



Youth4Governance

The Silent Giant

Lebanon's Quarry Sector



SIREN

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Executive Summary

The **Youth for Governance (Y4G) 2024** program, in collaboration with **Siren**, the **Ministry of Environment (MoE)**, and the **Faculty of Law and Political Science at USJ**, embarked on a transformative project aimed at restructuring **Lebanon's quarry sector**. With a focus on addressing long-standing environmental challenges and modernizing the regulatory framework, the project's core mission was to create a sustainable quarrying system that balanced economic needs with environmental protection.

Lebanon's quarry sector has long been marked by illegal operations, environmental degradation, and a lack of effective oversight. Despite the regulations introduced in 2002, over **1,247** quarries continued to operate until 2019, accumulating an estimated **\$3.7 billion** in uncollected fines, including **\$2.4 billion** representing environmental damage and rehabilitation costs.

The project had **three primary objectives**, each aimed at addressing critical issues within the sector.

The first objective focused on improving **quarry monitoring** through advanced tools. Traditional monitoring methods have been insufficient in tracking illegal expansions, environmental violations, and rehabilitation efforts. The project introduced an **AI-driven satellite imagery** solution capable of accurately detecting quarry expansions, measuring area usage, and providing real-time updates on rehabilitation progress. This technology allowed the MoE to monitor quarries remotely and track changes in quarry size, depth, and extraction volumes, providing a powerful tool to enforce regulations and ensure compliance.

Building a sustainable quarrying sector was the second critical objective. The project identified key areas for improvement, including rehabilitation planning, the connection between the cement sector and quarry operations, and decarbonization efforts. Rehabilitation was a major challenge, as the Lebanese legislation mandated it but lacked concrete guidelines. The project proposed **a systemized approach to rehabilitation**, focusing on reforestation, land restoration, and monitoring progress through digital tools.

The project also developed a unique feature called "**Talk to Your Data**," allowing users to query quarry data and receive instant answers, providing better data visualization and enabling data-driven decision-making. This feature supported the MoE in understanding the broader impact of quarries, offering insights into legal and environmental questions, **creating dashboards** to track key metrics, and providing more information for **policy decisions**.

Executive Summary

The third objective was to create a comprehensive framework to **collect unpaid dues** from quarry operators. To streamline this process, **a digitized platform** was developed, allowing the MoE to issue and track collection orders, making the process more transparent and efficient. The platform included automated systems ensuring timely notifications to operators and integrated real-time data to track payments and compliance.

Additionally, an **AI legal chatbot** was introduced as a critical tool for the Litigation Department (LD). With over 1,200 collection orders being issued with an expected wave of legal appeals, the chatbot simplifies legal document analysis, offering automated responses and facilitating workflow management for the 80 public defenders handling the cases. This tool expedites the legal process, significantly reducing the burden on human resources and helping the department handle the anticipated surge in litigation more effectively.

Finally, a comprehensive **survey** was conducted to assess the impact of quarry operations on local communities in regions hosting the seven largest quarrying sites. The survey revealed that while compensation and job creation within quarries could mitigate political resistance, residents not benefiting economically were more likely to oppose quarrying activities. This insight emphasized the need for **balanced policies that address both environmental concerns and economic development**.

This project not only considered immediate concerns in the quarrying sector but also laid the foundation for long-term sustainability. By **integrating digital solutions**, enhancing monitoring through AI, and aligning sector operations with market needs, this project represented a turning point in Lebanon, paving the way for **true environmental justice**.

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01

Introduction

Youth4Governance: Who Are We?

Created in 2021 by a group of USJ Alumni at Siren, Youth4Governance is an internship program that engages students, universities, and public administration in the drive for more accountable, transparent, and effective governance in Lebanon.



28 students conducted a perception study surveying opinions among the general public, civil servants, and Central Inspection staff on Lebanese public administration.

Click [here](#) for the full report.



42 students performed a survey across Lebanon to assess the reach of the ongoing Electronic Social Safety Net (ESSN) project in Lebanon.

Click [here](#) for the full report.



30 students were mobilized to reconstitute the Traffic Management Office (Nefaa) as a model of good governance, fiscal responsibility, and public service delivery.

Click [here](#) for the full report.



The Quarrying Sector: An Overlooked Crisis

Often overlooked, quarries are more than just stone—they reshape Lebanon’s landscapes, communities, and lives. This sector stands at the crossroads of Lebanon’s natural beauty and economic demands, making it a crucial focus for the future. However, the quarrying industry has long been plagued by corruption and mismanagement, with illegal permits, unauthorized expansion, and rampant resource exploitation. These practices not only damage the environment but also deplete public resources, bypassing legal frameworks and thereby highlighting the urgent need for reform.

The Hidden Environmental Crisis

The damage left by quarrying extends far beyond the pits, impacting forests, wildlife, and water sources. Lebanon’s rich environmental diversity is under constant threat from unchecked quarrying, making it a silent yet significant crisis. Deforestation, loss of biodiversity, and the destruction of water resources are just some of the environmental consequences that require immediate attention.



An Economic Engine with Hidden Costs

Quarrying fuels Lebanon’s construction industry, driving the demand for cement and building materials. However, this economic driver comes at a steep cost. Illegal operations avoid taxation, depriving the government of much-needed revenue, especially during an economic crisis. The complex dilemma of balancing economic benefits with environmental sustainability makes this sector a battleground for long-term planning.



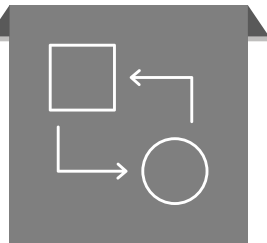
The Human Toll

The human cost of quarrying is profound. Individuals living near quarries face a host of health and social problems. Dust-filled air, noise pollution, and hazardous working conditions contribute to respiratory issues, stress, and even displacement. These invisible struggles disproportionately affect marginalized communities, making this a pressing social justice issue.



Governance in the Spotlight

The quarrying sector reflects Lebanon’s broader governance crisis. Corruption, weak regulatory enforcement, and political interference create an environment ripe for exploitation. The sector is a clear example of how governance failures allow illegal operations to thrive, and how accountability and transparency are essential for reform. This makes the quarrying industry a focal point for understanding governance challenges in Lebanon.



Amid crisis, an opportunity to change

Lebanon's quarrying sector faces complex challenges, yet every crisis presents a unique opportunity for impactful transformation. The 2024 Y4G Program focused on driving sustainable solutions through a comprehensive, multidisciplinary approach. Built on three strategic pillars, this project provided a clear, actionable roadmap for reform to generate long-term outcomes.

Monitor the quarries



Context: The MoE, like many other governmental entities (post-crisis), lacked sufficient human and material resources to independently carry out effective monitoring.

Objective: Implement a continuous, AI-driven monitoring system that allows real-time data collection and analysis, ensuring monitoring and compliance with environmental regulations.

Build a sustainable sector



Context : The quarrying sector has the potential to make significant contributions to the economy, but it must do so while preserving the environment.

Objective: Transform Lebanon's quarry sector into a sustainability model by aligning with market needs, promoting decarbonization, and implementing comprehensive land rehabilitation measures.

Collect the dues



Context: The quarries' environmental dues were estimated at \$2.4 billion, representing the cost of environmental degradation (\$588 million) and cost of rehabilitation (\$1.9 billion). This amount was to be collected by the MoE.

Objective: Deploy a streamlined, transparent collection process of environmental dues from quarry operators using advanced digital tracking systems and legal enforcement.

Driving Change through Fieldwork, Technology, and Research

The Y4G team followed 3 mainstreams: on-site field work, technology, and research.



On-site field work

- Archive organization
- Surveys
- Main stakeholder visits



AI and technology

- AI chatbot
- Process digitization
- AI satellite imagery



Research and analysis

- In-depth legal and institutional review

02

Overview

Quarries in Lebanon

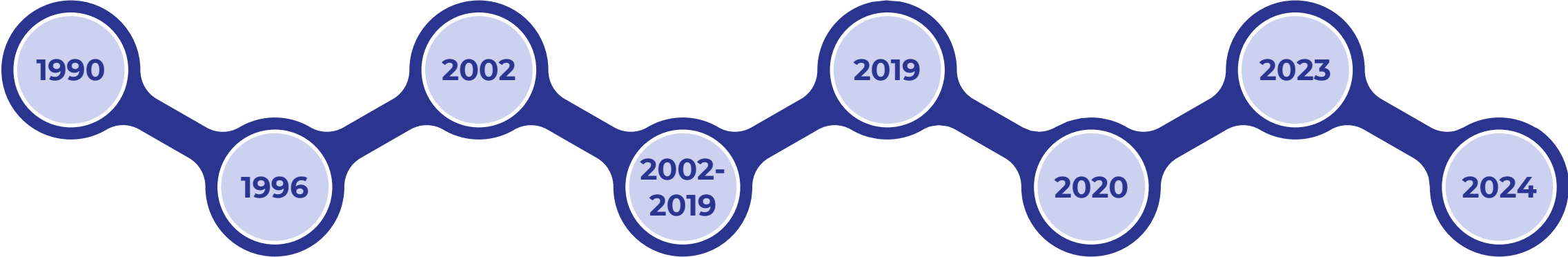
Lebanon's limestone-rich landscape has been at the heart of quarrying for decades, with a boom following the post-war reconstruction. Despite efforts to regulate the sector starting in 2002, the industry had expanded, fueled by legal loopholes and weak enforcement. The following outlines key moments in the evolution of Lebanon's quarrying sector regulations.

With reconstruction in full swing after the end of the Lebanese war, quarrying activity surged to meet the demand for cement and other materials vital for rebuilding Lebanon

A milestone in environmental regulation, Law 444 and Decree 8803 set the groundwork for legal quarrying

The Lebanese Armed Forces were tasked with surveying quarries across Lebanon, revealing widespread illegal operations and the sector's disorganization

In collaboration with UNDP, the Ministry of Environment detailed the environmental and financial costs of quarrying, totaling \$3.7 billion owed in dues and rehabilitation fees



Decree No.5616 aimed to address quarry licensing and environmental concerns, though enforcement remained weak

Despite regulations, weak governance led to rampant, unauthorized quarrying, causing severe environmental degradation and loss of state revenues

Decree 6569 introduced a framework for collecting quarry dues, marking the first major financial regulation of the sector in an effort to recover unpaid revenues

The Ministry of Environment initiated the process of collecting quarry dues, aiming to recover lost revenue and enforce environmental accountability

Quarries in Lebanon

Lebanon's 1,247 quarries cover an area of 26.65 km², equivalent to .25% of the nation's territory or 70% of Beirut's size. From 2007 to 2018, these quarries extracted 198 million m³ of materials, averaging 3 million m³ annually. This diverse industry extracts gravel, mosaic, sand, limestone, and various rocks.

1,247
Number of quarries

1
Quarry currently operating with a license

198,001,972 m³
Volume extracted

26.65 Km²
Area used

Mount Lebanon
Highest number of quarries

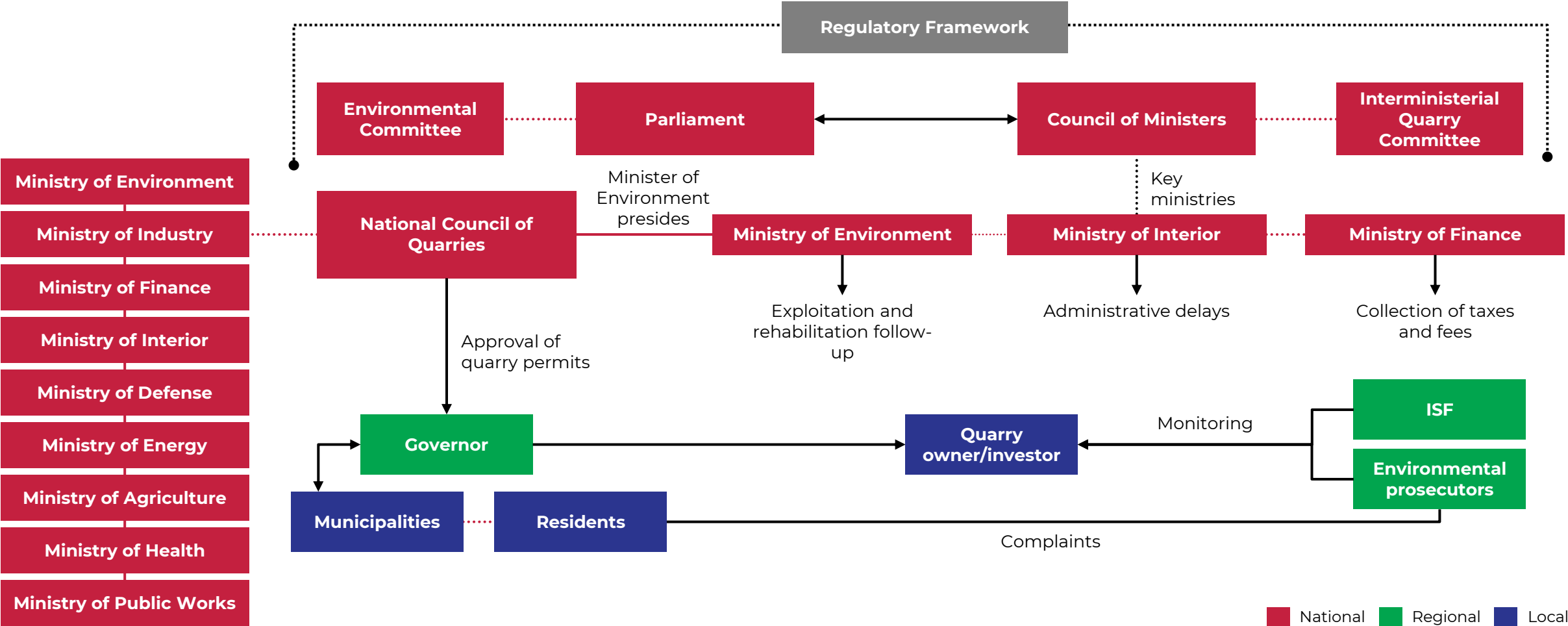
\$3.7 billion
Dues owed to the government



Distribution of Quarries in Lebanon. Yellow areas represent quarries identified by the Y4G team, red areas denote quarries mapped by environmental expert Antoine Atallah, and green areas show the designated zones according to the National Master Plan for Quarrying Activities.

Institutional Mapping of the Quarry Sector in Lebanon

The quarry sector involves a wide network of institutions and public entities at the national, regional, and local levels.



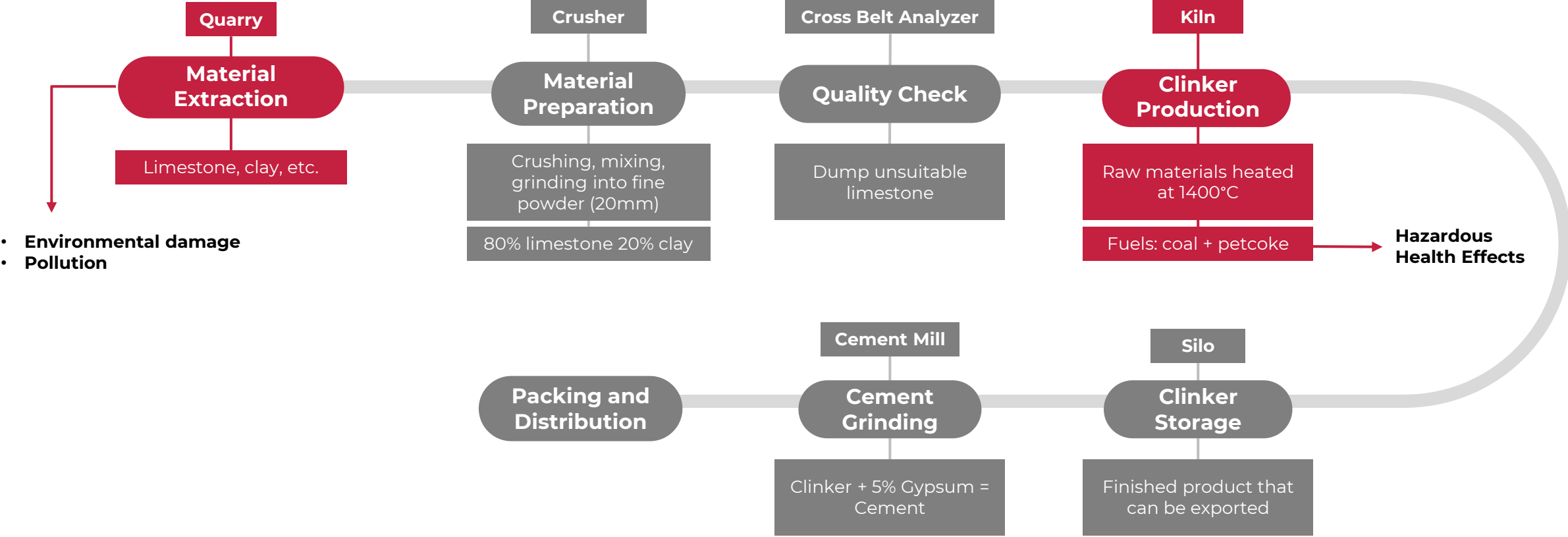
Regulatory Framework Governing Quarries in Lebanon

The quarrying sector in Lebanon operates under a detailed regulatory framework aimed at addressing environmental, safety, and operational standards. This table summarizes the most significant legal texts that have shaped and governed quarrying operations, rehabilitation efforts, and environmental safeguards over the years.

Legal text	Issued by	Overview
Decree no. 5616/1996	Government	One of the first regulations to address quarrying activities, setting guidelines for permits, quarry locations, and environmental considerations.
Decision no.1/186- 1997	Ministry of Environment	Contains detailed documents and specific conditions for investing in quarries related to cement activities, including mandatory rehabilitation requirements.
Law 444/2002	Parliament	Provides a general framework for environmental protection in Lebanon, including stipulations related to the impact of quarries on the environment. It emphasizes the need for environmental assessments and regulations to mitigate quarry impacts.
Decree 8803/2002	Government	Issued to complement Law no. 444, it outlines regulations for quarries and crushers. It sets conditions for the establishment of quarries, their operations, and the environmental safeguards they must follow.
Decree 9222/2002	Government	Internal regulations of the National Council of Quarries (NCQ).
Decision no.1/48-2009	Ministry of Environment	Applies to old quarries that remain unrehabilitated.
Decree no.2366/2009	Government	Though not solely focused on quarries, this plan provides guidelines on how quarries should be integrated into land use planning, emphasizing the controlled and sustainable exploitation of natural resources.
Decree no. 6569/2020	Government	Defines the scope of collecting dues from quarry operators and further refines the regulatory process governing quarry activities.

Concrete Consequences: The Environmental Cost of Cement Demand

Cement production accounts for 7% of global CO₂ emissions, making it a key contributor to global warming. The critical stages of cement production involve material extraction from quarries, which leads to environmental damage and pollution, and clinker production, which relies on coal and petcoke. Both pose significant health risks.



Cement Demand Through the Years: Shaped by Conflict and Recovery

Over the past two decades, cement deliveries have fluctuated significantly due to political and economic events, including regional conflicts and reconstruction efforts. The key periods included growth in the late 1990s and early 2000s, downturns during crises, and a recovery starting in 2013.

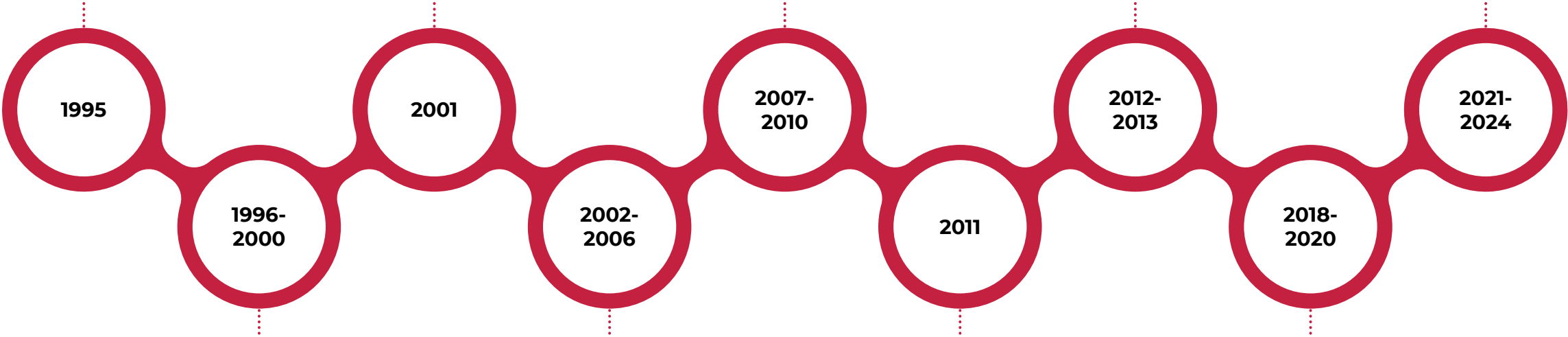
Strong cement demand driven by **urbanization** and **post-war rebuilding**. Per Capita Consumption: 1,309 kg

Improvement in political stability and **withdrawal of Israeli troops** boosted reconstruction activities

Cement deliveries surged from 3.83 Mt to over 5.20 Mt, with per capita consumption rising by 30%

Cement deliveries fell 4.3% to 5.31 Mt due to the **Syrian war**. Recovery began after the 2012 downturn

Beginning of the recovery after the housing crisis



1995

2001

2007-2010

2012-2013

2021-2024

1996-2000

2002-2006

2011

2018-2020

Israeli attacks, including "Operation Grapes of Wrath," disrupted the industry. Per Capita Consumption dropped by 34.7% to 810 kg/person

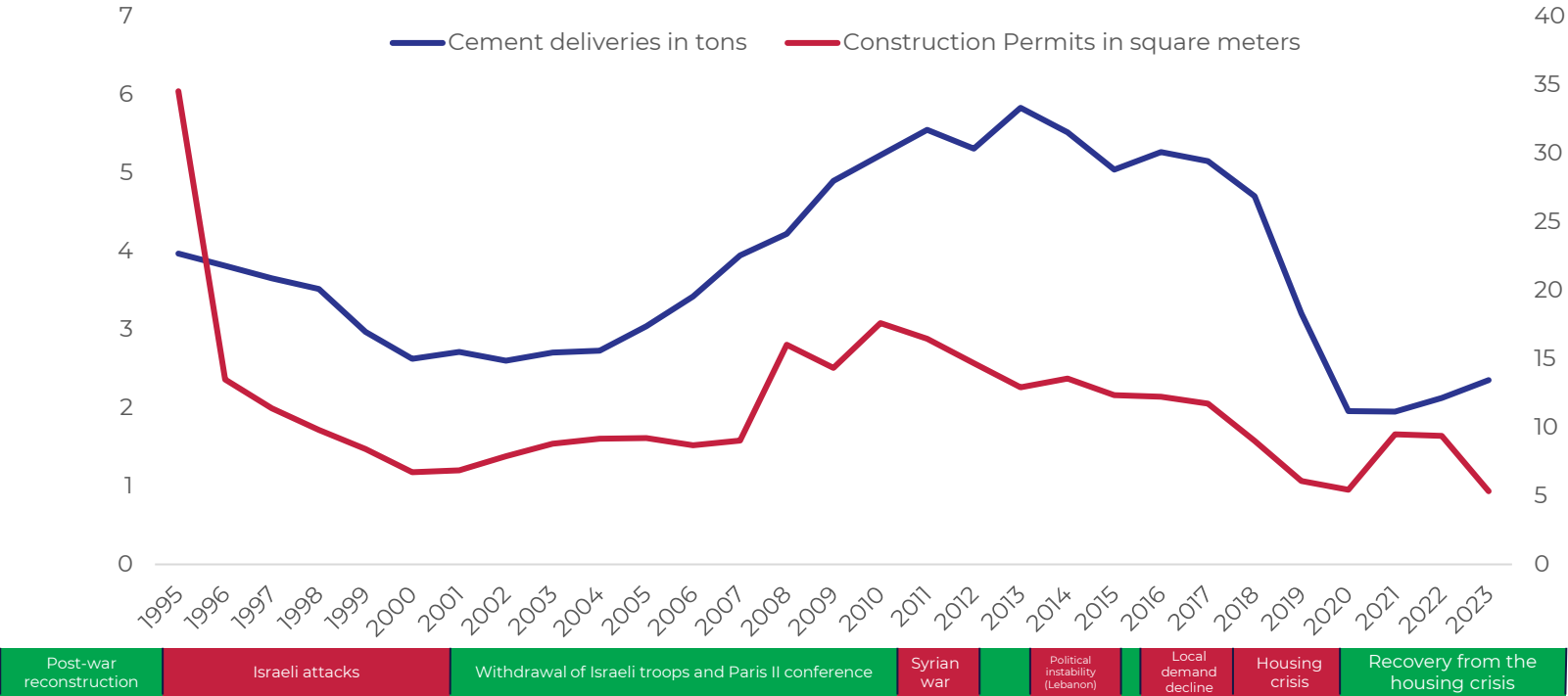
The **Paris II Conference** (2002) provided a boost to the cement industry

Deliveries grew by 6.1% but exports to Syria halved to 222,065 tons **due to the Syrian war**

Cement deliveries dropped primarily due to the **housing crisis**, along with the broader **economic and political challenges**

Cement Prices: Resilient or Manipulated

Any increase in the number of construction permits typically leads to a rise in the demand for cement. Despite a slowdown in real estate activity, cement prices in Lebanon preserved their average price, largely due to governance support and export activities. In 2013, prices held steady even as energy costs decreased, a significant factor considering the cement industry’s heavy reliance on energy.



Source: Banque du Liban, statistics and research, main indicators, cement deliveries, construction permits

03

Monitor the quarries

Monitoring the Quarries: Roles and Responsibilities

Multiple entities were responsible for monitoring the quarries, including the MoE, the ISF, and environmental prosecutors. However, due to the current economic crisis, these entities lacked the necessary resources to continue fulfilling their roles effectively.

Ministry of Environment



Regulatory Oversight: Ensures compliance with Law No. 444/2002, which governs environmental protection and natural resource management.

Environmental Impact Assessments (EIAs): Reviews and approves EIAs under Decree 8633 (2012), ensuring sustainable quarry operations.

Issuing Permits: Grants environmental permits based on compliance with laws and mitigation measures.

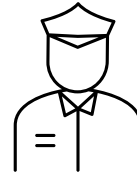
Compliance Monitoring: Oversees adherence to environmental standards, such as dust control and site rehabilitation.

Enforcement: Imposes penalties and sanctions for non-compliance, including fines or halting operations.

Interagency Coordination: Works with agencies like the ISF and municipalities to enforce regulations.

Environmental Restoration: Requires operators to restore quarry sites after operations, ensuring reforestation and land recovery.

ISF



Law Enforcement: Enforces compliance with environmental and operational regulations set by the Ministry of Environment and other relevant authorities.

Support in Inspections: Assists the Ministry of Environment in conducting inspections at quarry sites to ensure operations follow legal requirements.

Control of Illegal Quarrying: Identifies and takes action against illegal quarrying activities, terminating operations that lack permits or violate laws.

Coordination with MoE: Works closely with the Ministry of Environment to ensure the enforcement of penalties, site closures, and compliance with restoration mandates.

Public Order Maintenance: Ensures security during protests or disputes related to quarrying activities and enforces legal orders when necessary.

Environmental Public Prosecutors



Legal Enforcement: Prosecutes cases related to violations of environmental laws and illegal quarrying activities based on reports from the Ministry of Environment and the ISF.

Initiating Legal Actions: Takes legal action against individuals or companies operating quarries without proper permits or violating environmental regulations.

Collaboration with ISF and MoE: Works closely with the ISF and Ministry of Environment to ensure that legal measures are enforced and penalties for violations are applied.

Judicial Oversight: Ensures that environmental crimes, such as illegal extraction and environmental damage, are brought to court and handled in accordance with the law.

Imposing Sanctions: Recommends fines, operational halts, or imprisonment for offenders based on the severity of the environmental violations.

The Capacity of the Ministry of Environment

According to internal regulations, the MoE must have 215 active employees. However, due to the ongoing economic crisis, the ministry operates with only 60 staff members across all ranks. This severe shortage, coupled with inadequate resources like transportation, significantly hampers the ministry's ability to effectively monitor quarries.

Department	Number specified by Decree 2275/2009	Actual Number
Registrar	31	15
Service of Environmental Guidance	15	7
Service of Urban Environment	24	6
Service of Natural Resources	22	10
Service of Environmental Technology	23	10
Service of Planning and Programming	26	8
Secretariat of the Minister	/	3
Environmental Police	73	/
General Director	/	2
TOTAL	215	61

The Service of Natural Resources

The Service of Natural Resources, with only 10 employees, monitors and regulates all quarry operations in Lebanon.

Tasks

Oversees quarry operations, ensuring compliance with environmental regulations and conducts field inspections.

Limitations

Staff shortages and a lack of resources, such as transportation and equipment, severely limit the team's capacity to perform these tasks appropriately.

Digital Solutions for Enhanced Quarry Monitoring

As staffing and resources remain limited, digital tools provide a way to monitor quarry operations efficiently. By using satellite imagery and artificial intelligence, the MoE tracks quarry activities remotely and in real time.

A specialized model was developed, utilizing satellite imagery and AI, to enable efficient and accurate monitoring of quarries.

1

Train the AI Model

AI models were trained using satellite imagery to recognize quarry sites based on pre-labeled data.

2

Scan and Process Images

High-resolution images from platforms like Google Earth Engine, Sentinel Hub, and QGIS were scanned and processed to identify quarries.

3

Detect Quarry Features

The AI model detected quarry boundaries, marking them for further analysis using bounding boxes.

4

Segmentation Process

The detected quarries were passed through the segmentation model, which outlined the exact boundaries of the quarry sites.

5

Ensure Continuous Monitoring and Updates

Continuous updates of quarry data allowed for long-term analysis and decision-making.

6

Monitor Changes Over Time

Monitoring helped track quarry activity over time, allowing authorities to detect expansions.

7

Overlay Data and Compare:

Data from different sources - AI-detected quarries, historical data, and military reports - was overlaid to ensure comprehensive validation.

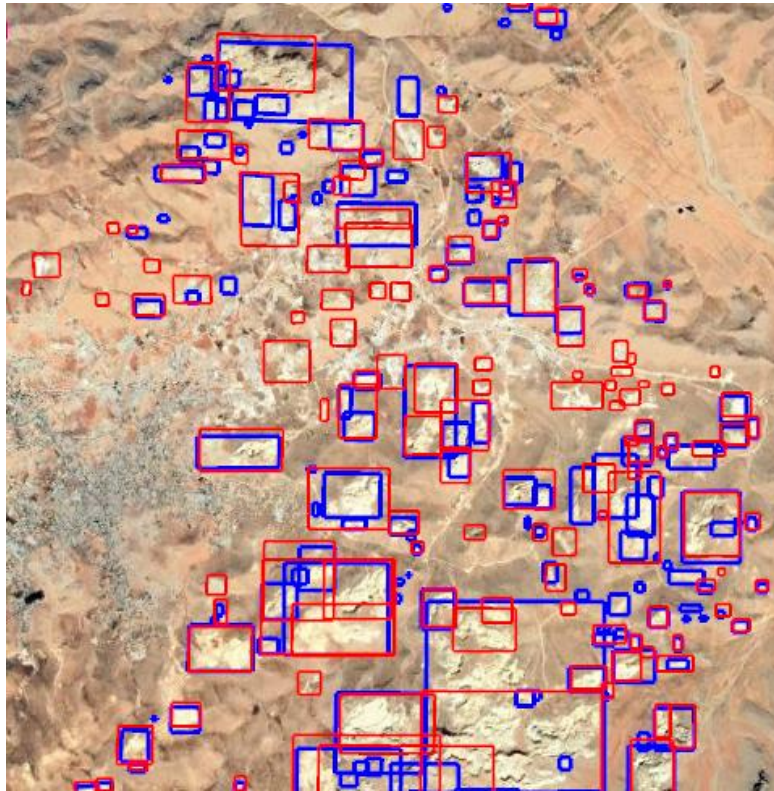
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Generate GeoJSON Files

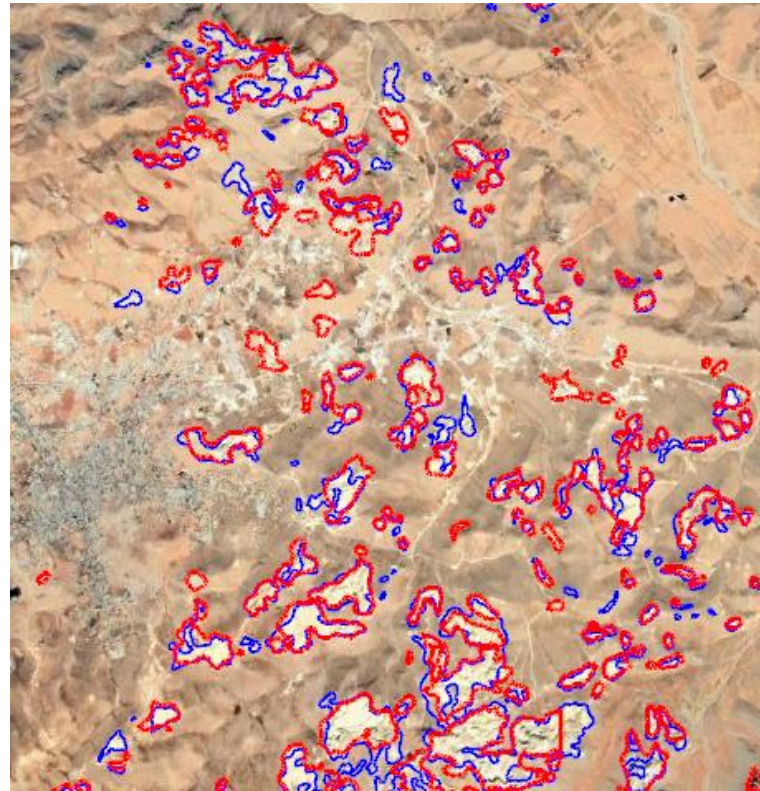
The detected quarry boundaries were converted into GeoJSON files for accurate geolocation and mapping on platforms like Google Earth Pro.

Visualizing Quarries with AI

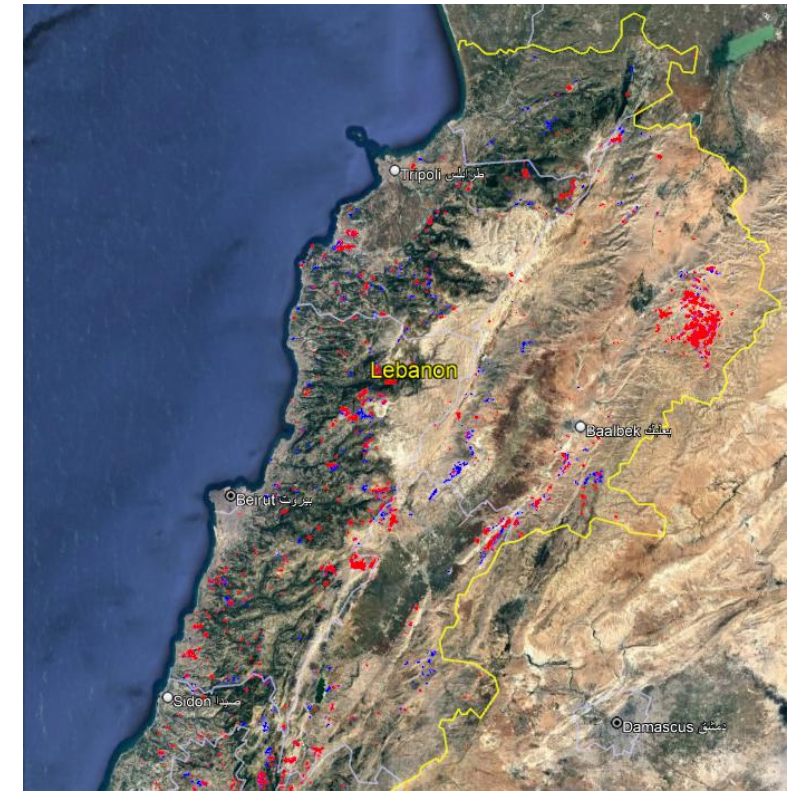
A comprehensive approach to quarry mapping is achieved by overlaying AI-detected quarries (in red), historical data from Antoine Atallah (in blue), and Lebanese military reports. This visualization helps the Ministry of Environment ensure accurate quarry detection and monitor changes in quarry activities over time, leading to better oversight and enforcement.



Detection



Segmentation



Overlaying

Real-Time Detection, Monitoring and Rehabilitation

This tool enables precise monitoring of quarries, tracking new sites, expansions, and rehabilitation efforts. It provides real-time data on extraction volumes and depth, empowering the Ministry of Environment to ensure sustainable practices and environmental protection.

Quarry Detection

Offers real-time detection of new quarries through AI and satellite integration. This allows the MoE to immediately identify unauthorized operations, enabling rapid intervention and coordination with relevant stakeholders to prevent environmental damage.

Continuous Area Monitoring

Provides precise tracking of the area used by quarries. This ensures that expansions beyond the permitted boundaries are instantly flagged, allowing for proactive monitoring of quarry operations and ensuring compliance with land-use regulations.

Rehabilitation Monitoring (ongoing)

Tracks rehabilitation progress, offering detailed insights into the number and types of trees planted, soil recovery, and vegetation growth. This feature supports the MoE's mission to ensure that post-quarry land restoration meets ecological and sustainability standards, enhancing long-term environmental recovery.

Volume and Depth Insights (ongoing)

Analyzes volumetric and depth measurements of extracted materials, providing the MoE with critical data on the environmental footprint of quarry operations. This feature revolutionizes resource management by giving the ministry the ability to assess the environmental and geological impact of extraction in real time.

04

Sustainable sector

Building a Sustainable Quarry Sector: A Holistic Approach

To develop a truly sustainable quarry sector in Lebanon, it is essential to view the entire ecosystem from the environmental rehabilitation of quarry sites to the production of cement and ensure that all processes are aligned with market demands.

Rehabilitation

Rehabilitation of quarry sites is crucial for restoring ecosystems and ensuring that natural resources are not permanently lost.



Licensing and market needs

Market needs should guide the issuance of quarrying licenses, ensuring that the extraction of resources is aligned with actual demand, rather than unregulated excess.



By connecting rehabilitation efforts, decarbonization in cement production, market demand analysis, and a sustainable licensing framework, Lebanon can transition to a more responsible and future-oriented quarry sector. This integrated approach ensures that the sector operates within ecological limits, prioritizes future generations, and minimizes irreversible damage to the environment.

Rehabilitation: Restoring Nature, Securing the Future

Lebanese quarry legislation (Decree 8803/2002) mandates rehabilitation but lacks clear guidelines, rendering the regulation largely ineffective. As a result, over 1,200 quarries remain abandoned, with minimal signs of rehabilitation, making it of critical concern.

Overview:

The National Council of Quarries (NCQ) is responsible for overseeing the rehabilitation process. If an investor fails to rehabilitate a quarry site, the NCQ issues a warning. If non-compliance continues, they issue a refusal and assess whether the investor's guarantee covers the rehabilitation costs. If the guarantee is insufficient, additional fees are collected through official orders. Should the investor still neglect their obligations, the NCQ intervenes to manage the rehabilitation, deducting costs from the guarantee. If this is not sufficient, personal assets may be seized, and the funds collected allow the Ministry of Environment (MoE) to proceed with the rehabilitation.

Challenges:

Unlicensed quarries: Quarries are operating without licenses, as there were no proper guidelines to follow in the early days. This complicates enforcement due to bureaucratic complexities preventing owners from obtaining licenses.

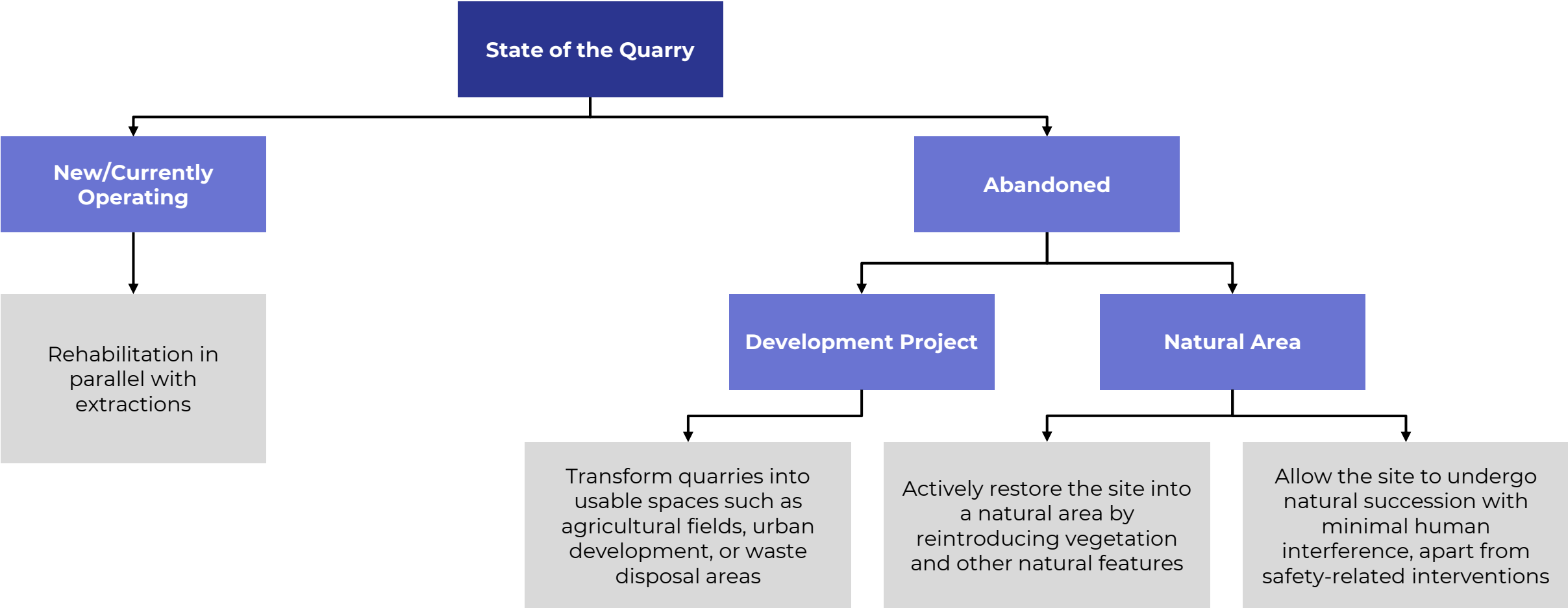
Insufficient Monitoring and Enforcement Capacity: The NCQ and MoE often struggled with limited resources, reducing their ability to monitor the rehabilitation of multiple quarry sites effectively.

Lack of Clear Guidelines for Rehabilitation: Even for licensed quarries, the current legislation lacks detailed rehabilitation guidelines, leaving room for interpretation and inadequate restoration efforts.

Inadequate Financial Guarantees: In some cases, even when guarantees were provided, the amounts were insufficient to cover the full cost of proper rehabilitation, putting additional financial strain on government agencies.

Rehabilitation: An Opportunity

Several scenarios emerged for quarry rehabilitation plans, making it essential to distinguish between recent or currently operating quarries and abandoned ones.



Quarry Rehabilitation: Criteria for Action

Due to the large number of unrehabilitated quarries, which made it impractical to address them all at once, the rehabilitation process was prioritized using well-defined criteria.



Official Status:

If the quarry was still active or abandoned.



Legality:

Compliance with regulations or illegal extraction activities.



Age of Abandonment:

Whether the quarry was operating before or after 2004.



Environment:

If the site was in a natural or urban setting.



Ecological Restoration:

Whether restoration was possible.



Endangered Species:

Presence of rare or endangered species in the area.

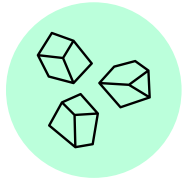
Exporting Quarry Materials: Profit or Long-Term Loss?

While exporting quarry materials may seem economically beneficial, the long-term environmental costs outweigh short-term financial gains. Quarry materials are non-renewable, and their extraction depletes Lebanon's natural reserves. Once exported, these resources are permanently lost, impacting the country's ability to meet future demands.

Lebanon exports significant quantities of sand, gravel, and cement. However, these exports come at a considerable cost to the environment and future generations.



Despite Lebanon's sand being of high quality, its extraction has led to significant environmental degradation, even affecting the quality of the sand itself. It is now cheaper to import sand rather than mine it domestically, raising concerns about unsustainable exploitation.



Lebanon sells gravel for **\$4/m²**, while imports from Turkey are priced at **\$32/m²**. This price discrepancy suggests that Lebanon is underpricing its natural wealth. When accounting for the hidden costs, such as environmental damage, erosion, and pollution, the actual price is even higher.



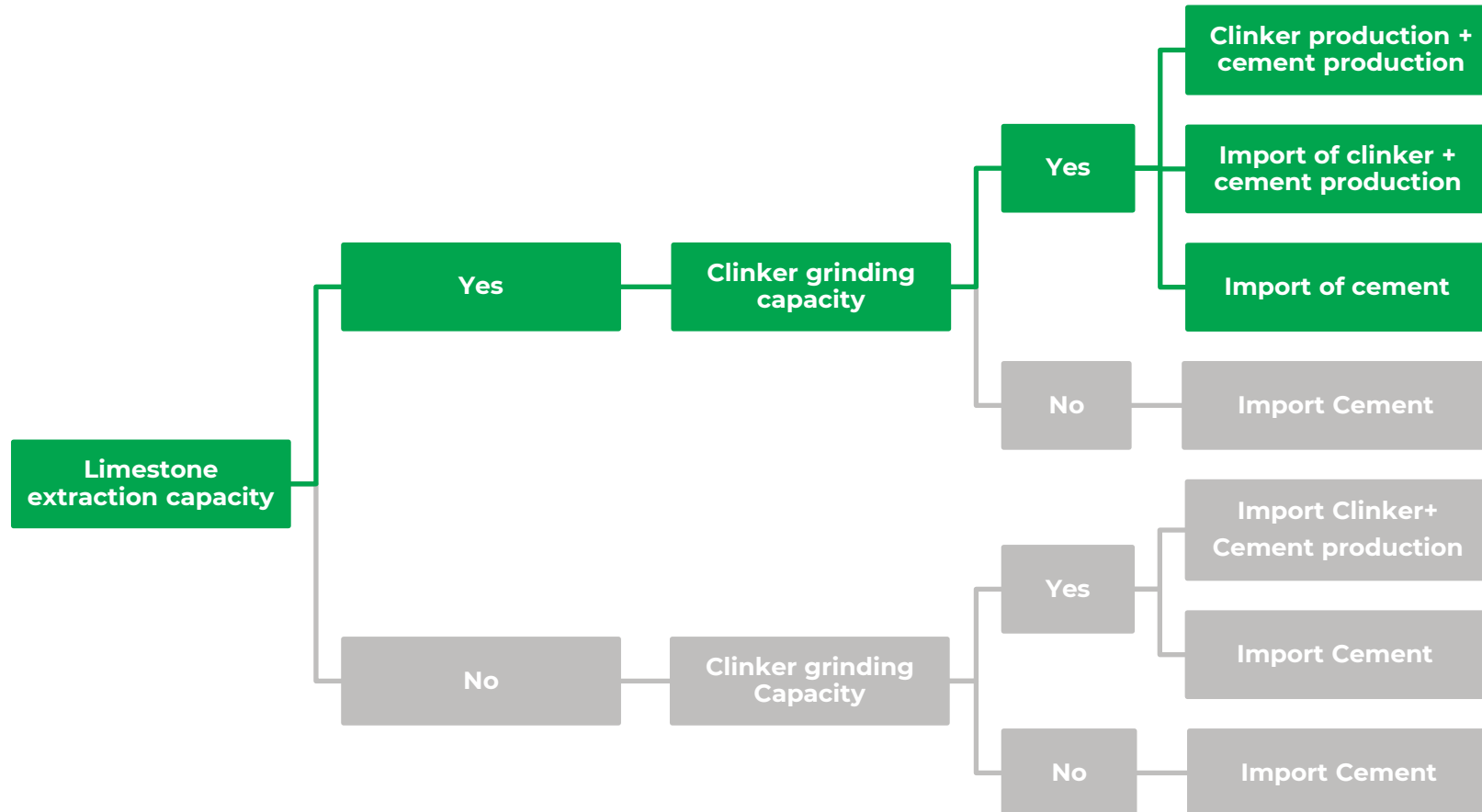
The domestic price of cement is **\$95/ton**, but Lebanese cement companies export cement at **\$45/ton**, nearly half the price (price regulated by the Ministry of Industry).

Lebanon's current export policies

The Ministry of Industry freely grants export permits with import restrictions, encouraging large-scale export while making it harder to import materials. As a result, Lebanon's irreplaceable resources are being transported abroad, with no strategy for long-term sustainability.

Strategic Options for Cement Production in Lebanon

Given Lebanon's rich limestone reserves, the country had three strategic options: produce clinker and cement domestically, import clinker to manufacture cement, or directly import finished cement.



CO2 Emissions Across Four Scenarios

For 2030, four scenarios outline potential CO2 emission trends in the cement sector: Business-as-Usual predicts nearly double emissions; Low-Carbon Growth sees a 1.6x increase; Improved Low-Carbon results in a 1.5x rise; and Accelerated Low-Carbon aims to reduce emissions to below 1.5x current levels through advanced decarbonization strategies.

01	Business-as-Usual (BAU) Scenario	Basis: Emission factors of 2019-20 and projected 2030 cement production. Impact: CO2 emissions nearly double by 2030.
02	Low-Carbon Growth Scenario	Basis: Past emission reduction intensity (1996-2017) and projected 2030 production. Impact: CO2 emissions increase by 1.6x .
03	Improved Low-Carbon Scenario	Basis: Voluntary emission reduction targets by large cement companies. Impact: CO2 emissions increase by 1.5x .
04	Accelerated Low-Carbon Scenario	Basis: Enhanced implementation of key decarbonization strategies (energy efficiency, carbon capture, etc.). Impact: CO2 emissions reduced to the lowest levels by 2030 (<1.5x).

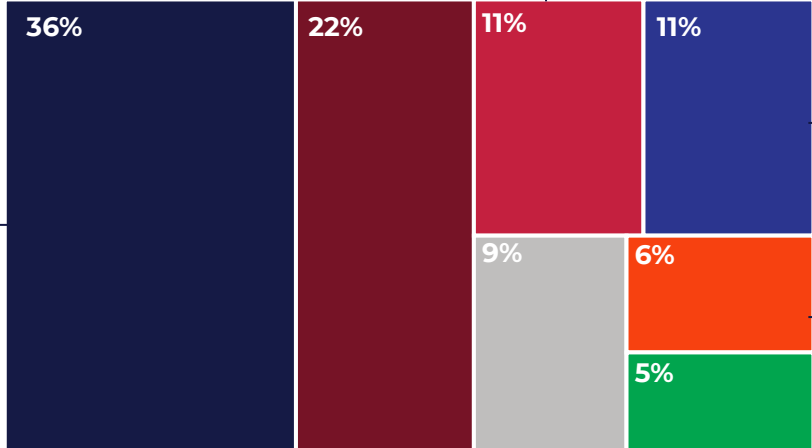
Clinker Production: The Major Source of Carbon Emissions

Clinker production drives the majority of CO² emissions in cement manufacturing, accounting for over **50%** of process emissions and **40%** of thermal emissions. Other stages, such as quarrying and transport, contribute less than **10%** combined, emphasizing the need to focus on clinker for significant emission reductions.

Decarbonizing the Cement Sector

Innovations in material use, energy efficiency, and design are poised to substantially cut emissions in cement production. Forecasts indicate major improvements by 2050, with carbon capture being the most effective method, potentially reducing CO2 output by 36%.

PERCENTAGE CONTRIBUTION TO NET ZERO AND CO2 EMISSION SAVINGS IN 2050



Carbon capture and utilization/storage
Involves **capturing CO2 emissions** from industrial processes and then **utilizing or storing** it.

Savings in clinker production
Substituting petcoke and coal with **alternative fuels**, such as **biomass** and **mixed fuels**.

Efficiency in concrete production
Switching to **industrial concrete batching** reduces CO2 emissions by improving mix accuracy and quality control.

Efficiency in design and construction
Optimize concrete usage, such as adjusting slab geometry, column spacing, and concrete strength, while still meeting performance standards.

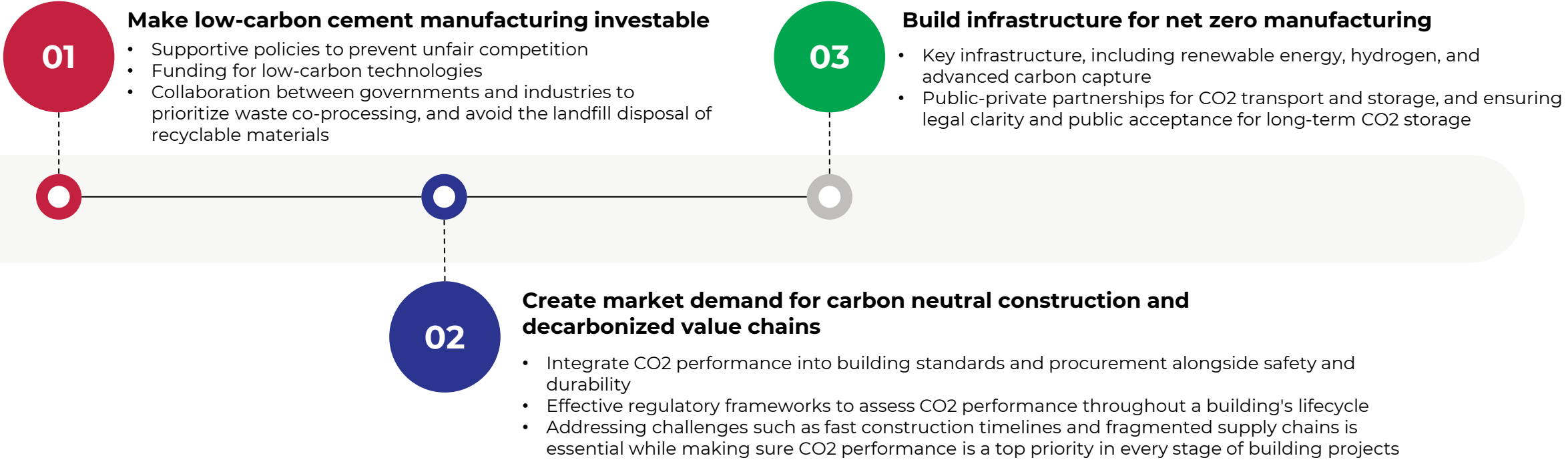
Savings in cement and binders
Clinker substitution with **fly ash, GGBS** (Ground Granulated Blast-furnace Slag) enhances performance.

Decarbonization of electricity
Transitioning to **renewable energy sources** such as wind, solar, and hydro, reducing reliance on fossil fuels.

CO2 Sink: Recarbonation
process by which **concrete absorbs CO2 from the air over time** (carbon dioxide from air + calcium compounds in concrete = calcium carbonate).

Pathway to Net-Zero Concrete: Industry Requirements

Achieving net-zero concrete involves making low-carbon manufacturing investable, creating market demand through effective policies, and building essential infrastructure to support renewable energy and carbon capture technologies.



Sustainable Licensing: Meeting Local Demand

The licensing process for quarry operations in Lebanon is well-defined by law and requires individuals to meet several criteria, including environmental impact assessments, operational plans, and rehabilitation guarantees. However, despite the stringent application process, the licensing system lacks a long-term strategy that aligns with Lebanon's real quarrying needs.

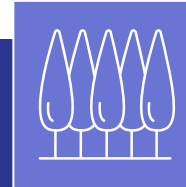
To build a more sustainable quarrying sector, it is essential to adapt the licensing system to Lebanon's actual needs. Quarry licenses should be issued based on market demand, considering:

Local construction needs



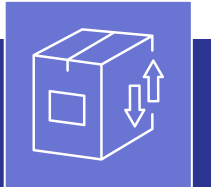
License issuance should align with ongoing and projected construction activity to avoid an oversupply of raw materials.

Environmental capacity



The environmental carrying capacity of specific regions should be assessed before approving any new licenses, ensuring that quarrying does not harm critical ecosystems.

Export limits



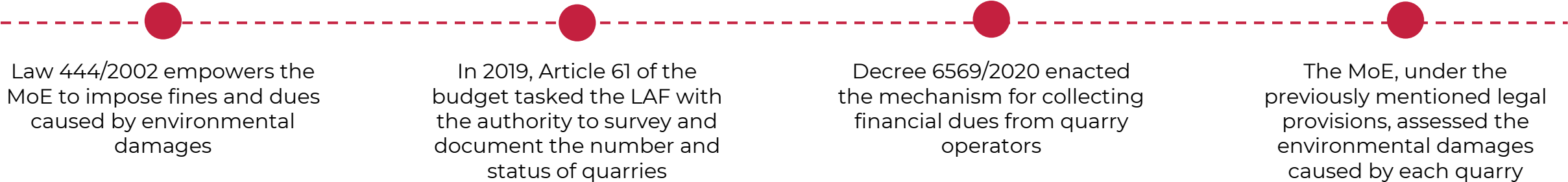
Stricter controls on the export of quarry materials should be implemented, ensuring that Lebanon's resources are used for domestic development rather than foreign markets, which offer little long-term gain for the country.

05

Collect dues

Collecting the Dues: A Path to Accountability

Lebanon's quarries have caused significant environmental damage estimated at \$2.4 billion. This figure includes \$588 million in cumulative environmental degradation and \$1.9 billion required for rehabilitation. However, these costs have largely gone unaddressed due to a lack of regulation enforcement and accountability.



Cost of Environmental Degradation (COED)
\$588 million

The COED refers to the monetary value of damage caused by quarrying activities, such as air and water pollution, loss of biodiversity, and disruption to ecosystems.

The COED is based on scientific assessments and international standards, as calculated by the Ministry of Environment.

Status of collection: **ON GOING**

Cost of rehabilitation
\$1.9 billion

The cost of rehabilitation refers to the estimated cost of restoring the damaged environment to its original or improved condition.

It is a legal requirement for obtaining quarrying licenses. However, numerous quarries operated illegally without obtaining the required licenses, complicating enforcement efforts. The rehabilitation cost must be assessed on a case-by-case basis, factoring in legal complexities and specific environmental damages.

Status of collection: **PENDING**

Collecting the Dues: Valuing the Environmental Damage

In 2023, after calculating the outstanding fees, the MoE decided to collect the environmental dues. To support this effort, the team conducted a legal study in collaboration with FDSP-USJ, ensuring that the most effective processes were in place to assist the MoE in collecting dues, starting with the first phase: the Cost of Environmental Degradation (COED).

1- Send collection order

 <p>MoE Authorization Assess and calculate compensation for environmental damage caused by quarries</p>	 <p>Issuing Collection Orders Issue collection orders based on the calculated damages</p>	 <p>Recipients Investor and quarry owner receive the collection orders</p>	 <p>Notification Process: Notifications sent through LibanPost</p>
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2- Cooperation with public stakeholders

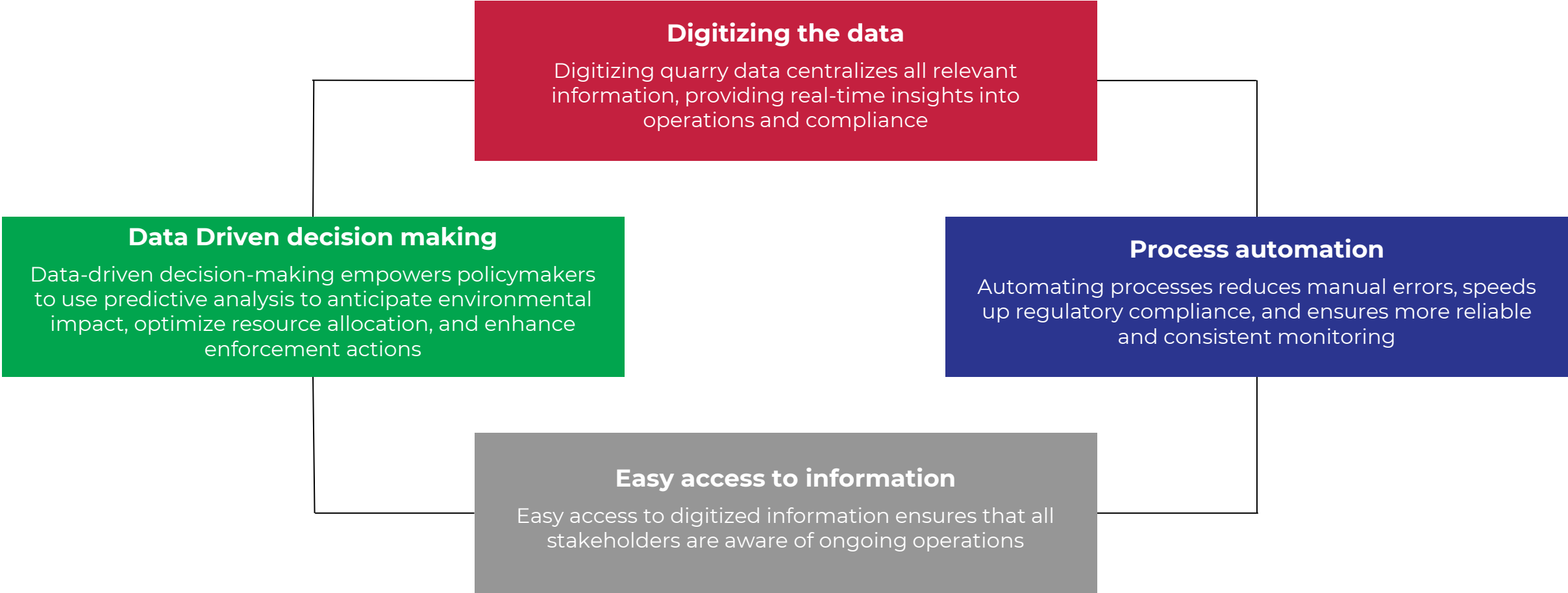
 <p>Coordination with Public Entities Copies of the collection orders sent to the MoF and the LD-MoJ</p>	 <p>Collection and Enforcement Funds processed by the MoF</p>	 <p>Legal Assistance In case of appeals, the LD will assign public defenders to handle the case</p>
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3- Options for investor/quarry owner

 <p>Payment Compliance Investors and owners are required to pay the full amount to avoid further legal action</p>	 <p>Negotiation Investors and owners may negotiate the amount due at a later stage if necessary</p>	 <p>Appeal Process Appeals can be submitted to regional courts if the investor or owner disputes the dues</p>	 <p>Failure to Pay If collection orders are ignored, a formal warning will be issued after two months. Failure to comply may result in the seizure of assets</p>
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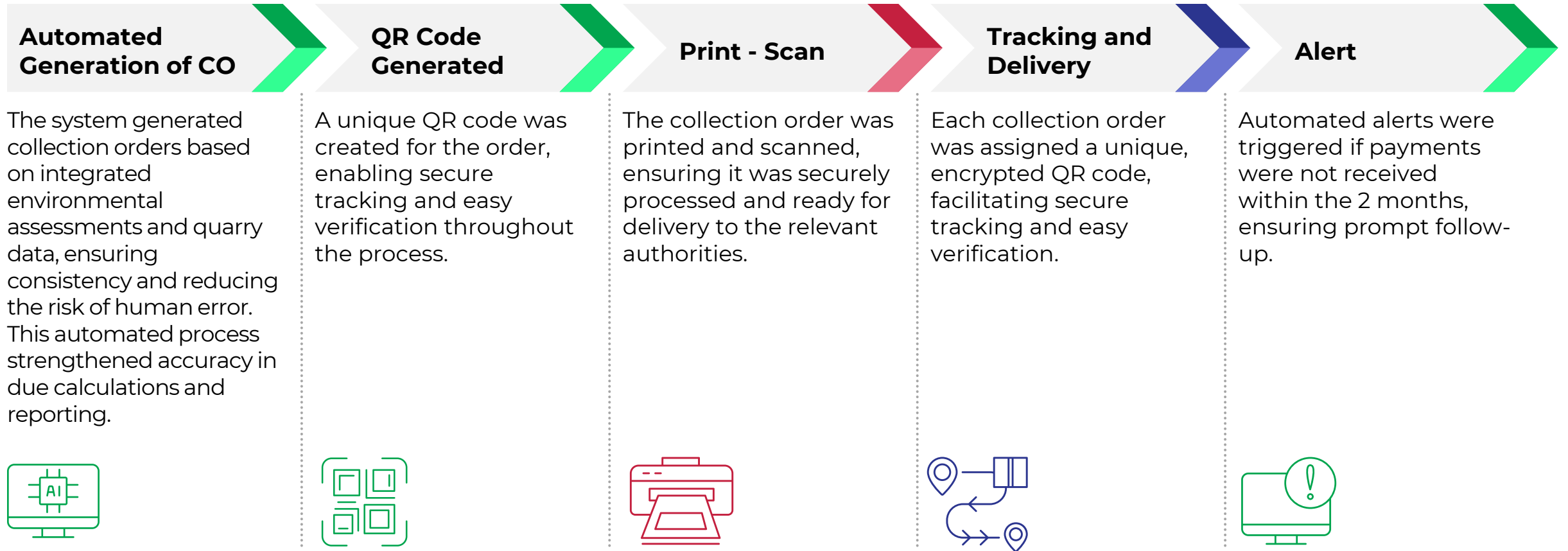
Digitizing the Process: A Leap Toward Efficiency

Digitizing quarry management processes became essential for addressing longstanding inefficiencies, reducing delays in information access, and streamlining the collection of dues. By automating tasks and improving data flow, the platform sought to overcome challenges of manual operations, limited human resources, and regulatory compliance.



Automated Process for Collection Orders

To minimize manual work and interference, the collection order (CO) automatically generated a unique QR code using system data. The entire process, from creation to completion, was updated on the platform.



Manual Automated Both

Centralized Data: A Unified Platform for Quarries

The platform centralized all quarry-related data, improving access and decision-making. It also featured an interactive map and dashboards for enhanced visualization. With these features, it provided a holistic view of the quarry sector.



Quarry data

This platform consolidated data on quarries, owners, and investors, enabling comprehensive tracking of licenses, environmental impact, and compliance.



Files and documents

All quarry-related documents, including ISF reports, NCQ records, and environmental assessments, were securely stored and easily accessible.



Interactive map

An interactive map on the homepage displayed quarry sites based on satellite imagery and previous studies, providing detailed location data.

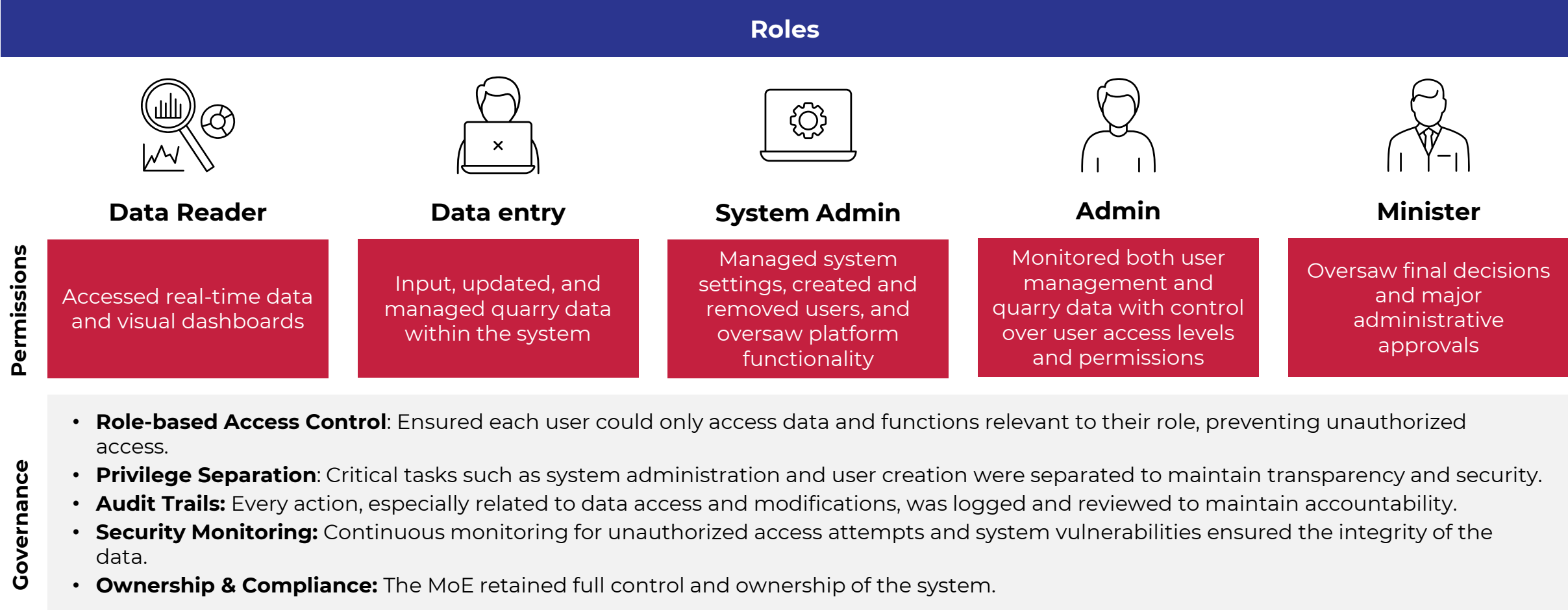


Dashboards

Interactive dashboards offered advanced data visualization, providing insights on quarry activities, financial dues, environmental impact, and operational efficiency.

User Management and Applied Governance

Users were assigned to specific roles, each with distinct permissions to manage quarry data and operations. This approach ensured that users had appropriate access based on their responsibilities, including data entry, data reading, ministerial approval, and administrative tasks.



Moving Forward: Toward an Inter-ministerial Platform

Online notification

Establishes a real-time notification system for quarry operations, payments, and environmental alerts through automated SMS and email updates. This reduces response times, ensures rapid compliance, and creates a direct communication channel between public authorities and quarry operators. Legal reforms are required to enable full automation of notifications.

Integration of all Public Stakeholders

Facilitates seamless collaboration between the MoF, MoE, LD and key public institutions through a unified digital platform. By providing each entity with tailored access, the platform ensures efficient coordination, enhances accountability, and improves policy enforcement. Shares real-time data across ministries, streamlines oversight, and reduces bureaucratic delays.

Digital Signature Implementation

Implements secure digital signatures to accelerate document approvals and administrative processes. This eliminates the need for physical signatures, reduces bureaucratic delays, and increases transparency. It also ensures the security and traceability of all quarry-related decisions and documents.

Interministerial platform

Establishes a unified platform that allows seamless collaboration between all relevant ministries and public institutions, and improves workflow efficiency, decision-making, and enforcement in the quarry sector.

Digitization of all processes

Achieves full digitization of all quarry management processes, including permits, environmental compliance, dues collection, and rehabilitation plans. This eliminates paperwork bottlenecks, reduces administrative delays, and increases transparency across all government levels.

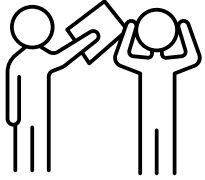
06

Legal Appeals

Post Collection Order: The Legal Avalanche

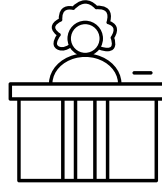
Following the notification to quarry operators, over 1,200 collection orders were predicted to trigger a wave of legal appeals. In turn, the Litigation Department (LD) would face an overwhelming number of cases, requiring public defenders to represent the government in court.

Large number of appeals



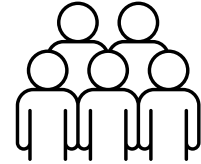
It is anticipated that the 1,200 quarry investors and owners will file appeals within two months of their notifications to avoid paying the collection orders.

Judges from first instance



The appeals will be addressed in front of the first instance courts across Lebanon. This will significantly increase the workload for judges, already burdened by large caseloads.

Public defenders



The LD will assign public defenders across Lebanon to represent the government in these appeals.

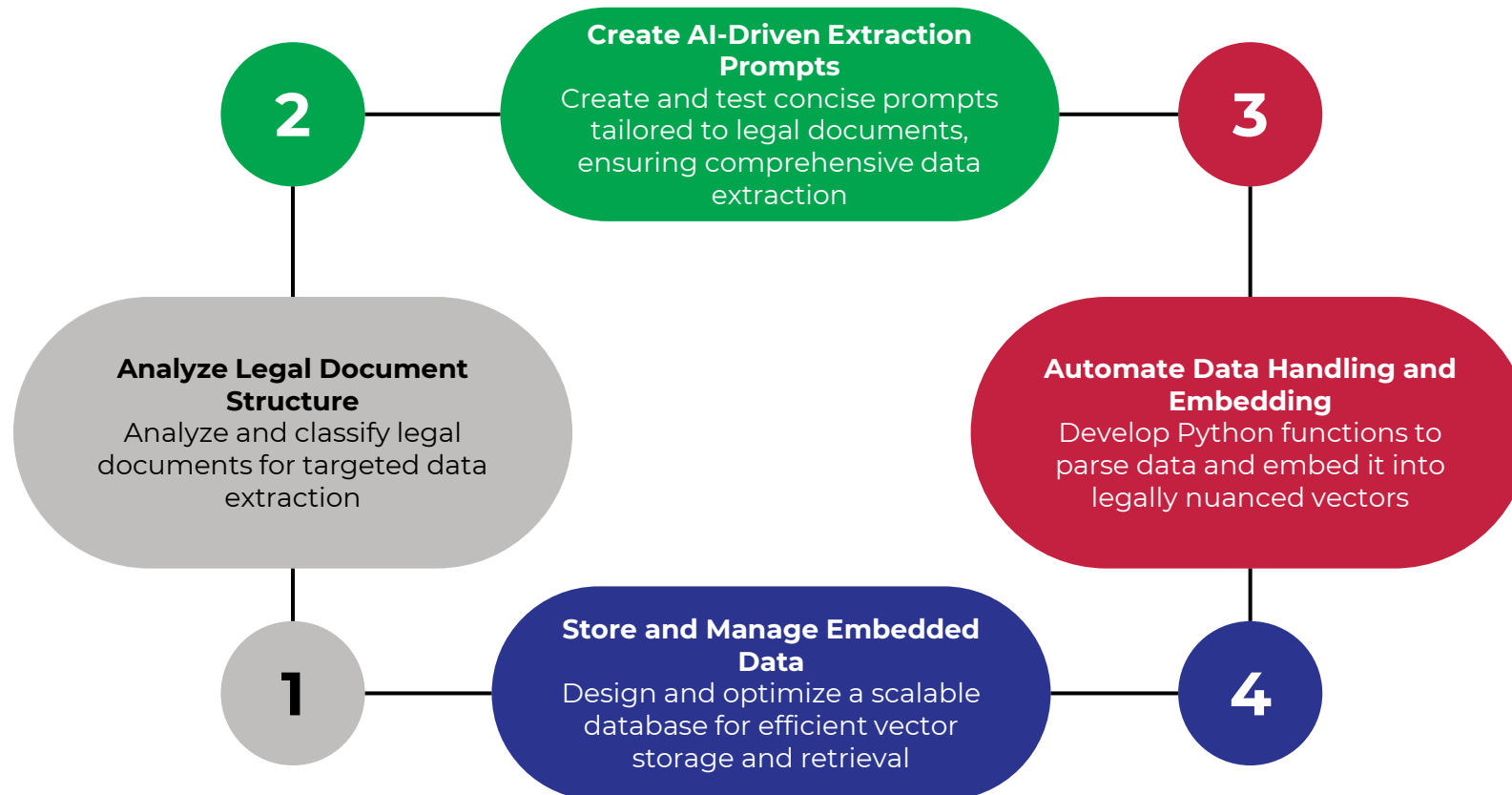


The appeals will inevitably stretch legal resources very thin, leading to significant delays. Public defenders and judges alike will grapple with overwhelming caseloads, extending the resolution timeline.

AI and Environmental Justice

The AI Legal Assistant offered automated help by quickly analyzing legal texts, speeding up workflows, and streamlining the process for public defenders.

HOW IT WORKS:



BENEFITS:

Automated Document Processing: Analyzes thousands of legal documents to quickly extract key information.

Enhanced Legal Decision-Making: Provides fast, data-driven answers to legal and environmental questions, improving the efficiency of public defenders.

Environmental Advocacy: Supports legal cases focusing on environmental protection, ensuring better enforcement of quarry rehabilitation and compliance.

07

Data driven-decisions

Leveraging Quarry Data for Strategic Decision-Making

“Talk to your data” is an innovative feature developed for the use of the MoE to enhance data-driven decision-making for quarry management. It empowers users to directly interact with the data by asking specific questions related to quarry operations, environmental impact, and regulatory compliance.

By simply querying the system, users receive instant, data-backed answers in the form of visual dashboards, tailored reports, and analytical insights.

Data visualization

Create interactive charts, graphs, tables, and others to derive meaningful insights

Interactive data exploration

Interact dynamically with data through filtering, cross filtering and drill down capabilities

Data at your command

Customized visual insights empower faster and more informed decision-making

Legal and environmental intelligence

Ask legal questions about environmental regulations and receive precise, real-time answers

Benefits:

- **Informed Policy Development:**

With comprehensive data from AI, historical records, and military reports, the MoE can craft policies that reflect real-time changes in quarry activity and environmental impact.

- **Targeted Enforcement:**

The MoE is able to focus its regulatory efforts on areas with unauthorized quarry expansion or environmental violations, leading to more efficient use of resources.

- **Environmental Restoration:**

Data allows the MoE to prioritize environmental restoration efforts in heavily impacted quarry zones, ensuring the sustainability of Lebanon’s natural resources.

08

Survey

Methodology

Survey Design and Instrumentation

- A **38-question survey** was developed to evaluate the **economic impact of quarrying** on local communities and the effectiveness of institutional responses.
- The survey was conducted across **16 Lebanese regions with the 7 largest quarries by area**, excluding Baalbeck-Hermel (due to inaccessibility issues).
- The survey combined multiple-choice and open-ended questions and was **piloted on July 19 in Kfarhazir**.

Sampling Strategy and Data Collection

- A **simple random sampling approach** was employed, ensuring comprehensive coverage of all streets and areas of targeted regions to maintain randomness and diversity in the sample.
- The sample comprised both **seasonal and permanent residents**, selected from these targeted areas to capture a comprehensive view of local perspectives.
- Data collection was executed through **face-to-face surveys** conducted by the Y4G team who were thoroughly trained for this purpose.
- **Data collection** took place on August 1, 2, and 5, 2024, with **542 surveys** completed using **KOBO** to ensure efficient, accurate, and secure data handling.

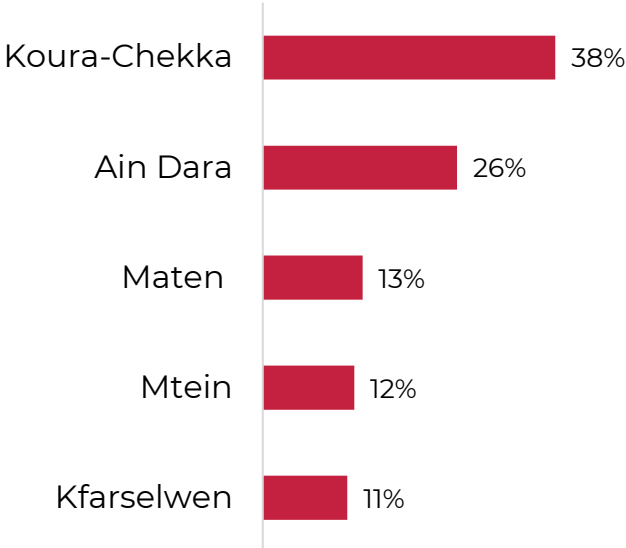
Data Analysis Procedures

- The initial **data cleaning** process involved categorizing similar responses to streamline analysis in Excel.
- Data analysis utilized **inferential and descriptive statistics**.
- Subsequently, **cross-tabulations** and **frequency distributions** were employed to explore relationships between variables and identify key patterns.
- To ensure the reliability and validity of the results, the **Chi-Square method** was applied, providing a rigorous assessment of the data's accuracy and robustness.

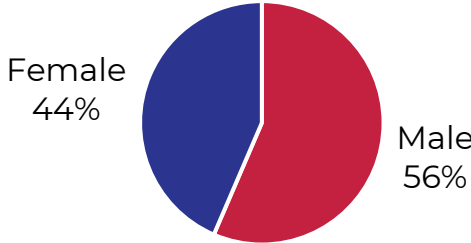
Demographic Overview of Respondents

The demographic profile was well-balanced in terms of gender, with fairly equal participation from men and women. It spanned a wide range of ages and educational levels, providing a comprehensive representation of the community’s views on quarrying activities. This wide-ranging demographic coverage provided a nuanced and thorough understanding of the impact of quarrying, reflecting a broad spectrum of views within the community.

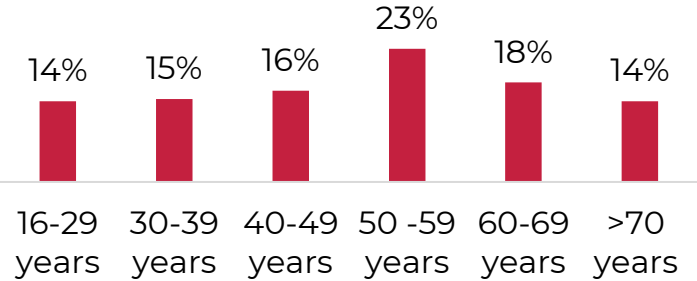
Distribution of Respondents by Quarry



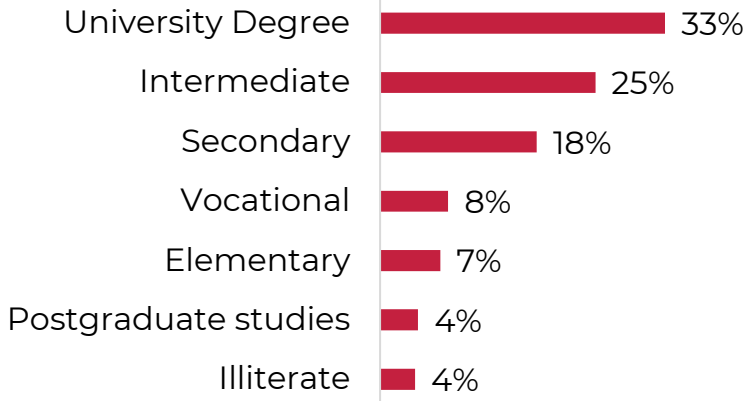
Distribution of Respondents by Gender



Distribution of Respondents by Age

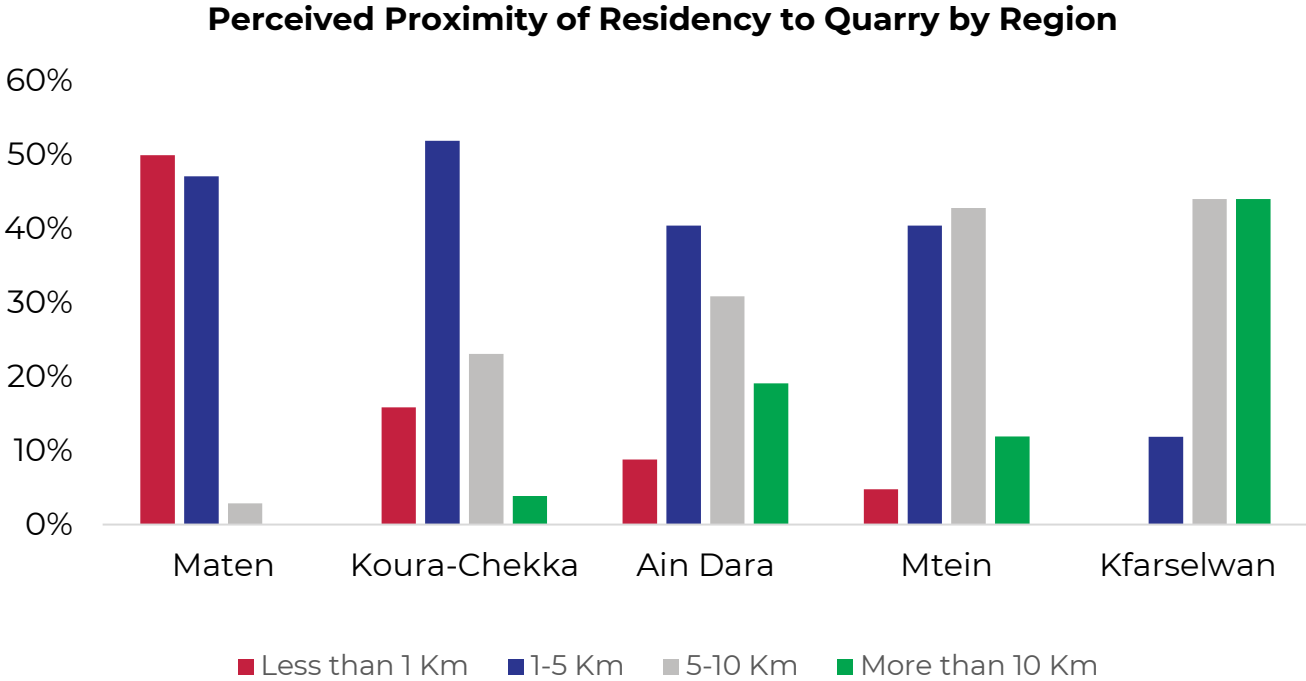
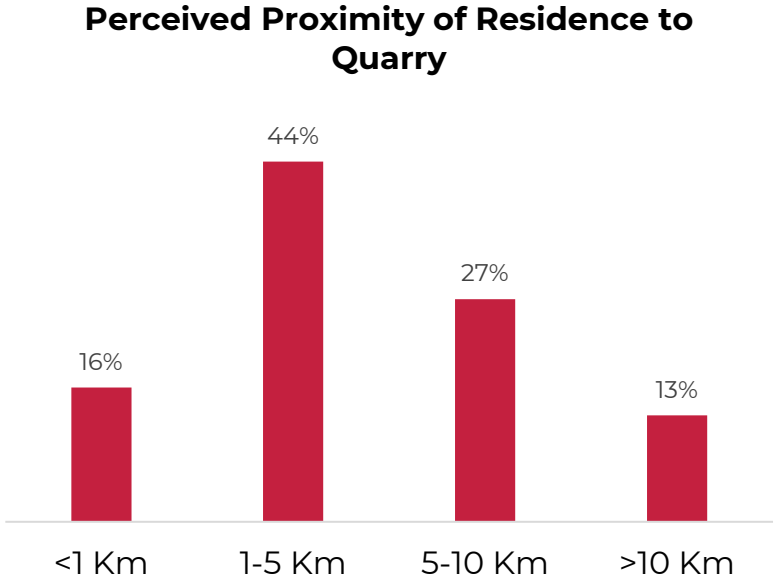


Distribution of Respondents by Educational Level



Proximity to Quarry Operations

Despite legal constraints on quarrying near residential areas, the survey revealed that a significant number of people lived in close proximity to these operations. Specifically, 44% of residents were located within 1-5 kilometers of a quarry, and 16% were even closer, within just 1 kilometer. The situation was particularly disconcerting in Maten, where half of the residents were situated within 1 kilometer of a quarry, highlighting a significant overlap between residential life and quarrying activities.

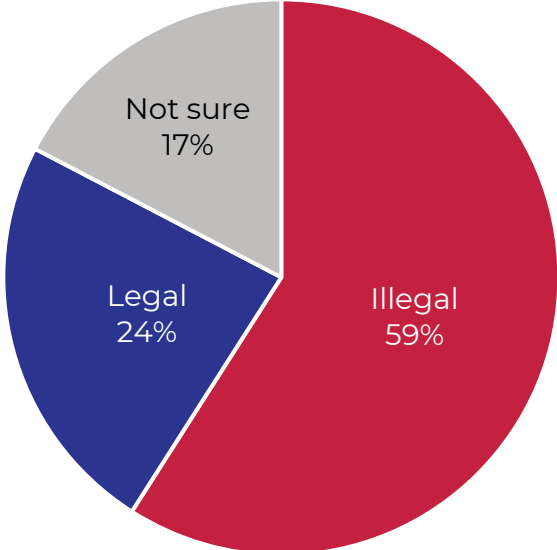


“We live inside the quarry.” – a resident from Mjaydel

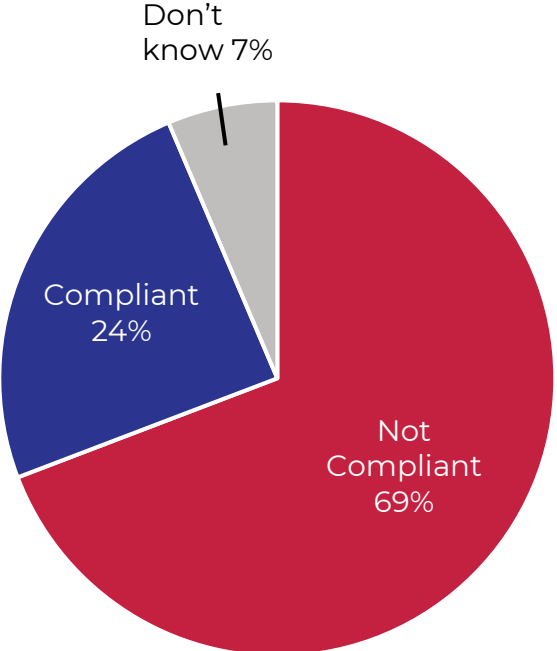
Public Awareness of Quarrying Legality and Licensing

Most respondents (59%) recognized quarrying in their region as illegal, yet 41% either believed it was legal or were uncertain, highlighting a significant public misunderstanding. Additionally, 69% viewed the licensing process as non-compliant, pointing to deep-rooted issues in regulatory enforcement. This concern was underscored by 85% of respondents who believed political figures were involved in the quarrying sector, indicating that political connections may have played a critical role in facilitating illegal operations.

Perceived Legality of Quarrying Operations



Perceived Compliance of Quarry Licensing with Legal Procedures

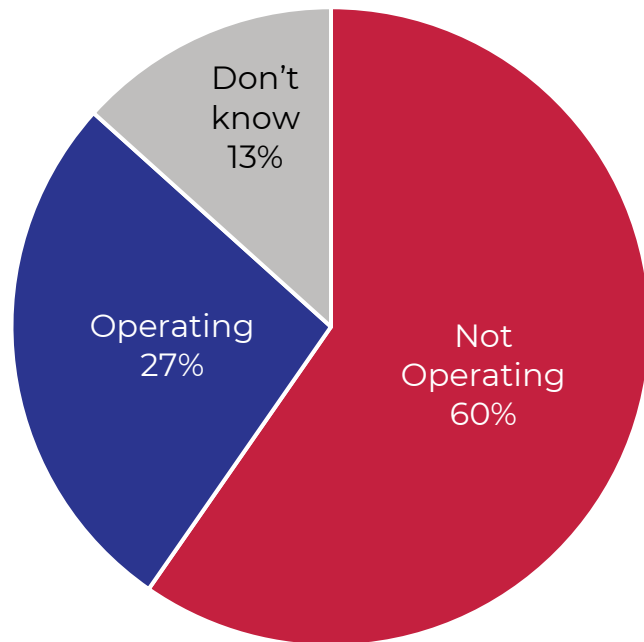


85% of respondents believed that politicians were involved in the quarrying sector

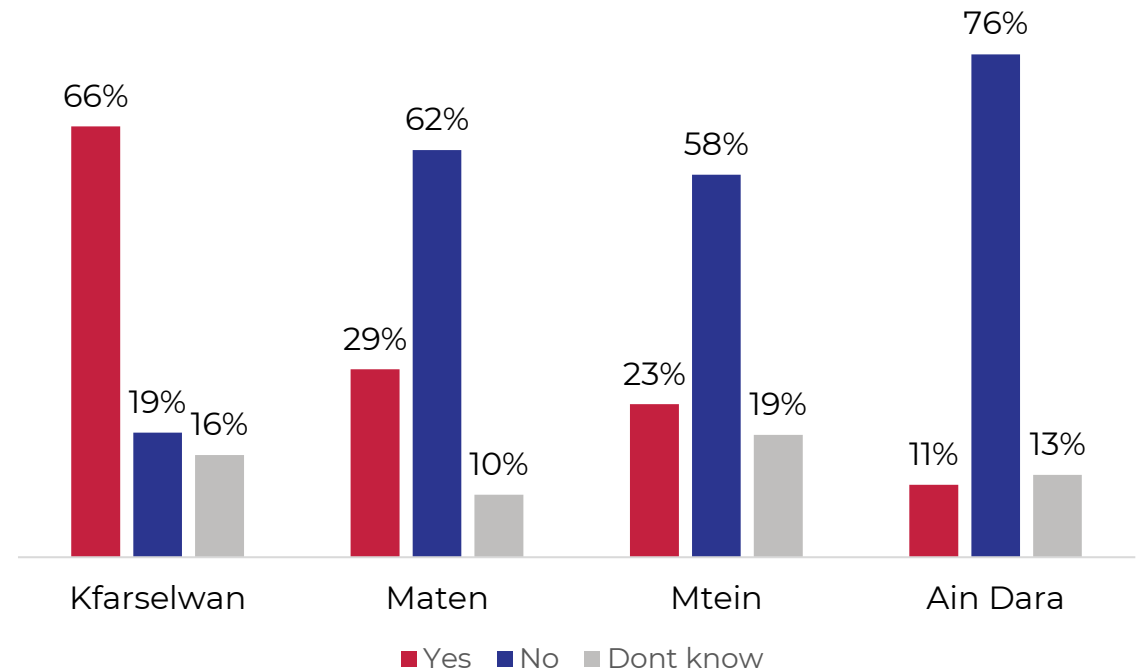
Status of Quarry Operations Across Regions

Although 60% of respondents believed that quarries were closed, 27% reported ongoing activity, with some stating that nighttime operations were occurring. Regional perceptions varied significantly, with Kfarselwan having the highest perceived level of operating activity at 66%, followed by Bsalim, Mtein, and Mrouj, which also reported higher levels of quarry activity compared to other regions. This variation highlighted the inconsistent enforcement and monitoring of quarry operations across different areas.

Perceived Operational Status of the Quarry



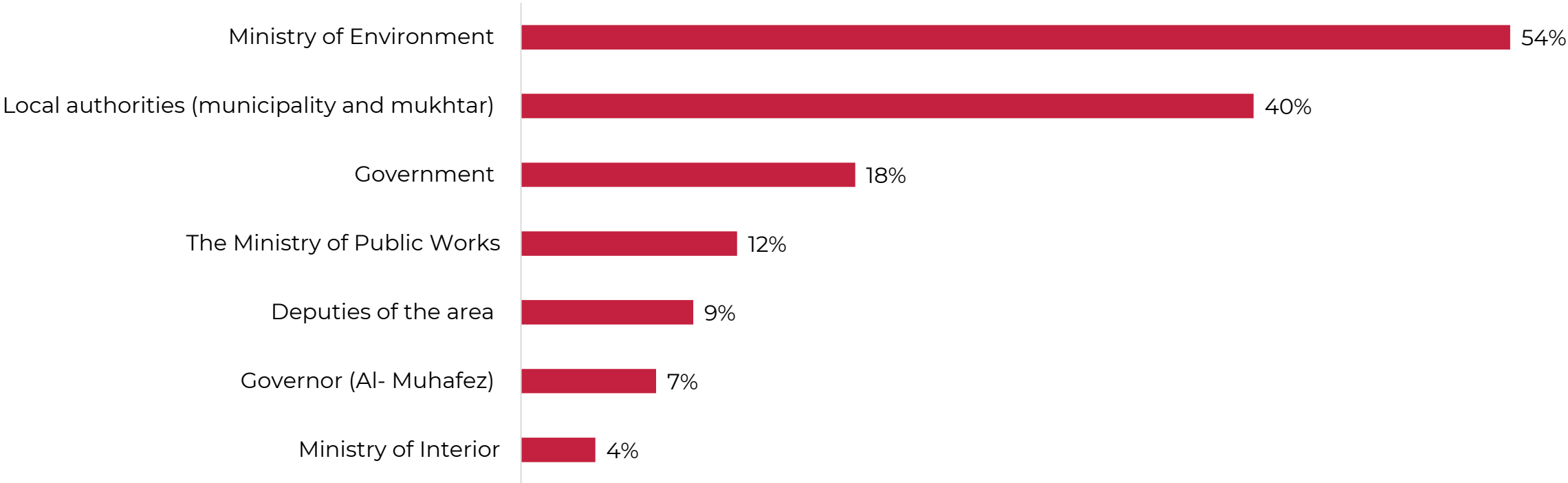
Perceived Quarry Operation Status Per Region



Monitoring and Accountability in the Quarry Sector

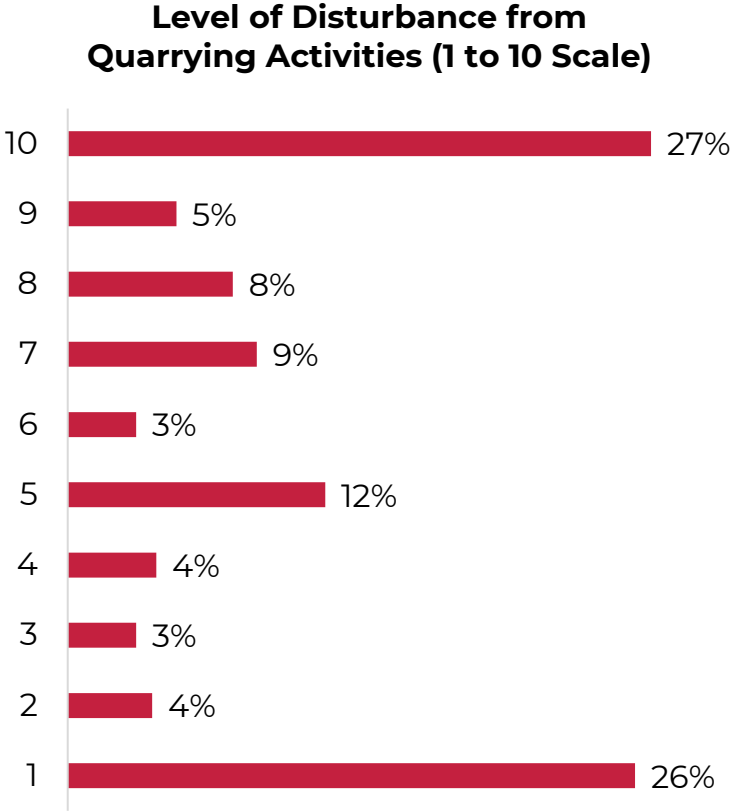
The Ministry of Environment was widely seen as the primary authority for overseeing the quarrying and crushing sector, with 54% identifying it as the leading body responsible for monitoring. Local authorities were also considered key players, recognized by 40% of respondents. In contrast, the Government, the Ministry of Public Works, and regional officials were mentioned less often, suggesting that monitoring duties were more strongly associated with environmental and local entities.

Perceived Responsibility for Monitoring the Quarrying and Crushing Sector (Multiple Choice)



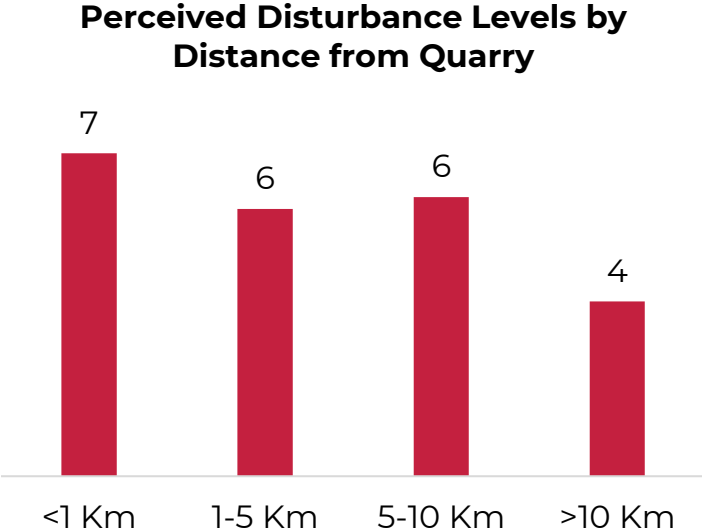
Impact of Quarry Proximity on Disturbance Levels

Respondent levels of disturbance from quarrying were polarized, with most rating their experience as either minimal (1) or extreme (10). Data showed that the closer residents lived to a quarry, the higher the disturbance level, while those further away reported less impact.



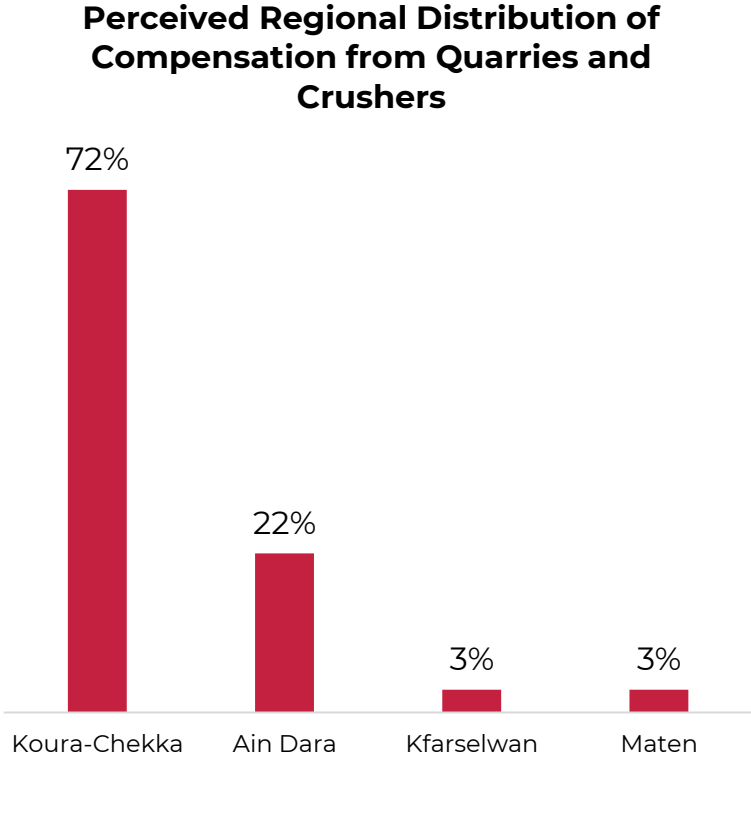
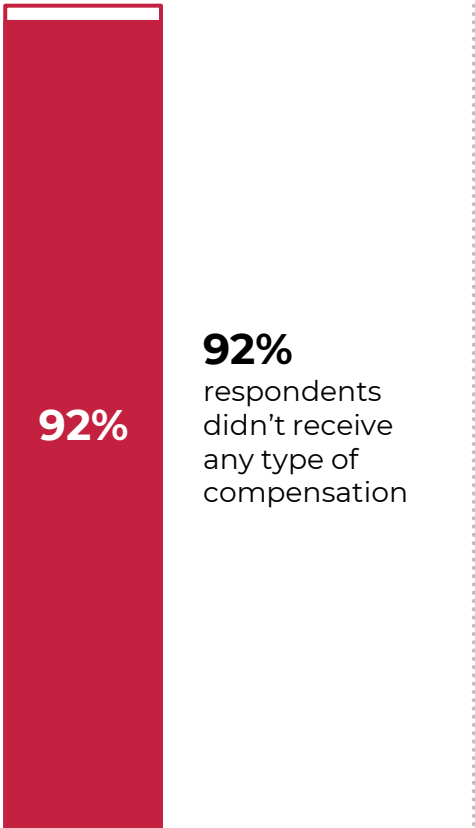
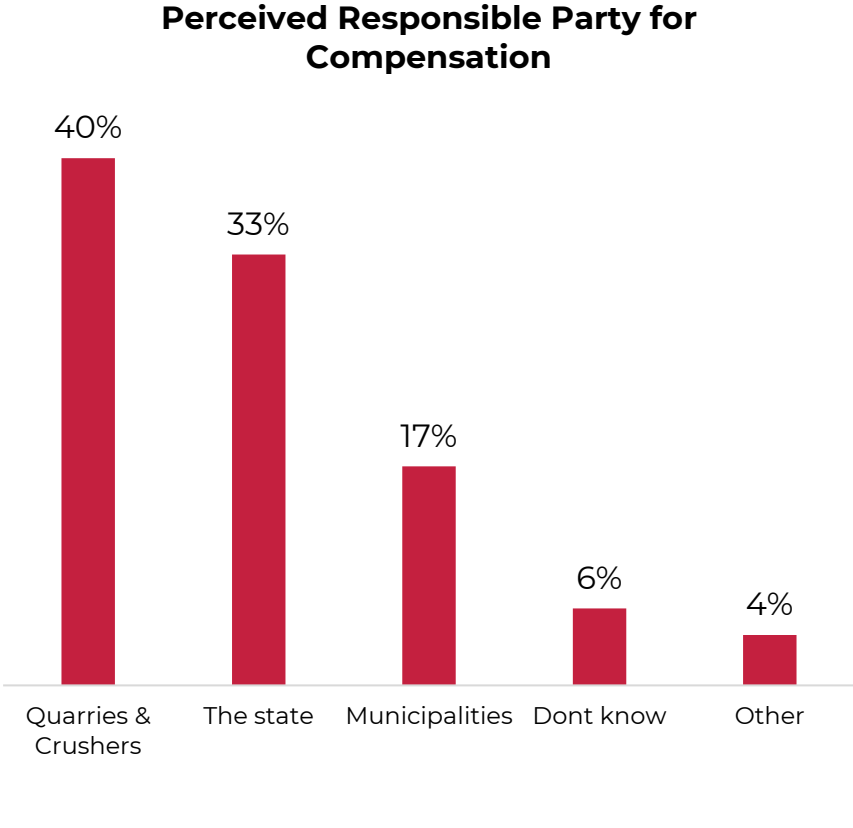
“Quarries are a lifeline for us because it's the only way our children can find work and stay in this country.” – a resident from Chekka

“The sound of quarries used to wake us up at 4 am every morning.” – a resident of Biakout.



Compensation and Regional Disparities

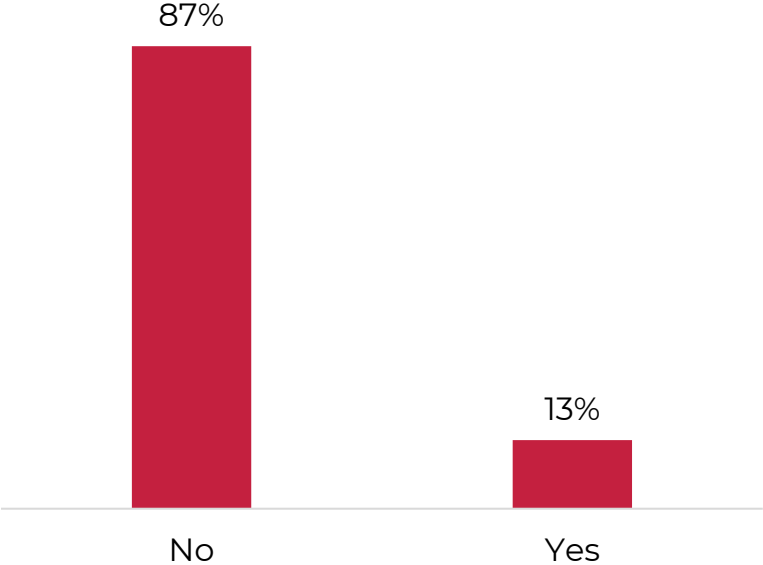
Many respondents (40%) believed quarries and crushers should provide compensation, with the state (33%) and municipalities (17%) also considered responsible; yet 92% reported not receiving any form of support. Compensation was most frequently given in the Koura and Chekka regions where 72% of beneficiaries lived, receiving various forms of assistance such as money, grocery cards, water, and electricity. This indicated that aid was concentrated in areas close to cement production facilities rather than being evenly distributed.



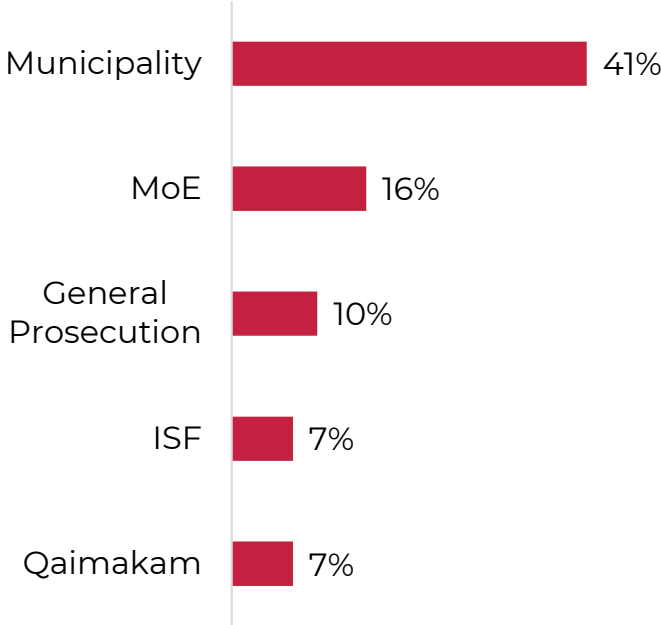
Reporting Quarrying Concerns: Overview and Channels

Most respondents (87%) had not reported concerns about quarrying activities, with only 13% taking action. Among those who did report, the municipality (41%) was the main channel used, likely due to its proximity. The primary issues raised were environmental degradation and dust, highlighting significant dissatisfaction with the impact of quarrying on the environment and air quality. Additionally, 61% of respondents felt they had sufficient channels to report quarrying concerns.

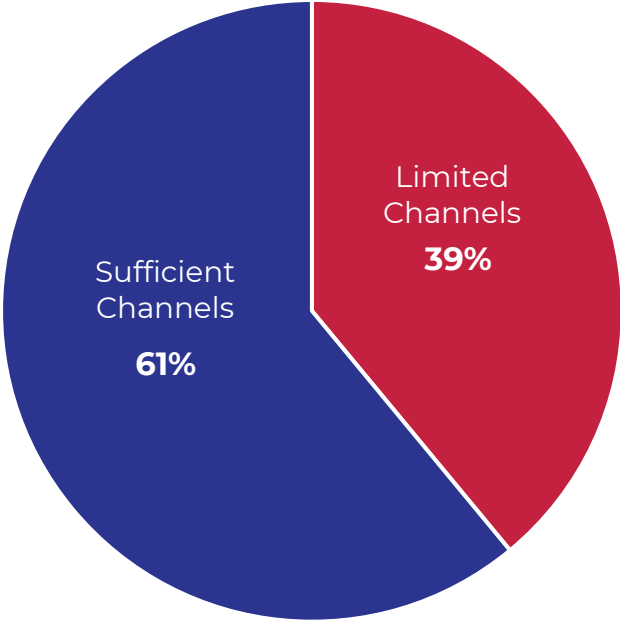
History of Reporting Quarrying-Related Concerns to Local Authorities



Top 5 Channels Used to Communicate Quarrying-Related Concerns

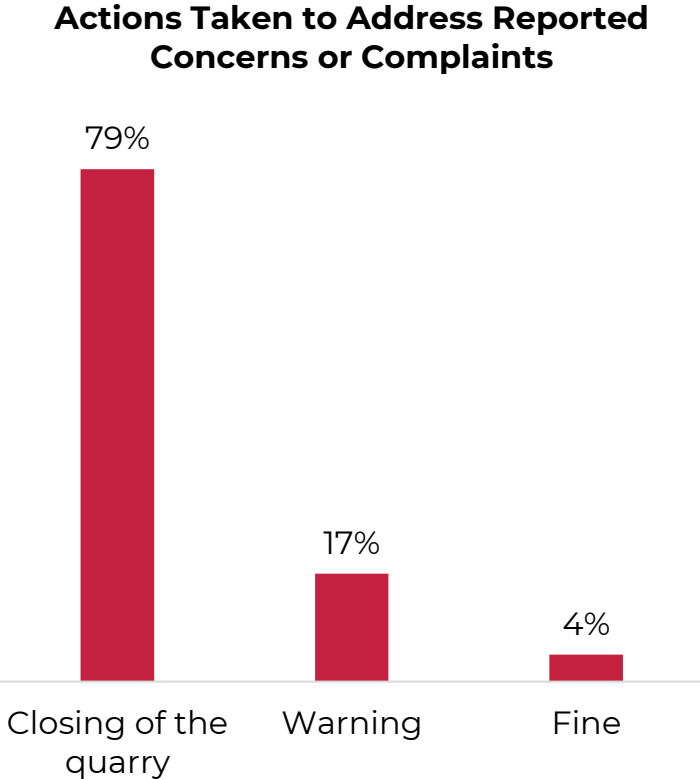
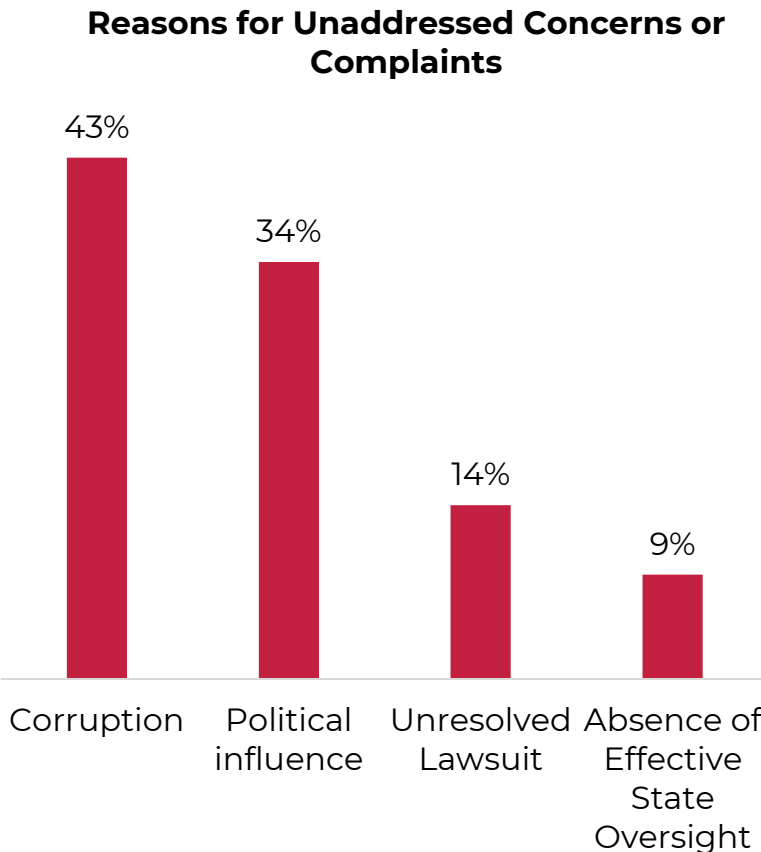
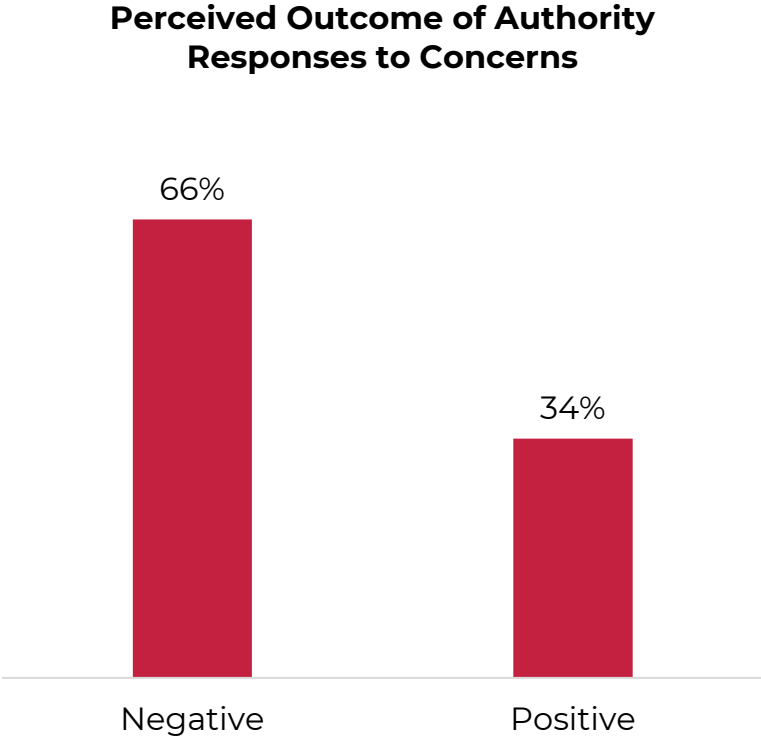


Adequacy of channels for reporting quarry and crusher concerns



Challenges and Outcomes in Addressing Quarrying Concerns

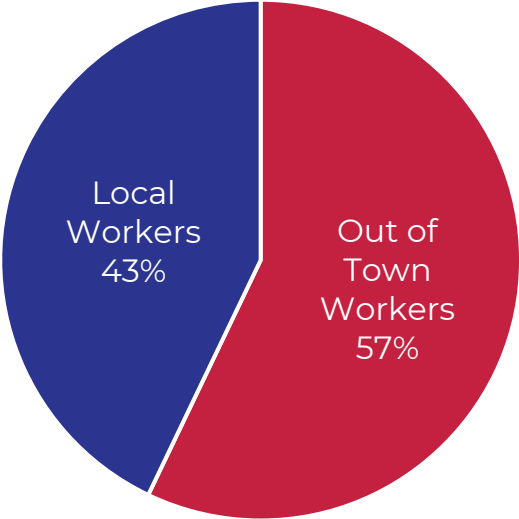
A significant 66% of respondents reported negative outcomes from authorities when addressing concerns, with corruption (43%) and political influence (34%) as key barriers. When positive outcomes occurred, they often resulted in quarry closures (79%). This suggested that while effective responses were rare, when they did occur, they often led to significant resolutions.



Economic Impact of Quarrying Activities

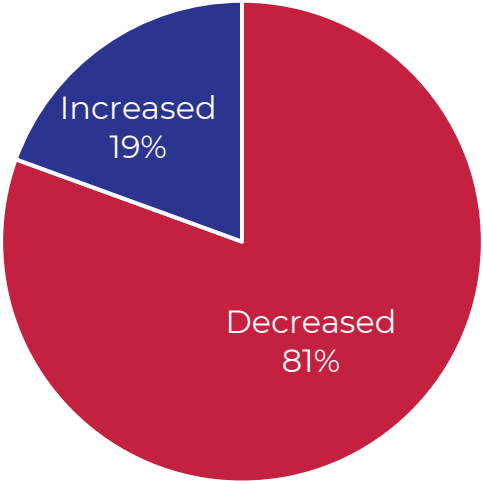
Opinions on the economic impact of quarries varied widely. Some people argued that quarries boosted the local economy by creating jobs for residents. In contrast, others expressed concerns that quarries lowered real estate values and deterred investment in the region. This split in opinion highlighted a contrast between immediate, individual benefits and broader, long-term regional concerns.

Perceived Employment in Quarries



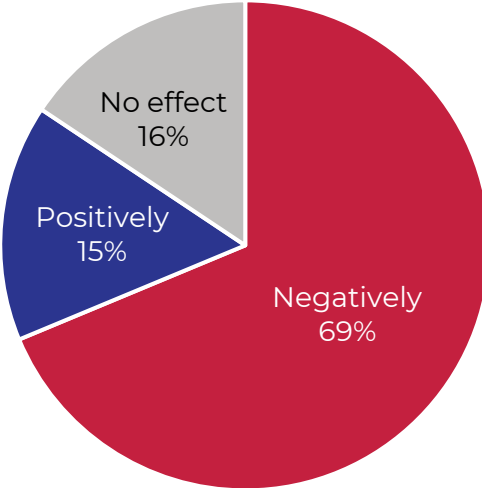
“When the quarries shut down, **most people in our area lost their jobs** and faced financial difficulties.”
– a resident of Chekka

Perceived Impact of Quarries on Real Estate Prices



“**No one wants to buy a property right next to a quarry**, especially if it's very close.”
– a resident of Kfarhazir

Perceived Impact of Quarry Presence on Regional Investment

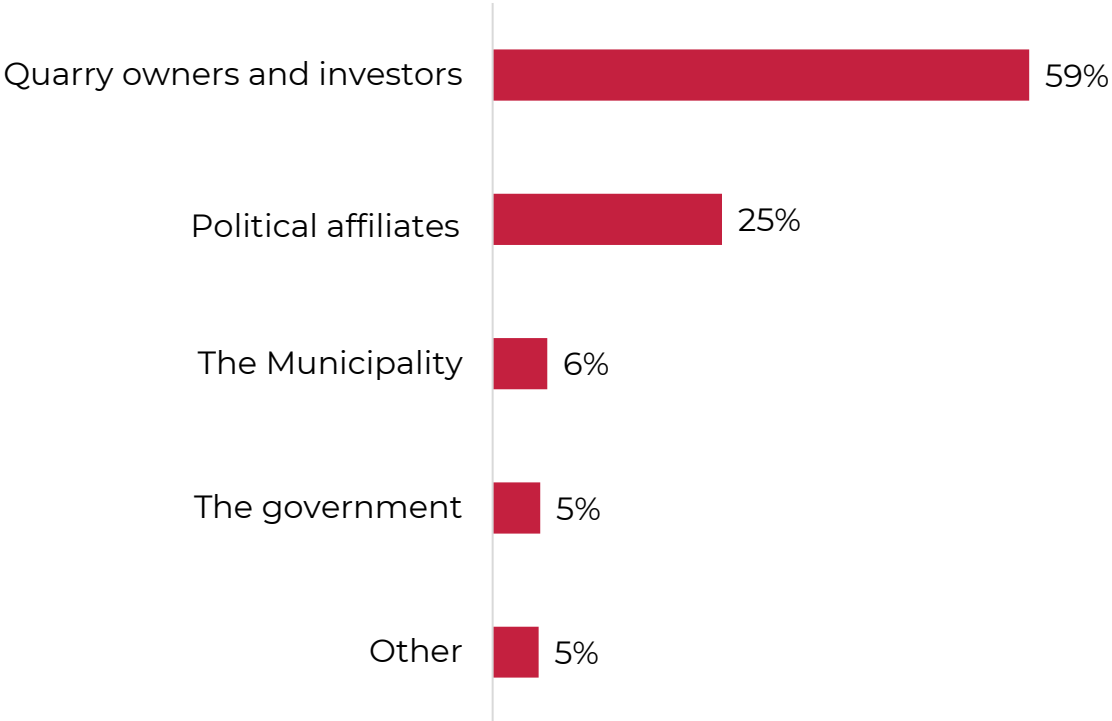


“Just look around, **you won't find many significant businesses** here besides the quarries.”
– a resident of Ain Dara

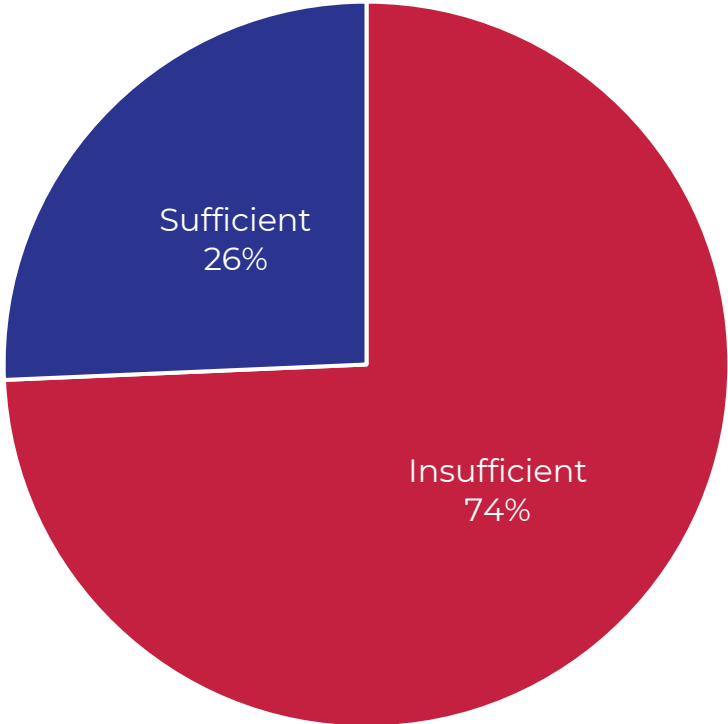
Economic Beneficiaries and Tax Contributions

Quarry owners and investors were viewed as the primary economic beneficiaries (59%), followed by political figures (25%). Despite this, 74% perceived tax contributions from quarries as inadequate, reflecting a disconnect between the economic benefits enjoyed by quarry operators and their contributions to the community and government.

Perceived Primary Economic Beneficiaries of Quarry Operations



Perceived Sufficiency of Tax Payments by Quarries



09

Conclusion and recommendations

Conclusion

The 2024 Y4G project underscores an undeniable truth - the quarry sector in Lebanon is at a crossroads. Through groundbreaking initiatives like AI-driven oversight, satellite imagery for monitoring, and a focus on data-driven decision-making, this project has laid the foundation for a future defined by sustainable practices and responsible governance.

The project exposes the critical need for immediate reform, enforcing environmental dues, ensuring comprehensive rehabilitation, and decarbonizing the cement sector. With a clear blueprint for action, including issuing licenses based on real market needs and prioritizing the preservation of Lebanon's natural wealth, this initiative demands decisive and swift intervention.

These findings go beyond technical recommendations — they are a call to transform the quarry sector into a model of sustainability. It's a call for the government and stakeholders to act now, ensuring that Lebanon's resources are managed responsibly, its environment protected, and its economy balanced. This project marks the beginning of a journey toward long-lasting change, where reform becomes not just a goal, but a reality that drives Lebanon's progress.

Recommendations: A Blueprint for a Sustainable Quarry Sector in Lebanon

1- Policy and Regulation

- **Revise Quarry Licensing Laws:** Transition towards a data-driven, dynamic licensing model that accounts for fluctuating market demand, environmental impact assessments, and rehabilitation efforts. The licensing process should be adaptive and regularly evaluated to prevent oversupply in the construction market. Quarries should be granted licenses only if they meet both market demands and a comprehensive Environmental Impact Assessment (EIA) to ensure a sustainable balance between resource extraction and environmental protection.
- **Limit the Number of Active Quarries:** Implement a scientifically-backed, nation-wide sustainability index that integrates advanced environmental, geological, and economic data to determine the optimal number of quarries. This data should inform policies to limit the number of quarries operating at any given time, reducing over-extraction and minimizing irreversible ecological damage.
- **Link Licenses to Rehabilitation Plans:** Institute a non-negotiable legal mandate that ties every new quarry license to a scientifically-validated rehabilitation plan which must be phased, measurable, and enforceable. Licenses should not be renewed or extended unless there is verifiable proof that rehabilitation milestones are being met according to a set environmental timeline. Failure to comply should result in immediate forfeiture of licenses and the imposition of financial penalties that fund environmental restoration projects.
- **Reform the National Quarry Law:** Overhaul and modernize the 2002 Quarry Law to reflect international best practices, prioritizing long-term environmental sustainability while incorporating emerging technologies like satellite monitoring and AI-based environmental analysis. This updated law should focus not only on extraction and exploitation but also on the *prevention of ecological damage*, continuous community involvement, and rehabilitation enforcement to safeguard Lebanon's ecosystems for future generations.
- **Align Quarry Operations with the Sustainable Development Goals (SDGs):** Ensure that quarry operations explicitly align with Lebanon's commitment to the SDGs, particularly SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land). This alignment should drive every aspect of quarry management, from reducing land degradation to promoting the sustainable use of natural resources. Licensing decisions must prioritize practices that minimize environmental damage, promote biodiversity conservation, and ensure responsible production to protect ecosystems for future generations.

Recommendations: A Blueprint for a Sustainable Quarry Sector in Lebanon

2- Environmental Sustainability

- **Enforce Mandatory Rehabilitation of Abandoned Quarries:** Prioritize the rehabilitation of abandoned quarries before new licenses are issued. Utilize strategies such as ecological restoration and development projects (e.g., converting old quarries into green spaces or urban projects) to minimize environmental damage.
- **Decarbonize Cement Production:** Establish stringent carbon-reduction targets for the cement industry, focusing on integrating green energy sources such as wind or solar to power production sites. Encourage the use of carbon capture and storage (CCS) technologies, as well as alternative fuels like biomass, to lower CO2 emissions during cement production. Lebanon should commit to achieving net-zero emissions by 2035 for all cement-related operations in alignment with global climate goals, including *SDG 13: Climate Action*.
- **SDG-Driven Environmental Accountability:** Ensure that quarry operations in Lebanon are aligned with the UN SDGs, particularly SDG 12: Responsible Consumption and Production and SDG 15: Life on Land. Quarrying practices must aim to protect ecosystems, promote biodiversity, and reduce the environmental harm caused by unsustainable extraction methods. Operators should report annually on their alignment with these goals, with independent audits ensuring compliance.
- **Leverage Circular Economy in Quarry Operations:** Introduce circular economy principles into quarry operations, where waste materials from the quarrying process are repurposed for other industries or construction activities. Encourage the use of quarry by-products like crushed stones, sand, and gravel in public works, reducing the demand for raw materials and promoting resource efficiency.
- **Implement Remote Environmental Monitoring Systems:** Install automated environmental monitoring systems in and around quarries, such as air quality sensors, noise pollution monitors, and water contamination detectors. These systems can track real-time environmental impacts and report data directly to the Ministry of Environment, ensuring accountability and transparency in quarry operations.

Recommendations: A Blueprint for a Sustainable Quarry Sector in Lebanon

3- Technological Innovation

- **AI-Based Environmental Impact Analysis:** Expand AI capabilities to conduct real-time environmental impact assessments. AI could continuously monitor air, water, and soil quality near quarries and provide early warnings for potential violations or risks to the ecosystem.
- **AI for Rehabilitation Plan Optimization:** Employ AI to design and optimize rehabilitation plans, considering various ecological and geographical factors.
- **Digital Workflows:** Digitize the entire documentation workflow for quarry operations, from licensing to compliance.
- **Market Analytics:** Apply predictive analytics to forecast demand for quarry products such as sand, gravel, and cement, allowing quarry operators to adjust production rates and inventory levels dynamically.
- **Use Legal AI Chatbot :** Use a chatbot to automate the legal aspects of quarry operations, such as preparing environmental impact reports, tracking compliance with local laws, and managing litigation cases.
- **Augmented Reality (AR) for Workforce Training:** Deploy AR technologies to train workers in safe and efficient quarrying practices. AR simulations create immersive training scenarios, enabling workers to gain hands-on experience without the risks of real-world operations.
- **Smart Environmental Sensors:** Install sensors across quarries to monitor air and water quality, noise pollution, and vibrations in real time. These sensors provide instant alerts if pollution thresholds are exceeded, ensuring compliance with environmental regulations.

Recommendations: A Blueprint for a Sustainable Quarry Sector in Lebanon

4- Economic and Social Responsibility

- **Quota-Based Export Regulation:** Introduce an adaptable quota system for quarry material exports based on Lebanon's domestic construction needs and environmental sustainability goals. Any exports beyond the quota should face higher tariffs.
- **Rehabilitation-Based Financial Incentives:** Provide tax credits or financial incentives for quarry operators that meet or exceed rehabilitation standards.
- **Market-Driven Pricing:** Implement a dynamic pricing system for quarry products (gravel, sand, cement) that fluctuates based on real-time market demand and environmental costs.
- **Circular Economy Model:** Encourage the recycling of quarry materials and concrete in Lebanon's construction sector, reducing the demand for new extraction. Introduce financial rewards for companies that use recycled materials.
- **Carbon Credits for Decarbonization Efforts** Allow quarries that adopt low-carbon technologies to earn carbon credits which they can sell on international carbon markets. This provides an economic incentive for quarry operators to invest in cleaner technologies.
- **Public-Private Partnerships for Economic Growth:** Form public-private partnerships (PPPs) to develop eco-friendly infrastructure around quarries. This includes renewable energy installations (solar or wind farms) and green transportation options for quarry material transport.
- **Establish a National Environmental Fund:** Create the environmental green fund (Law 444/2002) where the collected dues and quarry revenue are directed toward national environmental and rehabilitation projects.
- **Ensure that Quarrying Activities Align with the SDGs:** Promote job creation in sustainable industries (Goal 8), develop resilient quarrying infrastructure (Goal 9), encourage resource efficiency (Goal 12), minimize environmental impact (Goal 13), and ensure sustainable land use and rehabilitation (Goal 15).

Recommendations: A Blueprint for a Sustainable Quarry Sector in Lebanon

5- Legal Framework and Enforcement

- **Strengthen Legal Enforcement:** Introduce stricter penalties for operators who do not comply with environmental laws, including the seizure of personal assets if rehabilitation is not completed. Close loopholes that allow illegal quarrying operations and ensure that unlicensed operators are held accountable.
- **Activate Environmental Courts:** Consider the formation of specialized environmental courts to handle quarry-related disputes and cases. This can accelerate legal proceedings and ensure that environmental regulations are upheld.
- **Activate the Environmental Police:** Ensure rapid response capabilities, able to close illegal operations instantly, and carry out the prosecution of violators, removing the burden from general law enforcement.
- **Reinforce the Role of the MoE:** Grant expanded regulatory and enforcement powers to the MoE with a dedicated task force focused on quarry operations. This task force would have the authority to impose penalties, revoke licenses, and halt operations. The ministry should also have full oversight of all quarry data, including financial, environmental, and operational records. Furthermore, the MoE's budget should be significantly increased to ensure that it has the resources to effectively monitor and enforce regulations across the quarrying sector.
- **Decentralized Environmental Governance:** Establish regional environmental management units specifically tasked with monitoring quarry activities and enforcing environmental regulations. These units will ensure the decentralization of environmental governance, empowering local communities and regional experts to respond more rapidly to violations and ensure a better adaptation of policies to local conditions.



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