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From geothermal brine to battery: balancing technological innovation with environmental and social responsibility: a case study from Lithium Valley.

ALGAIAR, M.

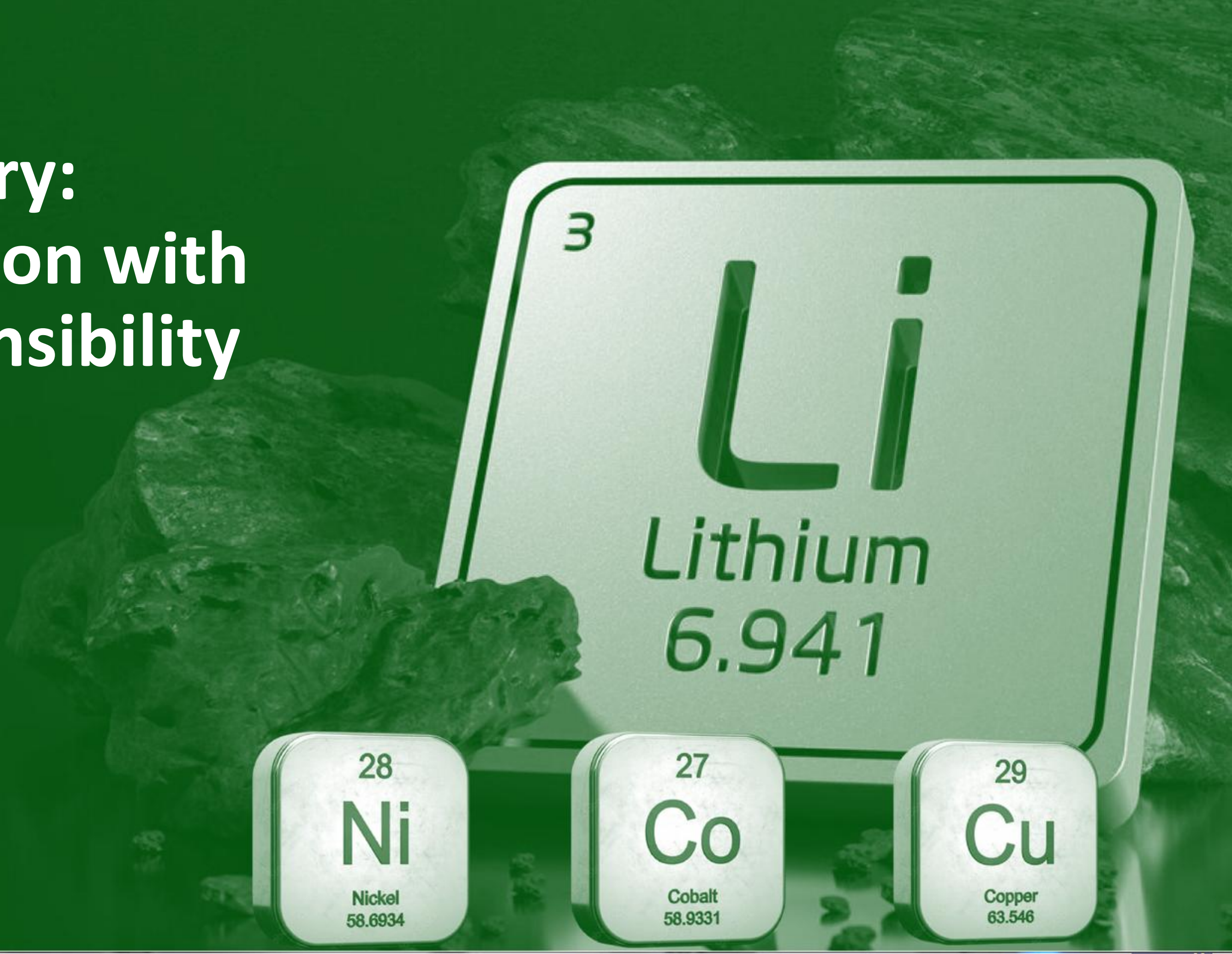
2025

SPWLA SAC 16th Topical Workshop

Shaping Sustainability: Exploring and Producing Transition Minerals

Society of Petrophysicists and Well Log Analysts
Saudi Arabia Chapter

From Geothermal Brine to Battery: Balancing Technological Innovation with Environmental and Social Responsibility



The Growing Importance of Lithium

Critical for Energy Transition

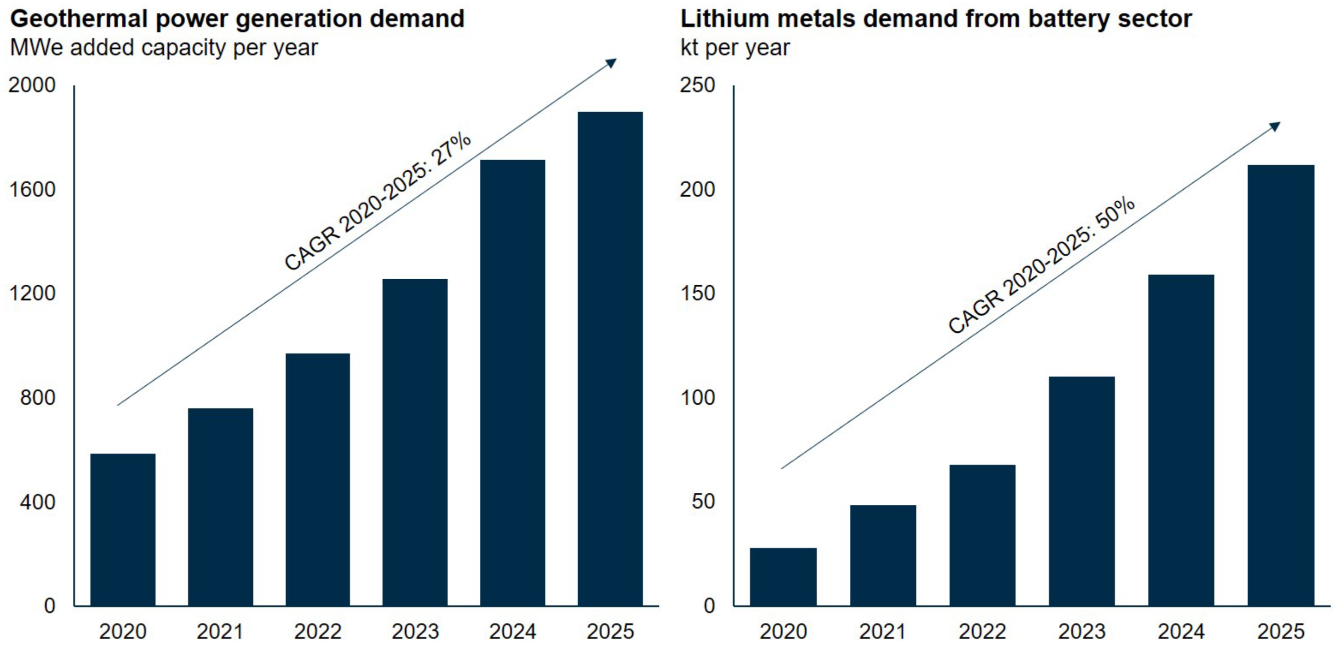
Lithium is a light and reactive metal that is the principal component in one of the most promising forms of high-energy-density batteries, going from 28,000 tons in 2020 to over 200,000 tons in 2025.

Diverse Industrial Applications

Beyond batteries, lithium is a critical component for for ceramics, glass, metallurgy, air treatment products, products, pharmaceuticals, and polymers.

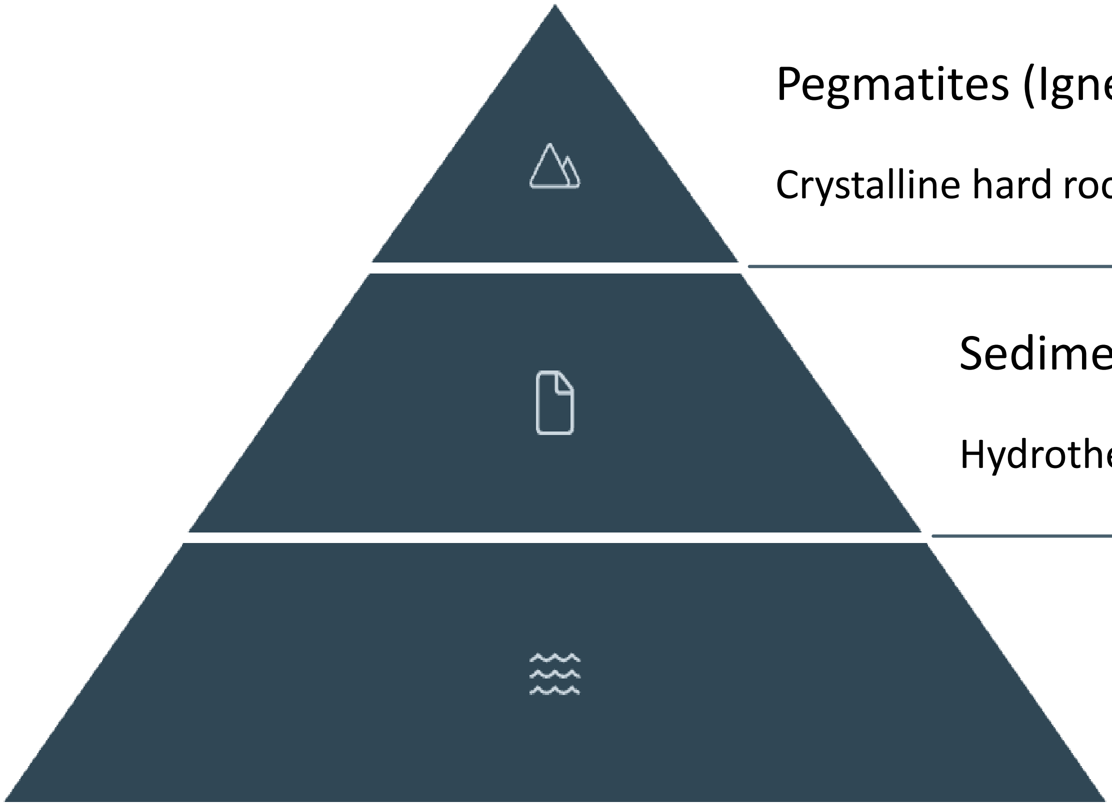
National Security Importance

USA considers lithium a critical mineral, emphasizing its importance for the economy and national security.



Source: Rystad Energy Geothermal Analysis Dashboard, Rystad Energy Battery Materials Analysis Dashboard

Lithium Resources



Pegmatites (Igneous Rock)

Crystalline hard rock mining

Sedimentary Deposits

Hydrothermally altered clays

Continental Brines

Saline subsurface waters

Lithium is found in three main types of deposits: saline subsurface waters (continental brines), hydrothermally altered clays (sedimentary deposits), and pegmatites (igneous rock).

Traditional Lithium Extraction Methods

Hard-Rock Mining

Mining blast spodumene ore containing around 5% to 6% lithium oxide (Li_2O)

- Requires extensive land disturbance
- Energy-intensive crushing and processing
- Significant waste rock generation
- Higher production costs

Ref: im-mining.com/2021/11/25/cornish-lithium

Evaporation

Evaporating water from lithium brine to produce lithium chloride ($LiCl$) or lithium carbonate (Li_2CO_3)

- Requires large evaporation ponds
- Process takes 18-24 months
- High water consumption
- Weather dependent

Ref: Solar Evaporation Ponds at Salar Atacama www.innovationnewsnetwork.com/wp-content/uploads/2021/04/INTERNA2-27379-fig-2.jpg

Environmental considerations

Water Consumption

Community Concern

Water usage is a key community concern.

Water Source

Lithium Valley primarily plans to use surface water from the Colorado River.

Regional Context

Contextualizing water consumption compared to regional agricultural use.

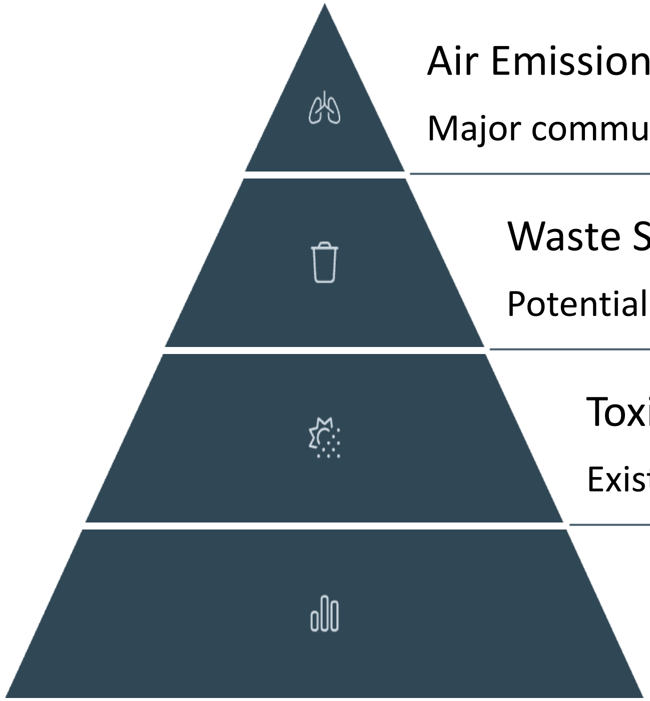
Scarcity Evaluation

Importance of evaluating water consumption in the context of regional scarcity.

Ref: www.lithiumvalleycommunitycoalition.org

Environmental considerations

Public Health



Air Emissions
Major community concern

Waste Streams
Potential environmental impact

Toxic Dust
Existing challenges from the area

Monitoring Needs
Transparent communication of health impacts

Local Ecology & Infrastructure

Community Interest	Impacts on soil and potential for restoration
Infrastructure Needs	Potential reclassification as an industrial zone

Direct Lithium Extraction Technologies

Ion-Exchange Adsorbents

Inorganic molecular sieves like aluminum hydroxides, manganese oxides, and titanium oxides with crystal structures that selectively allow lithium ions to enter

Organic Sorbents

Crown ethers and cyclic compounds that selectively bind lithium ions based on ion radius and cavity size match

Membrane Separation

Membranes with specific pore sizes and surface charges to selectively separate lithium ions

Solvent Extraction

Organic solvents with extractants that selectively complex with lithium ions for separation from brine

Ion-Exchange Adsorbents for DLE

Molecular Sieve Structure

Metal oxide and hydroxide sorbents are selective for lithium due to crystalline or layered properties that properties that act like molecular sieves

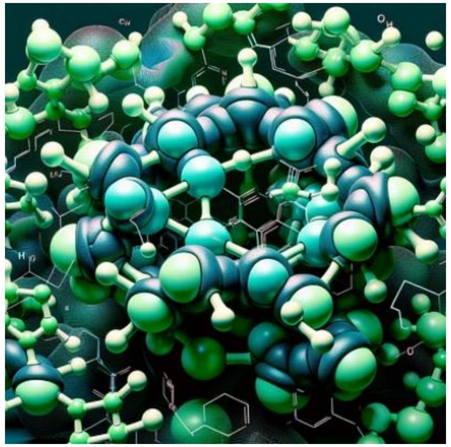
Size-Based Selectivity

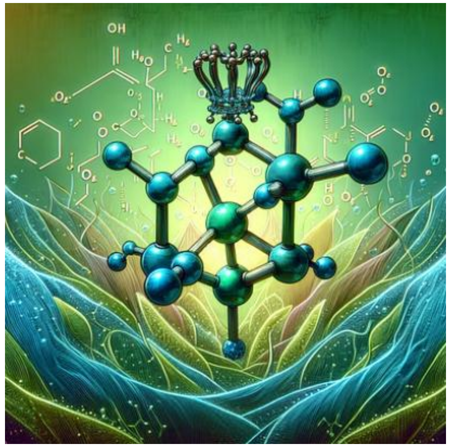
Allow lithium to enter ion-exchange sites, whereas larger ions are sterically excluded

Regeneration Process

After lithium capture, adsorbents can be regenerated for repeated use

Organic Sorbents for Lithium Extraction





Crown ethers and aza crown ethers have been shown to have selective reactivity with lithium. Cation extraction by the polydentate structure of crown ether is governed by the structure (steric properties) of the ether and electrostatic interactions between cation and oxygens in the crown ether. These cyclic chemical compounds can selectively bind lithium ions based on the match between the ion radius and the cavity size of the crown ether.

Solvent Extraction Methods

Mixing

Brine mixed with organic solvent containing lithium-selective extractants

Separation

Lithium transfers to organic phase while other ions remain in aqueous phase

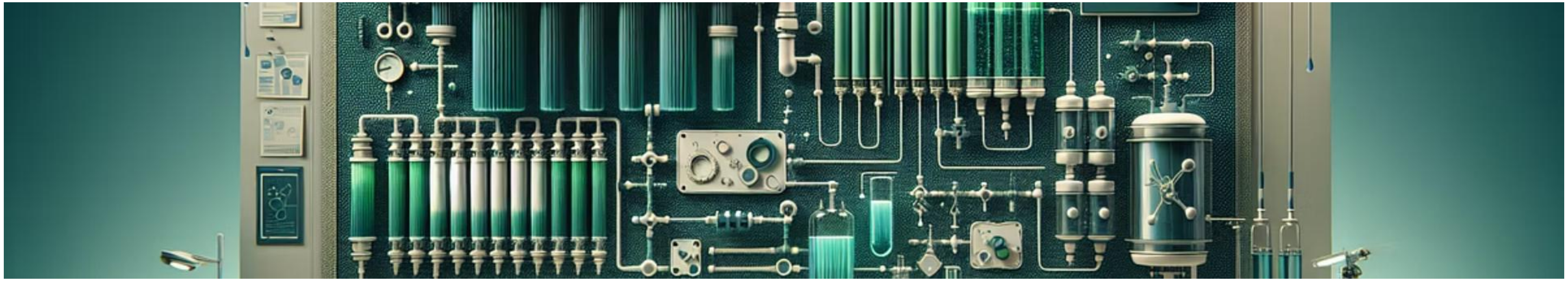
Stripping

Lithium recovered from organic phase using acid solution

Recycling

Organic solvent regenerated for reuse in the process

Membrane Separation Technologies



Nanofiltration

Membranes with specific pore pore sizes being investigated for for separating lithium from magnesium and other ions

Electrodialysis

Using electrical potential to drive ion separation through selective membranes membranes

Selective Membranes

Membranes with surface charges designed to preferentially allow lithium ions to pass through

Lithium Valley Case Study

High

Lithium Concentration

2-in-1

Co-Production Opportunity

Geothermal power plants bring lithium-rich brine to the surface for power generation, creating a potential co-production opportunity.

Synergies of Geothermal Energy and Lithium Extraction

Operational Synergies

Synergies

Potential for operational synergies and increased resource efficiency.

Plant Operations

Corrosive mineral removal benefits geothermal plant operations.

Additional Resources

Possibility of recovering other other valuable minerals from from the brine.

The Lithium Valley Region

Saudi Arabia Chapter

Geographic Context

The region encompasses the Imperial Imperial Valley (southern end), the the Coachella Valley (northern end), end), and the broader Salton Sea region.

Geothermal Energy Production

The Salton Sea Known Geothermal Resource Area in the Imperial Valley of California has been producing geothermal energy for decades, with high-temperature brines that also contain valuable minerals.

Lithium-Rich Brines

Geothermal fluids are important sources for lithium. All of the geothermal brine samples with lithium concentrations were from the Salton Sea KGRA in the Imperial Valley of California.

High Concentration

It is estimated that the average average concentrations of lithium in Salton Sea post-flash flash geothermal brines to be be approximately 200 mg/L.

Economic Viability Considerations

Factor	Consideration
Technology Effectiveness	A lithium extraction technology must be both technically effective and and economically sustainable
Recovery Rate	Higher lithium recovery percentages improve economic returns
Product Purity	Battery-grade lithium commands premium prices but requires additional purification
Capital Investment	Initial infrastructure costs for geothermal plants and extraction facilities
Operational Costs	Energy, water, chemicals, and maintenance expenses
Market Conditions	Lithium price volatility affects long-term profitability

Social Justice Considerations

Recognize Historical Context

The Imperial Valley has experienced previous environmental and economic challenges that have disproportionately affected disadvantaged communities.

Ensure Inclusive Decision-Making

Transparent stakeholder dialogue and meaningful community engagement are essential for addressing concerns and promoting environmental justice.

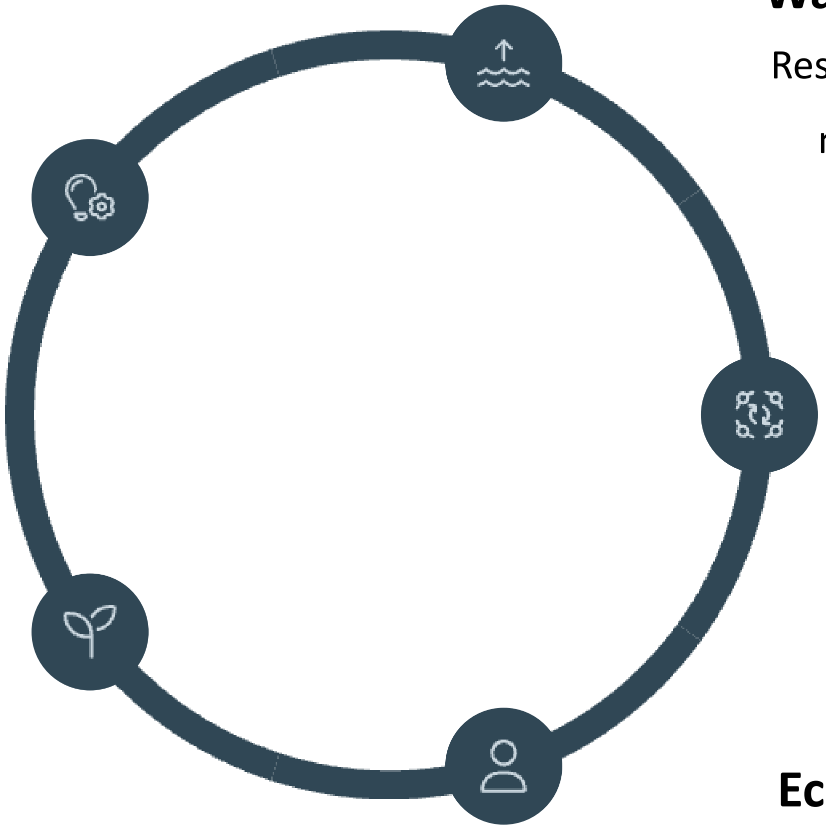
Equitable Distribution of Benefits

Economic opportunities from lithium development should benefit local communities through jobs, revenue sharing, and infrastructure improvements.

Minimize Environmental Impacts

Careful monitoring and mitigation of potential impacts on air quality, water resources, and public health are necessary to prevent further environmental burdens.

Conclusion: Balancing Technology & Responsibility



Technological Innovation

Continued development of more more efficient and environmentally environmentally friendly DLE technologies

Water Resource Management

Responsible water use and recycling to minimize impact in an arid region

Community Engagement

Meaningful involvement of local stakeholders in stakeholders in decision-making processes

Environmental Protection

Minimizing ecological footprint and addressing air quality concerns

Economic Viability

Ensuring projects are financially sustainable while while providing equitable benefits

Thank You
Q/A