Starting Soon: Reuse of Solid Mining Waste

- ITRC Resources: https://mw-1.itrcweb.org/
- CLU-IN Training Page: https://cluin.org/conf/itrc/MiningWaste/

Housekeeping

- This event is being recorded; Event will be available On Demand after the event at the main training page: https://cluin.org/conf/itrc/MiningWaste/

- If you have technical difficulties, please use the Q&A Pod to request technical support

- Need confirmation of your participation today?
  - Fill out the online feedback form and check box for confirmation email and certificate

Reuse of Solid Mining Waste

Sponsored by: Interstate Technology and Regulatory Council

Hosted by: US EPA Clean Up Information Network

ITRC – Shaping the Future of Regulatory Acceptance

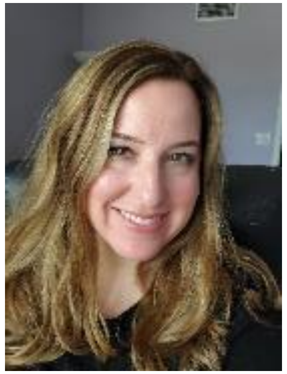
- Host Organization
- Network - States, PR, DC
- Federal Partners
  DOE DOD EPA
- ITRC Industry Affiliates Program
- Academia
- Community Stakeholders

- Disclaimer
  https://mw-1.itrcweb.org/about-itrc/#disclaimer
- Partially funded by the US government
  - ITRC nor US government warranty material
  - ITRC nor US government endorse specific products
- ITRC materials available for your use – see Terms & Conditions

Meet the ITRC Trainers

Samantha Fuchs
Geosyntec Consultants
Samantha.Fuchs@Geosyntec.com

Nick Anton
CDM Smith
AntonNR@cdmsmith.com



Nichole Osuch
Arizona Department of Environmental Quality
osuch.nichole@azdeq.gov

Matt McCaughey
Arcadis
Matthew.McCaughey@arcadis.com

Learning Objectives

- Understand solid mining waste context, issues, and opportunities
- Outline methods for site characterization, economic assessment, and life cycle and risk assessment
- Navigate regulatory requirements and stakeholder engagement needs
- Assess opportunities for solid mining waste reuse
- Define and contrast technologies involved reuse of mining waste

Training Roadmap

1. Introduction
2. Waste Characterization
   - Analysis
   - Economic Considerations
   - Life Cycle and Risk Assessment
3. Regulatory and Stakeholder Considerations
4. Applications
5. Technologies
6. What's next?

INTERSTATE TECHNOLOGY REGULATORY COUNCIL ITRC

ECOS

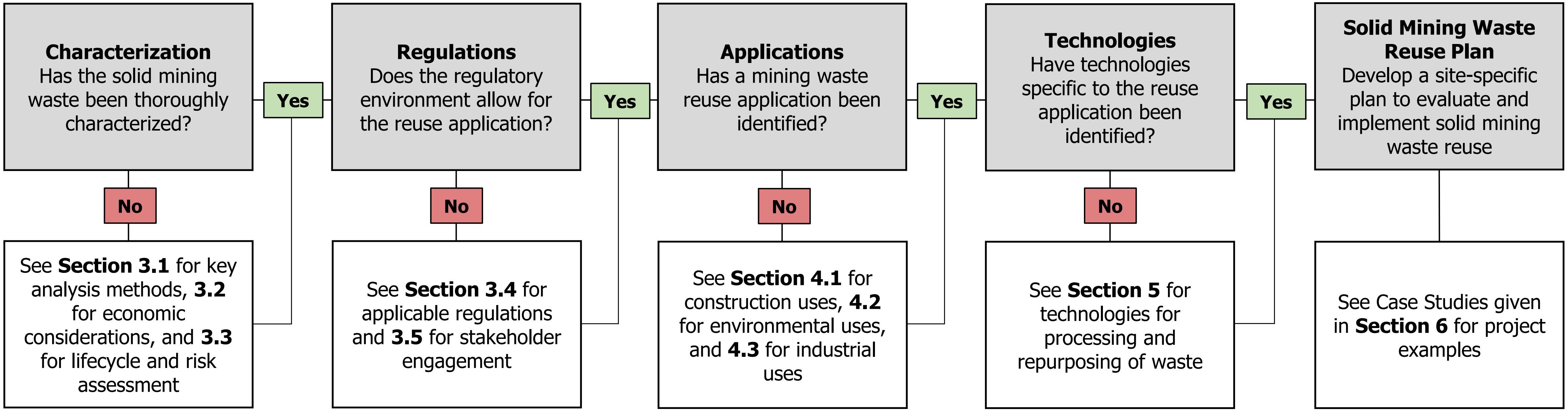
ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

Navigating the Guidance

Section 1 – Introduction

Section 2 – Mining and Mining Waste

Sections 3-6 and Navigation Graphic



MW-1, Figure 1-1

Key Definitions

Solid Mining Waste

Any naturally occurring material that has been disturbed by mining, milling, or smelting activity and is not utilized or marketed by that activity

- Waste/development rock; overburden; chat, tailings (fine and coarse); slimes or fine tailings; smelter waste; sludges;
- Soils and sediments affected by mining;
- Solid residues derived from treatment of mining influenced water; and,
- Suspended or dissolved solids in mining influenced water (sludge, filter backwash, reverse osmosis (RO) concentrate and regeneration fluids

Solid Mining Waste Reuse Plan

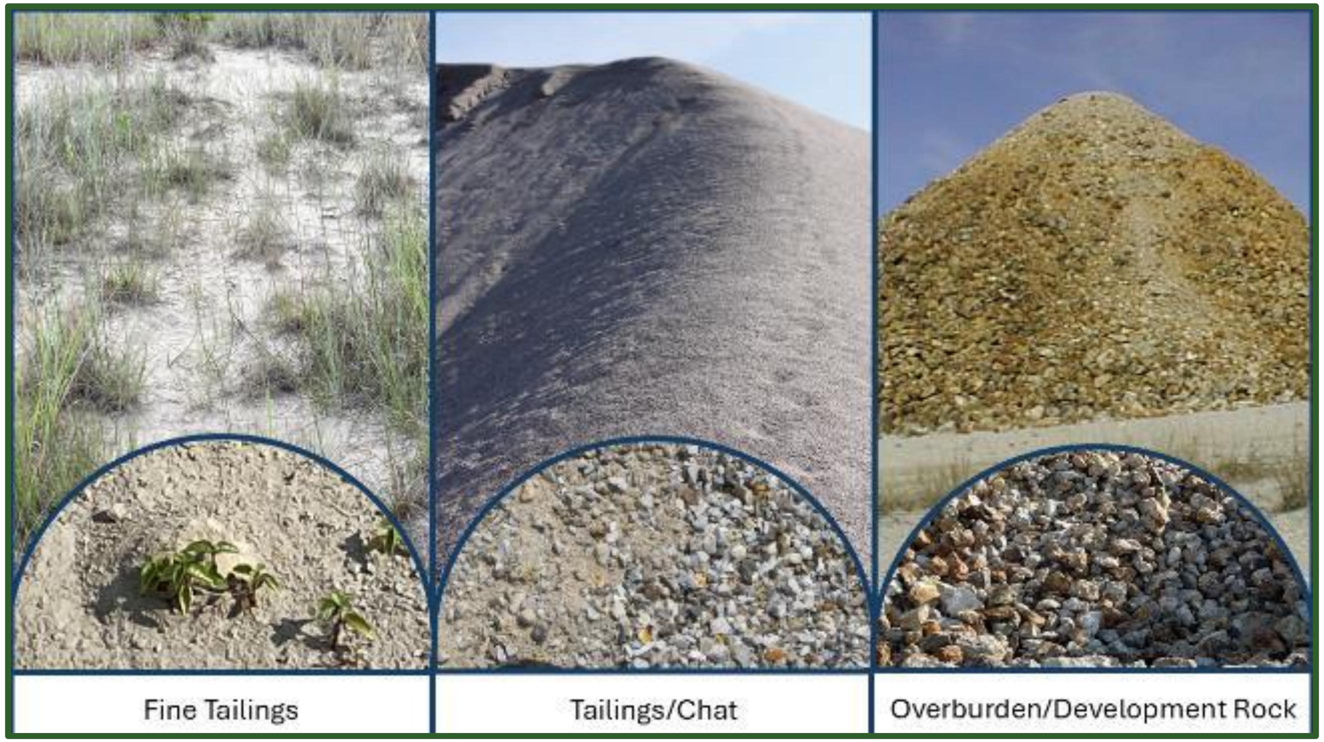
A site-specific document that outlines the site conditions, waste material, potential applications, life cycle assessment, risk assessment, and applicable regulations needed

Critical Minerals

Evolving lists of metals and materials deemed by the US Department of Energy and Department of the Interior to serve an essential function in energy technology and have a potential supply chain disruption

Common Mine Wastes

- **Waste/Development Rock:** All non-valuable rock that is excavated during mining operations, generally of cobble to boulder-sized material
- **Overburden:** Material that overlies a deposit of useful and minable materials or ores
- **Tailings:** The clay- to sand-sized waste material associated with milling and mineral concentration process; low in target mineral and metal value



MW-1, Figure 2-4

More Common Mine Wastes

Mining Influenced Water Residuals: Materials formed or accumulated from various physical processes, chemical reactions, and biological reactions

Slimes: Material of silt or clay in size, resulting from the washing, concentration, or treatment

Leachate: A solution or suspension formed when liquid travels through a solid and removes some components of the solid

Acid mine drainage: acidic or neutral water produced following the oxidation of sulfide minerals

Acid Mine Drainage.
Source: Oklahoma Department of Environmental Quality

Solid Mining Waste Challenges

- Global mining waste estimated at over 100 billion tons
- Hazardous chemicals to human health and the environment

Waste Pile Hazards

- Tailings impoundment/ tailings dam failures
- Sediment loading to surface waters

Fluid Leaching & Drainage

- Acid mine drainage
- Tailings leaching

Contaminants

- Metals, metalloids, nitrates
- Potential radioactivity

Mining waste piles at Tar Creek Superfund Site.
MW-1, Figure 6-20

Solid Mining Waste Opportunities

- Energy technology needs
- Construction and fill material
- Land redevelopment goals

Source: EPA

Mineral	U.S. Critical Mineral	Rare Earth Element	Energy Transition Applications
Aluminum (Al)	X		Power Lines
Cobalt (Co)	X		Rechargeable Batteries
Copper (Cu)			Power Lines
Graphite (C)	X		Rechargeable Batteries
Lithium (Li)	X		Rechargeable Batteries
Nickel (Ni)	X		Rechargeable Batteries, Wind Turbines
Zinc (Zn)	X		Electric Vehicle Motors
Dyprosium (Dy)	X	X	Electric Vehicle Motors, Wind Turbines
Neodymium (Nd)	X	X	Electric Vehicle Motors, Wind Turbines
Praseodymium (Pr)	X	X	Rechargeable Batteries, Electric Vehicle Motors, Wind Turbines
Terbium (Tb)	X	X	Electric Vehicle Motors, Wind Turbines

MW-1, Table 4-2

Check In!

Check In

What is the most common solid mining waste issue in your state/ region?

A. Mining influenced water/ residuals
B. Tailings/ solid mining waste facility management
C. Land redevelopment
D. No major issues
E. Unknown

Training Roadmap

1. Introduction
2. Waste Characterization
   - Analysis
   - Economic Considerations
   - Life Cycle and Risk Assessment
3. Regulatory and Stakeholder Considerations
4. Applications
5. Technologies
6. What’s next?

ITRC INTERSTATE TECHNOLOGY REGULATORY COUNCIL
ECOS
ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

Characterization
Has the solid mining waste been thoroughly characterized?

- Yes → Regulations
- No → See **Section 3.1** for key analysis methods, **3.2** for economic considerations, and **3.3** for lifecycle and risk assessment

Regulations
Does the regulatory environment allow for the reuse application?

- Yes → Applications
- No → See **Section 3.4** for applicable regulations and **3.5** for stakeholder engagement

Applications
Has a mining waste reuse application been identified?

- Yes → Technologies
- No → See **Section 4.1** for construction uses, **4.2** for environmental uses, and **4.3** for industrial uses

Technologies
Have technologies specific to the reuse application been identified?

- Yes → Solid Mining Waste Reuse Plan
- No → See **Section 5** for technologies for processing and repurposing of waste

Solid Mining Waste Reuse Plan
Develop a site-specific plan to evaluate and implement solid mining waste reuse

See Case Studies given in **Section 6** for project examples

Waste Analysis

Goals

- Resource identification
  - Economic value
  - Potential applications
- Environmental risk assessment
  - Physical risk
  - Chemical risk (e.g., acid-generating minerals)
- Regulatory compliance
- Communication with stakeholders

Limitations

- Site Access
  - Legal ownership
  - Unknown hazards
- Sampling considerations
- Cost and time constraints
- Predictive limits

Source: EPA

Analysis Considerations

- How much material is present?
- What is the overall composition?
- Are there contaminants of concern?
  - Low concentration mineral from remaining ore
  - Other metals or radionuclides
  - Spilled fuel or lubricants from mining equipment
  - Potential chemical interaction – like acid generating potential

Table 3-1. Common physical, geochemical, mineralogical, acid-base accounting, radiological, and toxicological methods and standards

Please click "+" to expand the table.

Physical Characterization	+
Geochemical Characterization	+
Mineralogical Characterization	+
Acid-Base Characterization	+
Radiological Characterization	+
Toxicological Characterization	+

Radiological Characterization -

Media	Analysis	Publishing Organization	Standard Number	Standard Title
Solids	Gamma radiation	International Atomic Energy Agency	IAEA-TECDOC-1363	Guidelines for Radioelement Mapping Using Gamma Ray Spectrometry Data (IAEA 2003 [J6NZGI3N])
Solids	Alpha radiation	ISO	ISO/DIS 23548	Measurement of Radioactivity—Alpha Emitting Radionuclides—Generic Test Method Using Alpha Spectrometry (ISO 2024 [58YU93XS])

See Guidance for Details

Section 3.1.4

Economic and Market Considerations

Composition

- Quantity of mining waste
- Quality of mining waste (i.e., grade of residual ore, mix of non-valuable material)

Legal Needs

- Site ownership
- Regulations
- Potential incentives

Location

- Location of waste compared to processing center
- Location of waste compared to final end-use location

Supply & Demand

- Buyer landscape
- Processing/technology cost
- Geopolitical considerations

Potential Incentives

Grants and incentives through government or private/non-profit groups

- Land reuse programs
- Critical mineral research and production, such as REEs
- Renewable power generation

Programs for Abandoned Mines

- Abandoned Mine Land (AML) Reclamation Program to reclaim coal mines abandoned before 1977
- Abandoned Hardrock Mine Reclamation (AHMR) Program for federal and state grants

Navajo Abandoned Mine Lands Closure and Reclamation.
Source: EPA

Project Example – Empire Mine State Historic Park, CA

- Abandoned Gold Mine purchased in 1975 by California Department of Parks and Recreation
- Remedial actions for mercury, cyanide, and arsenic to recreational risk-based levels
- Economic benefits
  - 43,000 tons of tailings at 0.25 ounces gold per ton
    - $2.5-3.9 million value (1985)
  - Mined waste rock and mill sands used for construction of California State Route 49
  - Land developed as a historic park and mining museum

Empire Mine Historic Estate and Equipment.
Source: Empire Mine SHP

See Guidance for Details
Section 6.1.2

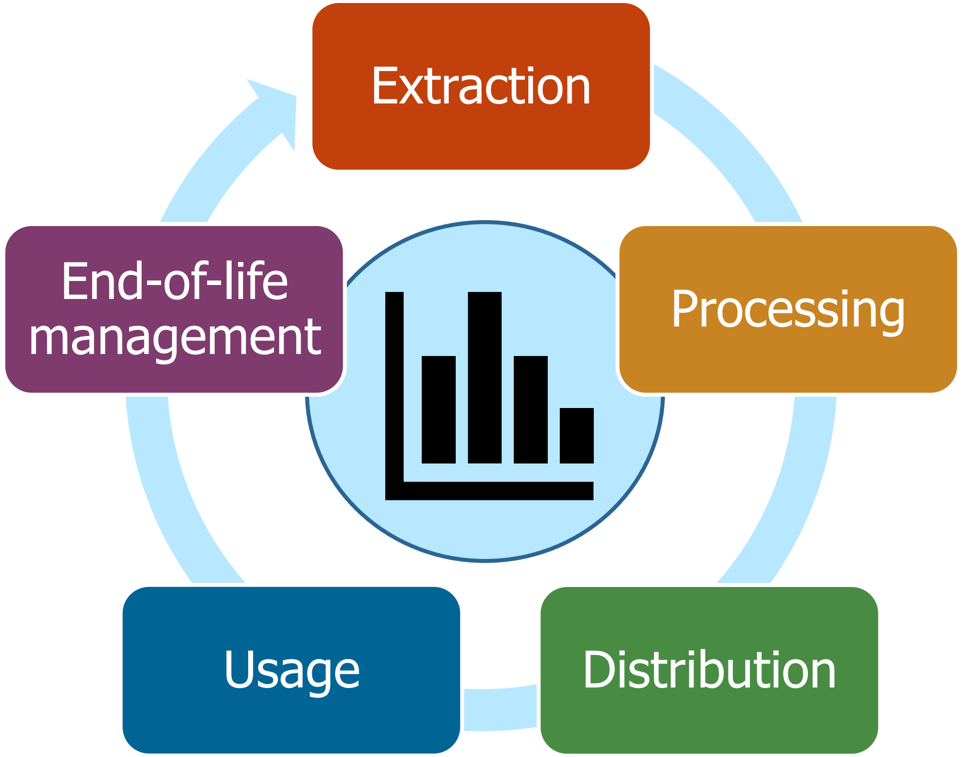
Life Cycle Analysis (LCA)

Measures the environmental impact of a material from extraction to disposal

Potential effects on different environmental impact categories

- Carbon footprint
- Water consumption
- Human and ecological toxicity

Allows for comparison of scenarios for reuse and disposal



See Guidance for Details

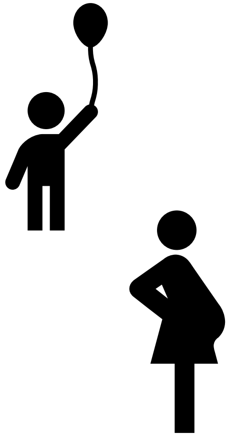
Section 3.3

https://mw-1.itrcweb.org/solid-mining-waste-reuse-considerations/#3.3

Risk Assessment

Formal assessment to evaluate and rank hazards

- Specific to site
- Exposure mediums and routes
- Regulations based on location and type of material

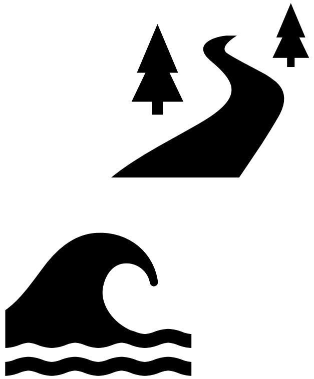


Human Health

- Risks at industrial, residential, and recreation exposures
- Specific populations

Ecological

- Broad groups of receptors (terrestrial, aquatic)
- Specific species



ITRC Bioavailability of Contaminants in Soil: https://bcs-1.itrcweb.org/

Solid Mining Waste Life Cycle and Risk Assessment

- Contaminants and potential exposure pathways
- Site conditions and potential geochemistry change
- Potential increased or decreased risks
- Materials, energy, water and emissions of each potential reuse

Required — Depending on Regulations

Beneficial — For Stakeholder Communication

Bonita Peak Kittimac Tailings Before and After Reclamation.
MW-1, Figure 6-2 and Figure 6-7

Learning Objectives

Characterization: Analysis, Economics, and Life Cycle and Risk Assessment

- Understand solid mining waste context and issues
- Outline methods for site characterization, economic assessment, and life cycle and risk assessment

Where are your biggest questions for solid mining waste reuse during characterization?

A. Waste Analysis

B. Economics

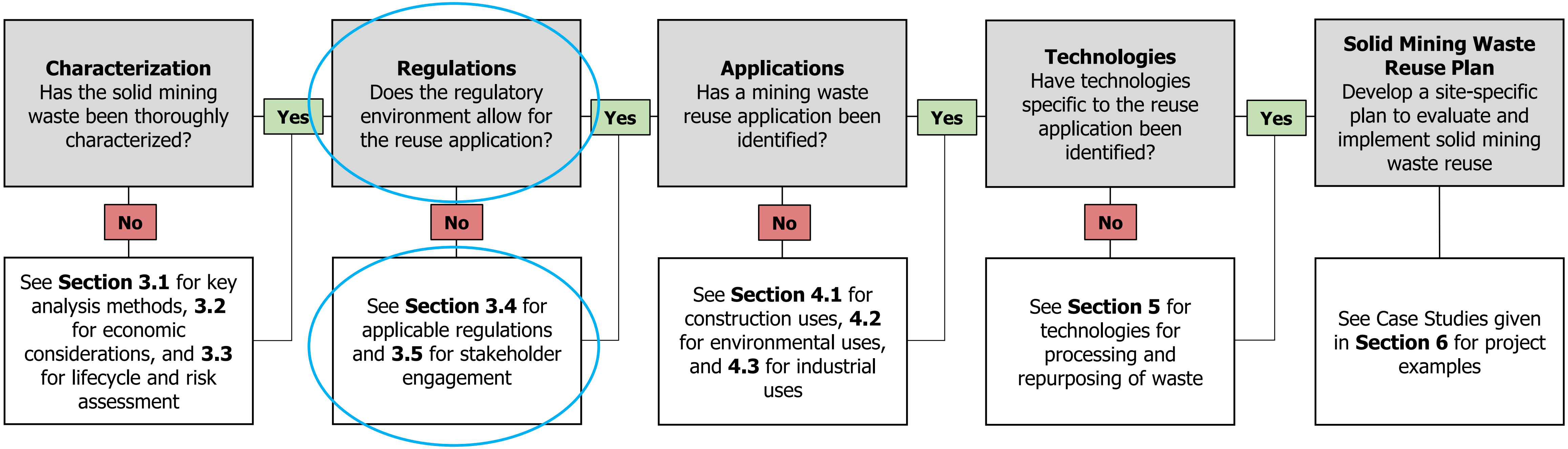
C. Life Cycle Analysis

D. Risk Assessment

Check In!

Training Roadmap

1. Introduction
2. Waste Characterization
   - Analysis
   - Economic Considerations
   - Life Cycle and Risk Assessment
3. **Regulatory and Stakeholder Considerations**
4. Applications
5. Technologies
6. What’s next?



Characterization
Has the solid mining waste been thoroughly characterized?
Yes
No
See **Section 3.1** for key analysis methods, **3.2** for economic considerations, and **3.3** for lifecycle and risk assessment
Regulations
Does the regulatory environment allow for the reuse application?
Yes
No
See **Section 3.4** for applicable regulations and **3.5** for stakeholder engagement
Applications
Has a mining waste reuse application been identified?
Yes
No
See **Section 4.1** for construction uses, **4.2** for environmental uses, and **4.3** for industrial uses
Technologies
Have technologies specific to the reuse application been identified?
Yes
No
See **Section 5** for technologies for processing and repurposing of waste
Solid Mining Waste Reuse Plan
Develop a site-specific plan to evaluate and implement solid mining waste reuse
See Case Studies given in **Section 6** for project examples

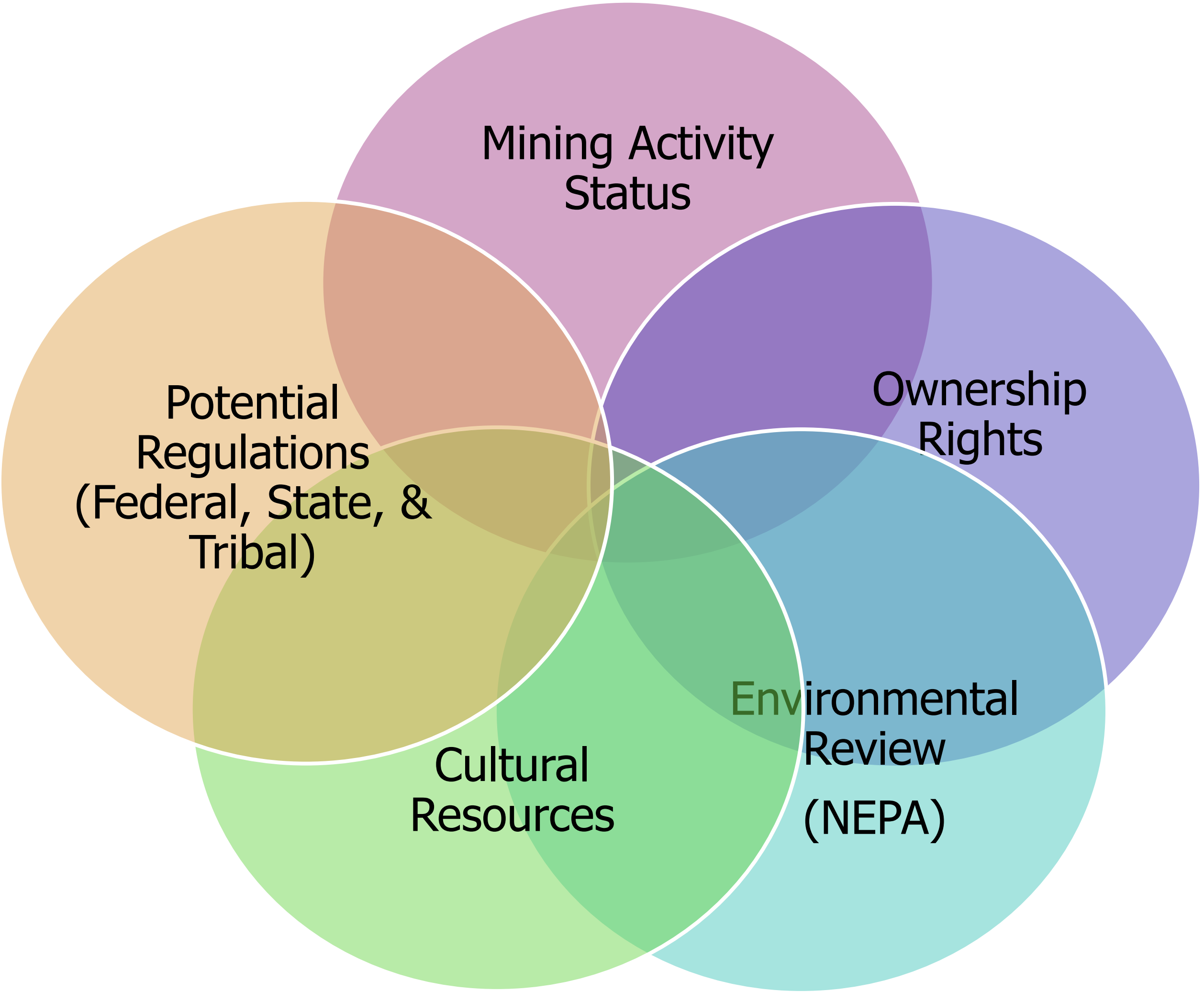
Check In

Check In!

What regulations could apply to a solid mining waste reuse project?

A. Clean Air Act; National Environmental Policy Act
B. Clean Water Act; Resource Conservation & Recovery Act
C. Surface Mining Control & Reclamation Act; Archaeological Resources Protection Act
D. Tribal Treaty Rights; Endangered Species Act
E. All of the Above

Regulatory Considerations



Mining Activity Status

ACTIVE MINE

INACTIVE MINE

ABANDONED MINE

CLOSED MINE

Determining the activity status and identifying a potentially responsible party (PRP) is critical when evaluating mining waste reuse opportunities.

Ownership Rights

Mineral - Mineral rights can encompass various below-the-surface resources such as oil, natural gas, gold, silver, copper, iron, coal, uranium, and other minerals.

Surface - The surface owner often has the rights to resources such as sand, gravel, and surface or groundwater, when considered part of the surface estate.

Water - Water rights are divided between surface water and groundwater, and most states have provisions for inevitable overlap between the two.

See Guidance for Details

Section 3.4.2

https://mw-1.itrcweb.org/solid-mining-waste-reuse-considerations/#3.4

Environmental Review

National Environmental Policy Act (NEPA)

- Requires federal agencies to assess environmental effects of proposed projects prior to decision-making

Council on Environmental Quality (CEQ)

- Some states and local jurisdictions have NEPA-like environmental planning review processes

Tribal Government & Cultural Consideration

- Federal and state laws require government-to-government consultation with tribes

Cultural Resource Considerations

Federal and Tribal Lands

- Antiquities Act
- Historic Sites Act
- National Historic Preservation Act
- Archaeological Resources Protection Act
- NAGPRA*

State and Local Lands

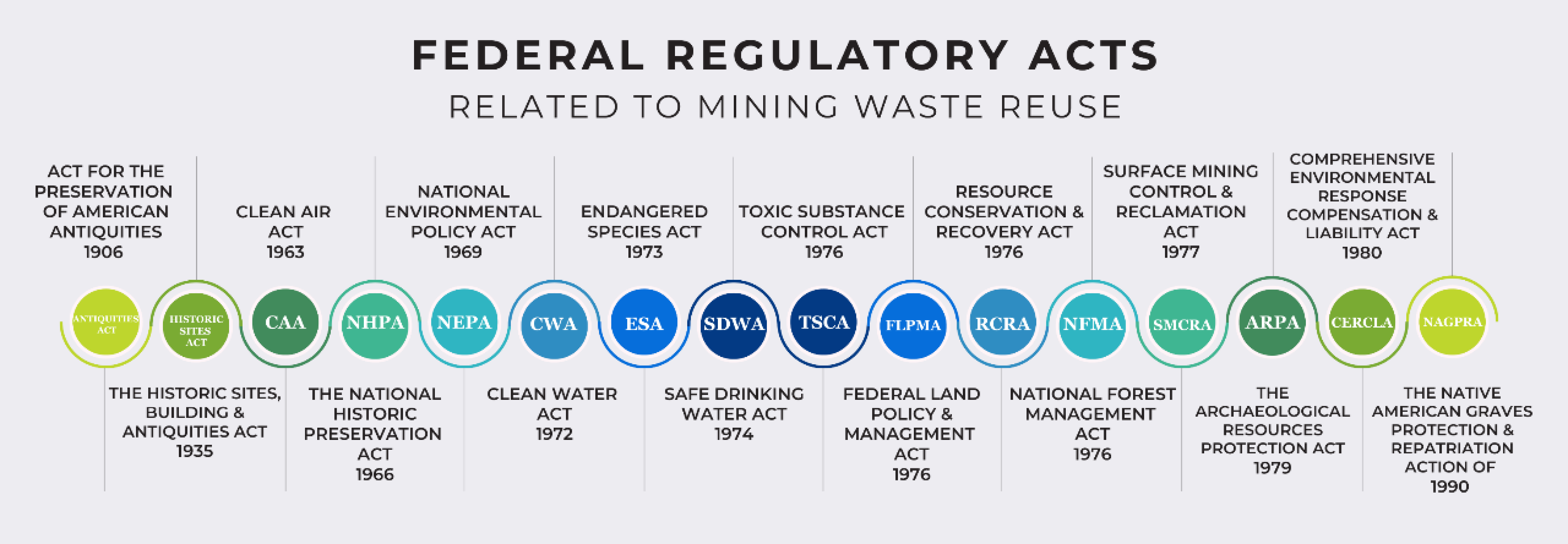
- Historic Preservation Office

Private Lands

- Site specific basis, due diligence should be completed to determine applicability

*Native American Graves Protection & Repatriation Act (NAGPRA)

Potentially Applicable Federal Regulations



See Guidance for Details

Figure 3.3

https://mw-1.itrcweb.org/solid-mining-waste-reuse-considerations/#3.3

State Regulatory Considerations

ITRC Reuse of Solid Mining Waste

Appendix A: State Agencies for Permitting of Solid Mine Waste Reuse

State	State Agency	Tribal Contacts	Abandoned Mines	Mineral Rights	Surface Rights	Water Rights	Mining Permit	Special Reuse Permit
Alabama	Alabama Department of Environmental Management						X	X
	Alabama Surface Mining Commission						X	
	ADECA, Office of Water Resources					X		
	Alabama Department of Labor		X				X	
	AIAC_Home_Page (alabama.gov)	X						
Alaska	Alaska Division of Mining, Land, and Water		X	X	X	X	X	
	DEC Tribal Relations (alaska.gov)	X						
Arizona	Arizona State Mine Inspector (asmi.az.gov)		X		X		X	
	Arizona Department of Environmental Quality (azdeq.gov)		X				X	X
	Arizona Department of Water Resources (azwater.gov)				X	X		
	Office on Tribal Relations | Office of the Arizona Governor (azgovernor.gov)	X						
Arkansas	Office of the State Geologist — Official Home Page (ar.gov)							
	Natural Resources — Arkansas Department of Agriculture					X		

Appendix A. State Table

The agencies involved in permitting the reuse of solid mining wastes vary from state to state. This appendix provides a list of potential state agencies with regulatory authority and links to aid in contacting each state individually.

Download Appendix A – State Agencies Table (.xlsx)

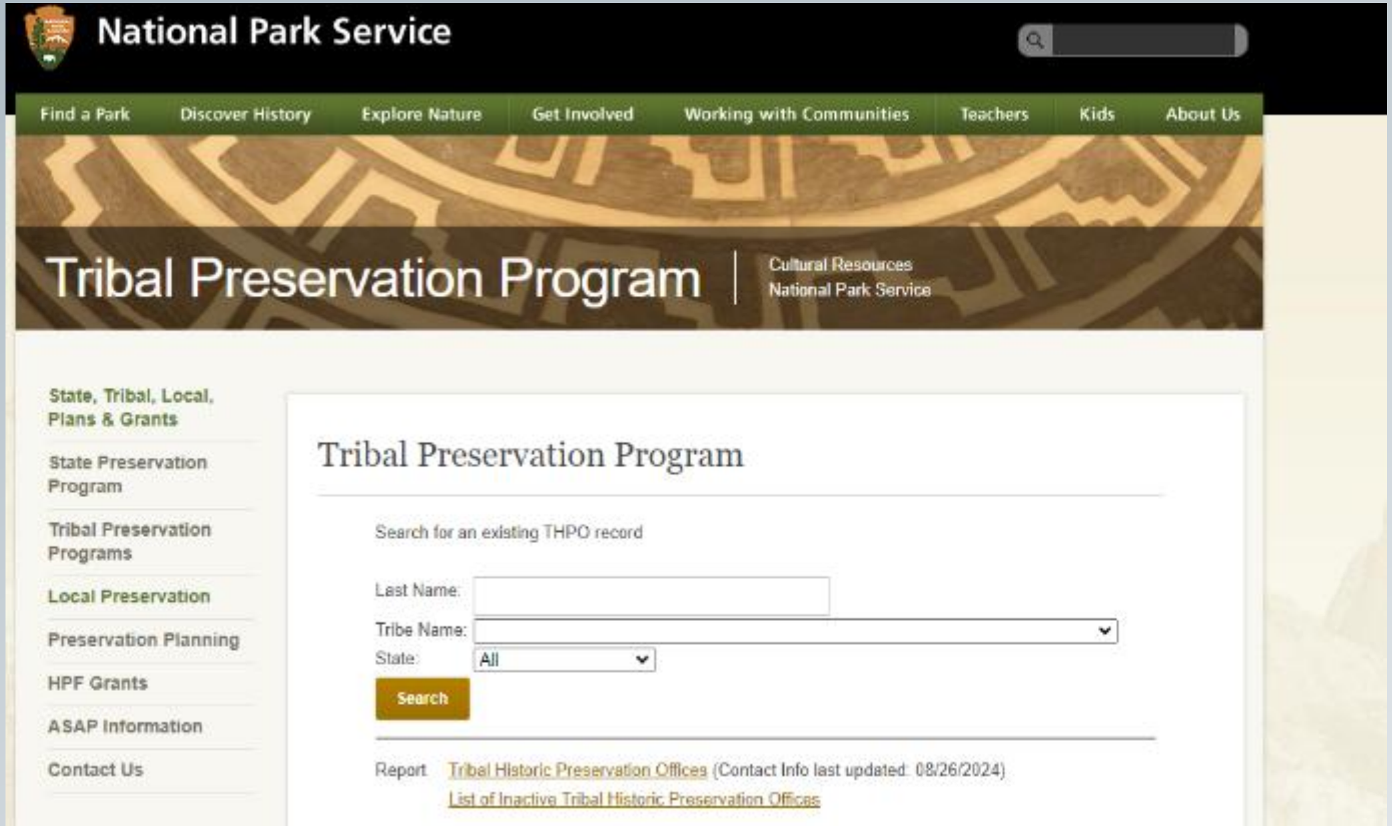
See Guidance for Details

Appendix A

https://mw-1.itrcweb.org/appendix-a-state-table/

Tribal Government Considerations

Check with Federal & state recognized tribes in your site area to determine process and procedure for consultation



Source: https://grantsdev.cr.nps.gov/THPO_Review/index.cfm

Stakeholders and Concerns

- Federal, state, local, and tribal governments
- Business and industry groups
- Landowners
- Community members and organizations
- Non-governmental organizations (NGOs)

- Public health and safety
- Environmental health
- Economic opportunities
- Cultural and historical value

Stakeholder Engagement

Engage

- Give consideration to community's health
- Initially & often throughout project

Open Communication

- Meetings, websites, fact sheets, press releases
- Promote success: jobs, health, safety, value

Project Example – Eagle Picher Mill Site, AZ

- Lead-zinc ore site covering 230 acres
- Underwent remediation in Arizona's Voluntary Remediation Program
- Property designed into a public park & donated to the town

Articulated Concrete Block at Eagle Picher Mill.
MW-1, Figure 6-1

A wa:ato. *Source: Arizona DEQ*

See Guidance for Details

Section 6.2.6

Learning Objectives

Regulatory & Stakeholder Considerations

- Understand solid mining waste issues and opportunities for reuse
- Process to navigate regulatory requirements and stakeholder engagement needs

Check In!

- List a stakeholder you would include in a mining waste reuse project

Questions

Training Roadmap

ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

Characterization
Has the solid mining waste been thoroughly characterized?

Yes → **Regulations**

No → See **Section 3.1** for key analysis methods, **3.2** for economic considerations, and **3.3** for lifecycle and risk assessment

Regulations
Does the regulatory environment allow for the reuse application?

Yes → **Applications**

No → See **Section 3.4** for applicable regulations and **3.5** for stakeholder engagement

Applications
Has a mining waste reuse application been identified?

Yes → **Technologies**

No → See **Section 4.1** for construction uses, **4.2** for environmental uses, and **4.3** for industrial uses

Technologies
Have technologies specific to the reuse application been identified?

Yes → **Solid Mining Waste Reuse Plan**

No → See **Section 5** for technologies for processing and repurposing of waste

Solid Mining Waste Reuse Plan
Develop a site-specific plan to evaluate and implement solid mining waste reuse

See Case Studies given in **Section 6** for project examples

Applications Overview

Construction (4.1): Any related engineering or construction application that involves civil, water, geotechnical, transportation, and structural components

Environmental (4.2): Land reuse, environmental remediation/reclamation of mines and other types of disturbed lands, soil amendments and fertilizers, and for solid or water treatment

Industrial (4.3): Removal of valuable and critical minerals for beneficial reuse in manufacturing

Construction Uses

Fill and Gravel Materials (4.1.1)

Rock Riprap (4.1.2)

Bricks (4.1.3)
Asphalt Concrete(4.1.4)
Cement Concrete (4.1.5)

Generally presented & defined as an "offsite" use

"Onsite" uses are presented & defined as an environmental-related reuse

May have more stringent restrictions in offsite uses due to nature of mining wastes that may contain metals

Critical to assess mining waste for:

- Metals content
- Potential acid generation
- Leachability
- Gradation and other physical properties

Tailing mining waste
MW-1, Figure 6-23

MW-1, Section 4

Construction Uses

Fill and Gravel Materials

- Many State DOTs allow beneficial but safe reuse of mining wastes in road construction as a fill/gravel
- Building foundations should avoid mining wastes that could contain acid-generating minerals

Rock Riprap

- Riprap could be segregated from a mixed-size mine waste pile by removing fines
- Riprap could be reused in transportation projects, shoreline or bridge pilar armoring
- Underwater uses submerge riprap which mitigates acid generation and leaching

Bricks, Asphalt Concrete, and Cement Concrete

- Potential particle size reduction and segregation needed to substitute for other industrially sourced aggregates
- Major benefit is that metals in the mining waste is solidified and encapsulated
- Acid-generating materials would likely be restricted for these reuses
- Large number of possible uses but slow to expand in the industry

Pairing Waste and Applications - Construction

What do you have?	What can you make?
Coarse gravel & boulder sized waste rock	• Fill material • Rip Rap material
Sand and fine gravel sized waste rock, tailings, slag, etc.	• Fill material • Concrete aggregate • Asphalt aggregate • Road-bed material • Stream and beach protection
Fine sand to clay particle sized waste rock, tailings, slag, etc.	• Bricks (pavers) • Soil amendments

Project Example – Tar Creek Superfund Site, OK

- Appropriate Reuse
  - Aggregate in Asphalt
  - Encapsulates metals within asphalt matrix
  - Chat Rule: *40 CFR part 278*
  - Recovery of Critical Minerals – potential for reuse but not current examples

- Inappropriate Uses (due to Cd, Zn, and Pb)
  - Road Base Material
  - Fill Material
  - Abrasive for Sand Blasting
  - Recreational Use

Asphalt concrete with mining waste (chat) making up part of the aggregate mix.
MW-1: Figure 4-1

See Guidance for Details

Section 6.2.2

Environmental Uses – Land Reuse

Land Reuse (4.2.1)

Remediation/ Reclamation (4.2.2)

Soil Amendments/ Fertilizer (4.2.3)

Carbon Sequestration (4.2.4)

Renewable Energy

- Solar, wind, geothermal
- Provides source of income for mine closure and long-term asset management/O&M
- May be Federal/State incentives to renewable energy programs

Recreation

- Hiking/biking trails
- Wetland habitats/nature preserves
- City/county/State parks
- Ball fields
- Golf courses

- Land use applications may need regulatory concurrence

Buffalo Mountain Wind Farm (TN).
Source: EPA

Pairing Waste and Applications – Land Reuse

What is your goal?	What can you use?
Redevelop land impacted by mining • Renewable energy open space (solar, wind, and geothermal) • Sport facilities and outdoor recreation (hiking, snow ski, community sports)	• Stabilized mine waste pile • Reclaimed tailings impoundment • Reclaimed smelter site
Mine reclamation, cover system materials	Solid mining wastes could be used in various cover system types

Solar installation at Chevron Questa Mine (NM)
MW-1, Figure 4-4

Black sand traps at the Old Works Jack Nicklaus signature golf course (MT)
MW-1, Figure 4-6

Environmental Uses – Remediation/Reclamation

Remediation/ Reclamation (4.2.2) → **Containment** | **Grading and Backfill** | **Gravel and Riprap** | **Treatment**

- Mine remediation typically requires granular materials for closure – Many benefits:
  - Cleanup of waste material
  - Mine closure
  - Cost efficiency
  - Reduce energy input

- Similar material types as presented under construction uses but for onsite reuse
- Onsite reuse must be:
  - Compliant with applicable cleanup goals
  - Should not result in future potential risk to human health or ecological receptors

Environmental Uses – Remediation/Reclamation

Containment

- Physical measure applied to control release and transport of contaminants

  1. Exposure barrier 2. Evapotranspiration (ET) cover 3. Low-permeability covers/liners

  - Higher reactivity/metal wastes below cover *(Case studies)*:
    - **Midnite Mine Superfund Site (WA)**
    - **Captain Jack Superfund Site (CO)**
  - Lower reactivity/metal wastes:
    - For use within the layering of an ET cover
    - If high clay content could be used to contain more reactive mining wastes

Grading and Backfill

- Lower reactivity/metal wastes to backfill excavation areas
- Paste backfill of underground mine workings

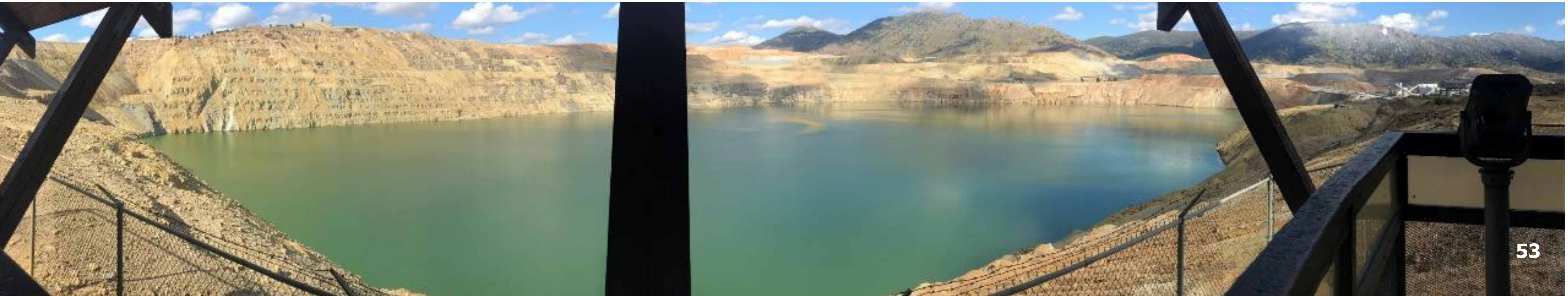
Environmental Uses – Remediation/Reclamation

Gravel and Riprap Material

- Gravel materials could be reused within a repository leachate collection system
- Lower reactivity/metal rock materials could be used for steep slope stabilization

Treatment Materials

- Some types of mining wastes could be used as adsorbents, for MIW neutralization, and for stabilization of acid-generating solid mining wastes
  - Bonita Peak Kittimac Tailings (CO) – MIW treatment sludge was blended with tailings for disposal in an impoundment
  - Silver Bow Creek/Butte Area Superfund Site (MT) – Berkeley Pit treatment using MIW treatment sludge



Pairing Waste and Applications – Remediation/Reclamation

What is your goal or need?	What can you use?
• Grading and backfilling	• Granular materials low reactivity potential
• Slope stabilization	• Large rock or overburden on steep slopes
• Geomembrane bedding	• Finer-grained and non-angular material
• Treatment/Stabilization	• Solid mining wastes with neutralization potential

Geomembrane Bedding at Midnite Mine Superfund Site, WA
Source: CDM Smith on behalf of USEPA Region 10

MIW Treatment Sludge Blending with Tailings at Bonita Peak Superfund Site, CO
MW-1: Figure 6-3

Environmental Uses – Other

Soil Amendments and Fertilizers

- Nutrient amendments
- Physical gradation amendments

Geochemical Carbon Sequestration

- Involves the removal and storage of carbon dioxide from the atmosphere through geochemical processes that convert carbon dioxide to bicarbonate ions or carbonate minerals
- Occurs naturally <u>and</u> can be enhanced through geo-engineering measures (involving the intentional spreading of fine ground alkaline-rich mining waste over large land areas)
- Key advantages -> the waste material is often accessible for use and more reactive (from grinding) compared to natural rock weathering

Industrial Uses

Manufacturing (4.3.1) | **Mineral Pigments (4.3.2)** | **Critical Minerals (4.3.3)**

Manufacturing

- Metal and mineral industrial manufacturing needs
- Countless industrial uses of metals and minerals

Mineral Pigments

- Powders or dyes to add color to raw materials and finished products
- Long history of natural-mineral based pigments

Critical Minerals

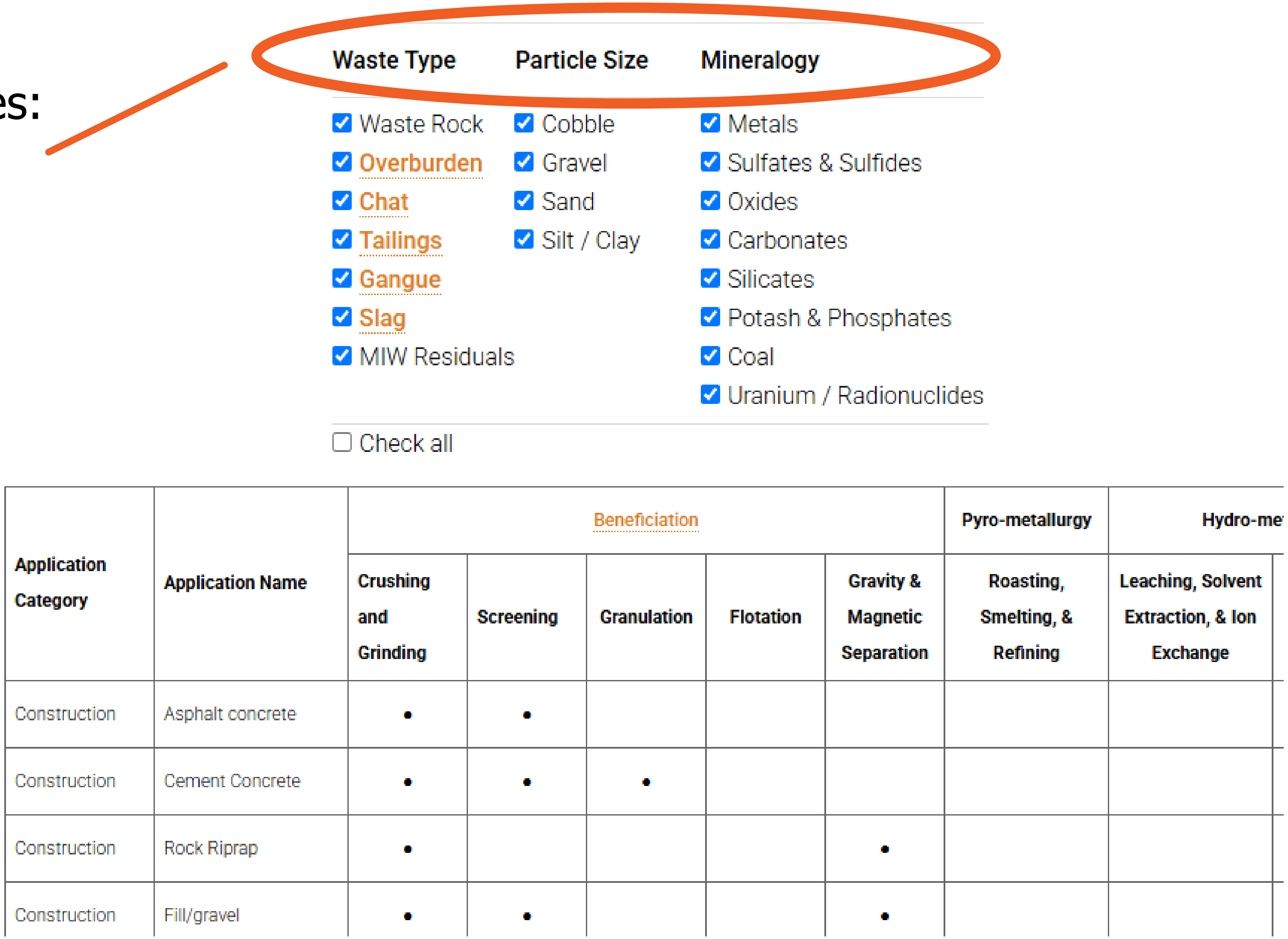
- Metals/materials essential in energy technologies and have potential supply chain disruption
- Fluctuating list published by DOE and DOI every 3 years
- Critical materials for energy and critical minerals lists
- Significant government investment to advance exploration, bolster supply, and technology innovation

Pairing Waste and Applications – Industrial

What do you have?	What can you make?
• Acid mine drainage	• Pigments from treatment sludge
• Critical minerals/rare earth elements	• Energy transition technologies – batteries, turbines, power lines, electric motors
• Residual metals	• Manufacturing

Webtool Overview

Primary sorting criteria or input categories: waste type, particle size, and mineralogy



https://mw-1.itrcweb.org/4-potential-applications-for-reuse-of-solid-mining-waste/#application_tool

Check In – Applications

Check In!

What application have you seen implemented at a site? *(Choose as many as applicable)*

- Offsite Construction - Fill, Gravel, Riprap
- Offsite Construction - Asphalt, Concrete, Bricks
- Land Reuse - Recreational
- Land Reuse - Renewable Energy
- Mine Remediation
- Soil Amendment/Fertilizer
- Carbon Sequestration
- Industrial
- None

Training Roadmap

1. Introduction
2. Waste Characterization
   - Analysis
   - Economic Considerations
   - Life Cycle and Risk Assessment
3. Regulatory and Stakeholder Considerations
4. Applications
5. **Technologies**
6. What’s next?

Characterization
Has the solid mining waste been thoroughly characterized?

No: See **Section 3.1** for key analysis methods, **3.2** for economic considerations, and **3.3** for lifecycle and risk assessment

Yes

Regulations
Does the regulatory environment allow for the reuse application?

No: See **Section 3.4** for applicable regulations and **3.5** for stakeholder engagement

Yes

Applications
Has a mining waste reuse application been identified?

No: See **Section 4.1** for construction uses, **4.2** for environmental uses, and **4.3** for industrial uses

Yes

Technologies
Have technologies specific to the reuse application been identified?

No: See **Section 5** for technologies for processing and repurposing of waste

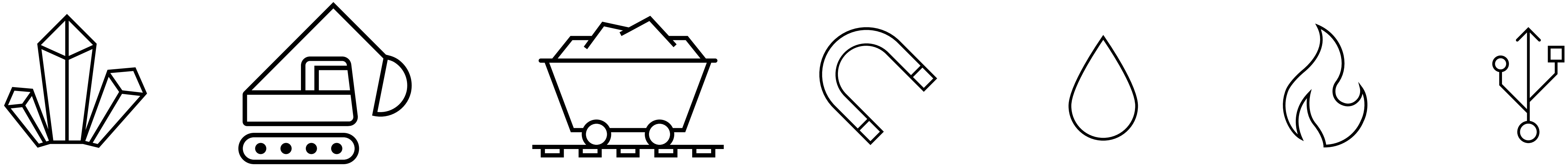
Yes

Solid Mining Waste Reuse Plan
Develop a site-specific plan to evaluate and implement solid mining waste reuse

See Case Studies given in **Section 6** for project examples

Organization

Major parts	Description
1. Evaluation criteria	Criteria used to identify waste reuse considerations
2. Mineral beneficiation technologies	Major bulk mechanical and physical separation processes including crushing, grinding, screening, granulation, flotation, and separation
3. Mineral processing technologies (for metals recovery)	Major refining and recovery processes including hydrometurallurgy, pyrometallurgy, electrometallurgy, and biometallurgy



Evaluation Criteria

Criteria	Description
Applicability	Applicability for reuse for different waste media
Effectiveness	Performance track record
Implementability	Maturity and/or operational complexity
Health protectiveness	Human and ecological health and worker safety considerations
Sustainability	Typical energy, water, and chemical use considerations

Microsoft 2024

Other criteria considered but not retained:

- Relative cost and stakeholder/community considerations because they are highly site specific.

Beneficiation Technology – Descriptions

Technology	Description / Purpose
Crushing, Grinding, and Screening	Initial bulk separation steps to improve the mined materials for handling and processing
Separation (Gravity and Magnetic)	Separation of valuable minerals based on gravity or magnetism
Flotation	Separation of valuable minerals based on surface properties using froth flotation methods
Granulation (Dry and Wet)	Granulation of fine particles to improve the mined materials for handling and processing; wet methods involve the use of a liquid binder

Bagdad Copper Mine, Arizona
(Dunbar et al. 2016)

Beneficiation Technology – Reuse Considerations

Technology	Major Reuse Considerations
Crushing, Grinding, and Screening	- Applicable for coarse and fine particles - Mature, effective, with low complexity - Can generate noise and dust - Energy intensive, some water use
Separation (Gravity and Magnetic)	- Applicable for fine particles - Mature and effective - Limited chemical and water use
Flotation	- Applicable for fine particles - Mature and effective - Involves chemical use; water intensive
Granulation (Dry and Wet)	- Applicable for fine particles - Mature and effective - Wet methods use chemicals and water - Reduces dust exposure

Highland Valley Copper Mine, British Columbia (Dunbar et al . 2016)

Mineral Processing Technology – Descriptions

Technology Group	Description / Purpose
Pyrometallurgy (Roasting, Smelting, Refining)	Use of heat to facilitate chemical reactions to separate and purify metals
Hydrometallurgy (Leaching, Solvent Extraction, Ion Exchange, Concentration, Precipitation)	Use of chemical reactions and solutions to dissolve and separate desired metals
Electrometallurgy (Electrowinning, Electrorefining, Electrocoagulation, and Electrokinetic Migration and Extraction)	Use of electrical energy to extract and refine metals from aqueous or solid phases
Biometallurgy (Biomining and Phytomining)	Use of biology to extract metals from waste

Mineral Processing Technology – Reuse Considerations

Technology Group	Major Reuse Considerations
Pyrometallurgy (Roasting, Smelting, Refining)	- Metals recovery from low-grade waste - Mature technology; fewer U.S. smelters today - Requires proper worker training and equipment - Energy intensive; minimal chemical uses, generates gases
Hydrometallurgy (Leaching, Solvent Extraction, Ion Exchange, Concentration, Precipitation)	- Metals recovery from tailings, mining-influenced water, slag - Mature technology with some novel materials - Requires proper worker training and equipment - Uses chemicals & water; uses less energy than smelting
Electrometallurgy (Electrowinning, Electrorefining, Electrocoagulation, and Electrokinetic Migration and Extraction)	- Metals recovery from mining-influence water - Mostly mature technologies - Requires proper worker training and equipment - Uses less chemicals and water than other technologies
Biometallurgy (Biomining and Phytomining)	- Metals recovery from mining waste - Emerging and promising technologies - Less chemicals and energy use than other technologies

Project Example 1 – Madison Mines, Missouri

- Former lead, copper, and cobalt mine
- Madison County, Missouri
- EPA Superfund site
- Portion of Superfund site near Fredericktown, MO acquired by metals recovery
- Legacy tailings reprocessed using crushing and grinding, flotation, and hydrometallurgy aqueous concentration to produce a filter cake material for electric vehicle batteries
- Future mining planned for cobalt and nickel

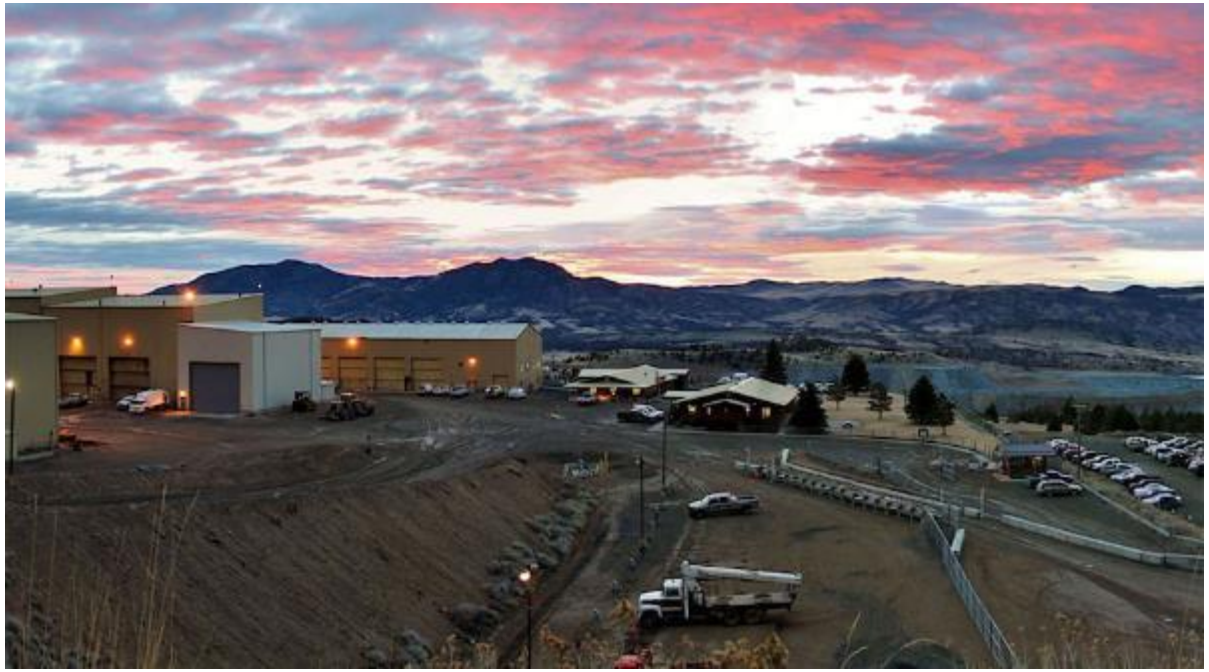
Flotation cell.
MW-1, Figure 6-12

See Guidance for Details

Section 6.2.4

Project Example 2 – Golden Sunlight Mine, Montana

- Former gold mine
- Southwest Montana
- Montana DEQ oversight
- Closure strategy
  - Reprocess tailings to reduce acid mine drainage and need for perpetual treatment
  - Concentrate is shipped to Nevada for gold and sulfur processing
  - Store benign material in the mine pit
- Reprocessing technologies: filtration, flotation, aqueous concentration



Golden Sunlight Mine (2021, www.mining.com courtesy of Barrick Gold)

See Guidance for Details

Section 6.2.5

Webtool Part 2 - Potential Technologies per Application

Waste Type	Particle Size	Mineralogy
☑ Waste Rock	☑ Cobble	☑ Metals
☑ Overburden	☑ Gravel	☑ Sulfates & Sulfides
☑ Chat	☑ Sand	☑ Oxides
☑ Tailings	☑ Silt / Clay	☑ Carbonates
☑ Gangue		☑ Silicates
☑ Slag		☑ Potash & Phosphates
☑ MIW Residuals		☑ Coal
		☑ Uranium / Radionuclides

☐ Check all

Application Category	Application Name	Beneficiation: Crushing and Grinding	Beneficiation: Screening	Beneficiation: Granulation	Beneficiation: Flotation	Beneficiation: Gravity & Magnetic Separation	Pyro-metallurgy: Roasting, Smelting, & Refining	Hydro-me: Leaching, Solvent Extraction, & Ion Exchange
Construction	Asphalt concrete	•	•					
Construction	Cement Concrete	•	•	•				
Construction	Rock Riprap	•				•		
Construction	Fill/gravel	•	•			•		

Waste Type	Particle Size	Mineralogy
☑ Waste Rock	☑ Cobble	☑ Metals
☐ Overburden	☑ Gravel	☐ Sulfates & Sulfides
☐ Chat	☐ Sand	☐ Oxides
☐ Tailings	☐ Silt / Clay	☐ Carbonates
☐ Gangue		☐ Silicates
☐ Slag		☐ Potash & Phosphates
☐ MIW Residuals		☐ Coal
		☐ Uranium / Radionuclides

☐ Check all

Application Category	Application Name	Beneficiation: Crushing and Grinding	Beneficiation: Screening	Beneficiation: Granulation	Beneficiation: Flotation	Beneficiation: Gravity & Magnetic Separation	Pyro-metallurgy: Roasting, Smelting, & Refining	Hydro-metallu: Leaching, Solvent Extraction, & Ion Exchange	Hydro-metallu: cor P
Construction	Asphalt concrete	•	•						
Construction	Cement Concrete	•	•	•					
Construction	Bricks	•	•	•					
Environmental	Renewable Energy	•	•	•		•			
Environmental	Recreation	•	•	•		•			
Environmental	Containment	•	•	•					
Environmental	Treatment Materials	•	•	•	•	•			
Environmental	Soil Amendments & Fertilizers	•	•	•					

Learning Objectives

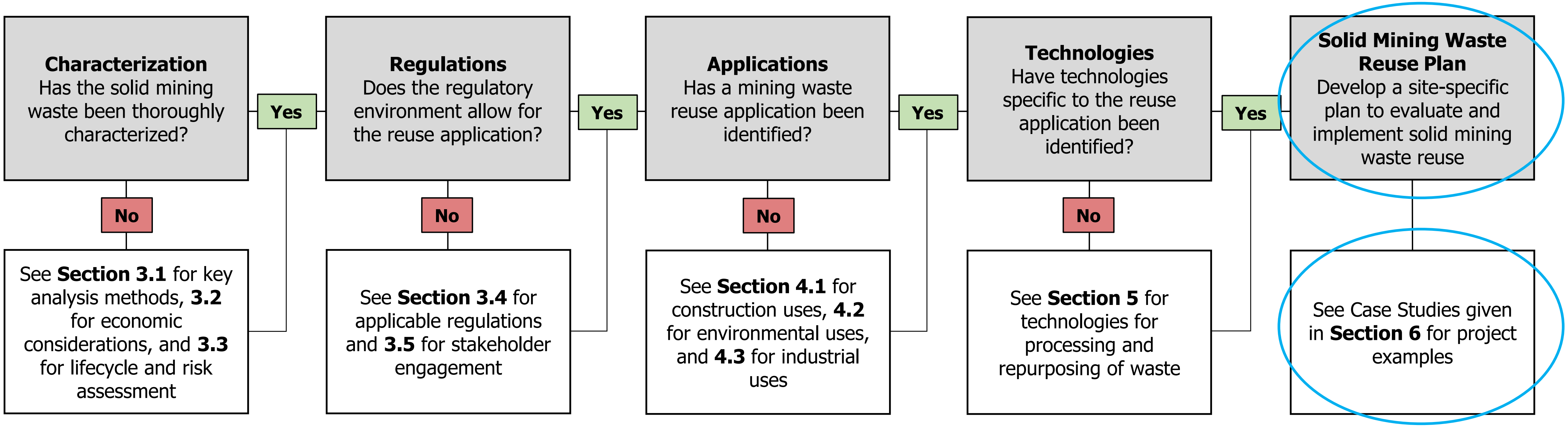
Technology Review

- Define and contrast applicable technologies involved in the beneficial reuse of mining waste

Training Roadmap

ITRC INTERSTATE TECHNOLOGY REGULATORY COUNCIL
ECOS
ERIS ENVIRONMENTAL RESEARCH INSTITUTE OF THE STATES

Process to evaluate reuse potential



Case Studies in Guidance

Project Summaries

- Shorter form, 1-2 paragraphs
- Examples for further research

Case Studies

- Narrative form, 1-5 pages
- More details and descriptions

Reuse of Solid Mining Waste

6. Project Summaries and Case Studies

This section presents several project summaries where mining waste reuse has been considered, and in some cases, successfully implemented. Table 6-1 lists the project summaries and the eight sites that have full case studies.

Table 6-1. List of mining sites with project summaries

State	Site Name	Mine Status	Target Application	Mining Waste	Mineral of Interest
AZ	Eagle Picher Mill Voluntary Remediation Program Site – Brief – Full Case Study	Closed	Remediation, land reuse	Tailings	Not applicable
CA	Empire Mine State Historical Park – Brief	Closed	Land reuse, metal recovery, road construction reuse, and potential remediation reuse	Tailings and waste rock	Gold and silver
CO	Bonita Peak Superfund Site, Kittimac Tailings – Brief – Full Case Study	Abandoned	Remediation, reclamation, two waste streams commingled for inert monofill	Water treatment sludge, tailings	Not applicable

Where to go from here as a site owner/interested party?

1. Characterize waste
2. Identify potential applications
3. Determine regulatory requirements
   - Risk assessment
   - Life cycle analysis
   - Stakeholder opinion
4. Assess economic feasibility
   - Compare technology and potential applications
5. Write solid mining waste reuse plan with chosen application
   - Confirm regulatory acceptance
6. Adapt following feedback
   - Additional potential characterization needs
   - Stakeholder communication

Where to go from here as a regulator?

1. Evaluate waste characterization
   - Any missing tests that weren't conducted? Data is comprehensive for the site?
2. Evaluate technology effectiveness
   - Is method supported by prior demonstrations?
3. Ensure compliance with applicable local, state, and federal requirements
   - Are there other offices to coordinate with?

What's New Since the ITRC Guidance?

NEW

- **Good Samaritan Remediation of Abandoned Hardrock Mines Act**
  - www.congress.gov/118/plaws/publ155/PLAW-118publ155.pdf
  - Clean up orphan mine sites with CERCLA waivers
  - Arizona House Concurrent Memorial (HCM) 2007 Hardrock Mine Remediation

- **U.S. Geological Survey**
  - Technical Approach for Prioritizing Critical Mineral Research (USGS, December 2024)
  - USGS Proposed Changes to Critical Mineral List

- **Environmental Monitoring and Remediation Technology Assessment Initiative** (EMRTAI) https://www.emrtai.org/

Learning Objectives – Overall Review

- Understand solid mining waste context and issues
- Outline methods for site characterization, economic assessment, and life cycle and risk assessment
- Identify processes to navigate regulatory requirements and stakeholder engagement needs
- Assess opportunities for solid mining waste reuse
- Define and contrast applicable technologies involved in the beneficial reuse of mining waste

Questions

https://mw-1.itrcweb.org/

Certificate of Completion https://cluin.org/conf/itrc/MiningWaste/
(emailed after you complete the Feedback Form)