2 MaDiTraCe approach for stakeholders' engagement and management.

This stakeholder engagement plan will be crucial for the implementation of the project and will count with the collaboration of all the WPs to ensure an effective engagement strategy.

6 Mirroring and Opportunities

6.1 Analysis of specific traceability solutions and identify gaps and opportunities in MaDiTraCe project.

Traceability solutions from different domains such as technology, fingerprinting and certification have been analysed and defined in D1.2. These solutions addressed share a common drawback: the absence of a holistic approach. The focal point of MaDiTrace project lies in addressing this integration gap. Taking advantage of this gap, MaDiTraCe will be focused on developing more interconnected and unified solutions, thereby enhancing the efficiency and productivity of traceability throughout the supply chain.

6.2 Aligned Smart Specialization Strategies

Regarding S3, different Thematic Platforms[10] such as Agrifood, Energy, Industrial Modernisation and Sustainable Blue Economy, serve as frameworks supporting interregional collaboration among Thematic Smart Specialization Partnerships (TSSSPs). These partnerships bring together regions to explore and initiate new value chains within the main areas of smart specialization strategies (S3P). TSSSPs align with specific EU priorities, maintaining a focus on S3P priorities across regions. S3P are now developed into S3 communities of Practice (S3-CoP), redefining their objectives, aims and goals for the next years of collaboration under European network premises.

In the case of MaDiTraCe, the Industrial Modernisation Platform aligns with the main objectives of the project. Specifically, partnerships related to Advanced Materials for Batteries for Electro-mobility and Stationary Energy Storage, Efficient and Sustainable Manufacturing, and Mining, are the ones that are particularly aligned with the project's goals.

- Efficient and Sustainable Manufacturing: This mission is focused on enhancing manufacturing efficiency and sustainability while bolstering competitiveness through the development of EU value chains. The main objectives of this partnership are based on embracing circular economy principles, integrating cutting-edge sustainable materials and processes, fostering digital transformation with Industry 5.0, and optimizing energy and materials consumption throughout the manufacturing processes. Figure 3 shows the participating regions of this partnership.

[10] https://s3platform.jrc.ec.europa.eu/

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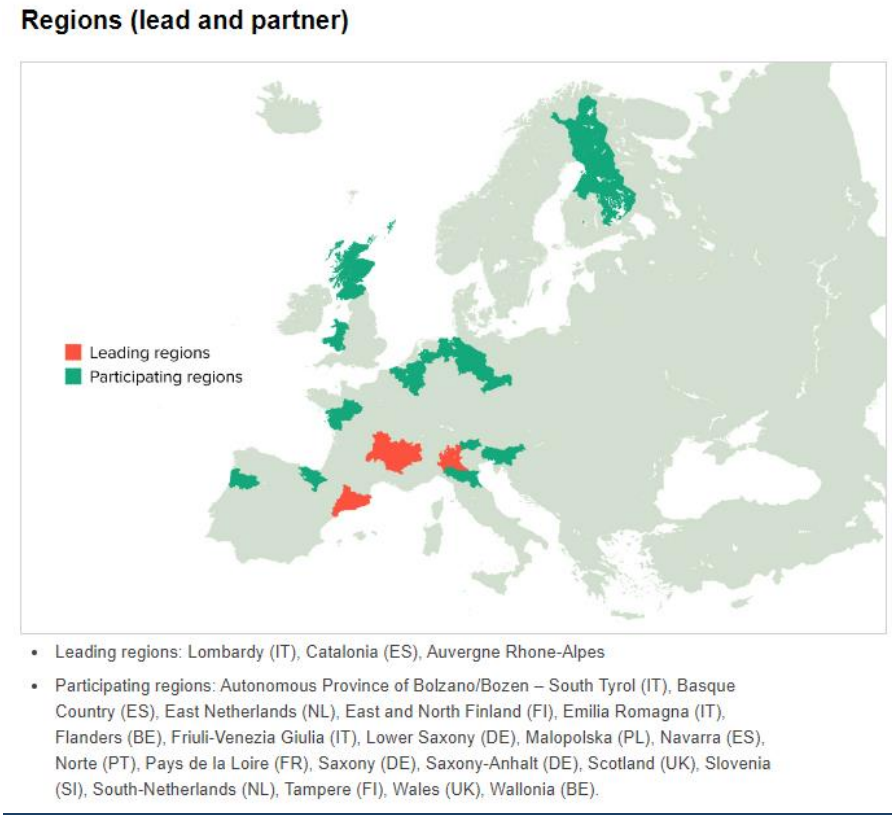

Figure 3 Regions and partners of the Efficient and Sustainable Manufacturing Partnership. (Source https://ec.europa.eu/regional_policy/policy/communities-and-networks/s3-community-of-practice/partnership_industrial_mod_efficient_sustainable_manufacturing_en)

- S3P mining industry and global value chains: This partnership is dedicated to improving the sustainability and availability of CRMs, while also fostering regional collaboration with SMEs to facilitate industrial transition and interregional growth. The key objectives of this mission are focused on enhancing innovation capacity among regions, identifying opportunities, disseminating knowledge to foster regional growth, and promoting the attraction of funding and investments. Figure 4 shows the participation regions of the mining partnership.

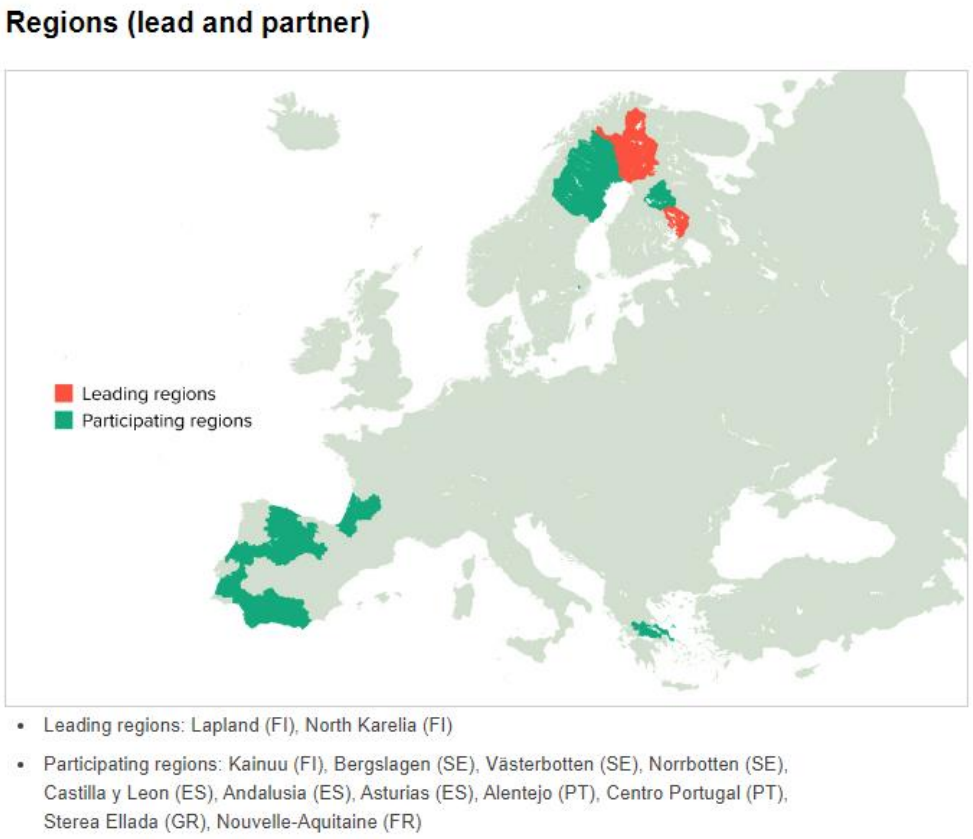

Figure 4 Regions and partners of the S3P Mining Industry and Global Value Chains (Source: https://ec.europa.eu/regional_policy/policy/communities-and-networks/s3-community-of-practice/partnership_industrial_mod_mining_en)

- Advanced Materials for Batteries for Electro-mobility and Stationary Energy Storage: This mission is centred on increasing the manufacture and development of advance materials and battery cells, employing sustainable and competitive technologies. The primary objectives of this partnership include the development of sustainable advance materials, ensuring access to raw material for battery manufacturing, and enhancing collaboration between research and industry (Figure 5).

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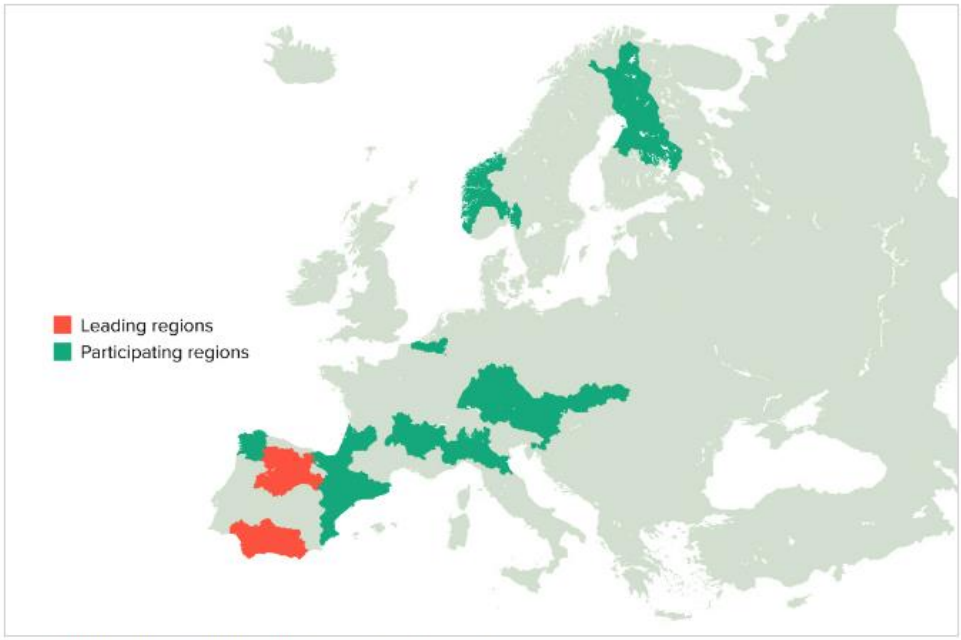
Regions (lead and partner)



- Leading regions: Andalusia (ES), Castile and Leon (ES)
- Participating regions: Aragon (ES), Austria (AT), Auvergne Rhone-Alpes (FR), Baden-Württemberg (DE), Basque Country (ES), Bavaria (DE), Brussels-Capital Region (BE), Catalonia (ES), Central Ostrobothnia (FI), Emilia Romagna (IT), Flanders (BE), Galicia (ES), Hessen (DE), Kainuu (FI), Lapland (FI), Lombardy (IT), Metropol Region Eindhoven (NL), Navarra (ES), North Karelia (FI), Northern Ostrobothnia (Pohjois-Pohjanmaa; Oulu subregion (city of Oulu)) (FI), Northern Savonia (Pohjois-Savo) (FI), Nouvelle Aquitaine (FR), Piedmont (IT), Slovakia (SK), Slovenia East (SI), Valencia (ES), Viken (NO), Western Norway (Vestlandet) (NO)

Figure 5 Regions and partners of the Advanced Materials for Batteries for Electro-mobility and Stationary Energy Storage partnership. (Source: https://ec.europa.eu/regional_policy/policy/communities-and-networks/s3-community-of-practice/partnership_industrial_mod_advanced_materials_en)

7 International Workshop

7.1 Description and outcomes of the workshop

An international workshop organized by MaDiTraCe project is scheduled to take place in Month 30 aimed at establishing a series of recommendations and findings, elaborated by key stakeholders invited to participate. This workshop will serve as an initial step towards implementing the roadmap designed to enhance collaboration between regions.

The primary aim of the workshop will be to explore the pivotal role of (S3) in facilitating the growth and discovery of new opportunities for sustainable economically viable industries within regions. To achieve this objective, it will be crucial to analyse previous works done under the S3, identify key insights and establish a set of recommendations for future collaborative actions. This workshop will provide a dynamic forum for MaDiTraCe stakeholders, including policymakers, researchers, and industry representatives, to engage in discussion on recent achievements, challenges, emerging policies and best practices. All the aspects detected and described in the current deliverable will be considered to design and take profit of the workshop to develop and implement the roadmap of the project.

7.2 Expected key participants and contributions

The international S3 workshop will serve to establish a comprehensive roadmap outlining the measures to secure raw materials supply into sustainable practices, with the main objective of enhancing the competitiveness of the European Union's raw material system. To achieve that, stakeholders from different sectors such as:

- Non-Governmental Organizations (NGOs): providing insights on sustainability and environmental impacts.
- Researchers and Academia: contributing with the latest scientific research and technological advancements.
- Industrial Stakeholders: offering practical perspectives on implementation and innovation within industries.
- Authorities and Policymakers: ensuring that proposed measures align with current regulations and policies.
- Regional and National Representatives: facilitating localized implementation and adaptation of strategies.
- European Commission (EC) and DG REGIO: leading coordination efforts and providing policy support.
- High-Level Expert Groups: offering advanced conceptual development and policy design insights.

The different points of view that each group brings to the table will enrich the dialogue and make the roadmap more realistic and effective.

In regions, S3 initiatives are typically managed by relevant regional authorities, often in collaboration with national bodies and the European Commission's DG REGIO. These authorities are responsible for the implementation of smart specialization strategies, coordinating with local stakeholders to address specific regional needs and priorities.

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S3 Thematic Platforms and partnerships organizes various types of events to support Smart Specialisation Strategies initiatives. These include joint events designed to explore partnership opportunities and introduce new financial instruments, and interregional cooperation events that focus on fostering collaboration between regions to share best practices and drive collective progress. Thematic partnerships events concentrate on specific sectors such as agri-food, energy, industrial modernization, and the sustainable blue economy. Additionally, S3 Community of Practice (CoP) conferences, held annually or bi-annually, bring together stakeholders for knowledge exchange and strategy development. Regular S3 forums aim to discuss advancements, challenges, and opportunities within the S3 framework. Working group meetings are held regularly to address implementation challenges, innovation diffusion, and industrial modernization. Lastly, targeted support assignments involve events and workshops designed to provide specific support to regions based on their unique needs, such as entrepreneurial discovery processes and participatory policy analysis.

The mission of the S3 thematic platforms extends beyond merely connecting regions. It aims to facilitate trans-regional cooperation, fostering the development of robust European value chains.

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8 Roadmap for Implementation

8.1 Development of a plan for common actions

A collaborative effort is needed for the development of a plan of common actions to integrate material traceability within the S3P, aimed at aligning regional, national, and international stakeholders with consortium partners. It will entail:

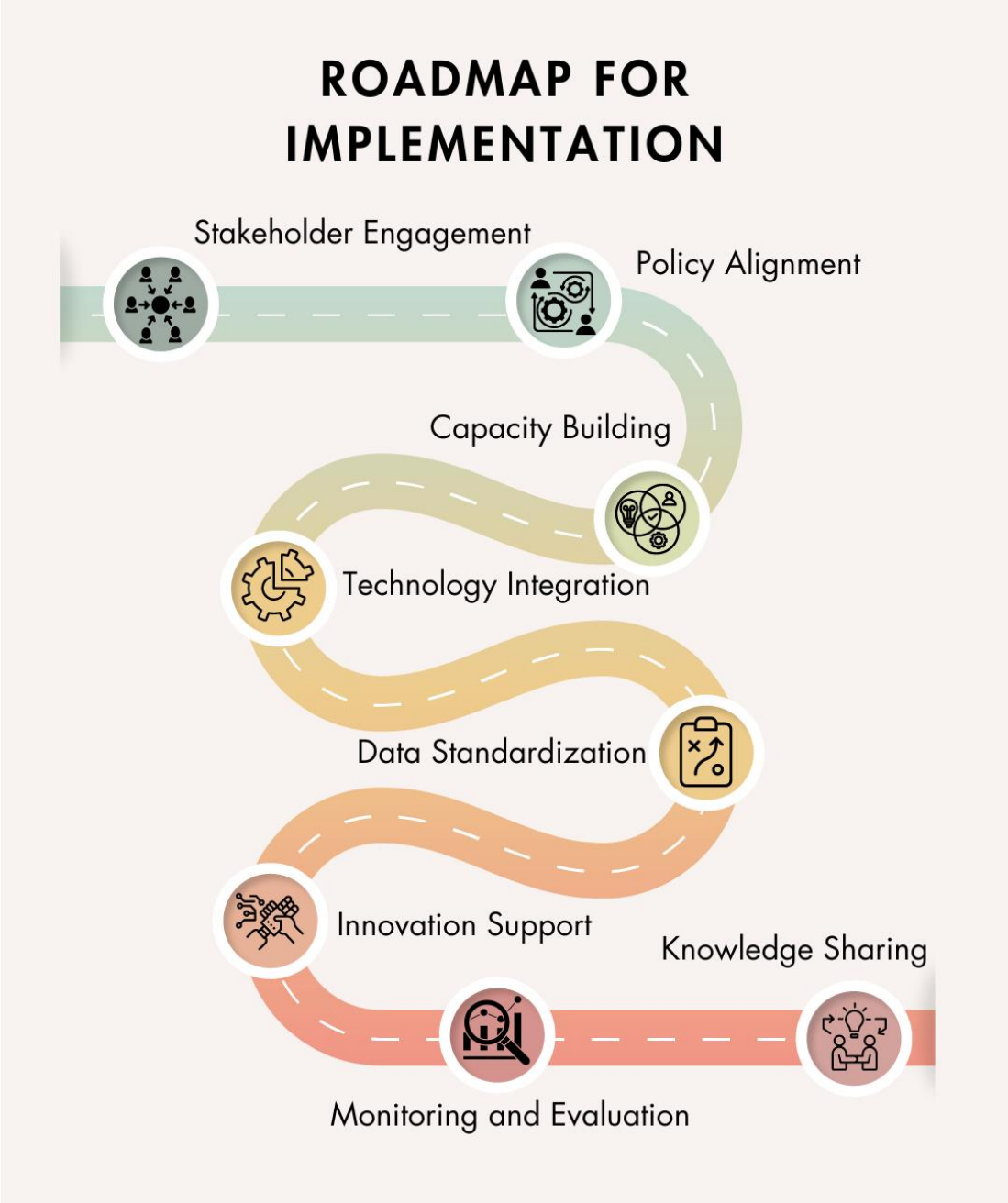

Figure 6 Roadmap for Implementation

- Stakeholder Engagement: With the main aim of facilitating dialogue and cooperation among stakeholders to understand their needs, challenges, and aspirations regarding material traceability within S3 Platforms.

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- Policy Alignment: Ensuring that material traceability initiatives are synchronization with existing regional, national, and international policies, frameworks, and strategies.
- Capacity Building: Providing necessary training, resources, and support to enhance the capacity of the interested stakeholders for implementing material traceability measures effectively.
- Technology Integration: Identifying and leveraging appropriate technologies for tracking and tracing materials throughout the value chain, promoting transparency and accountability.
- Data Standardization: Establishing common standards and protocols for data collection, storage, and sharing to facilitate interoperability and collaboration among stakeholders.
- Innovation Support: Encouraging innovation in material traceability solutions by fostering partnerships, incentivizing research and development, and supporting pilot projects.
- Monitoring and Evaluation: Setting up mechanisms to monitor the progress of material traceability initiatives, assess their impact, and make necessary adjustments to ensure their effectiveness and sustainability.
- Knowledge Sharing: Promoting knowledge exchange and best practices dissemination among stakeholders to facilitate learning and continuous improvement in material traceability efforts. Encourage participation in partnerships that align material traceability objectives within the S3P.

8.2 Starting points for the roadmap

As previously commented to initiate the roadmap development it would be necessary to conduct a comprehensive assessment to identify gaps, challenges and opportunities related to material traceability within the context of specialization strategies. A policy review of the existing regional, national and international policies, regulations and frameworks will be relevant to ensure the alignment and the support of the different stakeholders. The stakeholders will be another important point of reference, the engagement of industry, policymakers and civil society will be crucial to build consensus and foster collaboration in developing material traceability policies and identifying priority areas. Additionally, a commitment to continuous monitoring, evaluation, and iteration is indispensable. Establishing mechanisms for feedback and performance assessment enables stakeholders to course-correct as needed, ensuring the roadmap remains dynamic and effective in achieving its objectives.

8.3 Reflection on the importance of implementing the common strategy

As it has been reflected in the previous sections, having a common strategy towards the development of material traceability policies within smart specialization strategies is crucial. First, material traceability ensures transparency and accountability throughout the supply chain, building trust with consumers and stakeholders. This transparency is reinforced by the harmonization regulations set forth in the EU's 2023/1542 Regulation, which mandates comprehensive lifecycle management of batteries, from production to recycling.

Secondly, standardization policies boost the streamlining in the processes and reduce operational inefficiencies, promoting harmonization and reducing the risk of errors and discrepancies. Furthermore, material traceability supports sustainability initiatives by allowing for the monitoring and mitigation of environmental impacts, thereby promoting responsible sourcing practices and compliance with stringent environmental standards.

Implementing a common strategy for material traceability fosters innovation and competitiveness within specialized industries. By aligning specialization strategies with common traceability objectives, businesses can enhance their reputation, minimize risks, and contribute to a more sustainable and transparent global economy. A comprehensive plan for traceability in gigafactories is crucial for ensuring ethical sourcing, regulatory compliance, and sustainability. By leveraging advanced technologies like blockchain, IoT, and AI, companies can enhance transparency and efficiency in their supply chains, ultimately contributing to more sustainable and responsible manufacturing practices (Fig.7).

The traceability of raw materials for batteries is not merely a compliance or ethical issue; it represents a significant strategic opportunity for a regional partnership development within the S3Platforms. By fostering collaborations across industries and sectors, companies can collectively enhance transparency, compliance, sustainability, and innovation within the battery supply chain. These regionals partnerships can lead to improved brand reputation, greater market access, and long-term strategic advantages. Embracing traceability as an initiative aligns with broader trends towards responsible business practices and offers a pathway to a more sustainable and prosperous future for all involved stakeholders. As stated in the regulation, creating a harmonized regulatory framework is crucial for ensuring the long-term competitiveness and environmental sustainability of the European Union's battery market.

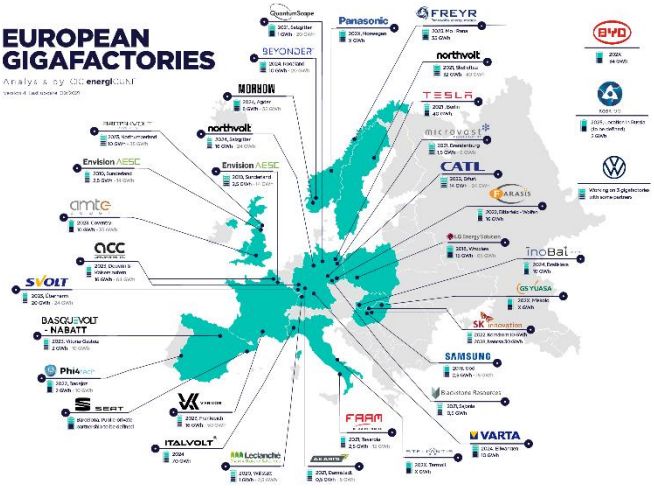

Figure 7. Map of EU gigafactories *Source: CIC energiGUNE.*

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9 Conclusions and recommendations

Effective traceability requires global cooperation facilitated by multi-stakeholder partnerships. The optimal approach to advancing traceability models is through global support, with companies, governments, NGOs and other stakeholders working together towards this objective.

Traceability stands as a key method for advancing towards raw material sustainability, both presently and in the foreseen future. By enabling the tracking of materials from their origin through the different stages of production and distribution, the transparency of processes will be ensured. This transparency will ensure consumer awareness, providing access to information and encouraging business to adopt more environmentally and socially responsible practices. Embracing traceability as a fundamental principle within supply chains is essential for driving progress toward a more sustainable and ethical global economy. Collaborative efforts involving all stakeholders are crucial to ensure the adoption and implementation of these methods across industries.

In terms of traceability, regions can adopt several strategies to ensure robust tracking of materials and products throughout the supply chain. Here are some proposals:

1. Implementation of Advanced Traceability Technologies.
    a. Blockchain Technology: utilize blockchain to create secure, transparent, and inmutable records of transactions and movements of goods.
    b. RFID and IoT Devices: implement Radio Frequency Identification (RFID) and Internet of Things (IoT) devices to enable real-time tracking and monitoring of products and materials.
2. Development of Traceability Standards:
    a. Establish standards for traceability that align with international best practices, such as ISO standards.
    b. Ensure these standards are adaptable and can be integrated with existing systems used by businesses.
3. Creation of a Traceability Platform:
    a. Develop a digital platform that allows all stakeholders to access and share traceability data.
    b. Ensure the platform supports interoperability with other traceability systems.
4. Promotion of Stakeholder Collaboration:
    a. Foster collaboration between different stakeholders, including manufacturers, suppliers, logistics providers, and regulators, to ensure seamless data exchange and transparency.
    b. Organize regular meetings, workshops, and forums to facilitate knowledge sharing and address common challenges.
5. Investment in Capacity Building and Training:
    a. Offer training programs and resources to educate stakeholders on the importance of traceability and how to implement effective traceability systems.
    b. Provide technical assistance and support to help businesses adopt new traceability technologies and practices

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6. Boost Traceability Adoption:
    a. Create incentives, such as grants or tax breaks, for businesses that implement robust traceability systems.
    b. Recognize and reward companies that demonstrate excellence in traceability and transparency.
7. Integration with Sustainability Initiatives:
    a. Link traceability efforts with sustainability goals to track the environmental impact of products and ensure compliance with sustainability standards.
    b. Promote the use of traceability data to improve resource efficiency, boost circular economy and reduce waste.
8. Regular Monitoring and Evaluation:
    a. Implement systems for regular monitoring and evaluation of traceability initiatives to assess their effectiveness and identify areas for improvement.
    b. Use collected data to refine and enhance traceability practices continuously.

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