MINING AND MINERALS SECTOR R&D Roadmap for Critical Minerals

Updated as of 29 February 2024

OVERALL STRATEGIES

Human Resource

- 1.Capacitate researchers on critical minerals extraction and processing
- 2.Participation in short courses/training abroad on critical minerals extraction and processing
- 3.Conduct benchmarking activities, visit laboratories, facilities, processing plants abroad related to critical minerals extraction and processing
- 4. Invite Balik-Scientists with expertise on critical mineral processing

Laboratory Facilities / Services

- 1.Equip SUCs, HEs and RDIs with advanced laboratory equipment 2. Availability of testing facilities needed in the research
- 3. Availability of facilities to produce target products at pilot scale level

R&D Technologies

- 1. Extensive ore exploration method with advanced ore characterization in support of critical minerals processing
- 2. Extraction of high value critical minerals from metallic (gold, copper, nickel, iron, chromite) and other metallic ores
- 3. Extraction of high value critical minerals from nonmetallic minerals
- 4. Extraction of high value critical minerals from mine tailings/wastes/silts
- 5. Processing/refining/purification of the extracted critical minerals for industrial application

S&T Policies:

- · R&D collaboration with HEIs, RDIs and private sector partners for the above research
- R&D collaboration with foreign funding agencies and foreign research institutions
- · Technically and scientifically sound basis research results for policy formulation on the value-addition of metallic and nonmetallic minerals and mine tailings and the establishment of processing facilities

50M

- nickel from nickel ores for electric vehicle (EV) battery Development of technology for the removal and stabilization of
- Development of technology for the extraction of gold from
- refractory gold ores • Development of technology for the extraction of rare earth
- elements (REE) from bauxite ores Development of technology for
- the extraction of copper from copper ores
- Development of refining innovative technology for technology to produce the extraction of copper 99.9999% high purity copper from copper mine tailings

· Development of extraction technology for nickel from nickel laterite



25M

technology for the

drainage (AMD)

Development of

ores

recovery of valuable

metals from acid mine

· Development of

 Available technology to recover mixed Ni-Co for battery application and REE/Sc and magnetic iron concentrates for other application Available technology to extract REE from phoshogypsum tailings Available technology on the recovery of Ni, Co, Cu, Pb and Cd from gold mining wastes using areen nanohvdrometallrugv

 Upgraded three (3) laboratories for critical minerals extraction Capacitated six (6) technical personnel on deep eutectic solvents (DES)

- Development of technology for the extraction and processing of
 - Development of extraction of REE from phosphogypsum
- arsenic in gold and copper ores tailings Development of
 - extraction of copper from small scale copper mine tailings
 - Development of technology for the recovery of REE from coal fly ash

30M

2024

- Novel technique for the recovery of valuable metals from AMD through bimetallic materials
- In-situ innovative methods using deep eutectic solvents (DES) for the extraction of copper from copper tailings Technology on the extraction
- Upgraded three
- mineral extraction
- technical personnel on critical minerals extraction
- support of the processing of minerals locally and adoption by the local partners

130M

mine tailings

- · Development of method for the extensive ore exploration with advanced ore characterization of critical minerals in mineral reserves Development of extraction technology of gold and
 - conductor and solar panels mercury from small scale gold

2026

100M

metallurgical methods to

extract high value metals

mineral reserves for semi-

from mine tailings and

Development of

 Technology on green novel organic solvents for laboratory stage extraction of gold and recovery of mercury in low grade ore and gold mine tailings Efficient and cost-effective recovery of radionuclides and REE extraction technology from phosphogypsum tailings

- Hydrometallurgical strategies for bench scale extraction of critical REE and strategic elements from Philippine
- Capacitated ten (10) technical personnel on process mineralogy
- Upgraded three (3) laboratory At least 40 capacitated/trained on facilities
- At least 10 capacitated/trained on refining minerals locally and adoption by the local partners

R&D Technologies

techniques

• Novel technologies on critical minerals processing from metallic, non-metallic and mine tailings/wastes

critical minerals extraction

critical minerals for specific application

100M

Development of metallurgical

methods to extract high value

metals from mine tailings and

Extensive data on critical

reserves (geological maps,

image data on host rocks.

advanced method analysis

minerals in mineral

etc) with novel and

on critical minerals

exploration and

characterization

Available advanced

technology on the

and solar panels

extraction and processing

mineral reserves and mine

tailings for semi-conductor

of critical minerals from

2027

mineral reserves for wind

turbines, magnets, etc

100M

Ongoing

 Development of metallurgical methods to process high value metals from mine tailings and mineral reserves for other emerging technology application

2028

VISION:

Done

Philippines as hub for critical minerals for emerging and green technology

application

Target

- Available advanced technology on the extraction and processing of critical minerals from mineral reserves and mine tailings for windmills, magnets, etc
- Capacitated ten (10) technical personnel on process mineralogy
- Upgraded six (6) laboratory facilities
- Policy recommendation in support of the processing of minerals locally and adoption by the local partners

OVERALL OUTCOMES

Facilities / Services

 Upgraded/established at least 10 laboratories for extraction and refining of critical minerals/elements

S&T Policies

 Policy recommendation on the value-addition of minerals and the establishment of critical minerals processing in the Philippines



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the extraction of REE from coal fly ash (CFA) Upgraded two (2) laboratories for critical minerals extraction Capacitated eight (8) technical

slag

- personnel on minera processing
- · Technical report in support of the valueaddition/processing of minerals in the country

2023 Available technology for the recovery of

scandium from pig iron

· Available technology on

of Ni and NiSO4 for EV battery

(3) laboratories on critical

• Capacitated six (6)

Policy recommendation in

2025

 Available processing technology to produce copper concentrate with reduced arsenic and waste product with stable arsenic · Eco-efficient method for refractory gold recovery · A green leaching process for

REE from bauxite using DES · Process for copper recovery using hydrometallurgy and solvometallurav

 Extraction of copper from copper skarn deposits and artisanal Au-Cu mine tailings using

· Extraction of nickel from nickel

 Capacitated ten (10) technical personnel on process mineralogy

Upgraded 6 laboratory facilities

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 Electrorefining process to produce high purity copper cathodes (99.9999%) ioonometallurgy techniques ores using DES

CFA

- Human Recourse
- Policy recommendation in support of the processing of

R&D Technologies	Ne		BUDGET ALLOCATION (PhP)							STATUS
Rad rechnologies	No	Projects	2022	2023	2024	2025	2026	2027	2028	31A103
Extraction of high value critical minerals from metallic ores	1	Recovery of Nickel, Cobalt, Iron and Rare Earth Elements from Low Grade Philippine Laterite Ores using Atmospheric Leaching with Reduction Pre-treatment	-							Completed
Extraction of high value critical minerals from mine tailings/wastes/silts	2	Extraction of Radionuclides, Rare Earths, and Other Valuable Industrial Elements from Philippine Phosphogypsum Tailings	-							Completed
Extraction of high value critical minerals from mine tailings/wastes/silts	3	Valorization of Mining Wastes by Green Nano-hydrometallurgy: Application of Green- mediated Leaching Process and Innovative Magnetic Nano-separations for the Recovery of (Precious)Metals	4,981,050.00							Completed
Extraction of high value critical minerals from mine tailings/wastes/silts	4	Recovery of Scandium from Laterite-based Pig Iron Slag by Dry Digestion and Precipitation Methods	1,146,250.76							Completed
Extraction of high value critical minerals from mine tailings/wastes/silts	5	Recovery of rare earth elements and strategic elements from coal fly ash by hydrometallurgical technique	2,256,612.00							Completed
Extraction of high value critical minerals from met allic ores	6	Extraction of Ni and NiSO4 from Nickel ores for EV battery application	10,642,043.24	6,473,793.24						On-going
Extraction of high value critical minerals from mine tailings/wastes/silts	7	A novel technique for the recovery of valuable metals from AMD through bimetallic materials	3,986,729.60	2,261,729.60						On-going
Extraction of high value critical minerals from mine tailings/wastes/silts	8	PROMT: Philippine Remediation of Mine Tailings (Large Grant)	6,031,905.60	5,818,057.54	4,774,404.38					On-going
Extraction of high value critical minerals from met allic ores	9	REVIVE PH: Responsible Extraction of Various Valuable Elements in the Philippine Laterite Deposits		6,286,627.20	5,336,627.20					On-going
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R&D Technologies	No		BUDGET ALLOCATION (PhP)							OTATUO
		Projects	2022	2023	2024	2025	2026	2027	2028	STATUS
Extraction of high value critical minerals from metallic ores	10	Removal and stabilization of arsenic in gold and copper ores using aqueous and nonaqueous solvents		4,950,144.00	3,735,545.85					On-going
Extraction of high value critical minerals from metallic ores	11	Innovative technology for refractory gold extraction using deep eutectic solvent (DES) and hypochlorite solution		4,943,127.40	3,492,320.62					On-going
Extraction of high value critical minerals from mine tailings/nonmetallic minerals	12	Rare earth elements in bauxite: characterization and extraction of a potential resource		3,277,692.42	2,750,797342					On-going
Extraction of high value critical minerals from metallic ores	13	Cu-HySolvEr: Copper Hydrometallurgical and Solvometallurgical Extraction from Sulfides and Oxides		3,542,360.00	2,386,512.00					On-going
Extraction of high value critical minerals from metallic ores	14	Electrorefining Process Development for the Production of 6N Copper Cathodes (Cu- Refine)		3,211,274.00	1,746,898.00					On-going
Extraction of high value critical minerals from mine tailings/wastes/silts	15	From Waste to Wealth: Hydrometallurgical Strategies for Bench Scale Extraction of Critical Rare Earth and Strategic Elements from Philippine Coal Fly Ash, and Other Environmental Applications)			8,870,600.00					On-going
Extraction of high value critical minerals from mine tailings/wastes/silts	16	Application of Ionometallurgy for Recovery and Extraction of Copper from Copper Ore and Artisanal Copper-Gold Tailings (I- REACT			4,999,142.40					New
Extraction of high value critical minerals from mine tailings/wastes/silts	17	Extraction of Radionuclides, Rare Earths, and Other Valuable Industrial Elements from Phosphogypsum Tailings			7,797,521.80	4,926,521.80				New
Extraction of high value critical minerals from mine tailings/wastes/silts	18	NEAT-ORE: Novel Extraction of Au and other critical metals in Artisanal Tailings and Low-Grade Ores using organic solvents			7,232,365.10					New



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MINING AND MINERALS SECTOR - R&D Roadmap for Technologies in Support of the Remediation of Mined Areas

10M

Development of a technology

for industrial application

utilizing mine tailings/wastes/silt

Target

VISION:

Appropriate

technologies

to reduce

negative

environmental

impacts and

improve mine

rehabilitation

techniques

Updated as of 29 February 2024

OVERALL STRATEGIES

Human Resource

- 1. Capacitate researchers on (1) circular economy in mine tailings/wastes/silt and rehabilitation/remediation/restoration techniques and (2) ex-ante assessment of offshore and onshore mined area
- 2. Participate in short courses/training abroad on mine tailings/wastes/silt circular economy and rehabilitation/remediation/restoration techniques and (2) ex-ante assessment of mined area (legacy, artisanal small-scale mines, offshore mining)
- 3. Conduct benchmarking activities/visit laboratories, facilities, processing plants abroad
- 4. Invite Balik-Scientist with expertise on circular economy in mining and rehabilitation techniques

Laboratory Facilities / Services

- Equip SUCs, HEsl and RDIs with advanced 1. equipment
- 2. Availability of testing facilities needed in the research
- 3. Availability of facilities to produce target products at pilot scale level

R&D Technologies

- 1. Utilization of mine tailings/wastes/silt for industrial application
- 2. Application of circular economy
- Innovative, environment friendly rehabilitation/remediation/restoration techniques for mined-out/abandoned mine areas
- Assessment of the impact of legacy and artisanal 4. small-scale mines
- 5. Assessment of offshore mining

S&T Policies:

- 1. R&D collaboration with HEIs, RDIs and private sector partners for the above research
- 2. R&D collaboration with foreign funding agencies and foreign research institutions 3. Technically and scientifically sound basis
- research results for policy formulation on (1) processing mine tailings/wastes/silt, (2) circular economy application for mine tailings/wastes/silt,and (3) sustainable management/ development of marine mineral resources in the country.

5M · Development of an active remediation

technique for environmental

treatment of acid mine drainage (AMD)



Mobile app for primary data collection Management tool for

sediment yield calculation and evaluating sitespecific sediment control and rehabilitation plans Capacitated two (2) technical personnel on the development of a

monitoring and

rehabilitation tool in a

surface mine area

analysis for

- species that could be used for policy system sediment making on matters of land use and development of the area.
 - Capacitated four (4) technical personnel on (1) Hg speciation and

10 M

technology utilizing copper

mine tailings as valuable

technology utilizing nickel

mine wastes for industrial

2023

Available cost-effective process of

Policy recommendation on (1)

Development of a

· Development of a

products

application

samples

(2) processing tailings to useful products

10M Development of a

- technology utilizing phosphogypsum tailings for industrial application
 - 2024
 - Available technology to produce ferrite treating AMD
- of AMD Technology utilizing copper tailing and river silt for the analyzing total mercury and mercury production of a cementitious species from different environmental material for 3D printing
- applications Available technology to produce Valorization of Nickel Mine bricks, pots, garden statue, and other Wastes in Palawan as products from gold mine tailings Sustainable Materials for
- Feasibility study adopting Circular the Production of Nano-Economy and Industrial Symbiosis modified Drilling Fluids Upgraded three
- (3) laboratories monitoring of mercury concentrations in sediments and crustaceans in Capacitated six (6)
- coastal areas of Puerto Princesa near technical personnel on mercury mine and small-scale gold mine waste processing and
- mining sites in the country and (2) spatial distribution map of different Hg AMD management

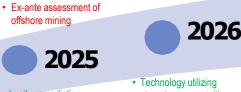


2025 In-situ remediation techniques for mine tailings using Deep Eutectic Solvents (DES)

40M

offshore mining

- Novel methods on the following:
 - to predict future mines contamination patterns methodologies on water
 - quality monitoring approach
 - methodology to simulate water quality in river catchments
 - Capacitated ten (10) technical personnel on novel remediation techniques and novel
 - assessment method • Upgraded two (2)
 - laboratories/facilities



phosphogypsum tailings through carbon sequestration and cementitious material to achieve low-carbon circular

20M

Assessment of artisanal small

scale mining (gold/copper)

- economy Capacitated three (3) technical personnel on low carbon circular economy
- Upgraded one (1) laboratory facilities

Human Recourse

- At least 20 trained on mine remediation /rehabilitation/restoration techniques
- At least 20 trained on utilization of mine tailings
- At least 10 trained on development of method analysis for assessment of legacy mines, offshore mining and artisanal small-scale mines

R&D Technologies

- Technologies on mine remediation/restoration
 - Technologies on the utilization of mine

- technical personnel on sustainable management of small scale mines • Upgraded two (2) laboratory facilities
- OVERALL OUTCOMES

Facilities / Services

Upgraded/Established at least 10 laboratories for research on the utilization of mine tailings/wastes/silt

S&T Policies

- Policies on sustainable management of mine tailings, wastes and silt
- Policies on remediation of abandoned mines
- Policies on sustainable management of marine minerals resources



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• tailings/wastes/silt

to valuable products

ex-ante assessment of offshore mining Upgraded one (1) laboratory facility

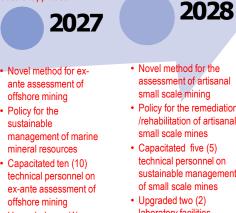
10M

Development of a technology

tailings/wastes/silt for

industrial application

utilizing mine





R&D Technologies	No	Projects	BUDGET ALLOCATION (PhP)							07.17110
			2022	2023	2024	2025	2026	2027	2028	STATUS
Innovative, environment friendly rehabilitation/remedia tion/restoration techniques for mined-out/abandoned mine areas	1	SMART MINE: Development of Sediment Monitoring and Analysis for Rehabilitation Tool in a surface MINE area	-							Completed
Utilization of mine tailings/wastes/silt for industrial application	2	Gold Mine Tailings Utilization for Waste Reduction and Socioeconomic Benefits	4,853,910.44							Completed
Assessment of the impact of legacy mines	3	Speciation and Isotopic Characterization of Mercury in Honda Bay and Puerto Princesa Bay, Palawan	3,795,786.00							Completed
Utilization of mine tailings/wastes/silt for industrial application	4`	A two-step neutralization ferrite process as active remediation technique for environmental treatment of AMD	3,986,729.60	2,261,729.6						Completed
Utilization of mine tailings/wastes/silt for industrial application	5	Valorization of Nickel Mine Wastes in Palawan as Sustainable Materials for the Production of Nano-modified Drilling Fluids		4,997,428.80						Completed
Utilization of mine tailings/wastes/silt for industrial application	6	Marindu-crete 3D: Development of a Cementitious Material from Tailings and Silt for 3D Printing Applications		4,945,934.58						On-going
Assessment of the impact of legacy and artisanal small scale mines	7	Philippine Mining at the National to Catchment Scale: from Legacy Impacts to Sustainable Futures (Project PAMANA)	6,122,011.00	4,652,763.00	4,225,225.60					On-going
Utilization of mine tailings/wastes/silt for industrial application	8	Carbon sequestration and low-carbon cementitious material from Phosphogypsum repurposing (CARBOPHOS)			5,593,244.60	4,355,744.60				New

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