WP2-A2. Comparative study of the curricula focused on Waste management of Ornamental Rock Industry and connected industries in the participating countries.

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Centro Tecnológico del mármol, piedra y materiales

Transilvania University of Brasov

Contents

1. INTRODUCTION

This document presents the findings of activity WP2.A2, focused on a comparative analysis of curricula related to Waste Management within the Ornamental Rock Industry and its connected sectors. The primary objective is to map and evaluate the existing educational landscape across the participating partner nations and the broader European Union context.

Through a comprehensive review of national reports, this study identifies both successful educational practices and critical gaps where current curricula fail to meet industrial and environmental needs. These insights provide the evidentiary basis for the subsequent phase, WP2.A3: *"Definition of the learning objectives and learning outcomes of the curriculum,"* ensuring that the proposed training is grounded in the specific reality of the stone sector.

2. WASTE MANAGEMENT IN THE ORNAMENTAL ROCK INDUSTRY

Waste management plays a key role in the ornamental stone sector, not only as a driver for improving industrial sustainability, but also as a tool for reducing the environmental impact of the activity. As an extractive industry, the amount of waste generated during the extraction, processing, and finishing stages of stone is considerable. If these by-products are not managed properly, they can cause serious environmental damage, such as habitat destruction, soil erosion, and water source contamination.

On the contrary, having robust management systems in place opens the door to more effective recovery strategies. Through the principles of the circular economy, materials that were previously considered waste can be recycled and reused, becoming usable resources.

Internationally, various actions have been promoted to improve waste management schemes, developing policies and best practices that seek to reduce waste generation at source, especially in the extraction and processing stages. This approach also promotes the responsible use of by-products, integrating them sustainably into related sectors, such as construction and infrastructure development.

2.1. Introduction to waste management in the ornamental rock industry

Waste management in the ornamental stone sector covers the entire life cycle of the material, from waste reduction in the extraction phase to recycling and utilization of by-

products. The main types of waste generated, such as stone slurry, fragments, and fine dust, pose a considerable environmental risk if not handled properly. Therefore, management in this industry is based on three strategic pillars:

- **Waste reduction:** This step is key from the early stages, such as clearing and cutting blocks, and requires the application of optimized techniques. The use of high precision cutting tools and equipment that improve the value of stone processing increases efficiency and reduces environmental impact at the source.
- **Recycling and reuse:** Waste such as stone slurry and fragments can be treated and converted into useful materials for construction, for example, as aggregates, fillers, or cement additives. These practices not only reduce the volume of waste but also help conserve natural resources and improve the profitability of the process.
- **Sustainable management:** This involves implementing environmental management systems based on international standards, ensuring responsible waste treatment. This allows companies in the sector to reduce their ecological footprint and make a concrete contribution to global sustainable development goals.

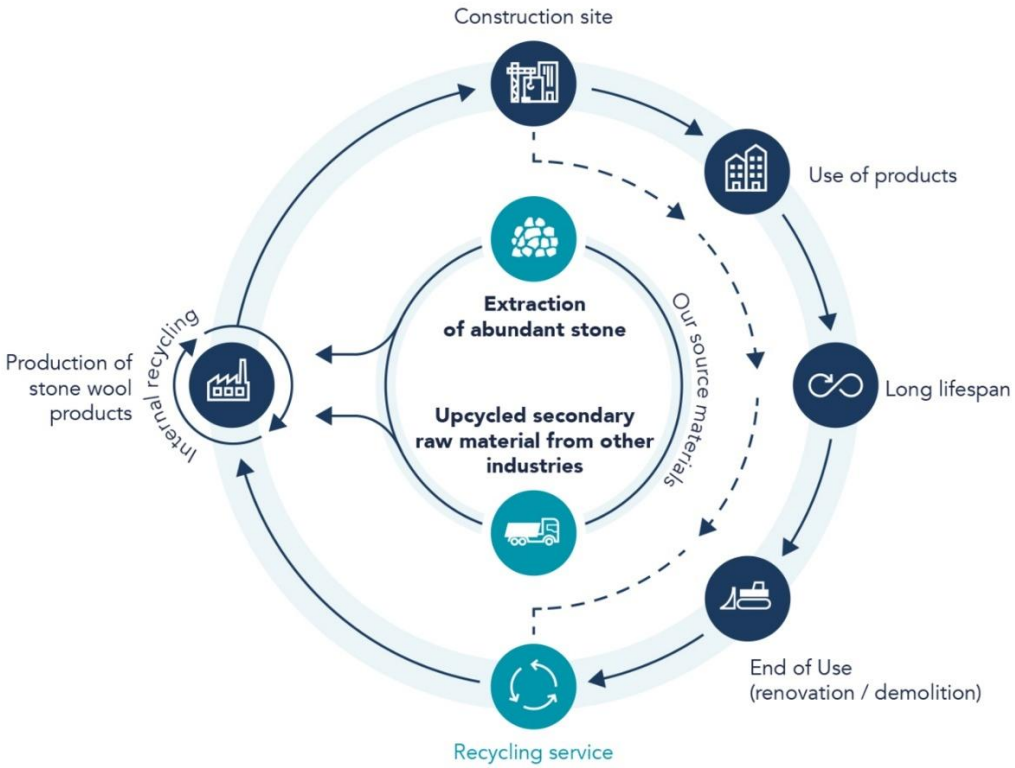

Figure 1: Circular economy on ornamental rock and construction sector.

2.2. Impact of waste management on the industry and environmental sustainability

The implementation of effective waste management strategies offers both economic and environmental benefits for the ornamental stone industry. Adopting sustainable measures not only reduces the consumption of raw materials, but also decreases environmental impact, driving more efficient processes throughout the sector.

2.2.1. Environmental and economic benefits

Applying techniques to minimize waste is essential to prevent soil degradation caused by improper stone disposal, as well as to reduce water pollution caused by sludge runoff. From an economic perspective, companies that incorporate circular economy principles—especially through the reuse of stone by-products—can significantly reduce their operating costs while generating additional revenue through recycled materials. These practices also reduce the need for landfills, resulting in lower expenses and greater financial sustainability for the sector.

2.2.2. Social responsibility and regulatory compliance

From a social perspective, managing waste sustainably allows companies to demonstrate their commitment to Corporate Social Responsibility (CSR) and environmental protection. This approach strengthens the institutional image and positions the stone sector as a player committed to complying with international environmental regulations.

Figure 2: Tripple bottom line diagram

2.3. Waste management education and professional training

Specialized education and professional training are fundamental pillars for transforming the ornamental stone industry. Having personnel prepared to adopt sustainable practices is not only a desirable improvement, but a key necessity to ensure the sector's long-term viability. Therefore, it is essential that educational programs, both vocational and university, systematically integrate content on environmental management and waste reduction. This training is crucial to prepare professionals who will face the environmental and regulatory challenges specific to the sector.

2.3.1. Vocational Education and Training (VET): Practical and operational approach

In the field of technical education, it is important to go beyond general concepts and focus on specific job skills. Curricula should focus on technical skills that are directly applicable in the field, such as:

- **Extraction optimization:** Use of advanced mining techniques that reduce the generation of waste material and unnecessary fractures at the source.
- **Processing efficiency:** Training in the precise adjustment of cutting and polishing machinery to reduce the production of sludge and fine dust.
- **Valorization of by-products:** Development of practical skills to classify, treat, and reuse processing waste as secondary materials for construction.

2.3.2. Higher Education: Strategic Management and Comprehensive Vision

At the university level, engineering and management programs should adopt a broader, more systemic approach. Curricula in environmental or mining engineering, for example, should address issues specific to the ornamental stone sector, such as:

- **Circular economy-based design:** Training to create closed systems in which waste from one process becomes input for another (e.g., the use of stone sludge in cement manufacturing).
- **Environmental impact assessment (EIA):** Advanced knowledge of regulatory compliance, life cycle analysis (LCA) methodologies, and long-term environmental monitoring in quarry areas.
- **Innovation and technology:** Integration of emerging tools, such as digitization and the use of blockchain, to track waste flows and certify the sustainability of stone products.

2.4. The Role of Waste Management in Vocational Education

Vocational Education and Training (VET) is a key link in the functioning of the ornamental stone sector. It plays a fundamental role in ensuring that workers in the sector not only have theoretical knowledge, but also the technical skills necessary to apply specific waste management solutions daily. Systematically integrating waste reduction

techniques and sustainable strategies into curricula makes it possible to train skilled personnel to drive environmental innovation and significantly improve the efficient use of resources.

The training approach should focus on practical learning, especially in the use of sustainable technologies for stone processing and waste management. Knowing how to use cutting and polishing machines accurately is key to reducing the generation of fines and sludge, which directly contributes to lowering the industry's environmental impact.

At the same time, education must go beyond the technical aspect and foster a sustainability-oriented mindset. When workers understand the environmental consequences of each stage of the process, from extraction to finishing, they become agents of change, capable of actively applying waste reduction strategies as a natural part of their daily work.

3. WASTE MANAGEMENT CURRICULA

3.1. GERMANY

Germany combines one of the most advanced waste management systems in the European Union with considerable waste generation, especially in the construction and demolition sector. According to recent data, approximately 207.9 million tons of mineral construction waste were produced in 2022. Of that total, about 58.7% was soil and stones, making this waste the most voluminous category in the country. Although more than 90% of these materials are recovered, a large part is used for low-value purposes, such as land filling, highlighting the need for innovation in higher-quality recycling and reuse strategies for natural stone waste.

The legal framework is defined by the Kreislaufwirtschaftsgesetz (Circular Economy Act), which adapts the EU Waste Framework Directive to the German context. This regulation establishes a strict five-level hierarchy for waste management, giving priority to prevention, reuse, and recycling over energy recovery and final disposal. This regulatory environment generates high demand for professionals trained in recycling, circular economy, and environmental protection, especially in sectors that handle large volumes of mineral waste, such as construction, aggregates, and natural stone extraction.

The German education system responds to this demand through a combination of dual vocational training programs, technical studies at specialized schools, and university degrees focused on environmental and industrial topics.

3.1.1. Waste Management in Vocational Education and Training (VET)

In Germany's dual vocational training system, occupations related to waste management are regulated at the federal level and combine practical training in companies with theoretical studies in vocational schools. In the case of the ornamental stone and construction sectors, the most relevant programs focus on the recycling of mineral construction waste, excavation materials, and environmental protection in industrial settings.

Recycling and Waste Management Technician (Fachkraft für Kreislauf- und Abfallwirtschaft)

- **Institution:** Dual System / Federal Institute for Vocational Education and Training (BIBB)
- **Link:** BIBB Profile
- **Description:** A nationally regulated three-year dual apprenticeship preparing technicians to operate and optimize municipal and industrial waste management systems. Trainees learn to identify, classify, and sort waste, organize logistics, and apply environmental law. The updated profile explicitly addresses the separate handling and recycling of mineral construction waste and aggregates, making it directly relevant for quarrying and natural stone processing.

Environmental Protection Technical Assistant

- **Institution:** Berufliche Schule Butzbach (School-based VET)
- **Link:** Berufliche Schule Butzbach Program
- **Description:** A two-year full-time program training assistants to perform measurements and analyses on air, water, soil, and waste. The curriculum combines environmental chemistry and laboratory practice with waste characterization and sampling. Graduates are equipped to work in laboratories and environmental departments of extractive companies, monitoring quarry waste deposits and sludge.

Company Waste Officer (Basic Course)

- **Institution:** TÜV SÜD Akademie / Chambers of Industry and Commerce (IHK)
- **Link:** TÜV SÜD Course
- **Description:** German law requires waste-intensive companies (including quarries and stone processors) to appoint a Waste Officer. This basic course provides the legally prescribed specialist knowledge in waste legislation, documentation duties, and hazardous waste handling. It explicitly covers mineral construction waste, making it essential for compliance managers in the stone sector.

Continuing VET for Recycling and Waste-Management Professionals

- **Institution:** Federal Institute for Vocational Education and Training (BIBB)
- **Link:** BIBB Certificate Supplement
- **Description:** Advanced courses for certified technicians aiming to deepen competencies in process optimization and circular economy strategies. These

programs focus on improving recycling quality for mineral waste and construction debris, supporting the transition from disposal to high-value reuse of quarry by-products.

3.1.2. Waste Management in Higher Education

At the university level, several institutions offer specialized degrees in recycling engineering and environmental engineering. Although these programs do not focus exclusively on ornamental stone, they include comprehensive modules on construction waste and mineral materials, which are essential for the sustainable management of waste generated in quarries.

B.Eng. Recycling, Environment, and Sustainability

- **Institution:** Hochschule Magdeburg-Stendal
- **Link:** Program Details
- **Description:** A seven-semester degree focusing on recycling engineering and sustainability. It places particular emphasis on construction and demolition waste, mineral aggregates, and secondary raw materials. This makes it highly relevant for designing recovery routes for stone residues from quarrying.

B.Eng. Environmental and Recycling Technology

- **Institution:** Hochschule Nordhausen
- **Link:** Program Details
- **Description:** Trains engineers in environmental process engineering and resource-efficient production. The curriculum includes materials science and recycling technologies. Case studies frequently address mineral fractions and industrial by-products, enabling graduates to develop solutions for reusing stone-cutting residues in construction materials.

M.Sc. Environmental Process Engineering and Recycling

- **Institution:** Technische Universität Clausthal
- **Link:** Program Details
- **Description:** An advanced master's program covering waste technologies, process design, and recovery of secondary raw materials. It includes case studies on recycling mineral materials and industrial by-products directly transferable to stone processing operations.

M.Sc. Waste Management and Contaminated Site Treatment

- **Institution:** Technische Universität Dresden
- **Link:** Program Details

- **Description:** Focuses on sustainable waste management and contaminated site remediation. Modules cover landfill design and material flow management. Theses often address mineral waste and soils, relevant for regions with intense quarrying activities where legacy waste deposits are an issue.

M.Eng. Environmental and Recycling Technology

- **Institution:** Hochschule Nordhausen
- **Link:** Program Details
- **Description:** Deepens competencies in advanced recycling technologies and plant optimization. Its focus on materials engineering equips graduates to develop innovative recycling chains for mineral waste, including transforming quarry residues into high-quality secondary raw materials.

3.2. SPAIN

Over the last decade, Spain has made significant progress in developing policies and regulations related to waste management and the circular economy. The national framework is articulated through the State Waste Management Framework Plan (PEMAR) and its new version for the period 2024–2035, which establishes strategic lines to prevent waste generation, encourage recycling, and promote the use of secondary raw materials in all sectors. These plans are implemented within the framework of Law 7/2022 on waste and contaminated soil, which reinforces Extended Producer Responsibility (EPR) and imposes stricter targets for construction and demolition waste (CDW).

Construction and demolition activities are among the main sources of waste in the country. It is estimated that around 37 million tons of CDW are generated each year. Within this category, the ornamental rock and quarrying sector contributes a significant amount of waste in the form of cutting sludge, cuttings, and cover materials. However, this volume also represents an opportunity to recover this waste as secondary aggregates, components for "green concrete," or other innovative eco-friendly products.

The Spanish education system is responding to these challenges through a combination of vocational training courses, professional certificates, and specialized centers such as the Escuela del Mármol de Fines (Fines Marble School). At the university level, degrees in environmental engineering and mining engineering offer advanced training tailored to the needs of the sector.

3.2.1. Waste Management in Vocational Education and Training (VET)

In Spain, vocational training related to waste management is mainly organized through Professional Certificates. In the case of the ornamental rock industry, there are two key

training areas: on the one hand, cross-cutting qualifications in industrial waste management, and on the other, specific qualifications for the extractive industries sector.

Urban and Industrial Waste Management (Code SEAG0108 - Level 2)

- **Institution:** SEPE (Public State Employment Service) / Various Providers
- **Link:** Certificate Details
- **Description:** The core national qualification for operators in waste management. It covers the collection, transport, and operation of recycling facilities. The competence profile includes the separate handling of inert and construction waste, making it directly applicable to companies involved in quarry restoration and the management of mineral residues.

Auxiliary Operations in Natural Stone Processing Plants (IEXD0308 - Level 1)

- **Institution:** SEPE / Escuela del Mármol de Fines
- **Link:** Specialty Details
- **Description:** This certificate defines the basic operative profile for natural stone processing plants. Training modules include stone block handling, cutting equipment operation, and basic maintenance. It provides a natural entry point to integrate topics such as the reduction, segregation, and internal recycling of stone residues into workplace-based learning.

Training Itinerary: Natural Stone Processing & Digital Competences

- **Institution:** Escuela del Mármol de Fines (National Reference Centre)
- **Link:** CRN Piedra Natural
- **Description:** The *Escuela del Mármol de Fines* (Almería) offers specialized itineraries combining technical stone cutting training with digital skills. As the National Reference Centre for the sector, its programs are explicitly aligned with industry needs, including the efficient use of raw materials and the responsible management of stone by-products.

Construction and Demolition Waste Management

- **Institution:** Professional Associations / Specialist Providers
- **Link:** Course Example
- **Description:** Short VET courses aimed at site managers and technicians. They address Spanish and EU legislation on CDW, the design of waste management plans, and selective demolition. For the natural stone sector, these courses are essential to ensure that stone-based waste is channeled into authorized recycling routes rather than landfills.

3.2.2. Waste Management in Higher Education

At the university level, the country offers a wide range of degrees in environmental engineering and mining engineering. Although most of these programs have a multisectoral focus, many include specialized modules on mining restoration and the use of recycled aggregates, knowledge that is directly applicable to the ornamental stone value chain.

M.Sc. in Sustainable Mining (Máster Universitario en Minería Sostenible)

- **Institution:** Universidad Politécnica de Madrid (UPM)
- **Link:** UPM Program
- **Description:** An official master's degree focusing on mining technologies and environmental management. The curriculum covers environmental impact assessment, mine-waste management (tailings), and the reclamation of extractive sites. Case studies often feature Spanish quarries, making the competences highly relevant for stone residue reuse and quarry restoration.

M.Sc. in Waste Management and Resource Recovery

- **Institution:** Universidad Autónoma de Madrid (UAM)
- **Link:** UAM Program
- **Description:** A specialized program training professionals to design systems for waste management with a strong focus on resource recovery. Students study technologies for the valorization of solid waste and sludge. For the stone sector, these approaches can be applied to the treatment and reuse of cutting sludge and inert mineral waste.

M.Sc. in Environmental Engineering

- **Institution:** Universitat Politècnica de València (UPV) & Universitat de València
- **Link:** Joint Master Program
- **Description:** Provides advanced training in the prevention and control of environmental impacts from industrial activities. Modules include landfill design and life-cycle assessment (LCA). Theses often address inert waste landfills for quarry spoil, providing a direct bridge to the challenges of the ornamental rock industry.

M.Sc. in Circular Economy

- **Institution:** Campus Iberus (Zaragoza, La Rioja, Lleida, Navarra)
- **Link:** Campus Iberus Program
- **Description:** An inter-university master's degree training graduates to manage complex material flows. It covers industrial symbiosis and circular economy metrics. Projects frequently address construction materials and mineral by-

products, offering tools to design circular business models for natural stone waste (e.g., artificial reefs or 3D printing).

3.3. ROMANIA

Romania has made significant progress in adapting its waste management system to European Union requirements; however, it still has one of the lowest municipal waste recycling rates in the bloc. In 2022, municipal waste generation was approximately 303 kg per capita, well below the EU-27 average (513 kg), but most of it still ends up in landfills, with recycling rates of only around 12–14%, well below the targets set for 2025.

Some recent initiatives, such as the national Deposit and Return (SGR) system for beverage containers, launched at the end of 2023, have significantly improved the collection of packaging waste. However, these flows represent only a small part of the total waste volume and do not address waste generated by construction, demolition, mining, and quarrying. At the same time, Romania has significant ornamental stone resources whose extraction and processing generate large amounts of waste: cuttings, sludge, and fines that urgently need to be recovered under circular economy criteria.

These structural challenges have driven the development of a wide range of educational programs in both vocational training and higher education, focused on environmental protection. Although most have a cross-cutting approach, content on waste classification, integrated management, and recycling technologies is particularly relevant to the management of complex mineral waste such as that from the ornamental stone sector.

3.3.1. Waste Management in Vocational Education and Training (VET)

In Romania, training in waste management outside the university setting is mainly organized through specialization programs accredited by the ANC, linked to specific occupational codes in the Romanian Occupation Catalog (COR). These courses are aimed primarily at environmental managers and technicians working in companies that generate large amounts of industrial waste, such as quarries and stone processing plants.

Waste Management Specialist (COR 213310)

- **Institution:** Various Providers (ANC Accredited)
- **Link:** Course Details
- **Description:** This nationally accredited specialization prepares professionals to coordinate waste management activities at the organizational level. The curriculum covers waste classification, the design of internal collection schemes, and reporting to environmental authorities. For mining and stone cutting

operators, this profile is essential for managing mineral waste streams and developing recycling routes instead of landfilling.

Environmental Officer (COR 325710)

- **Institution:** Various Providers (ANC Accredited)
- **Link:** Course Example
- **Description:** Focuses on broader environmental responsibilities within companies. Participants learn to identify environmental impacts, ensure compliance with permits, and monitor emissions and waste. In extractive companies, graduates act as key intermediaries between production departments and regulatory authorities, ensuring compliance with environmental law.

Waste Management Officer (ANC-Recognized Vocational Course)

- **Institution:** Various Providers (ANC Accredited)
- **Link:** Course Details
- **Description:** Aimed at staff directly responsible for day-to-day operations: sorting, labeling, and storage. Training includes Romanian waste legislation and the correct use of European Waste Catalogue (EWC) codes. Essential for avoiding uncontrolled dumping of stone residues and ensuring traceability in quarries.

Waste Management Specialist (Online Specialization)

- **Institution:** Avangarde Academy
- **Link:** Online Course
- **Description:** A fully online specialization combining regulatory updates with applied case studies. It covers the National Waste Management Plan (PNGD) and treatment technologies. The flexible format is particularly suitable for engineers in geographically dispersed sectors like quarrying who need to integrate modern circular economy practices without interrupting operations.

3.3.2. Waste Management in Higher Education

In terms of higher education, several Romanian universities offer specific programs in waste management and circular economy, generally within the framework of environmental engineering faculties. These courses provide advanced training in treatment technologies and life cycle assessment, key skills for addressing the challenges of the ornamental stone sector from a sustainable perspective.

M.Sc. in Waste Recovery Engineering

- **Institution:** Babeș-Bolyai University (Cluj-Napoca)
- **Link:** Master Program

- **Description:** Trains specialists in the engineering of waste transformation into secondary resources. Core topics include waste characterization, recycling technology optimization, and circular economy indicators. Its multidisciplinary profile makes it suitable for addressing complex issues like the reuse of stone slurry in construction materials.

M.Sc. in Waste Management, Treatment and Valorization

- **Institution:** Gheorghe Asachi Technical University of Iași
- **Link:** Master Program
- **Description:** Focuses on advanced waste management engineering. Curriculum covers prevention, treatment plant design, and recovery of secondary raw materials. Graduates are prepared to design integrated systems for industrial waste, directly applicable to optimizing the valorization of mineral waste in mining regions.

B.Sc. in Environmental Engineering

- **Institution:** Babeș-Bolyai University (Cluj-Napoca)
- **Link:** Bachelor Program
- **Description:** Provides a broad foundation in environmental sciences, pollution control, and waste management. Students complete practical projects with local authorities and companies. Highly relevant for planning waste systems in construction and mining, where engineers must design monitoring schemes and ensure legal compliance.

3.4. CROATIA

Croatia generates between 6 and 7 million tons of waste per year, which is equivalent to approximately 1.3–1.5 tons per inhabitant. A significant portion of this waste comes from construction, demolition, mining, and quarrying activities, especially in the form of mineral waste. Although the country has improved in terms of selective collection and recycling, landfilling remains the main method of municipal waste treatment, so efforts are being stepped up to meet European targets for recycling and reducing landfill use.

The Republic of Croatia's Waste Management Plan 2023–2028 reinforces measures such as prevention, separate collection, and recycling, while promoting the creation of regional waste management centers, with a particular focus on construction waste and minerals. This strategy is particularly relevant for Croatia's well-established non-metallic minerals sector, where historic ornamental stone quarries generate large volumes of cuttings, sludge, and mineral waste that could be recovered as secondary raw materials.

In this context, the Croatian education system offers a combination of vocational education and training (VET) programs in environmental protection and quarrying, along

with micro-qualifications for adults and a diverse range of higher education programs in environmental and civil engineering.

3.4.1. Waste Management in Vocational Education and Training (VET)

At the vocational education and training (VET) level, Croatia offers both initial upper secondary education programs and qualifications for adults, with a focus closely linked to environmental protection and resource efficiency. Although most curricula have a cross-cutting approach, the skills acquired, especially in environmental monitoring and waste logistics, are easily applicable to ornamental stone construction and exploitation activities.

Environmental Protection Technician (Ekološki tehničar)

- **Institution:** Various VET Schools (e.g., Graditeljska, prirodoslovna i rudarska škola Varaždin)
- **Link:** Profile Details
- **Description:** A four-year upper-secondary qualification (ISCED 3–4) preparing technicians to monitor and protect environmental media in industrial contexts. Students study environmental legislation, impact assessment, and dedicated modules on waste management (classification, collection, recycling). These competences are directly applicable to monitoring dust and sludge flows in quarrying facilities.

Stonemason / Stonemasonry Technician (Klesar / Klesarski tehničar)

- **Institution:** Klesarska škola Pučišća (Stone Masonry School)
- **Link:** Curriculum PDF
- **Description:** Located on the island of Brač, this specialized school offers programs in quarrying, cutting, and finishing natural stone. While waste management is not a stand-alone subject, the curriculum embeds outcomes related to the rational use of raw materials, minimization of stone losses, and safe handling of sludge and off-cuts, directly relevant for sustainable quarry management.

Waste Management Micro-qualification (Gospodarenje otpadom)

- **Institution:** Adult Education Providers (Voucher Scheme)
- **Link:** Program Details
- **Description:** Delivered under the national voucher scheme for adult learning, this micro-qualification (approx. 75 hours) covers Croatian and EU waste legislation, classification, and basic circular economy principles. It targets workers handling waste in construction, municipal services, and stone processing enterprises.

Certified Waste Management and Environmental Protection Specialist

- **Institution:** Seminari.hr / Verlag Dashöfer
- **Link:** Course Details
- **Description:** An advanced online course for professionals requiring operational and regulatory knowledge. It covers integrated system planning, hazardous waste management, and best available recycling techniques. The profile matches the needs of managers responsible for large mineral waste streams in quarrying plants.

3.4.2. Waste Management in Higher Education

In terms of higher education, Croatian universities offer undergraduate and graduate programs in environmental engineering and civil engineering, which specifically address mineral waste, construction and demolition waste, and circular economy approaches aimed at recovering value from these materials.

B.Sc. in Environmental Engineering

- **Institution:** University of Zagreb, Faculty of Geotechnical Engineering (Varaždin)
- **Link:** Program Details
- **Description:** Provides core competences in environmental protection, waste management, and geotechnics. Modules on solid waste management and environmental monitoring prepare students to plan and supervise systems in mining and construction, including the valorization of mineral wastes.

M.Sc. in Environmental Engineering (Environmental Management Track)

- **Institution:** University of Zagreb, Faculty of Geotechnical Engineering
- **Link:** Track Details
- **Description:** Deepens analytical and managerial competences for sustainable resource use. Advanced subjects cover circular economy strategies, risk assessment, and regional infrastructure planning. Graduates are equipped to design integrated solutions for high-volume mineral waste flows from construction and quarrying.

Waste Management Course (Civil Engineering)

- **Institution:** Josip Juraj Strossmayer University of Osijek
- **Link:** Course PDF
- **Description:** Introduces future civil engineers to integrated waste management systems, with specific attention to recovering construction and demolition waste. This provides graduates with the knowledge needed to incorporate recycled aggregates and stone by-products into infrastructure projects.

Sustainable Waste Management and Recycling Course

- **Institution:** University of Slavonski Brod
- **Link:** Course Details
- **Description:** Focuses on sustainable management of solid waste and recycling technologies within the Eco-engineering program. Students analyze sorting lines and circular economy models, preparing for roles in industrial enterprises aiming to increase material recovery, including mineral-based products.

Urban Forestry and Environmental Protection Studies

- **Institution:** University of Zagreb, Faculty of Forestry
- **Link:** Program Details
- **Description:** Integrates ecological sciences with urban environment management. Graduates contribute to planning green infrastructure where mineral and construction wastes interact with broader landscape management objectives.

4. ANALYSIS OF RESULTS

This chapter presents a comparative analysis of educational programs and curricula related to waste management in the ornamental stone industry in the participating countries. The main objective is to assess the extent to which these training programs are aligned with the project's goals, particularly the promotion of sustainable waste management practices within the sector.

By comparing training content, skills acquired, and methodologies applied, this analysis seeks to highlight good practices that promote sustainability and efficiency in the management of waste generated during stone extraction and processing. In addition, it examines how different national education systems are responding to the specific environmental challenges posed by this industry.

The study also identifies significant gaps, i.e., areas where current programs fail to respond to the real needs of the sector or adequately address certain environmental issues. These findings form the basis for a series of recommendations aimed at improving future vocational training.

Ultimately, the goal is to ensure that new generations of professionals are prepared to actively contribute to the circular economy, environmental management, and sustainable development throughout the ornamental stone value chain.

4.1. GERMANY

Germany is one of Europe's most established leaders in waste management. Its educational offerings are deeply integrated into a solid circular economy framework, backed by legislation that prioritizes high-quality recycling over simple disposal.

4.1.1. Waste Management Applied to Industry and Sustainability

The German educational ecosystem in waste management is broad and closely linked to the productive sector. Dual vocational training includes occupations such as *Fachkraft für Kreislauf und Abfallwirtschaft* (Recycling and Waste Management Technician), which combines internships in companies with technical training in specialized schools. In addition, there are school programs focused on environmental protection.

Added to this are highly specialized undergraduate and graduate degrees, such as Environmental Process Engineering and Recycling Engineering, which develop advanced skills in waste treatment technologies, resource efficiency, and life cycle assessment (LCA). For the purposes of this project, Germany represents a clear example of how a mature education system can support ambitious circular economy policies.

4.1.2. Integration of Waste Management in the Ornamental Rock Industry

Despite the strength of the system, the ornamental stone industry is not addressed as a specific focus but is included within the broader category of construction and mineral waste. Apprentices and students acquire knowledge about the handling of soil, stones, and rubble as part of standard operations, mainly related to the production of aggregates or concrete recycling.

These skills are easily transferable to the management of cover material, stone cuttings, and quarry by-products. However, curricula rarely address sector-specific aspects such as the aesthetic value of recovered stone, the technical handling of fine sludge, or the development of high-value products from stone waste. Given the country's strong industrial and research fabric, there is great potential for developing advanced value chains, if training programs incorporate case studies focused on ornamental rock.

4.1.3. Emphasis on Legislation and Compliance

The German system places strong emphasis on the legal and organizational aspects of waste management. A key element is the legal requirement that many facilities have a *Betriebsbeauftragte:r für Abfall* (Company Waste Manager). This professional figure is responsible for regulatory compliance, documentation, internal audits, and relations with the authorities.

Training and refresher programs for this role ensure detailed knowledge of the Circular Economy Act (KrWG) and applicable technical regulations. In the case of quarries and stone processing plants, this figure represents a key pillar for compliance, although from a project perspective, there is room to evolve this role: moving from simply complying with regulations to actively promoting circularity, exploring new opportunities for industrial symbiosis for stone waste.

4.1.4. Final Projects and Case Studies

Universities of Applied Sciences (*Fachhochschulen*) in Germany actively promote project-based learning and theses developed in collaboration with industry. Many environmental engineering and recycling students are already working on topics related to mineral by-products and treatment plant design.

Incorporating the ornamental stone sector into this context would not require major curricular changes, but rather a better definition of approaches and topics. Collaboration with industry associations could lead to projects that analyze the viability of new products from stone waste, optimize processing chains, or evaluate digital tools, including blockchain, for tracking circular material flows.

4.1.5. Overall Conclusions

Germany is a highly mature educational benchmark, especially when it comes to mineral waste recycling. The main challenge lies not in a lack of skills, but in the absence of a clear connection with the specificities of the ornamental stone sector.

For the development of the RockChain curriculum, German expertise provides advanced technical content on mineral waste recycling, process optimization, and regulatory models. In turn, the project can offer a necessary sectoral perspective, highlighting ornamental stone as a high-value field of application for these skills. This mutual enrichment, combining Germany's systemic experience with a focused exploration of stone waste, will contribute to a European curriculum that is technically ambitious and aligned with industrial reality.

4.2. SPAIN

An analysis of the educational landscape in Spain reveals a solid but somewhat fragmented ecosystem. It consists of cross-disciplinary Professional Certificates focused on urban and industrial waste, specialized vocational training in extractive industries, and a wide range of master's degrees in Environmental Engineering and Circular Economy.

4.2.1. Waste Management Applied to Industry and Sustainability

Together, these programs address key technical skills related to the waste hierarchy, treatment technologies, pollution prevention, and circular economy strategies applicable to resource-intensive sectors. However, the connection between these general skills and the specific sustainability challenges in the ornamental stone value chain (such as the management of cutting sludge, cuttings, or covering materials) remains largely implicit in the curricula, without being addressed in a differentiated or specialized manner..

4.2.2. Integration of Waste Management in the Ornamental Rock Industry

Direct integration with the sector is most evident in specialized institutions such as the Fines Marble School, or in specific certificates such as IEXD0308 (Auxiliary operations in natural stone processing plants). In these cases, training takes place in real stone processing environments, where waste management is part of the learning outcomes, integrated with content on efficiency in the use of materials, industrial hygiene, and occupational safety.

In contrast, general vocational training and university programs tend to treat stone as a subcategory of construction and demolition waste (CDW) or as inert industrial waste. Therefore, although students acquire transferable skills, they do not gain a complete understanding of the life cycle of ornamental stone waste, nor its potential for recovery beyond basic crushing for aggregates.

4.2.3. Emphasis on Legislation and Compliance

Both vocational training and higher education in Spain place great importance on environmental legislation. Certificates such as *SEAG0108* and specialized courses in CDW devote significant time to studying Spanish and European regulations, Extended Producer Responsibility (EPR), and waste management planning. Similarly, university degrees prioritize Environmental Impact Assessment (EIA) frameworks.

This regulatory approach provides a solid foundation for a sector such as ornamental stone, which operates under dense mining and environmental regulations. However, there is a lack of specific training on how to translate these generic obligations into concrete protocols for the management of cutting sludge or quarry materials. In addition, the application of digital tools, such as traceability through blockchain to improve transparency and compliance, is not yet part of the current curriculum.

4.2.4. Final Projects and Case Studies

Most master's degrees in environmental engineering or Circular Economy include a final project or thesis, often developed in collaboration with companies. These projects represent a great opportunity—still largely untapped—to link education with the challenges facing the sector.

Currently, case studies focus on urban waste, wastewater, or generic CDW. Directing these projects toward topics such as sludge recovery, eco-design of stone products, or the use of stone waste as a secondary raw material could significantly increase the relevance and specialization of the programs. This would create a graduate profile familiar with the specific waste flows of the stone extraction and processing sector.

4.2.5. Overall Conclusions

In Spain, many of the elements needed to build an advanced curriculum in ornamental stone waste management already exist, although they are currently scattered:

- Cross-disciplinary professional training in waste management.
- A national reference center specializing in natural stone (Marble School).
- High-level university programs in engineering and circular economy.

However, the link between these elements and the specific material flows in the ornamental stone sector is still weak. For the RockChain project, this represents a clear strategic opportunity: to design a modular curriculum that acts as a bridge. This curriculum should connect existing generic skills with specific sector-specific content, digital traceability (blockchain), and innovative ways of adding value.

Rather than duplicating existing offerings, RockChain should focus on interconnecting these scattered strengths, adapting them to the real needs of the ornamental stone sector.

4.3. ROMANIA

4.3.1. Waste Management Applied to Industry and Sustainability

Waste management training programs in Romania have a markedly practical approach and are geared toward regulatory compliance. ANC-accredited vocational training courses, such as Specialist în managementul deșeurilor and Responsabil de mediu, focus on the application of current legislation, the development of waste management plans for companies, and the logistical organization of collection.

At the university level, master's degrees such as Ingineria valorificării deșeurilor offer a more strategic vision, addressing treatment technologies and circular economy indicators. Together, these programs prepare professionals to operate integrated systems in industrial environments, including heavy industries where mineral waste is significant.

4.3.2. Integration of Waste Management in the Ornamental Rock Industry

Currently, none of the programs analysed are specifically geared toward the ornamental stone sector. This sector is addressed indirectly, within general modules on industrial or mining waste. Although the professional profiles trained in Romania theoretically have the necessary skills to manage waste such as sludge or stone cuttings, the lack of specific examples creates a knowledge gap.

Without specific sector-specific training, graduates are likely to be unaware of relevant technical aspects, such as the particular rheological behaviour of stone sludge or the aesthetic limitations of recycled products. Integrating case studies linked to local experiences would significantly improve the applicability of training to the sector.

4.3.3. Emphasis on Legislation and Compliance

Vocational training in Romania places significant emphasis on national and European environmental legislation, such as Law 211/2011. Students must demonstrate detailed knowledge of permits, reporting obligations, and applicable regulations. For mining companies, this provides a solid foundation for regulatory compliance.

However, from the perspective of the ornamental stone sector, there is an opportunity to go beyond basic compliance. Curricula could incorporate content on Best Available Techniques (BAT) for the restoration of mining sites and long-term monitoring of quarry waste, aspects that are often overlooked in more general courses

4.3.4. Final Projects and Case Studies

Master's programs often include applied research projects, frequently in collaboration with local administrations. Currently, these projects focus mainly on municipal or hazardous waste. Redirecting part of this academic effort toward the challenges facing the sector (for example, optimizing sludge treatment in marble cutting workshops) would generate a valuable knowledge base aligned with the objectives of the RockChain project.

4.3.5. Overall Conclusions

Romania has a dense and coherent education system in waste management, with strong technical and legal components. However, the ornamental stone industry is not yet visible as a training context. For a project such as RockChain, the country offers a solid skills base, but with a clear need for sectoral contextualization.

The incorporation of digital tools and the use of real demonstration sites could transform stone waste, currently perceived as an invisible industrial liability, into an attractive field of technical learning and applied innovation.

4.4. CROATIA

4.4.1. Waste Management Applied to Industry and Sustainability

Croatia offers a coherent training ecosystem that combines upper secondary vocational education programs, micro-qualifications for adults, and university degrees in environmental engineering. These programs address key topics such as monitoring, waste sorting, and regional planning.

Given that national policy prioritizes reducing mineral waste disposal, the educational offering is well aligned with sustainability goals. This has enabled more and more technicians to be trained to understand waste not only as a disposal problem, but as part of broader circular strategies.

4.4.2. Integration of Waste Management in the Ornamental Rock Industry

Croatia stands out among the partner countries for having a school specializing in stonemasonry, the Klesarska škola Pučišća, located in a region with a strong tradition in ornamental stone. Initial vocational training offers in-depth knowledge of the properties and processing of stone. However, content on waste management is integrated across the board, for example in the rational use of materials, rather than as specific modules.

On the other hand, university programs in environmental engineering develop advanced skills in construction waste management. The connection between craft training in stonemasonry and the more technical approach of environmental engineering is still largely untapped. The sector would benefit greatly from joint projects addressing the recovery of stone waste and the restoration of quarries.

4.4.3. Emphasis on Legislation and Compliance

Training programs such as *Gospodarenje otpadom* devote significant attention to Croatian and European legislation, preparing professionals to work in recycling centres and interact with inspection authorities. This legal approach reinforces regulatory compliance in quarries. However, current training rarely addresses emerging issues such as data-driven monitoring, Material Passports, or the use of blockchain to track stone by-products throughout the value chain.

4.4.4. Final Projects and Case Studies

University programs often incorporate practical projects. With minor adjustments, these could include ornamental stone-producing regions, such as Brač or Istria, as living labs. Students could analyse scrap and sludge flows to design circular circuits in collaboration with local municipalities. In vocational training, introducing small projects on waste minimization in school workshops would help internalize the circular economy through daily practice.

4.4.5. Overall Conclusions

Croatia brings unique value to the project: a combination of specialized vocational training in stonework and a solid higher education in environmental engineering. The main weakness is not a lack of content, but rather the absence of explicit connections between craft training and systemic waste management.

The strategic opportunity for RockChain lies in creating training “bridges,” where stonemasonry and environmental engineering students collaborate in common learning units. This collaborative methodology would leverage the strengths of both worlds to generate real examples of sectoral innovation, aligned with European circular economy objectives.

5. BEST PRACTICES

A comparative analysis of waste management training programs in Germany, Spain, Romania, and Croatia reveals several common elements that characterize the most effective proposals in vocational training (VT), higher education, and continuing education. At the same time, persistent gaps are identified in relation to the ornamental stone industry, especially with regard to the integration of the circular economy and the digital traceability of waste streams.

5.1. Common features of effective waste-management curricula

The analysis identifies five fundamental pillars that define the current standard of quality in waste management education among the partner countries

5.1.1. Clear and well-integrated legal framework

In all four countries, the strongest programs link waste management to a rigorous regulatory framework. Students are trained to understand and apply the waste hierarchy, Extended Producer Responsibility (EPR), and environmental permitting procedures.

- **Romania** and **Germany**: Accredited profiles (such as waste management specialists or environmental managers) make legal compliance and documentation key elements of learning.
- **Spain** and **Croatia**: Vocational training and university programs systematically integrate national legislation and European directives, such as the Waste Framework Directive, into technical modules.

Impact: Graduates are trained to design systems that comply with regulations in industrial settings, an essential skill in highly regulated sectors such as mining and stone processing.

5.1.2. Practical approach to actual waste streams

Effective programs avoid treating waste as an abstract concept, focusing instead on specific categories such as industrial waste, construction and demolition waste (CDW), and mining waste.

- **Germany** and **Spain**: Focus on mineral waste, aggregate recycling, and debris management.
- **Romania**: Master's degrees in engineering address complex flows such as industrial sludge and hazardous waste.
- **Croatia**: Links civil engineering with the planning of regional waste management centers.

Impact: The skills acquired (such as waste classification, segregation, and logistics) are directly transferable to the heavy and bulky waste typical of the ornamental stone industry (sterile material, cuttings, sludge).

5.1.3. Project-based and work-based learning

A recurring strength is the combination of theory and practice.

- **Higher education**: In all countries, programs include theses or final projects developed with companies or public entities.
- **Vocational training**: Dual systems (as in Germany) or on-the-job training (Spain, Croatia) enable learning in real-world environments. In Romania, ANC-accredited courses include applied tasks such as waste management plans for companies.

Impact: This approach offers a direct route to RockChain. Existing frameworks can be easily adapted to include practical cases focused on ornamental stone.

Cross-cutting integration of the circular economy and resource efficiency

Curricula are shifting from a vision focused on waste disposal to one that considers waste as a usable resource.

- **Engineering**: Material flow analysis and life cycle assessment (LCA) are being promoted.
- **Vocational training**: Lot of courses include content on resource efficiency and the use of secondary raw materials.

Impact: Although ornamental stone is rarely mentioned explicitly, the conceptual tools for treating waste as a resource are already in place. This paves the way for the introduction of circular circuits focused on stone by-products (such as recycled aggregates or restoration materials).

5.1.4. Modularity and lifelong-learning orientation

A shared structural feature is the diversity of educational formats, which facilitates continuing education.

- **Specific certifications**: Spain, Romania, and Croatia offer certificates aimed at environmental specialists and managers.
- **Mandatory continuing education**: In Germany, initial training is supplemented by mandatory refresher courses for waste managers in companies.

Impact: This flexibility supports lifelong learning and allows experienced technicians to update their skills without leaving the labor market. This validates RockChain's approach: designing flexible training units that can be easily integrated into both vocational training and higher education.

5.2. Gaps and lessons for a project focused on ornamental stone and circular economy

Despite the positive aspects identified in national education programs, the analysis highlights three critical gaps that directly justify the existence of the RockChain project:

5.2.1. Lack of sector-specific focus on ornamental stone

Most educational programs adopt a sector-neutral perspective, classifying waste into broad categories such as "*construction and demolition waste*" or "*industrial waste*." Even in countries with a strong tradition in natural stone, such as Spain or Croatia, the content rarely addresses the technical challenges specific to the sector. In particular, generalist courses do not usually include:

- The specific physical and environmental characteristics of the sludge generated in stone cutting (such as filtration cakes).
- The management of quarry waste as a long-term environmental and landscape liability.
- The design of recycled or hybrid products from stone waste, such as artificial stones.

Although there are specialized schools, environmental aspects are usually dealt with implicitly, without being consolidated as a structured training field with innovation indicators.

5.2.2. Fragmentation between technical, environmental, and digital skills

A recurring weakness is the lack of connection between key disciplines, which creates a "silo" effect. Currently, three essential skill sets are taught separately:

- Technical: Cutting, processing, and quarry operation (vocational training).
- Environmental: Waste hierarchy and recovery routes (engineering).
- Digital: Traceability and data monitoring (IT).

Quarrying programs are rarely linked to environmental engineering, and virtually none of the programs mapped integrate digital traceability tools, such as blockchain, into waste management teaching. This limits graduates' ability to design integrated solutions, where technical efficiency and environmental transparency reinforce each other.

5.2.3. Underuse of projects applied to the stone sector

Although project-based learning is a widely used methodology, cases focused on ornamental stone are scarce. Final projects tend to revolve around municipal waste or wastewater.

This represents a missed opportunity: the stone sector offers complex and multidimensional problems spanning landscape, materials, and circularity, ideal for interdisciplinary student work.

5.3. Summary of recommendations for RockChain

Based on the best practices and gaps identified, the following roadmap is proposed for the development of the RockChain curriculum:

5.3.1. Leverage existing strengths

There is no need to start from scratch. The legal, technological, and circular economy foundations already present in partner countries should be reused and explicitly linked to the waste streams specific to the ornamental stone sector (sludge, cuttings, tailings, and stone-based demolition waste).

5.3.2. Give visibility to the sector in projects and learning scenarios

Convert project-based learning into specific challenges for the sector, using real or simulated data from quarries and processing plants as a basis for tasks, case studies, or serious games.

5.3.3. Overcome fragmentation between technical, environmental, and digital skills

Design learning outcomes that simultaneously integrate:

- Process knowledge (stone extraction and transformation).
- Environmental management (waste hierarchy, recovery routes).
- Digital traceability (data recording, basic blockchain concepts).

5.3.4. Use modular formats compatible with vocational training, university, and continuing education

Structure RockChain as a set of short, cumulative modules that can be easily integrated into vocational training cycles, university programs, and adult education, adding value without the need to reform existing curricula.

5.3.5. Positioning ornamental stone as a European pilot case

Leveraging the complementary strengths of Germany, Spain, Romania, and Croatia to present the stone sector as a model of innovation where the principles of circular economy, advanced waste management technologies, and digital traceability can be tested within the Erasmus+ context.

6. CONCLUSIONS

A comparative review of waste management training programs in Germany, Spain, Romania, and Croatia reveals an evolving educational landscape, but one that still has significant structural gaps when it comes to the ornamental stone sector.

On the one hand, waste management is a well-established discipline: there are dual training professional profiles in recycling and the environment, accredited specializations, and a wide range of undergraduate and graduate degrees in engineering. On the other hand, this offering remains largely horizontal: it is organized around general categories such as urban or construction waste, with few specific references to the material flows and operational realities of ornamental stone.

One of the most relevant findings is the disconnect between the technical soundness of waste management systems and the absence of specific content in training plans. Partner countries have a good grasp of key concepts such as the waste hierarchy, regulatory compliance, and the circular economy. However, these skills rarely reach the professional profiles closest to the sector: quarry operators, processing plant workers, or managers in SMEs.

The problem is not a lack of training, but rather its misalignment: existing programs are too general or academic to address specific challenges such as cutting mud management, quarry waste rock, or processing residues.

From a methodological point of view, all the countries analyzed show a clear preference for combining theory and practice. Dual vocational training systems allow learning in real work contexts, and university studies require the completion of applied projects.

This approach is ideal for a sector such as ornamental stone, where waste is visible, abundant, and complex. Activities such as planning sludge treatment or designing strategies to restore quarries are ideal training scenarios for project-based work and learning based on games or simulations.

In all countries, training places a strong emphasis on legislation and documentation. Professionals learn to interpret regulations, keep records, and interact with authorities. This regulatory foundation opens up a strategic opportunity: the same principles that underpin regulatory compliance can be extended to the use of digital traceability systems.

Thus, current training focused on “documentary compliance” can evolve towards digital transparency, incorporating tools such as blockchain to track stone waste and recycled materials.

A persistent obstacle is that many advanced programs in waste management are aimed at university or engineering profiles. There are few structured offerings for technical or

middle management profiles, even though they are the ones who make daily decisions about waste management in quarries or plants.

To activate the circular potential of the sector, it is essential to adapt training programs in terms of language, duration, and access requirements so that they are truly accessible to these operational profiles.

This analysis suggests that the best strategy for RockChain is not to replicate what already exists, but rather to complement and redirect current programs. The challenge lies in translating each country's strengths into specific lessons for the ornamental stone sector:

- Raise awareness of stone waste as an issue.
- Directly connecting the principles of the circular economy with the “quarry to market” value chain.
- Integrating digital traceability in a way that is useful and understandable for operators.

In this way, RockChain can fill a real training gap in current systems, while aligning itself with the trends and public policy priorities identified in this comparative review.

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- **Figure 1**

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- **Figure 2**

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