The Assessment of the Life Cycle Environmental Impacts of Copper Production

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What is Environmental Impact Assessment (EIA)?

- EIA is a problem-solving approach to the decision making process.
- EIA is the process and the document.

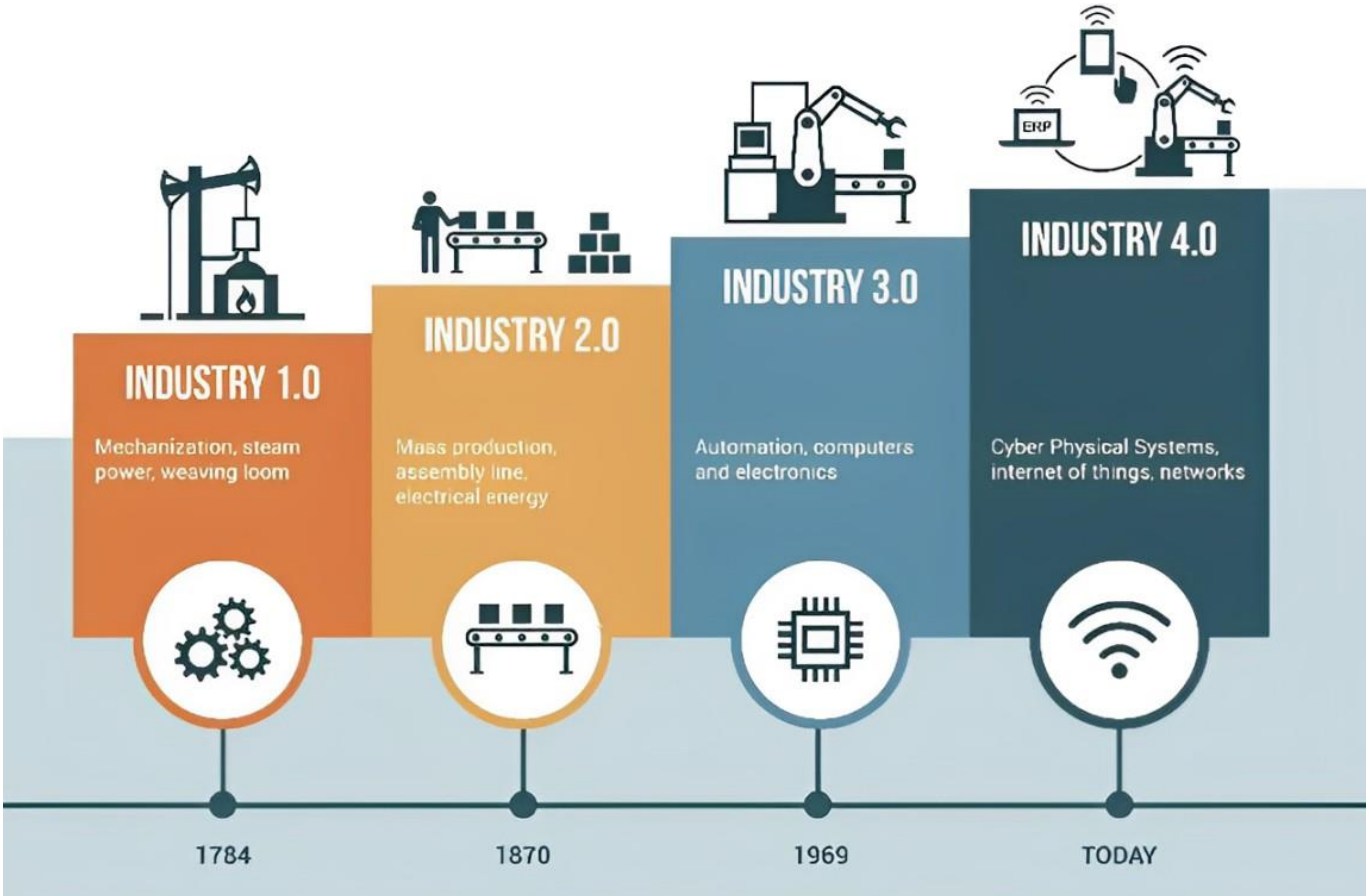
What is EIA?

- EIA is both a decision making process and provides a systematic, reproducible, and interdisciplinary evaluation of the potential effects of a proposed action and its practical alternatives on the physical, biological, cultural, and socioeconomic attributes of a particular geographical area.

- Sustainable Development and Environmental Conservation

Material Engineering Evolution

Industrial Evolution: From 1 to 4



Evolution in Underground Mining

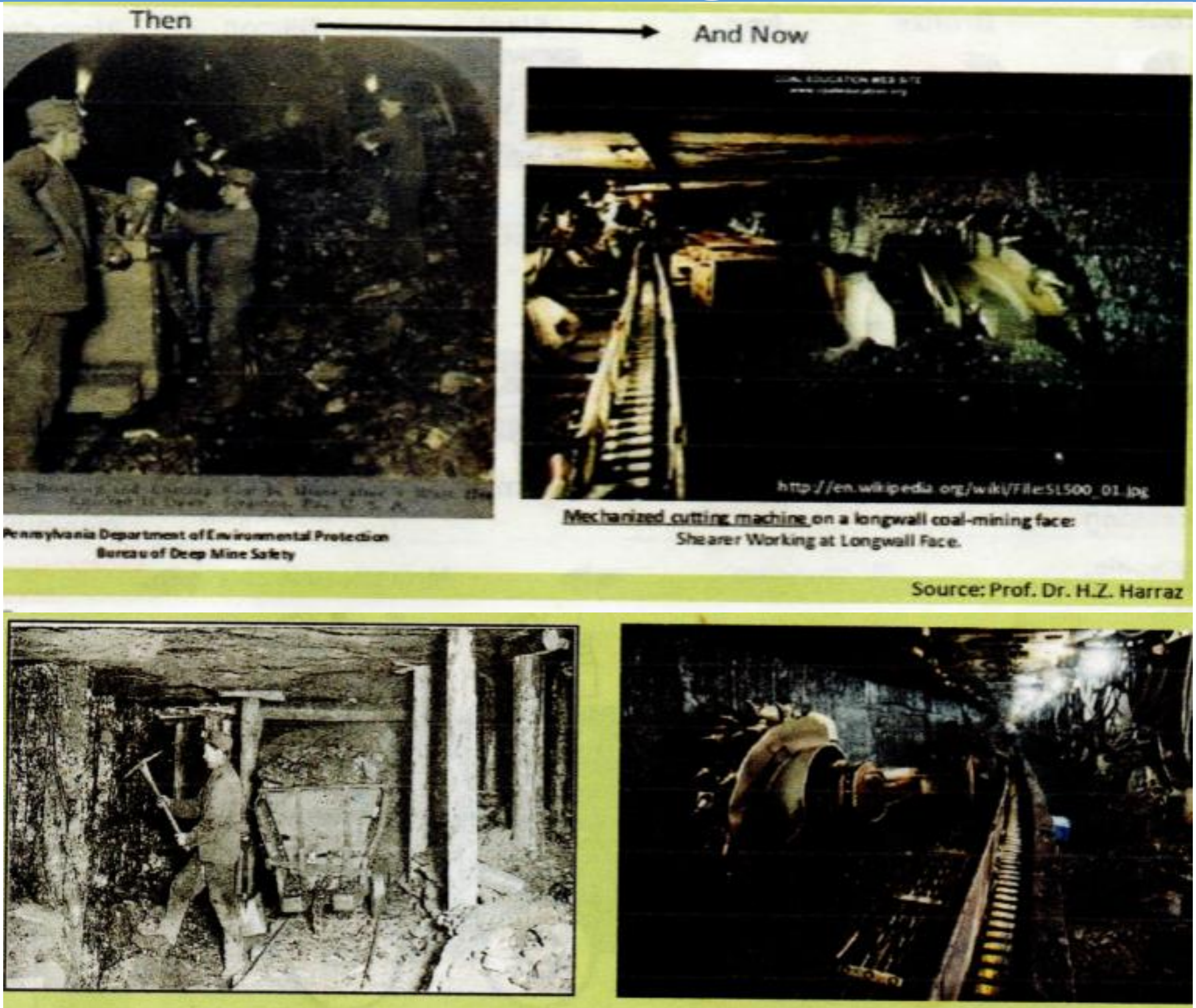
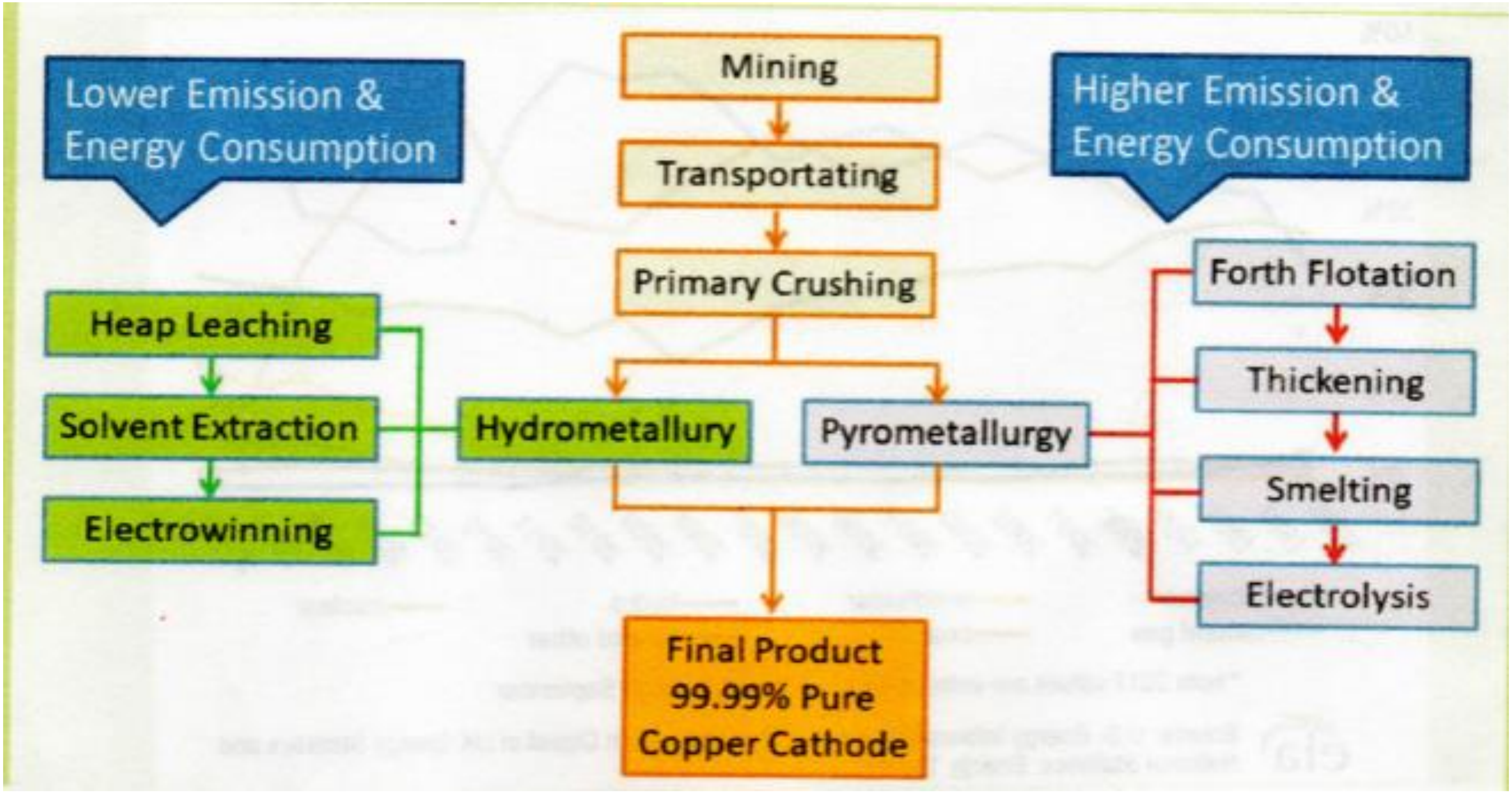
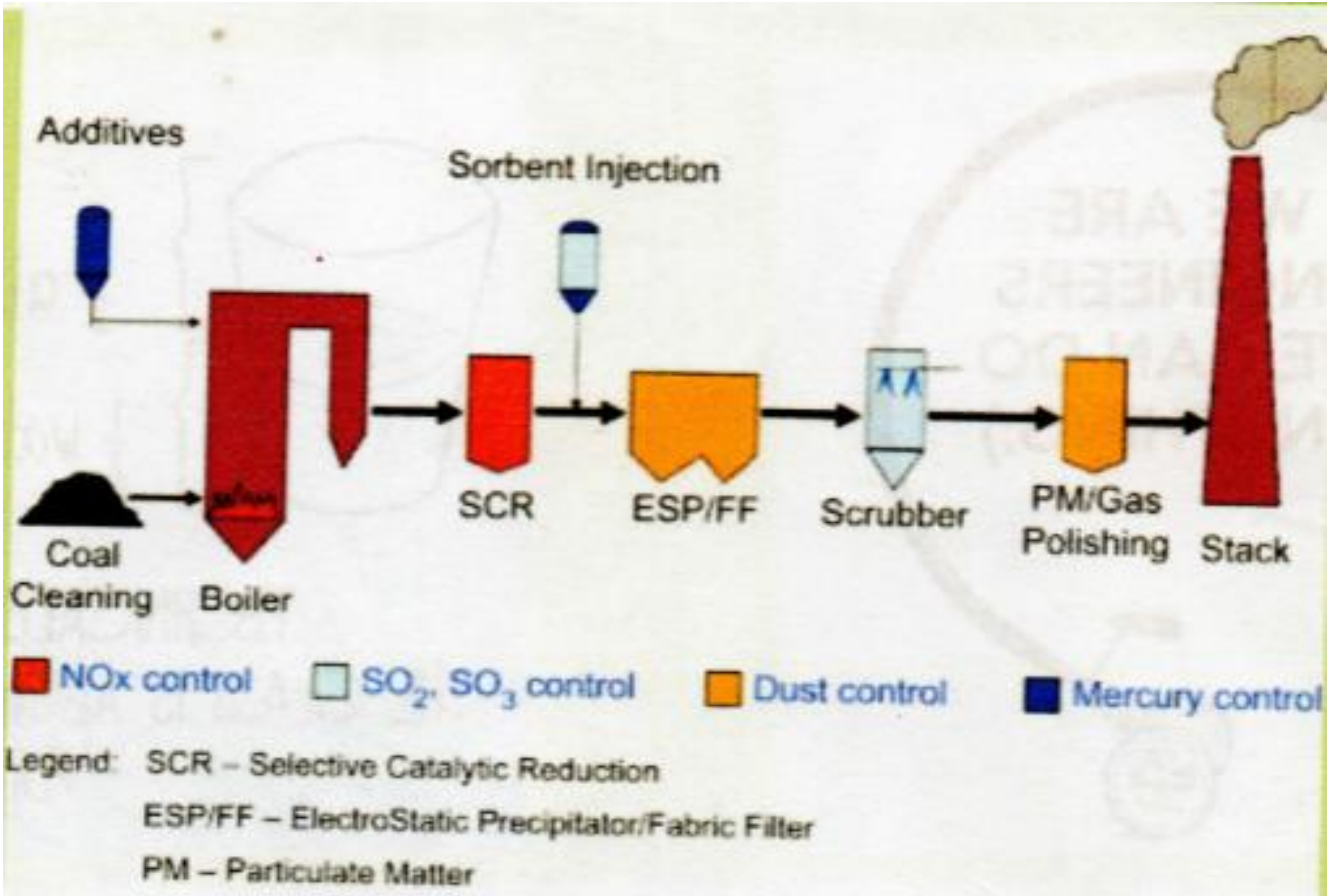


Fig: Longwall face digging between man and mechanical power

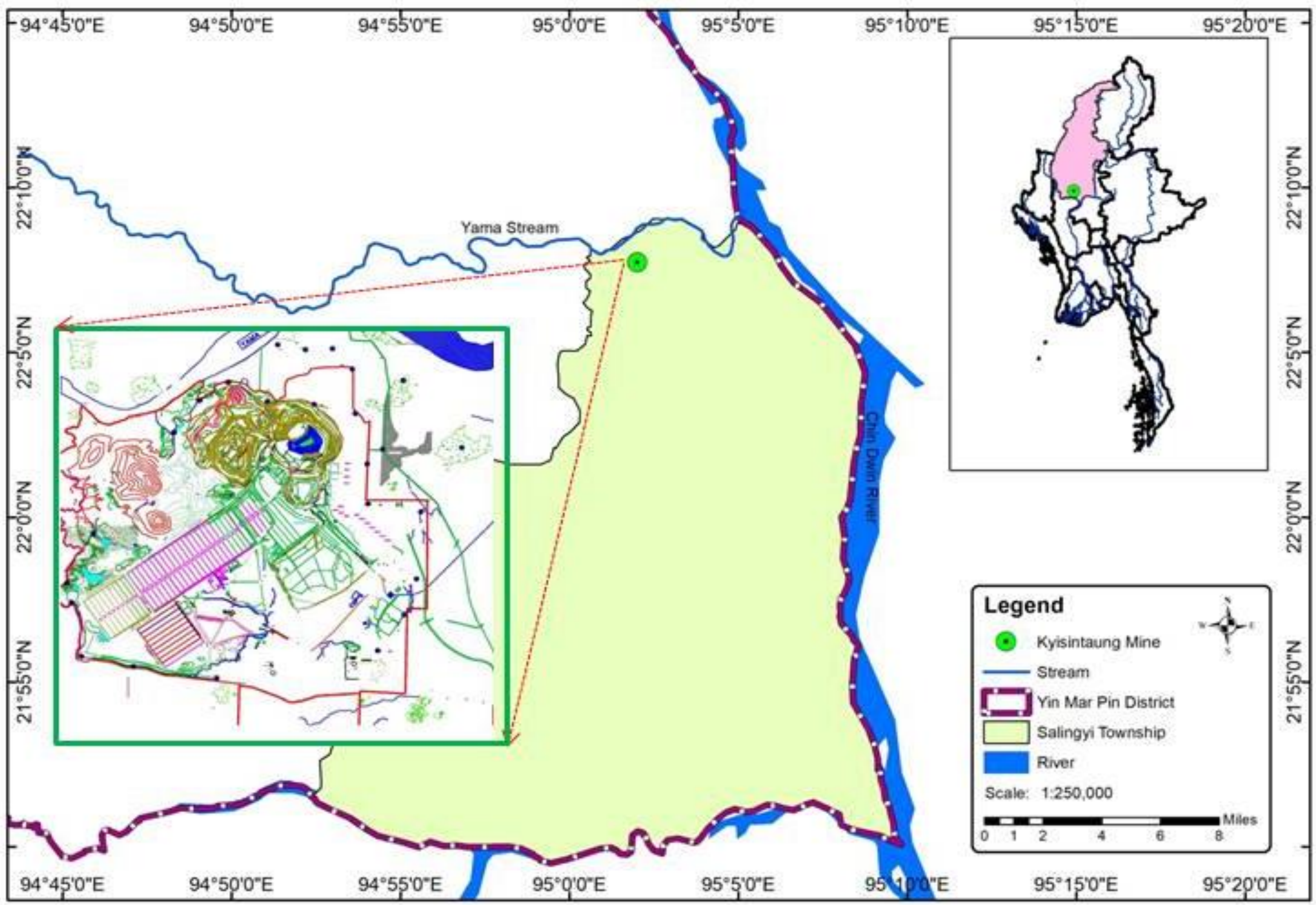
Evolution in CU Metallurgy Process



Stack Emission Reduction Technology



Location Map of Sabetaung-Kyisintaung Mine Drainage



HOW TO MAKE IMPACT ASSESSMENT

Logical Sequences of Program

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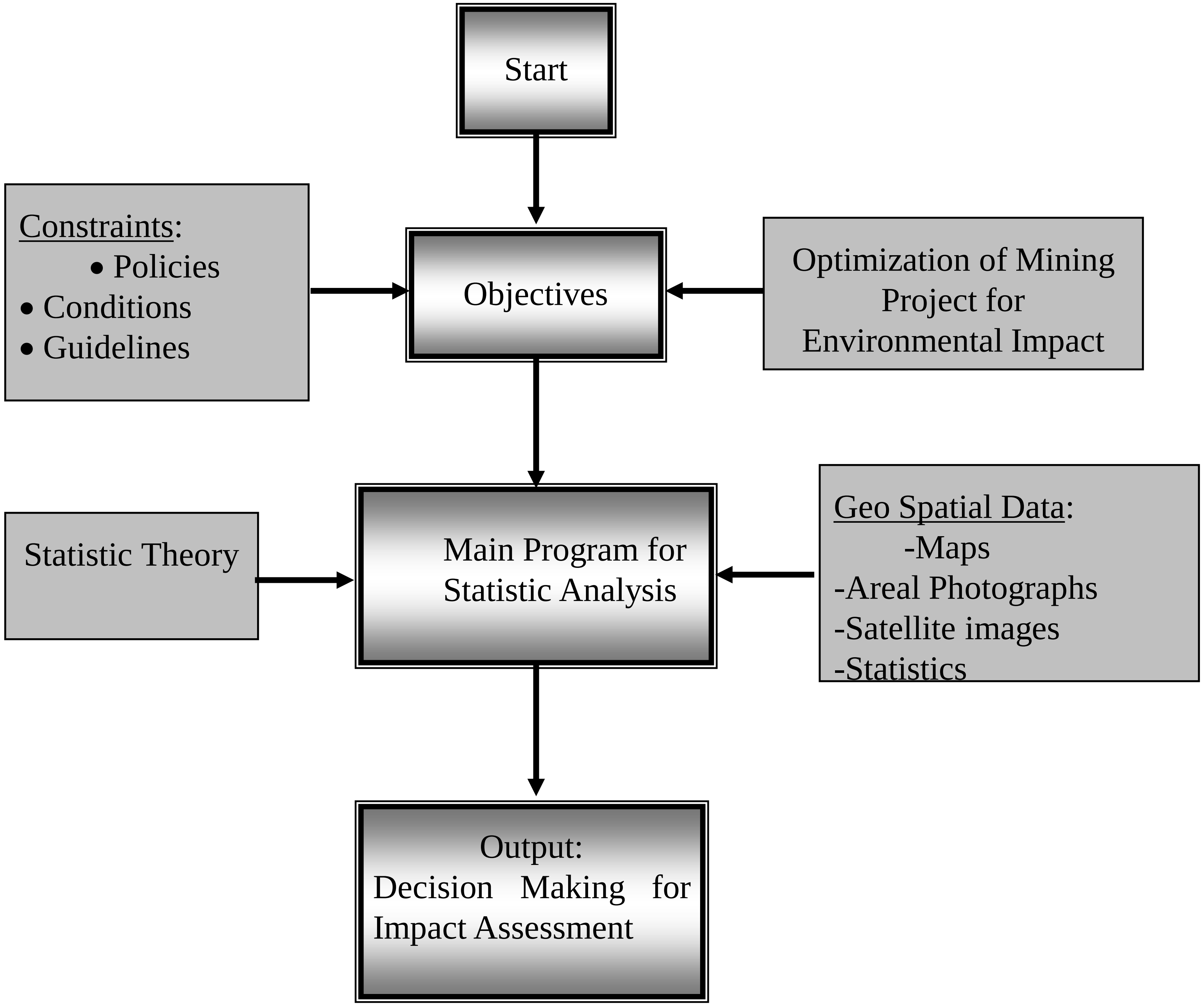

Logical Sequence of Program ALTPG for Statistic Analysis

Methods for Forecasting and Assessing Environmental Impacts

Considerations in forecasting:

- Models
- Threshold levels
- Statistical methods
- Prior, related assessments

Environmental impact assessment methodologies

Habitat Evaluation Methods –

- Assign certain values (which may be binary, incremental, or continuous) to certain environmental conditions.
- These habitat evaluation methods may be generalized for specific regional habitats, or may be specific to particular species of concern.
- The U.S. Fish and Wildlife Service has, with the help of expert ecologists, produced many of these habitat evaluation methods, or "models," termed Habitat Evaluation Procedure (HEP) models, and programmed these models to be used interactively on microcomputers.

Mathematical Modeling –

- In this approach to environmental impact assessment, the principal cause-effect relationships of a proposed action are described in terms of mathematical functions and combined to yield a mathematical model capable of predicting future environmental conditions.
- Mathematical models come in all degrees of complexity, from simple variations on mass balance equations (e.g., for estimating nitrate nitrogen in groundwater) to highly complex multivariate systems.
- The mathematical functions may be purely determined by existing conditions, or may have strong random elements contributing to the model output. Some models include statistical routines for estimating error associated with model outputs. Most commonly used mathematical models for impact assessment have been adapted for computers, in either batch or interactive modes.

Mathematical modeled would include:

- Energy
- Noise
- Transportation
- Air Emissions
- Stormwater Runoff
- Pollutant Transport in Water
- Pollutant Transport in Soils
- Risk Assessment
- Ecological Risk Assessment

Geographical Information Systems (GISs)

Geographical Information Systems (GISs) –

- These systems are essentially computerized graphical overlays and interacting data files.
- Environmental features are mapped, and the mapping digitized and stored in the GIS data base.
- The mapped features can be combined to produce computer generated displays of one or more environmental features in a specified geographical area.
- If the GIS mapping is conducted systematically, information acquired on specific projects can be combined, and the GIS data base becomes more detailed over time.

Development of Environmental Assessment Model

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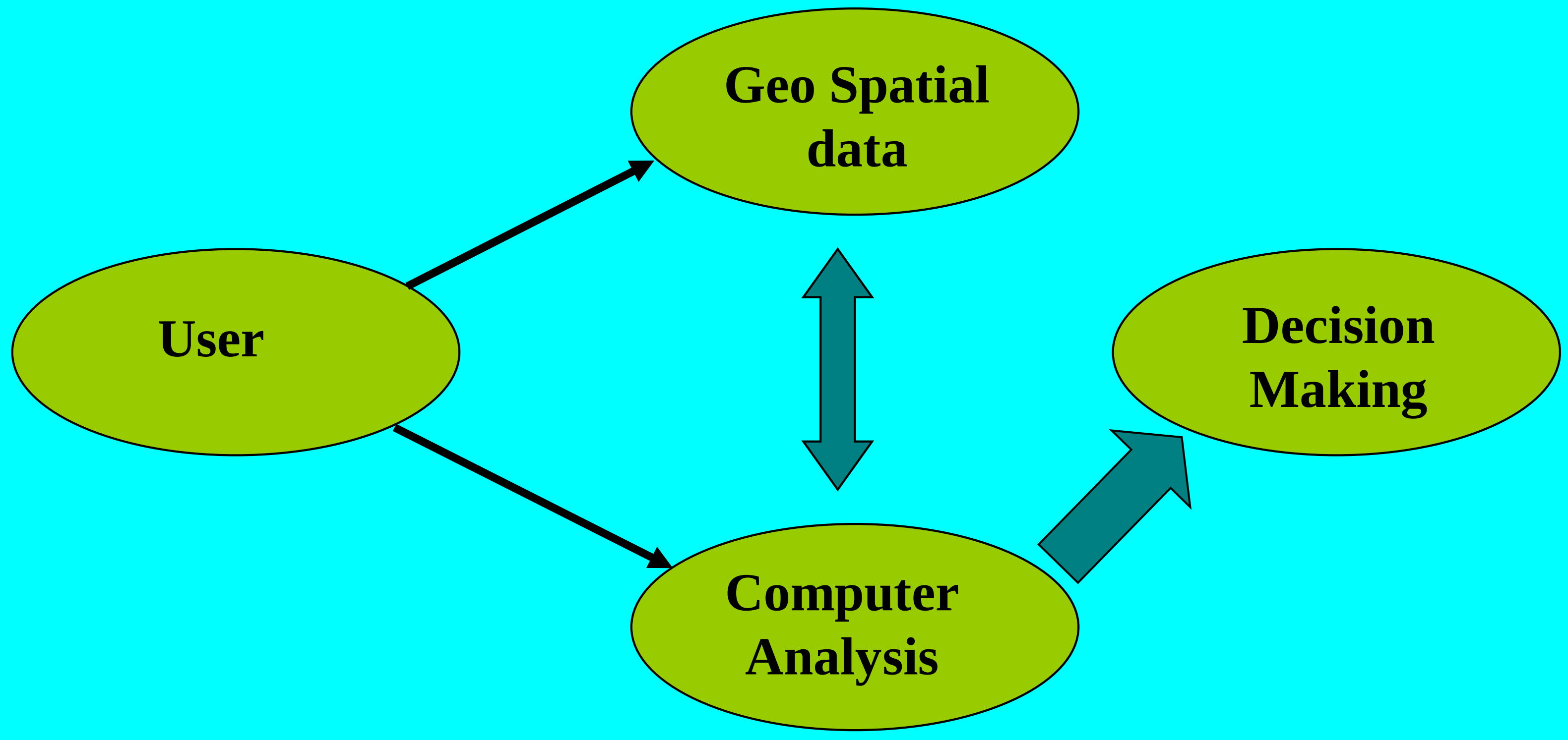


Components of GIS Model

Risk Assessment

- This refers to a category of analyses by which the potential risk of harm to individuals, communities, and ecosystems can be evaluated.
- The general techniques include comparison of expected conditions with prevailing environmental standards, modeling of expected conditions and estimation of error terms associated with model estimates, and
- Monte Carlo simulation of the frequency of certain events under expected conditions.

Matrices

MATRICES

- Matrices are very likely the most popular and widely used EIA methodology. One common application is in the comparison of alternative actions.
- Alternative actions (measures, projects, sites, designs) are listed as column headings, while the rows are the criteria that should determine the choice of alternative. In each cell of the matrix, a conclusion can be listed indicating whether the alternative action is likely to have a positive or negative effect relative to the indicated criterion. Very often, the conclusion is stated as a numerical value or symbol indicating the level of intensity of the effect.
- There is an opportunity, moreover, to apply relative weighting to the various criteria when evaluating the completed matrix.

Checklists

- The use of checklists for identifying and, to a limited extent, characterizing, environmental impacts, is very common throughout existing EIA processes.
- A checklist forces the assessment to consider a standardized set of activities or effects for each proposed action, thus bringing uniformity to the assessment process.
- Checklists can be used to determine environmental impact thresholds, thus indicating whether a full-scale EIA is needed for a particular project or whether a finding of no significant impact could be issued.

Anticipated Impacts Analysis and Mitigation Measures

- Potential environmental and social impacts of the project are analyzed in three phases such as:

  (a) Identification – specification of the impacts associated with each phase of the project and the activities undertaken

  (b) Prediction – forecasting the nature, magnitude, extent and duration of the main impacts

  (c) Evaluation - determining the significance of the residual impacts after taking into account how mitigation will reduce the predicted impact .

Methodology

Methods of Impact Identification, Prediction and Significance of Impacts

- Impact identification was done with a logical and systematic approach. The aim of impact identification is to take account of all of the important environmental and social impacts and interactions which may be potentially significant.

Introduction to the Significance of Impact and Alternatives

- The assessment of determination of significance of impacts in ESIA is considered to be the central point of EIA reports. It is helpful for a project to define and compare the alternatives arising, and to provide a clear basis of choice for decision-makers and the general public.
- **Qualitative approach:** in which descriptive information on each alternative is presented,
- **Quantitative approach:** in which quantitative information on each alternative is presented,
- **Ranking, rating or scaling approach**. in which the qualitative or quantitative information, on each alternative is summarized through the assignment of rank,
- rating or scale values,
- **Weighting approach:** in which the importance in weight of each alternative is presented in view of the relative importance of the decisive factors, and
- **Weighting-ranking/rating/scaling approach:** in which the relative importance of either environmental factors or impacts are determined and numerical weights are assigned to each factor or impact.

Myanmar National Environmental Quality (Emission) Guidelines

December, 2015

Compliance with Environmental Quality Standards
Effluent Standards for Mining Sites

Table A3.1. Effluent limit values for exploration and mining sites

Parameter	Unit	Effluent Limit Value	Reference
Arsenic	mg/l	0.1	Myanmar National Environmental Quality (Emission) Guidelines, December 2015.
Cadmium	mg/l	0.05	As above
Chemical oxygen demand	mg/l	150	As above
Chromium (hexavalent)	mg/l	0.1	As above
Copper	mg/l	0.3	As above
Cyanide	mg/l	1	As above
Cyanide (free)	mg/l	0.1	As above
Cyanide (weak acid dissociable)	mg/l	0.5	As above
Iron (total)	mg/l	2	As above
Lead	mg/l	0.2	As above
Mercury	mg/l	0.002	As above
Nickel	mg/l	0.5	As above
pH	S.U.[a]	6-9	As above
Temperature	°C	<3 degree differential	As above
Total suspended solids	mg/l	50	As above
Zinc	mg/l	0.5	As above

Effluent Standards for Work Camps, Sanitary Facilities, Domestic Wastewater

Table A3.2. Wastewater, Storm Water Runoff, Effluent and Sanitary Discharges

Parameter	Unit	Guideline Value	Reference
5-day Biochemical oxygen demand	mg/l	50	National Environmental Quality (Emission) Guidelines, December 2015
Ammonia	mg/l	10	As above
Arsenic	mg/l	0.1	As above
Cadmium	mg/l	0.1	As above
Chemical oxygen demand	mg/l	250	As above
Chlorine (total residual)	mg/l	0.2	As above
Chromium (hexavalent)	mg/l	0.1	As above
Chromium (total)	mg/l	0.5	As above
Copper	mg/l	0.5	As above
Cyanide (free)	mg/l	0.1	As above

Ambient Air Quality Standards

Table A3.3. Ambient air quality standards

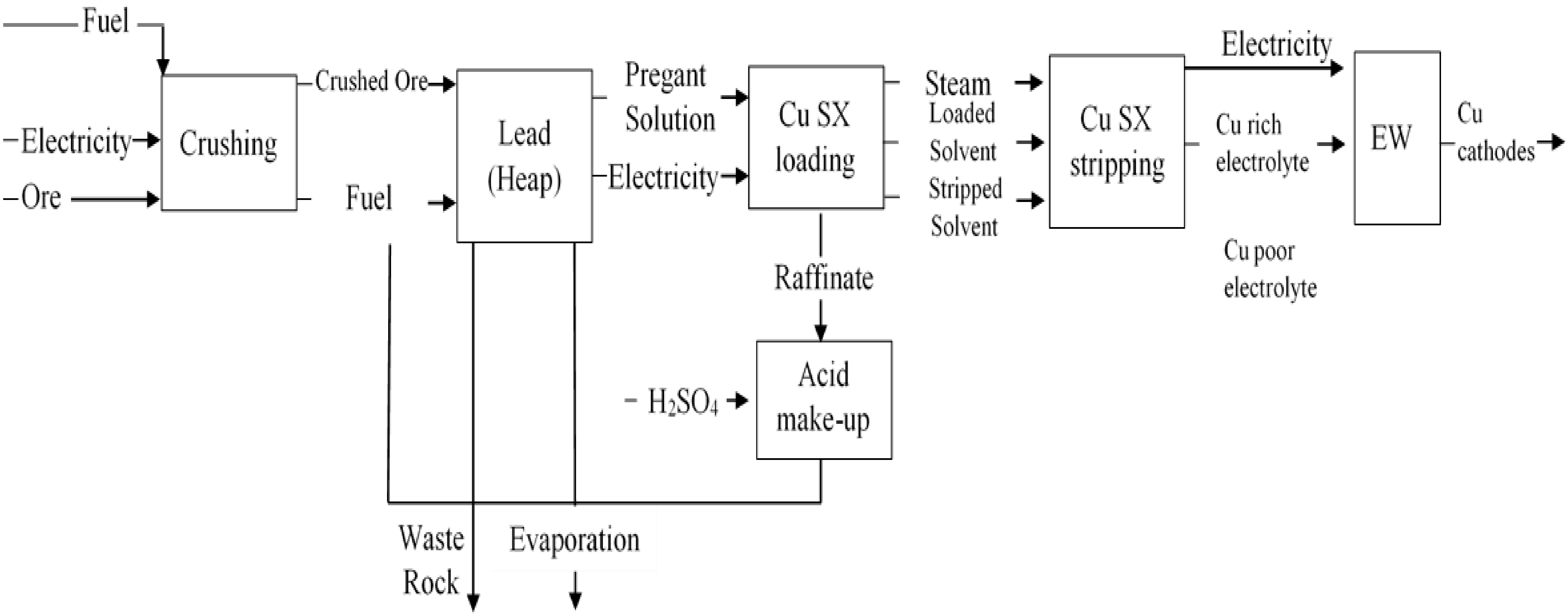
Substance	Averaging Period	Standard $\mu g/m^3$	Reference
Sulphur dioxide	24 hours 10 minutes	20 500	Myanmar National Environmental Quality (Emission) Guidelines, December 2015.
Nitrogen dioxide	1 year 1 hour	40 200	As above
Particulate matter PM_{10}	1 year 24 hours	20 50	As above
Particulate matter $PM_{2.5}$	1 year 24 hours	10 25	As above
Ozone	8-hour daily maximum	100	As above

Ambient Noise Standards

Table A3.4. Ambient noise standards

Receptor	One Hour L_{Aeq} (dBA)		Reference
	Daytime 07:00-22:00	Nighttime 22:00-07:00	
Residential, institutional, educational	55	45	Myanmar National Environmental Quality (Emission) Guidelines, December 2015.
Industrial, commercial	70	70	As above

Generic Copper Hydrometallurgy Extraction Method Flow Diagram



Source: Codelco, 2009

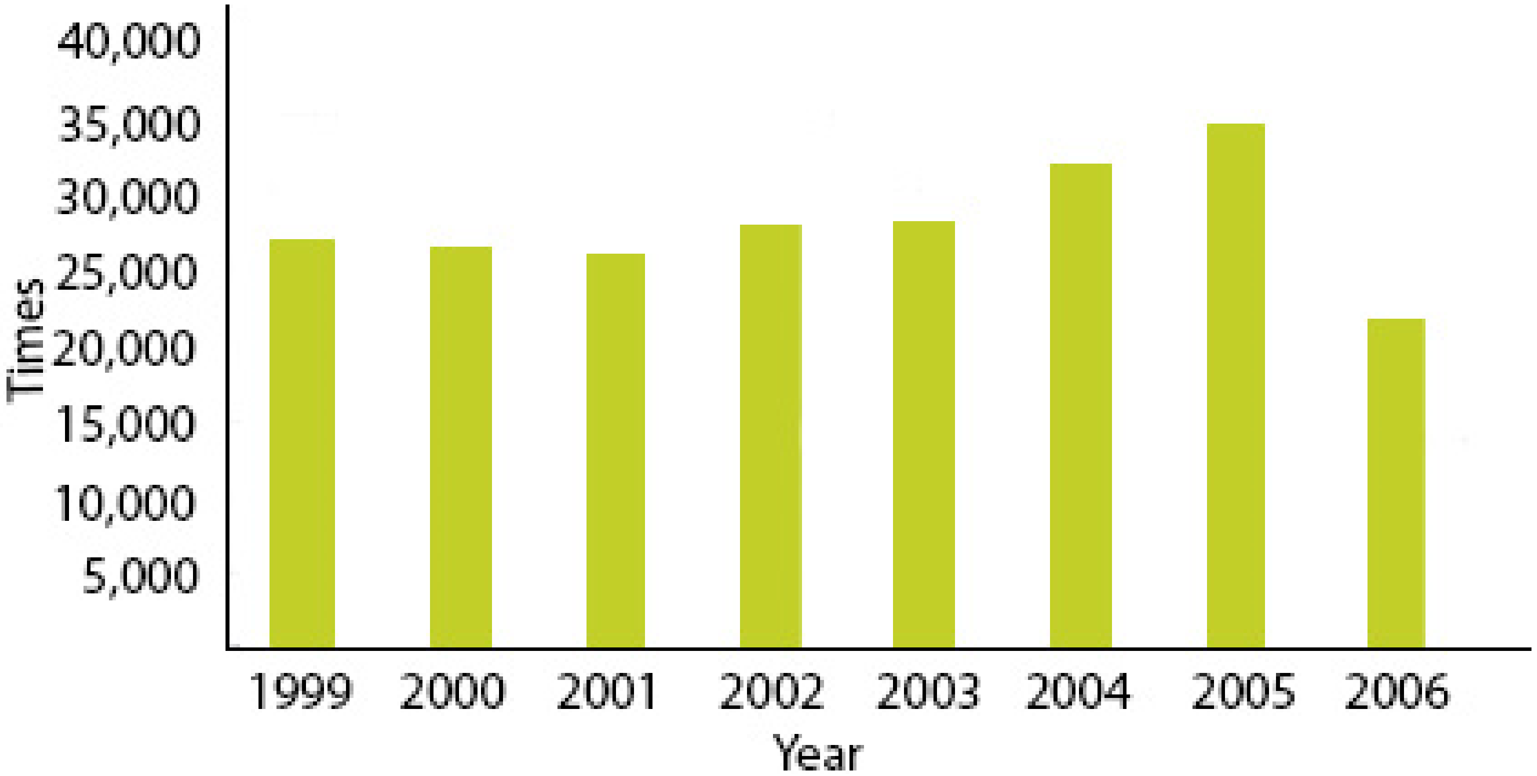
Mineral Resources and Reserves at the S & K Mine

Deposit	Measured		Indicated		Inferred		Total	
	Tonnes (millions)	Grade(1) (%)Cu	Tonnes (millions)	Grade(1) (%)Cu	Tonnes (millions)	Grade(1) (%)Cu	Tonnes (millions)	Grade(1) (%)Cu
Sabetaung	37	0.35	72	0.26	104	0.24	213	0.26
Kyisintaung	100	0.40	282	0.33	108	0.28	390	0.31
Letpadaung	577	0.44	492	0.36	409	0.31	1478	0.38

Source: Responsible Mining (MICCL, 2006)

(1)Cut-off grades are 0.15% for Sabetaung, 0.15% for Kyisintaung and 0.10% for Letpadaung.

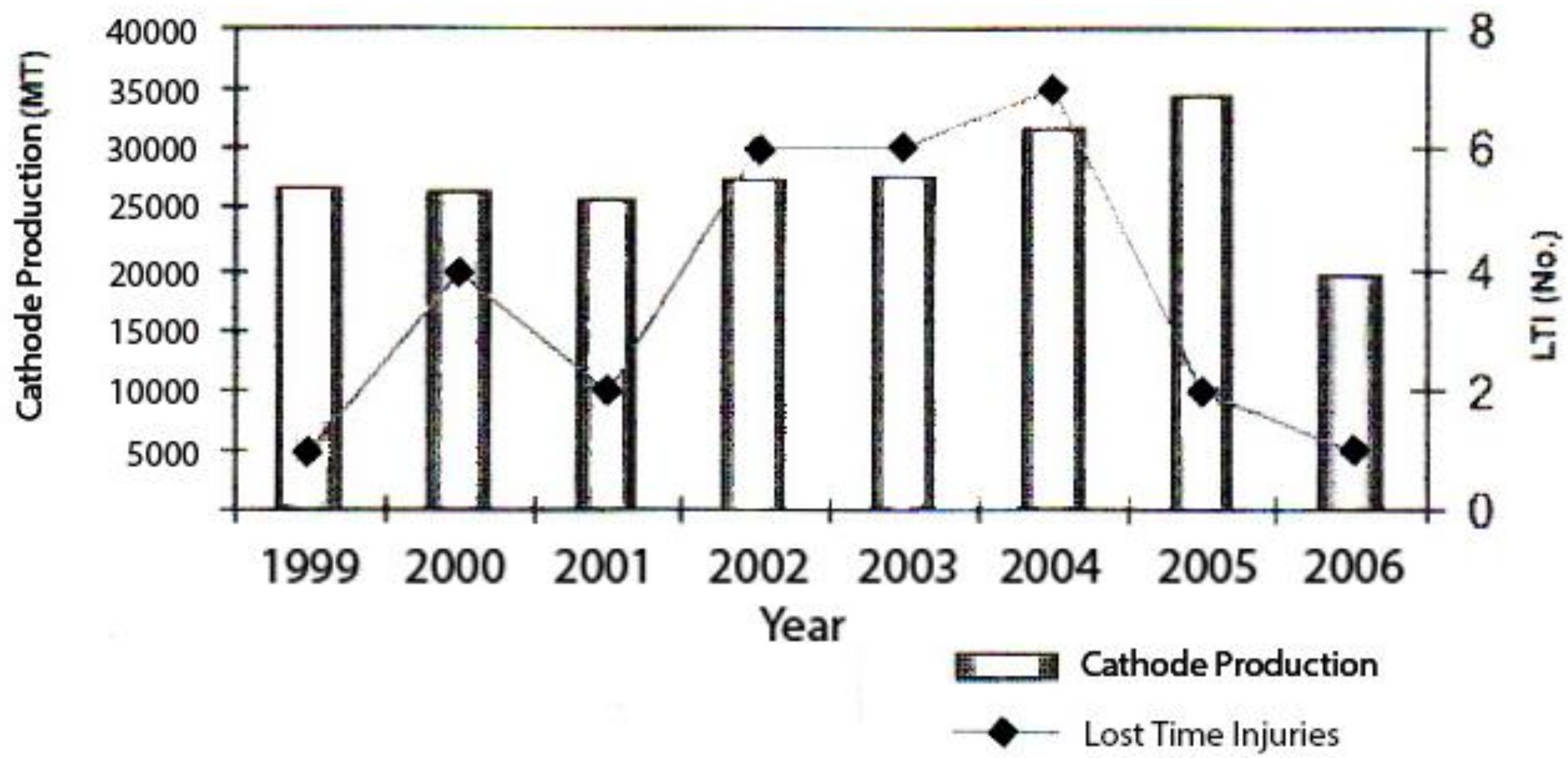
(2)Cut-off grades for Sabetaung are 0.16% Cu for low/medium clays and 0.17% Cu for high-clay ores.



Cathode Copper Production 1999 to 2006

Source: Responsible Mining, Myanmar Lvanhoe Copper Company Limited, 2006

Cathode Copper Production & Lost Time Injury



Source: Responsible Mining, Myanmar Lvanhoe Copper Company Limited, 2006

- MICCL successfully continued three international certifications in 2006.

- the ISO 14001 Certificate for Environmental Management;
- the AS/NZS 4801 Certificate relating to Occupational Health & Safety Management; and
- the ISO 9001 Certificate relating to Quality Management.

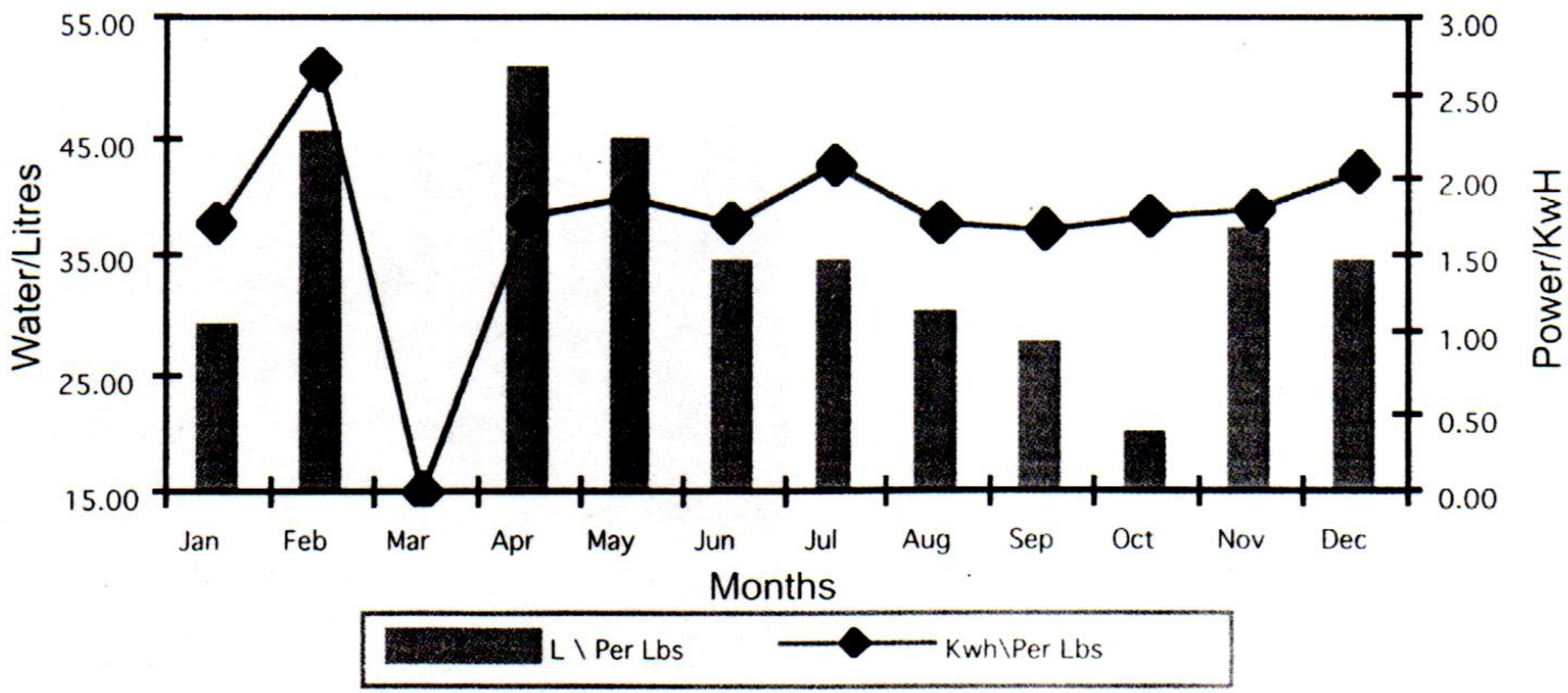
MICCL also maintained its cathode quality in accordance with LME Grade specifications.

MICCL is striving to maintain a Best Practices international performance standard throughout its operations, while achieving continual improvements in quality, environment, health and safety standards.

- Minerals are the most exploited non-renewable resources worldwide, which involve a great deal of natural resources extraction and environmental impact.

- Copper can be found in the piping used to supply water, in electrical wires, in electronics including gadgets such as mobile phones, for example, and in many other products.
- Energy consumption is also of great importance. This includes the electricity obtained from the national power grid mix and on site combustion processes that use different kinds of fuels, such as, coal, natural gas, heavy fuel oil and diesel, to name a few.
- In general terms, water is nowadays considered as "the new carbon". This is because, like for carbon, the management of water issues is increasingly important in mitigating climate change.

2006 Power & Water Consumption Per Lbs of Cathode Copper



Source: Responsible Mining, Myanmar Lvanhoe Copper Company Limited, 2006

Injury of Items & Number of 1999 to 2006

Item	1999	2000	2001	2002	2003	2004	2005	2006
First Aid Injuries	12	19	15	17	36	37	30	26
Lost Time Injuries	1	4	2	6	6	7	2	1
Total Injuries	13	23	17	23	42	44	32	27
Near Miss	31	69	66	57	38	57	56	30
Equipment Damage	80	84	75	125	121	127	96	90
Total Accidents/ Incidents	124	176	158	205	201	228	184	147
LTIFR	0.75	1.83	0.63	1.63	1.69	2.00	0.63	0.28
Cathode Production	26737	26413	25864	27541	27870	31756	34479	19554

Source: Responsible Mining, Myanmar Lvanhoe Copper Company Limited, 2006

Mine Town & Employees Population

Sr.No.	Departments	Population
1	MICCL Employee-Permanent	586
2	MICCL Employee-Seconded	247
	Sub-Total	833
3	ME-1 Employee	31
4	Mine Town Community	3,178
	Total	4,042

Source: Responsible Mining, Myanmar Lvanhoe Copper Company Limited, 2006

Hospital Statistics

Year	Out-Patient Treated	In-Patient Treated
1999	8712	353
2000	13592	351
2001	18005	459
2002	25023	571
2003	30417	470
2004	33611	494
2005	38579	519
2006	36548	456

Source: Responsible Mining, Myanmar Lvanhoe Copper Company Limited, 2006

Yearly Philanthropic Hospital

Year	In Patient							Out-patient						Surgical Operation		
	Maternity					Under 5	Grand Total	Maternity				Under 5	Grand Total			
	Live Birth	Still Birth	Abortion	Other	Total			AN-1st Visit	AN-FU	Other	Total			Major	Minor	Total
2002	59	6	16	22	103	109	212	197	480	23	700	818	1518	40	56	96
2003	98	4	25	23	150	52	202	330	797	137	1264	1972	3236	61	90	151
2004	121	3	15	31	170	74	244	366	939	205	1510	2382	3892	83	117	200
2005	117	2	22	33	174	87	261	351	960	168	1479	2439	3918	84	175	259
2006	120	4	23	38	185	57	242	384	1352	245	1981	1754	3735	82	127	209
Total	515	19	101	147	782	379	1161	1628	4528	778	6934	9365	16299	350	565	915

Source: Responsible Mining, Myanmar Lvanhoe Copper Company Limited, 2006

Mine Town Hospital Statistics Ten Top Leading Yearly Special

Sr. No	Name of Disease	1999	2000	2001	2002	2003	2004	2005	2006	Remarks
1	Influenza	137	368	645	999	1399	1452	2481	2094	
2	Conjuntivitis	61	56	55	152	520	173	224	277	
3	Hypertension	80	78	38	107	167	181	146	101	
4	Dysentery	81	70	54	92	140	182	178	218	
5	Dog Bite	25	24	25	59	50	36	27	21	
6	Diarrhea	93	75	59	43	7	1	0	0	
7	Malaria	26	15	18	41	34	18	24	35	Imported
8	Viral epatitis	9	7	10	25	22	4	18	18	
9	Tuberculosis	4	6	6	14	24	13	21	10	
10	Snake Bite	11	6	6	12	9	11	9	7	

Source: Responsible Mining, Myanmar Lvanhoe Copper Company Limited, 2006

Recorded Environmental Incidents in 2006

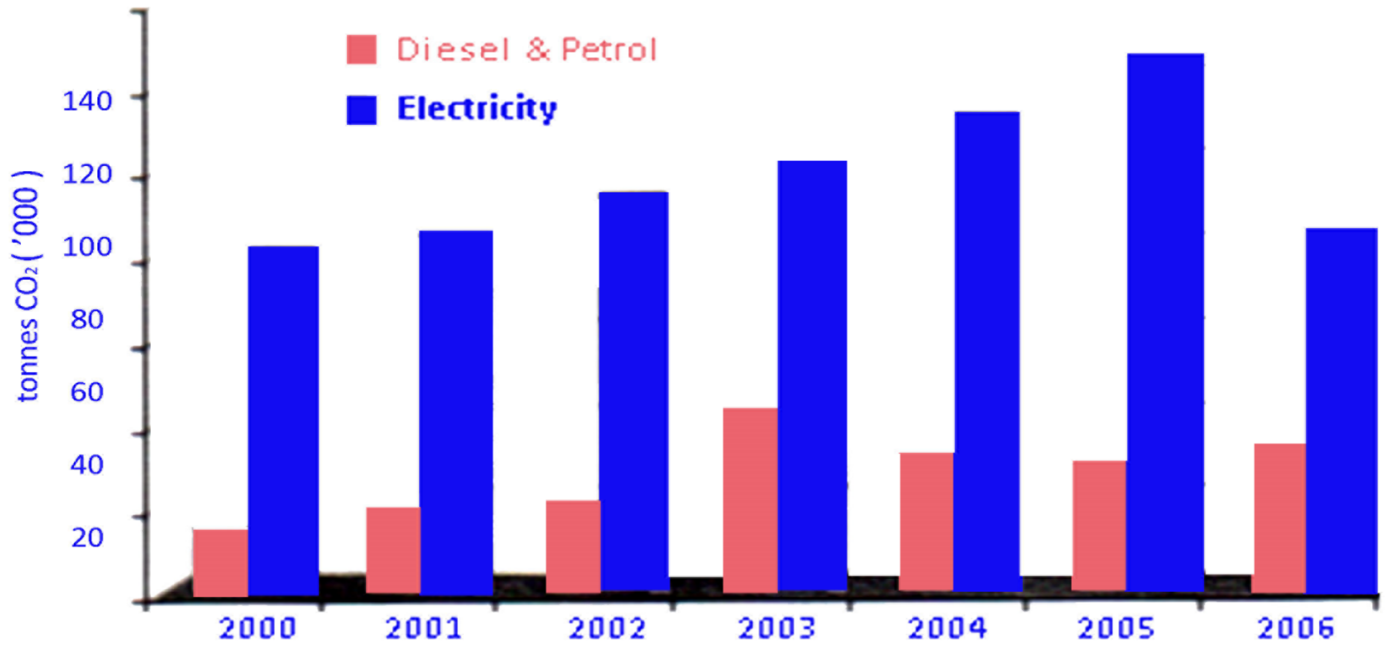
Date	Incident	Actions
3-1-06	Irrigated solution backed up the internal drain and flooded over the haul road at Pad 3 cell 10.	Contained the solution inside berm of heap cell. Cleaned up the contaminated soil with grader and fed back to heap.
4-2-06	Raffinate solution was spilled on the ground near Pad 2 cell 18 due to failure of pump delivery flange joint.	Repaired the pump flange joint. Cleaned out the contaminated soil and sent it to heap cell.
17-4-06	Contaminated solution leaked from failed HG plant discharge pump and spread out near SX container yard.	Cleaned up the contaminated soil. Covered with red earth.
15-5-06	Contaminated solution from external drain entered into wetland 1 through fresh water drain.	Pumped the solution back into Storm-Water Pond.
3-6-06	Raffinate solution leaked from cracked pipeline. Contaminated solution reached Road 2 through PE channel.	Cleaned up all contaminated soil and sent it back to heap cell by O & K Loader.
3-6-06	Pad 3 PLS solution spilled out from cracked pipeline and spread on Road 1.	Cleaned out the contaminated soil using workers and O & K Loader.
4-6-06	Contaminated solution spread near EW Plant due to failure of cracked Pipeline.	Cleaned out the contaminated soil and sent it to heap cell.
5-7-06	Contaminated solution leaked from failed pump-casing liner and the solution flowed into Road 2 drain.	Repaired the pump casing liner. Cleaned out contaminated soil and sent it to heap.
8-9-06	Raffinate solution leaked from cracked pipeline; spread inside & outside fencing of SX-EW Plant.	Contained solutions in the sump inside the plant and pumped out to stormwater pond. Cleaned up all contaminated soil.
27-12-06	ILS solution entered into pre-settling pond under repair due to incorrect valve operation.	Pumped out the contaminated solution and removed the contaminated soil.

Source: Responsible Mining, Myanmar Lvanhoe Copper Company Limited, 2006

$$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O \quad [2.1]$$

$$Cu^{2+}(aq) + 2RH(org) \rightarrow R_2Cu(org) + 2H^+ \quad [2.2]$$

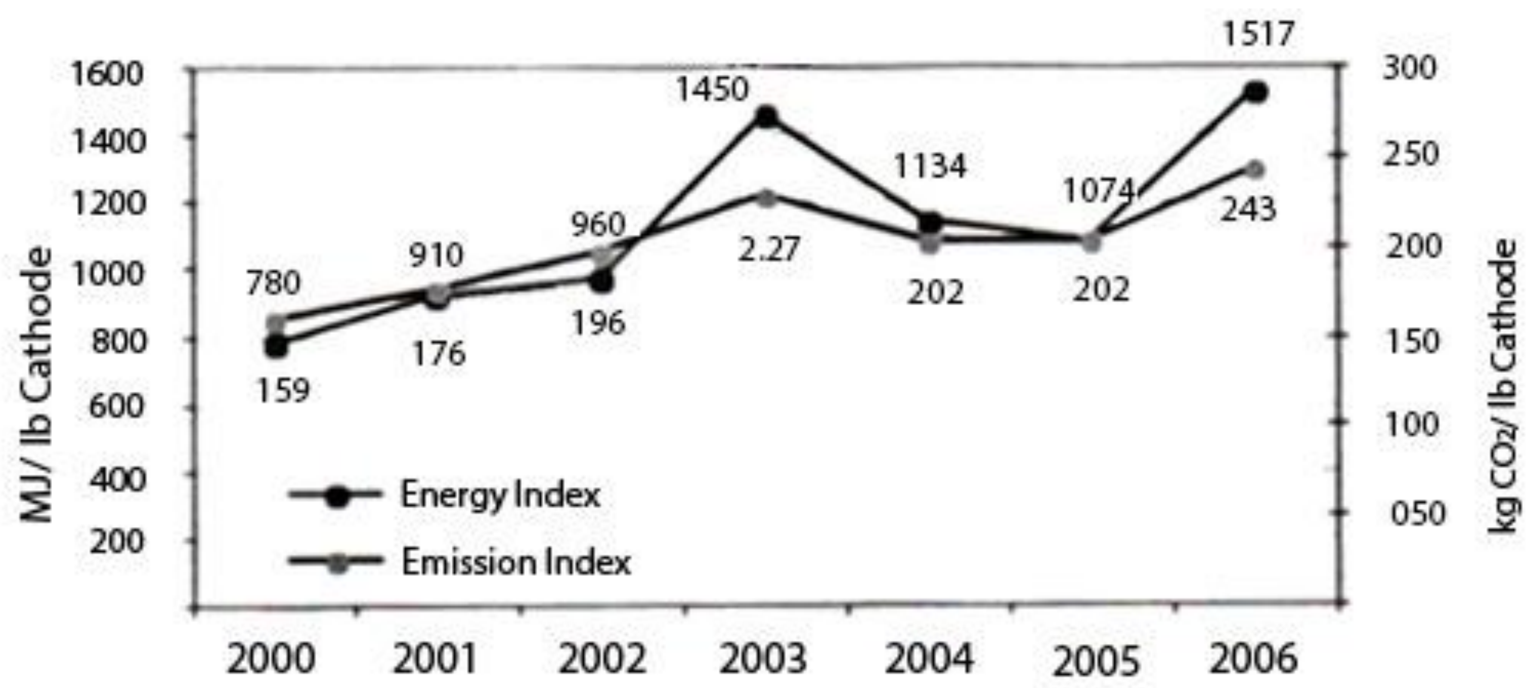
$$Cu^{2+} + SO_4^{2-}) + H_2O \rightarrow Cu^{o} + 12\, O_2 + 2H^+ + SO_4^{2-}$$



CO_2 Emission – A Year-by-Year Comparison

Source: Responsible Mining, Myanmar Lvanhoe Copper Company Limited, 2006

Energy and Emission - per lb of Cathode Copper Produce

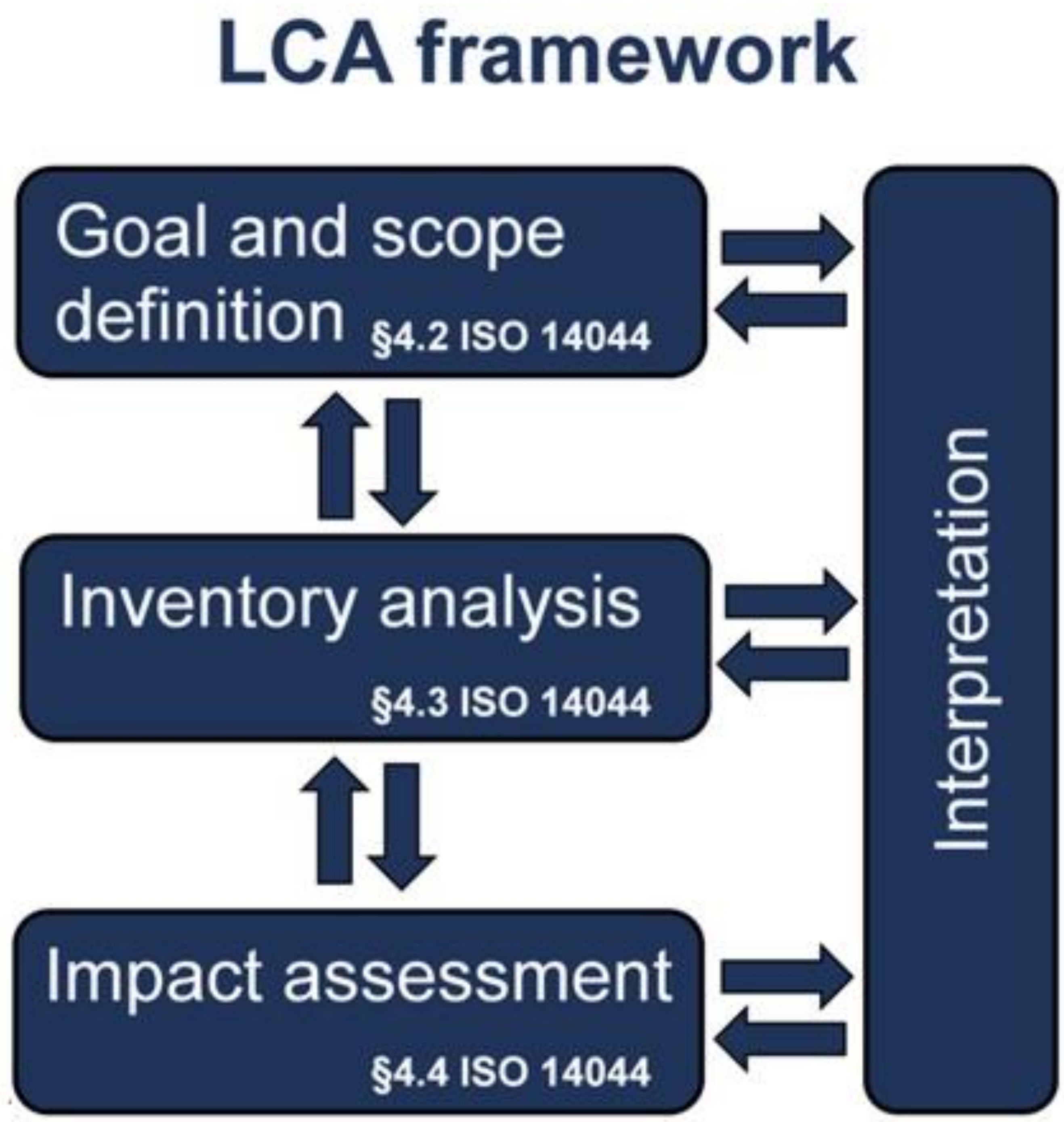


Source: Responsible Mining, Myanmar Lvanhoe Copper Company Limited, 2006

Life Cycle Assessment

- Life Cycle Analysis or assessment (LCA) comprises four steps and are conducted according to the ISO 14040 series of standards (ISO, 2000; 2002; 2003; 2006a; b)

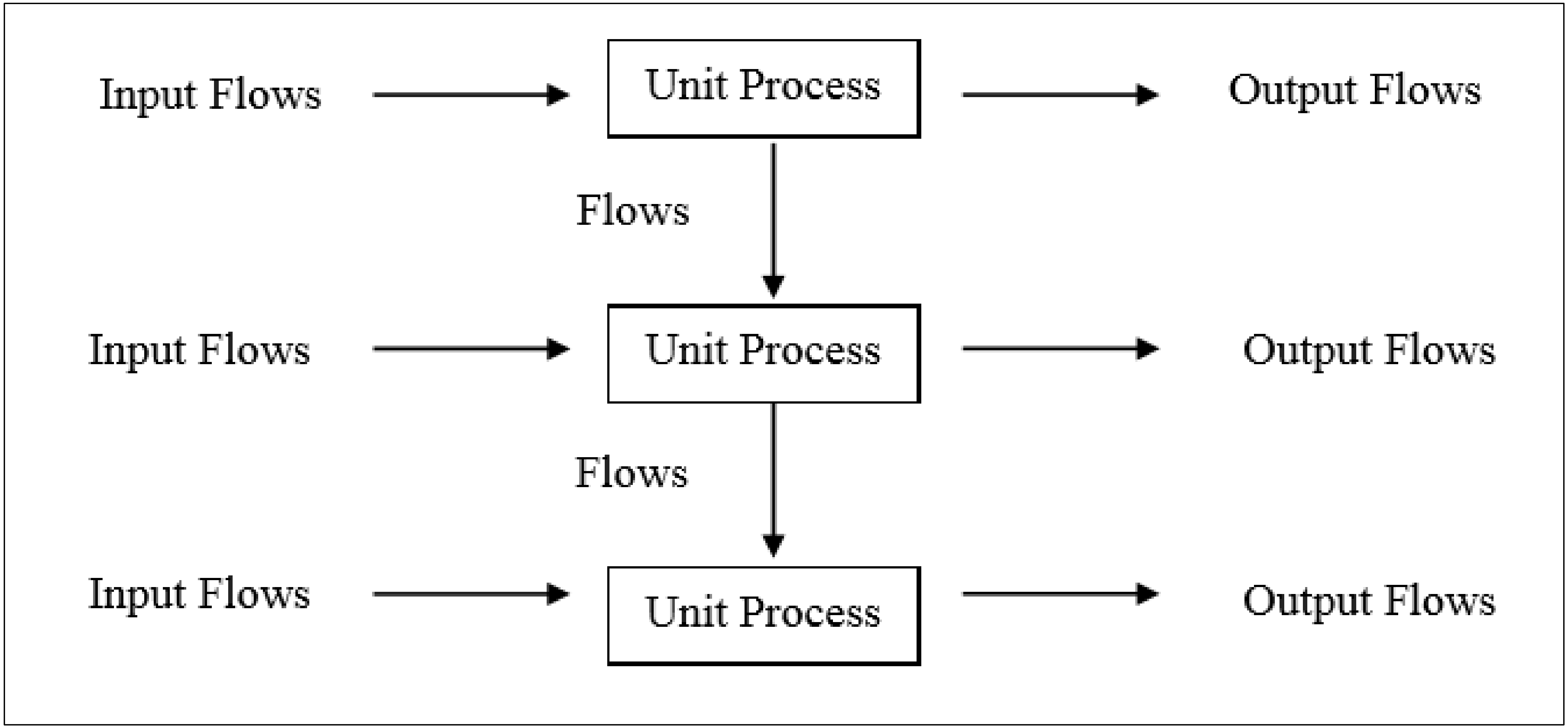
  - Goal and scope definition
  - Inventory analysis
  - Impact assessment
  - Interpretation



Steps of a Life Cycle Assessment According to ISO 14044

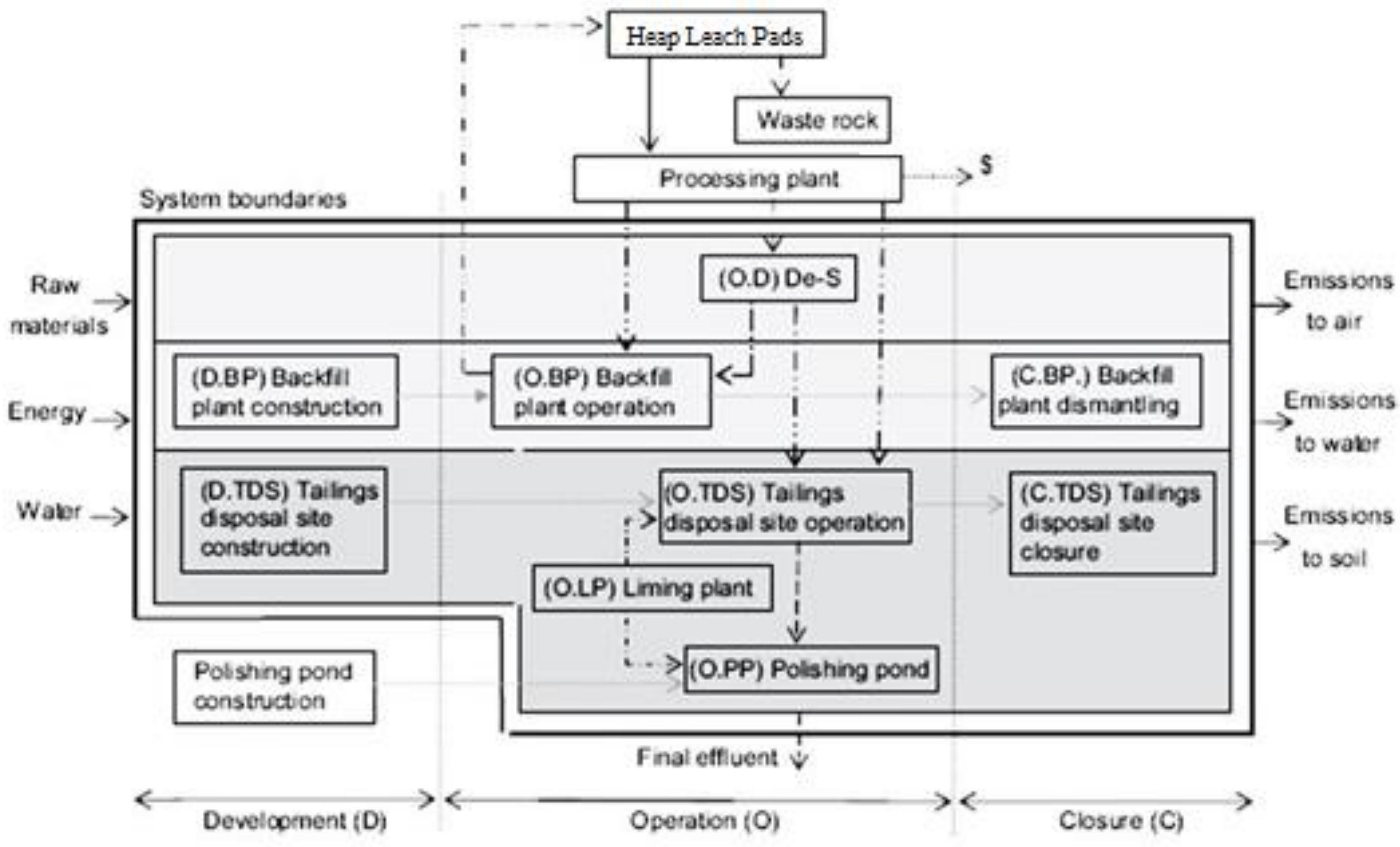
Source: PE International, 2009

Example of a Set of Unit Processes within a Product System



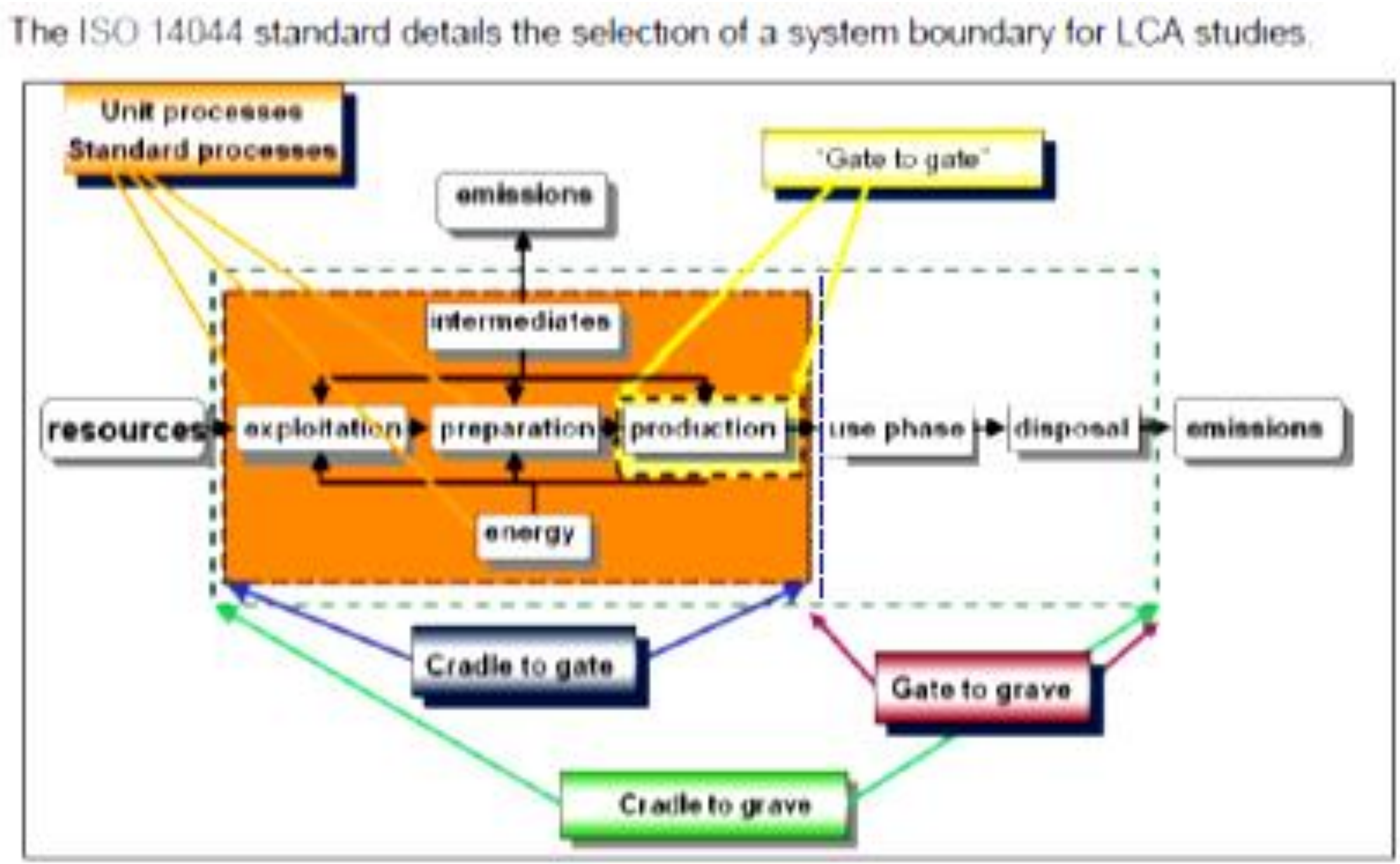
Source: ISO, 2006a

Illustration of Life Cycle Boundaries and System Diagram Used for Life Cycle Assessment of Mine Tailings Management.



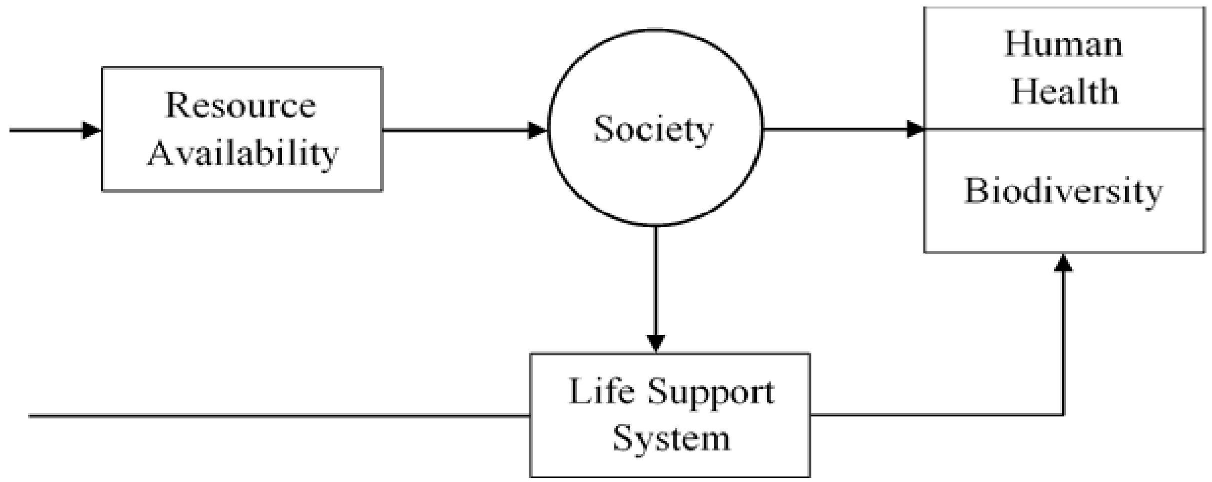
Source: Reid ,2009

System Boundaries



Source: Tao Li, 2013

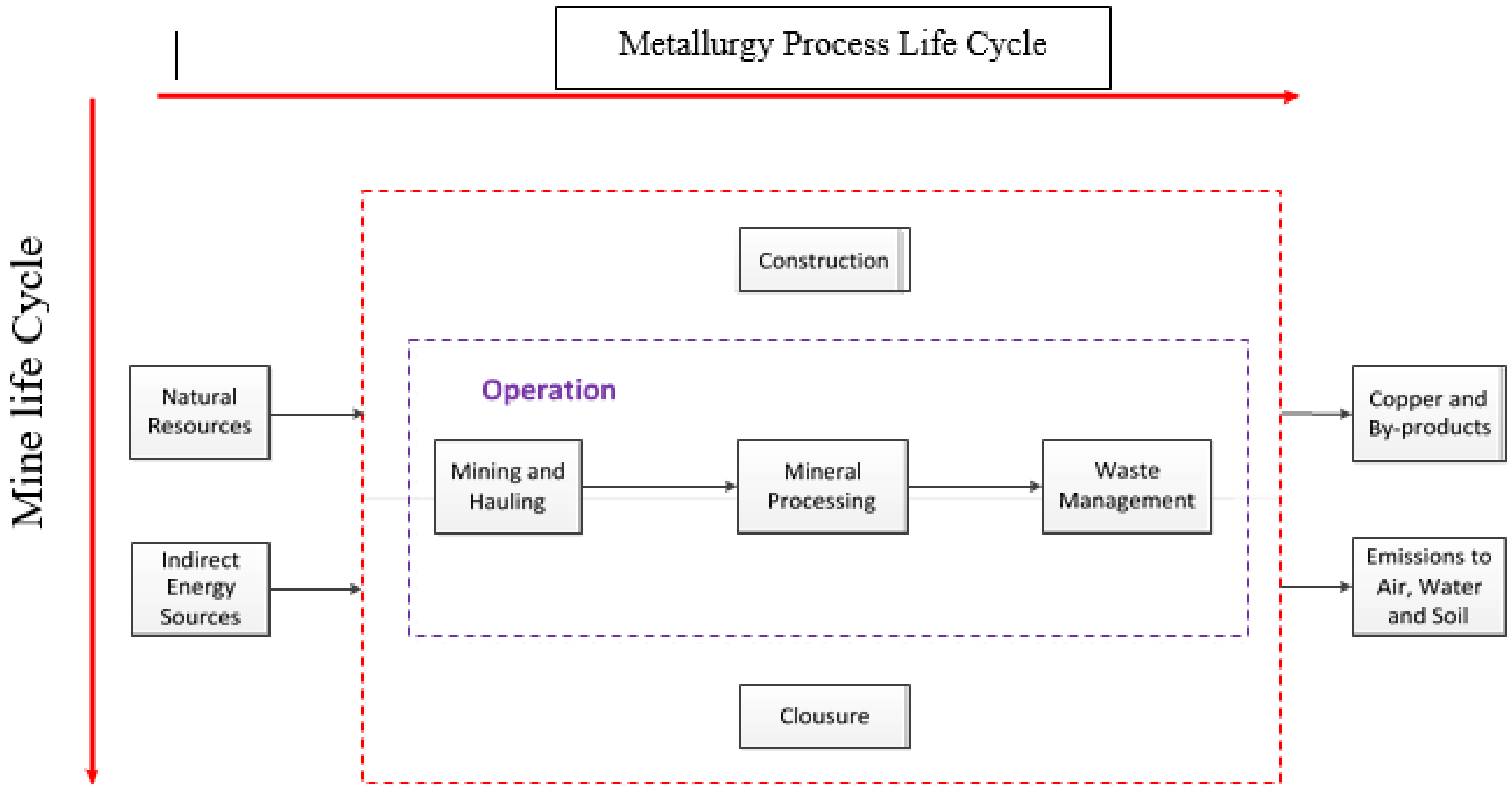
Applied Framework for Four Areas of Protection Based on both Midpoint and Endpoint Indicators



Resource Availability	Life Support System	Human Health
Abiotic resources	Climate change	Trop. Oxidant form
Biotic resources	Strat. Ozone depletion	Human Toxicity
Land competition	Acidification	Radiation
Nutrification	Noise, odour	
Soil erosion	Work Environment	
Hydrological change	Biodiversity	
	Land productivity	Ecotoxicity
	Hunting	
	Introd. New species	
	Land use: species loss	

Source: ISO 14044, (2006a, b) Standards

System Boundaries of LCA of K&S Copper Surface Mining, Mineral Processing and Waste



(K&S) Copper Surface Mining, Mineral Processing and Waste Management

LCA System, Individual Processes,

Operation Phase

Mining

Overburden removal
- Truck loading (excavator)
- Hauling
- Dumping

Primary Fragmentation
- Drilling
- Blasting

Ore Loading and Hauling
- Truck loading (excavator)
- Hauling
- Stockpile loading

(Hoisting)

Waste management
- Solid waste collection
- Water drainage
- Waste water treatment
- Dust suppression
- (Ventilation)

Copper Mineral Processing

Pyrometallurgy

Comminution
- Crushing
- Milling

Beneficiation
- Collective flotation
- Selective flotation
- Thickening
- Filtration and drying

Mineral Extraction
- Feed blending
- Smelting
- Converting

Refining
- Pyro-refining
- Electro-refining

Waste management
- Tailings dewatering
- Waste water treatment
- Slag treatment system
- Gas cleaning system
- Sulphur recovery system

Hydrometallurgy

Comminution
- Crushing

Mineral Extraction
- Leaching
- Solvent-extraction (SX) loading
- Solvent-extraction (SX) stripping
- Acid make-up

Refining
- Electro-winning (EW)

Waste management
- Waste water treatment

Waste Storage Facilities

Disposal
- Tailings disposal site operation
- Leaching pads site operation
- Leached ore storage facilities
- Waste rock piles and dumps

Waste management
- Waste water collection
- Waste water treatment
- Solid waste treatement
- Backfill plant
- Water infiltration to underground water

Ore. concentrate and waste transport between facilities

(K&S) Copper Surface Mining, Mineral Processing and Waste Management LCA System, Individual Processes, Sub-Processes and Corresponding Unit Processes for the Construction Phases

Construction Phases

Mine

Overburden removal
- Truck loading (excavator)
- Hauling
- Stockpile Loading
- Dumping

Primary Fragmentation
- Drilling
- Blasting

(Hoisting)

(Filling)
- Backfilling (sand, tailings, concrete)

Structures Construction
- Facilities construction (Concrete, structural metals)

Waste management
- Solid waste collection
- Water drainage
- Waste water treatment
- Dust suppression
- (Ventilation)

Copper Mineral Processing Facilities

Pyrometallurgy

Hydrometallurgy

Surface preparation an Material removal
- Truck loading (excavator)
- Hauling
- Stockpile loading
- Dumping

Structures Construction
- Facilities construction (concrete, structural metals)

Waste management
- Waste water collection
- Waste water treatment
- Solid waste collection

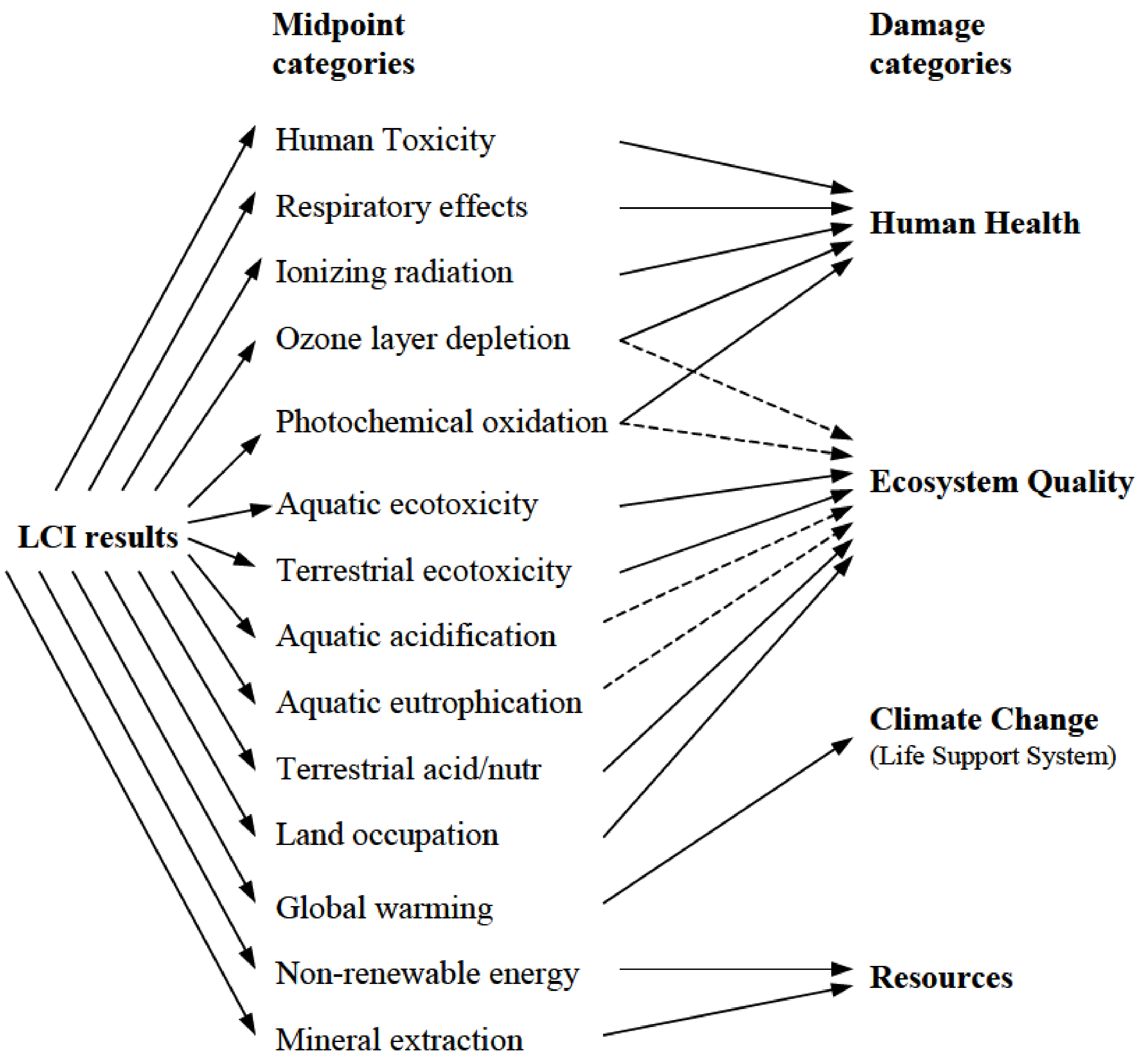
Waste Storage Facilities

Surface preparation and Material removal
- Truck loading (excavator)
- Hauling
- Stockpile loading
- Dumping

Structures Construction
- Walls
- Liners, layers and covers
- Facilities construction (concrete, structural metals)

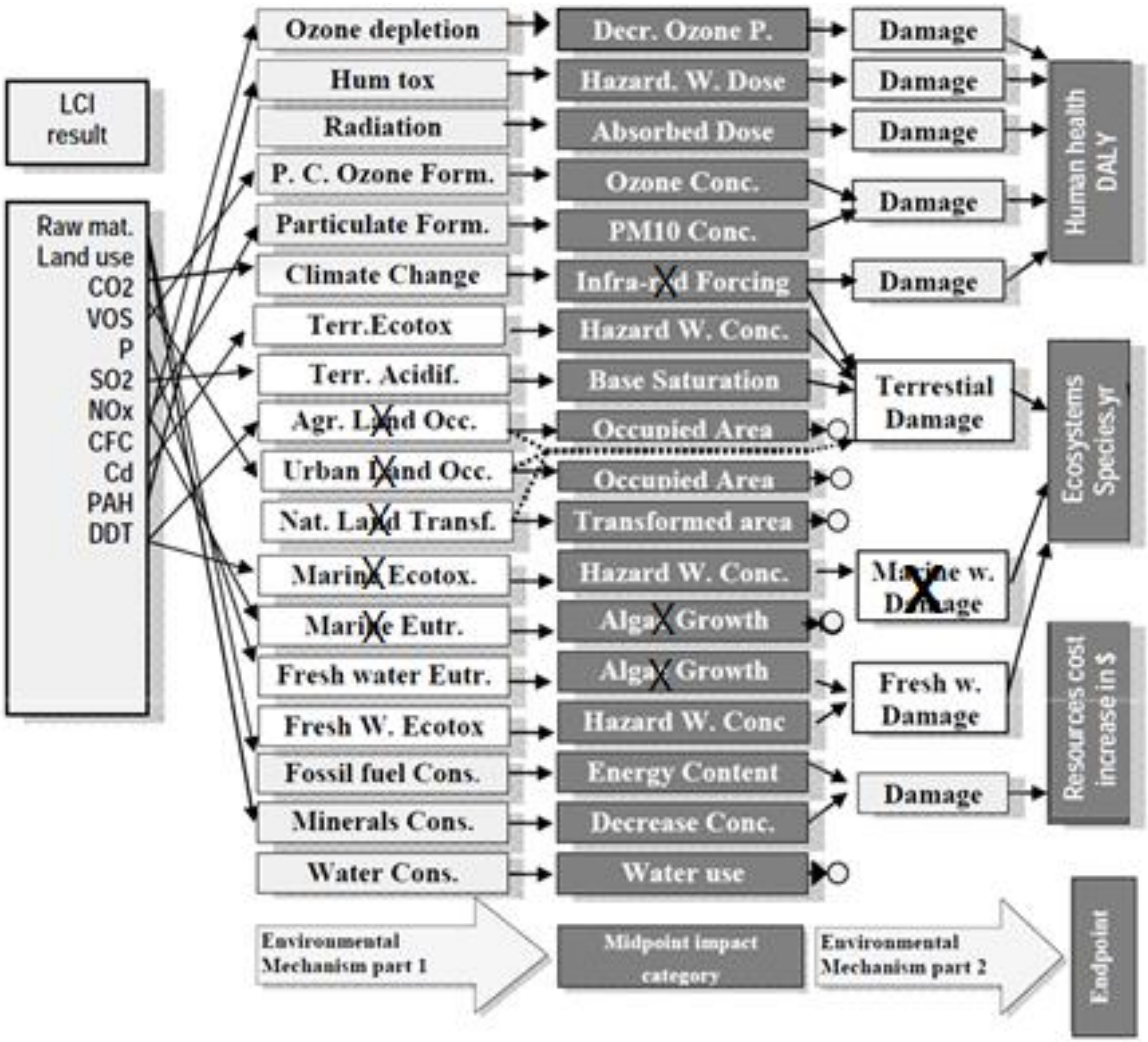
Waste management
- Waste water collection
- Waste water treatment
- Solid waste collection

Overall Scheme of the IMPACT 2002+ Framework, Linking LCI Results Via the Midpoint Categories to Damage Categories



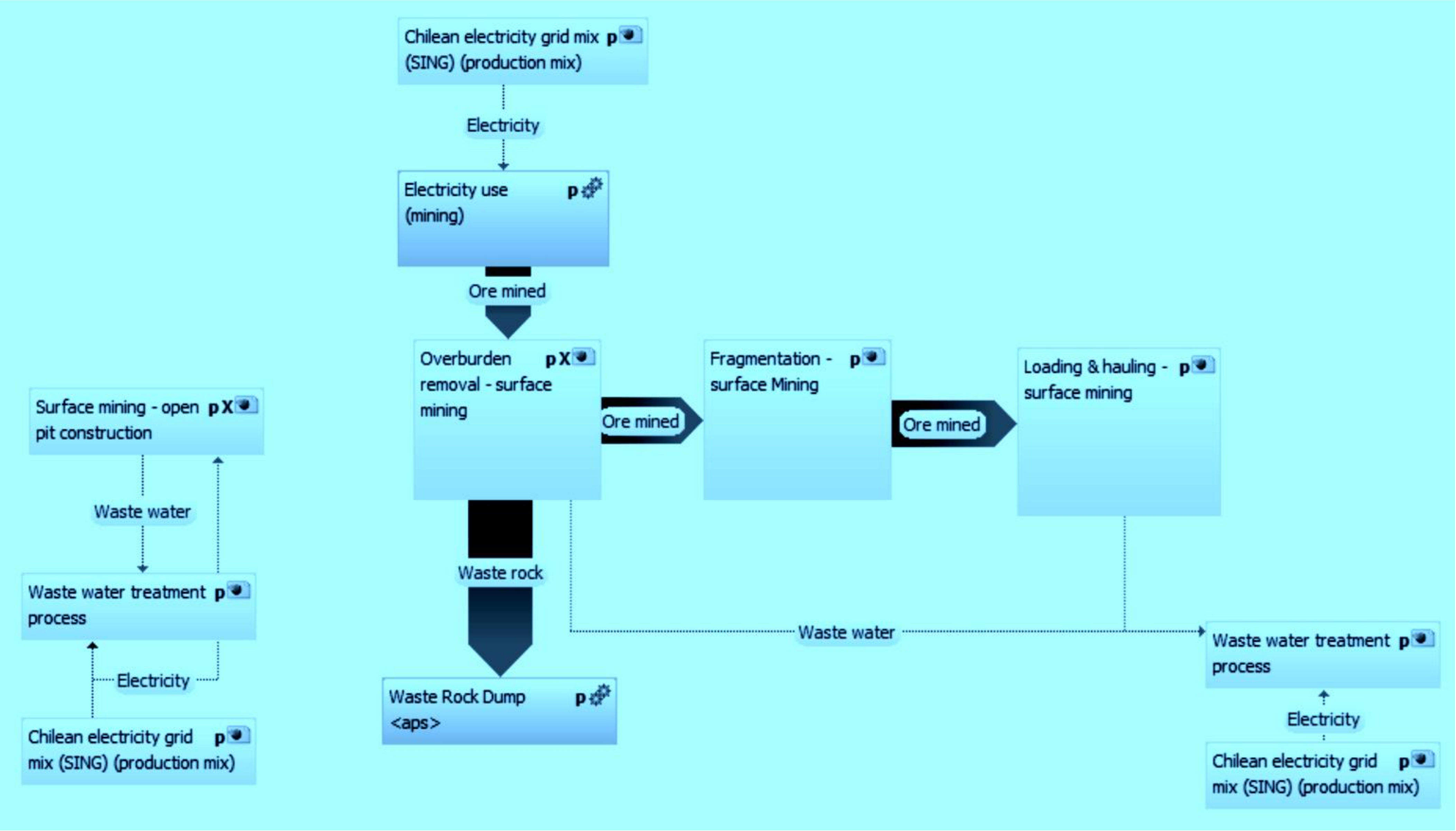
Source: Humbert 2005, IMPACT 2002+ Framework

Overall Scheme of the ReCiPe Framework, Linking LCI Results Via the Midpoint Categories to Damage Categories



Source: Goedkoop et al. (2013) ReCiPe Framework.

Generic Surface Mining LCI Model Developed in Gabi 6



Object Tree of the Main Processes and Sub-Processes Developed for Surface Mining

- Surface Mining - Open Pit (Copy)
  - Fragmentation - surface Mining
    - Fragmentation machinery (NONRAD2008a model, diesel, surface mining)
    - Fragmentation processes - surface mining
    - US: Diesel mix at refinery PE
    - US: Heavy fuel oil at refinery (0.3wt.% S) PE
  - Loading & hauling - surface mining
    - Loading & hauling machinery (NONROAD2008a model, diesel, surface mining)
    - Loading & hauling processes - surface mining
    - US: Diesel mix at refinery PE
  - Overburden removal - surface mining
    - Overburden removal machinery (NONROAD2008a model, diesel, surface mining)
    - Overburden removal processes, surface mining
    - US: Diesel mix at refinery PE
  - Waste water treatment process
    - DE: Calcium hydroxide (Ca(OH)2; dry; slaked lime) (EN15804 A1-A3) PE
    - GLO: Waste water treatment PE <u-so>
  - Electricity use (mining)
  - Waste Rock Dump <aps>

Object Tree of Processes Developed for Overburden Removal

- Overburden removal processes, surface mining
  - GLO: Dumping overburden <u-so>
  - GLO: Loading stockpiles (overburden) <u-so>
  - GLO: Truck overburden loading with excavator <u-so>
  - GLO: Trucks traffic on unpaved roads on overburden removal <u-so>
  - GLO: Wind erosion exposed areas on overburden removal <u-so>
  - GLO: Wind erosion stockpiles (overburden) <u-so>
  - Waste rock extracted from mines (operation) <aps>
  - Water use (overburden)

Emission Factors for ANFO and Emulsion Explosives

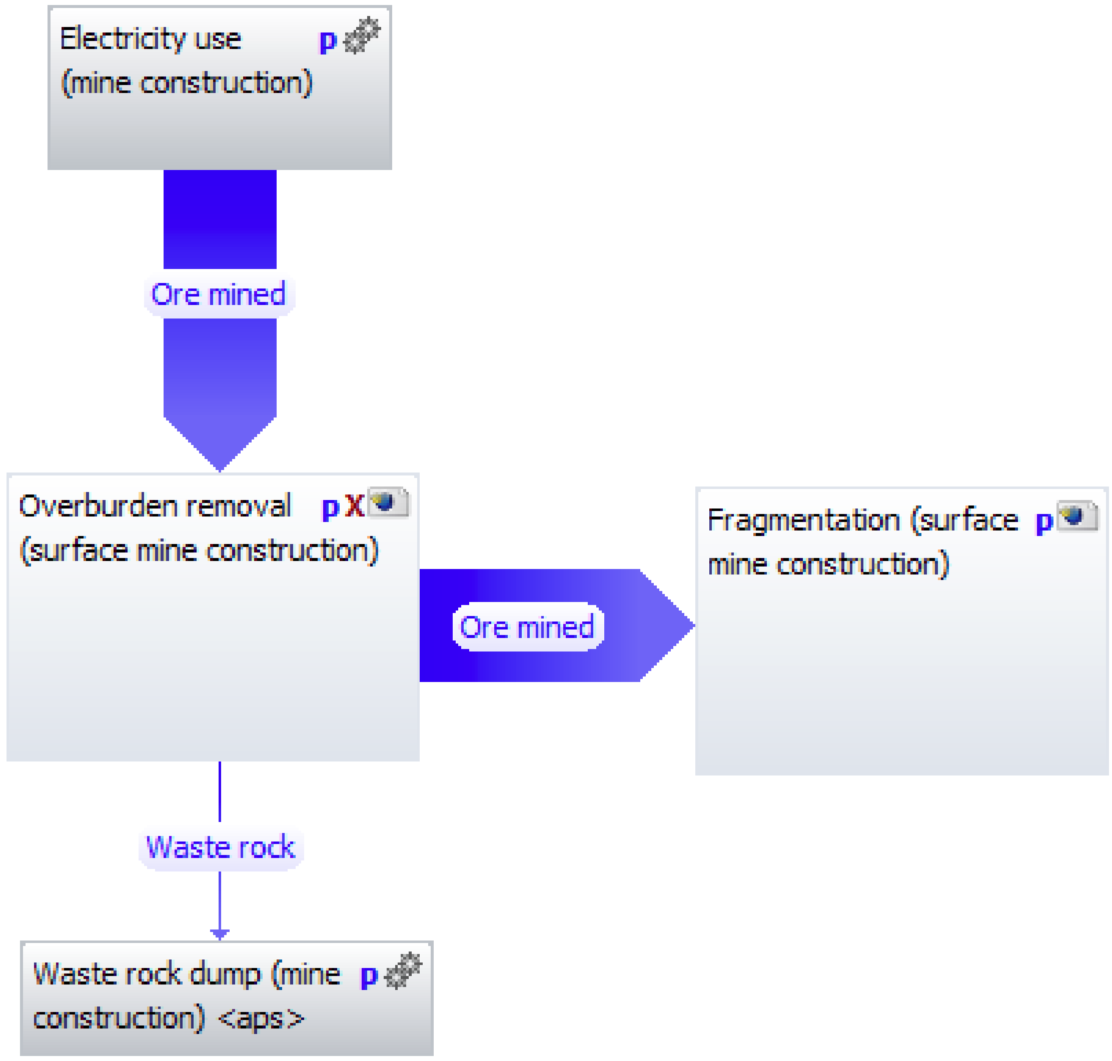
	kg/tonne	
	ANFO	Emulsion
CO	34	52
NOX	8	26
SO_2	0.06	1
CH_4	-	0.3
CO_2	167	166

Source: AGO, 2006

Object Tree Machinery and Transport Vehicles Developed for the Overburden Removal Stage

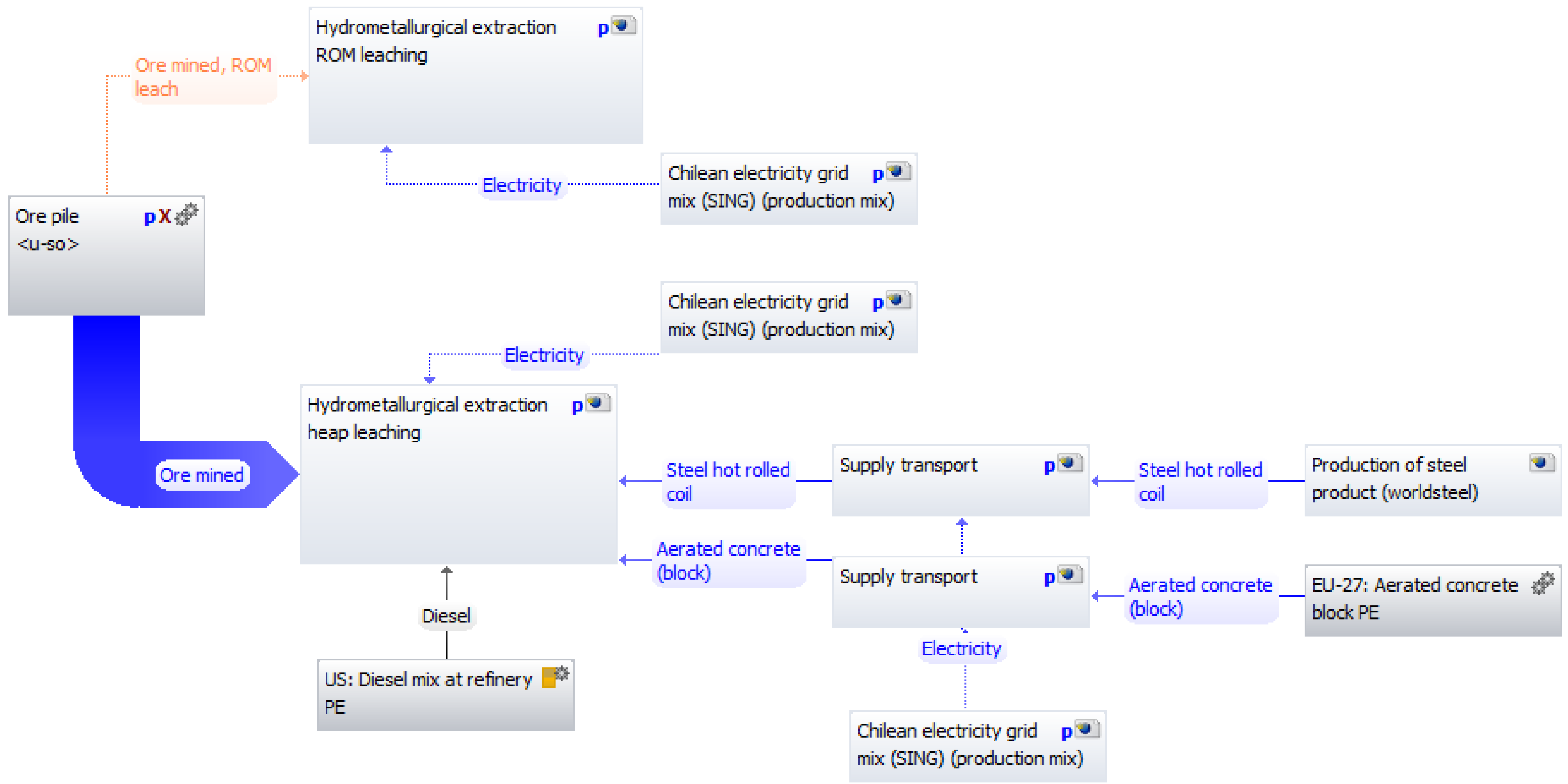
- Overburden removal machinery (NONROAD2008a model, diesel, surface mining)
  - GLO: Car diesel PE <u-so>
  - GLO: Mining truck PE <u-so>
  - GLO: Truck PE <u-so>
  - GLO: Truck-trailer PE <u-so>
  - Ore mined <aps>
  - US: Crawler tractor/dozers >= 175 to <300 hp <u-so>
  - US: Crawler tractor/dozers, >= 100 to <175 hp <u-so>
  - US: Crawler tractor/dozers, >= 300 to <600 hp <u-so>
  - US: Crawler tractor/dozers, >= 600 to <750 hp <u-so>
  - US: Crawler tractor/dozers, >750 hp <u-so>
  - US: Dumpers/tenders, >= 100 to <175 hp <u-so>
  - US: Dumpers/tenders, >= 175 to <300 hp <u-so>
  - US: Dumpers/tenders, >= 300 to <600 hp <u-so>
  - US: Dumpers/tenders, >= 600 to <750 hp <u-so>
  - US: Dumpers/tenders, >750 hp <u-so>
  - US: Excavator, >= 100 to <175 hp <u-so>
  - US: Excavator, >= 175 to <300 hp <u-so>
  - US: Excavator, >= 300 to <600 hp <u-so>
  - US: Excavator, >= 600 to <750 hp <u-so>
  - US: Excavator, >750 hp <u-so>
  - US: Graders, >= 100 to <175 hp <u-so>
  - US: Graders, >= 175 to <300 hp <u-so>
  - US: Graders, >= 300 to <600 hp <u-so>
  - US: Graders, >= 600 to <750 hp <u-so>
  - US: Graders, >750 hp <u-so>
  - US: Rubber tire dozers, >= 100 to <175 hp <u-so>
  - US: Rubber tire dozers, >= 175 to <300 hp <u-so>
  - US: Rubber tire dozers, >= 300 to <600 hp <u-so>
  - US: Rubber tire dozers, >= 600 to <750 hp <u-so>
  - US: Rubber tire dozers, >750 hp <u-so>
  - US: Rubber tire loader, >= 100 to <175 hp <u-so>
  - US: Rubber tire loader, >= 175 to <300 hp <u-so>
  - US: Rubber tire loader, >= 300 to <600 hp <u-so>
  - US: Rubber tire loader, >= 600 to <750 hp <u-so>
  - US: Rubber tire loader, >750 hp <u-so>
  - US: Scrapers, >= 100 to <175 hp <u-so>
  - US: Scrapers, >= 175 to <300 hp <u-so>
  - US: Scrapers, >= 300 to <600 hp <u-so>
  - US: Scrapers, >= 600 to <750 hp <u-so>
  - US: Scrapers, >750 hp <u-so>
  - US: Tractors/loaders/backhoes, >= 100 to <175 hp <u-so>
  - US: Tractors/loaders/backhoes, >= 175 to <300 hp <u-so>
  - US: Tractors/loaders/backhoes, >= 300 to <600 hp <u-so>
  - US: Tractors/loaders/backhoes, >= 600 to <750 hp <u-so>
  - US: Tractors/loaders/backhoes, >750 hp <u-so>

Generic Surface Mine Construction LCI Model Developed in Gabi 6



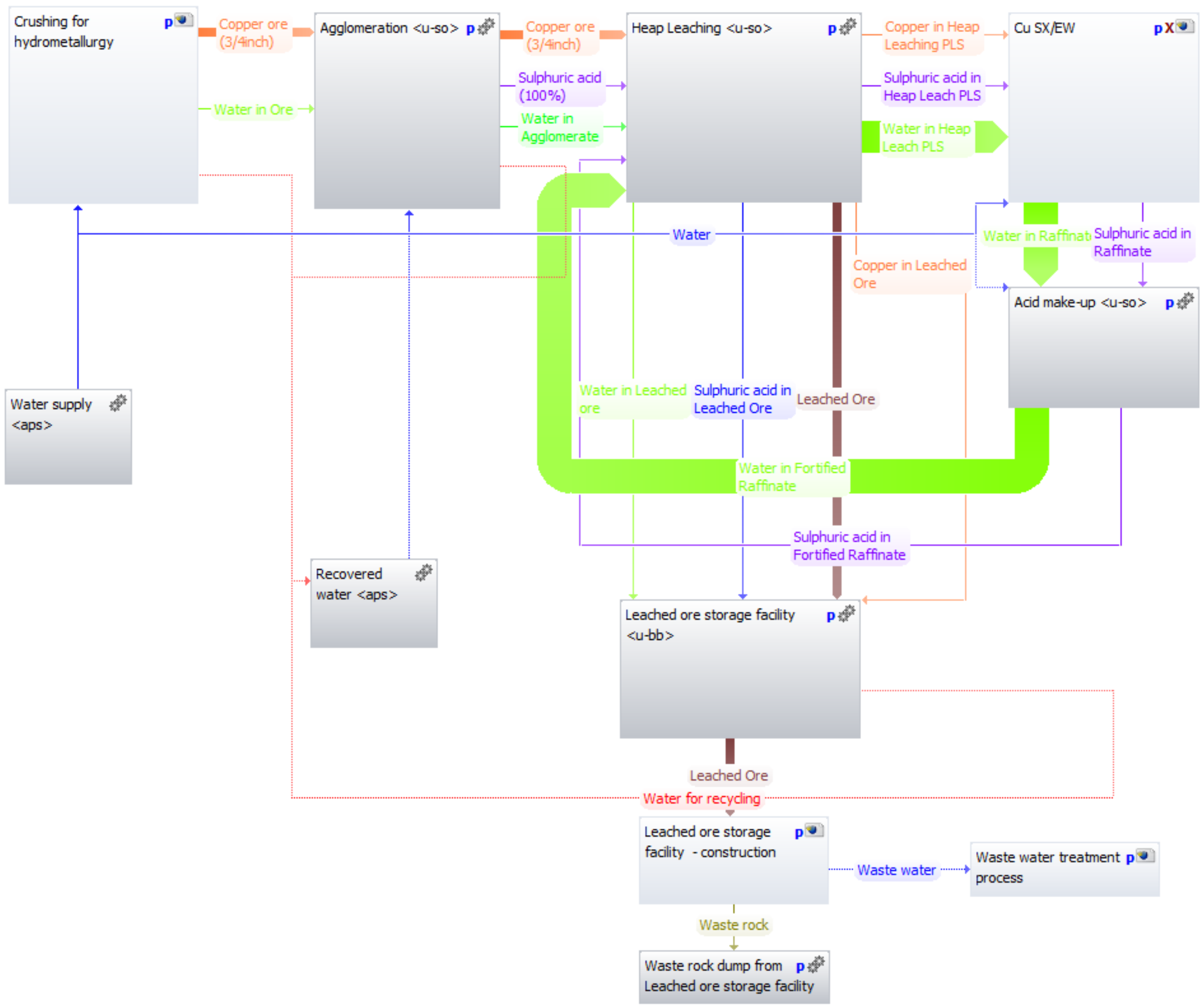
Source: Gabi 6 Software

Hydrometallurgical Extraction of Copper LCI Model developed in Gabi 6



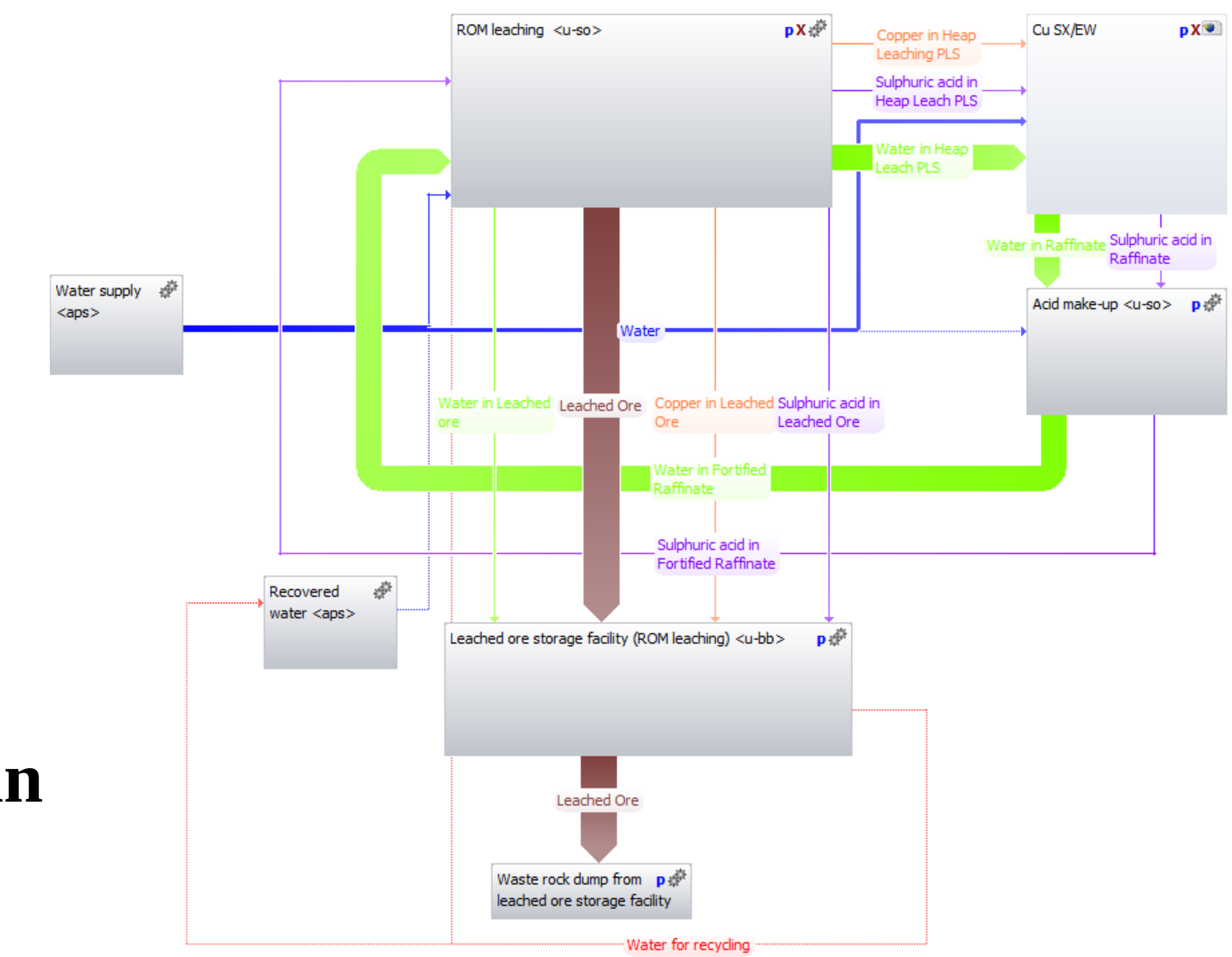
Source: Gabi 6 Software; for Hydrometallurgical Extraction of Copper

Heap Leaching LCI Model Developed in Gabi 6

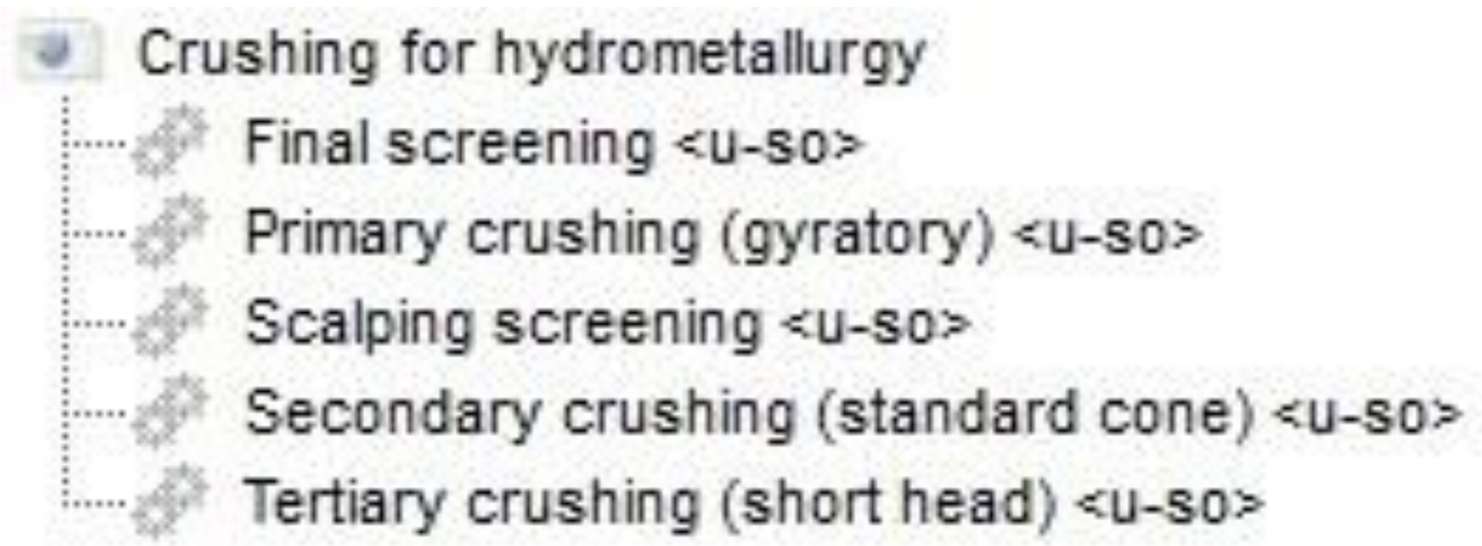


Source: Gabi 6 Software; for Heap Leaching LCI model

ROM Leaching LCI Model Developed in Gabi 6

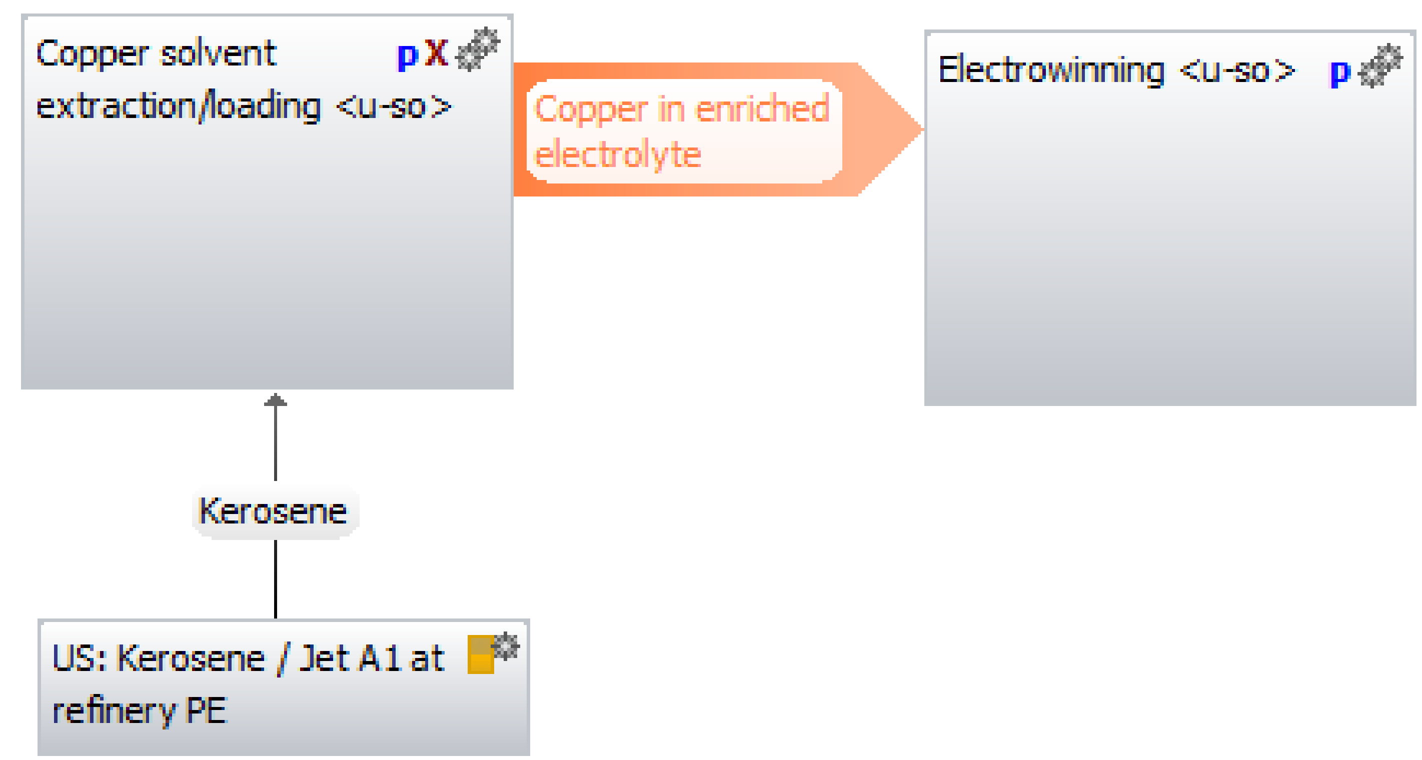


Source: Gabi 6 Software; for ROM Leaching LCI Model



Object Tree Developed for the Comminution Process in Copper Hydrometallurgy

Copper SX/EW LCI Model Developed in Gabi 6



Source: Gabi 6 Software; for Copper SX/EW LCI Model

Mining Machinery Fleet and Activity in the Case Study Mine

Non-Road 2018 Vehicle Type	HP	Tier	No. of Vehicles	Stages
Dump Truck	450	TIER II	50	Overburden Removal, Loading & Hauling
Water boxer	190	TIER II	4	Water Spray
Excavator	1260	TIER II	9	Overburden Removal, Loading & Hauling
Graders	265	TIER I	2	Overburden Removal, Loading & Hauling
Graders	500	TIER I	2	Overburden Removal, Loading & Hauling
Rubber tire dozers	800	TIER II	3	Overburden Removal, Loading & Hauling
Rubber tire dozers	480	TIER II	2	Overburden Removal, Loading & Hauling
Crawler Tractor/Dozers	850	TIER IV	3	Overburden Removal, Loading & Hauling
Crawler Tractor/Dozers	580	TIER I	2	Overburden Removal, Loading & Hauling
Backhoe	255	TIER I	3	Overburden Removal, Loading & Hauling
Bore/Drill rigs	760	TIER I	2	Fragmentation
Bore/Drill rigs	350	TIER I	3	Fragmentation
Rubber Tire Loaders	1800	TIER I	2	Overburden Removal, Loading & Hauling

	mg/kg			
	min	max	average	delta
SO_4^{-2}	210	350	275	67.5
Cu	0.006	0.19	0.1020	0.0970
Mo	0.007	0.36	0.1880	0.1812
Pb	0.007	0.02	0.0130	0.0060
Fe	0.005	0.37	0.1920	0.1870
Mn	0.01	2.70	1.35	1.35
As	0.001	0.05	0.0254	0.0245

Constituents Concentration in Tailings Return Water

Machinery Fleet of Using H.P for Tailings Storage Facilities Construction

Non-Road 2018 Vehicle Type	Horsepower
Rubber Tire Loaders	240
Backhoe	200
Bore/Drill rigs	100
Crawler Tractor/Dozers	400
Bore/Drill rigs	150
Rollers	120

Tailings Storage Facility Construction Parameters

Parameter	Value	Units
Waste rock average density	1.7	t/m^3
Mass of waste rock extracted	84,750,000	t
Volume of waste rock extracted for the construction of walls and others	49,852,000	m^3
Volume of waste rock extracted	20,750,000	m^3
Tailings average density (dried)	1.45	t/m^3
Tailings capacity (mass)	14,310,000	t
Tailings capacity (volume)	1,500,000	m^3
Waste rock extracted / Tailings capacity	1.520	t/t
Water in tailings/Ore rate	0.430	t/t ore
Tailings (with water)/Ore rate	1.405	t/t ore
Average wall height	80	m
Area of tailings impoundment	1,200,3000	m^2
Area/Tailings mass ratio	**0.020**	**m^2/t**

Source: The Sustainability Report (2014-2015)

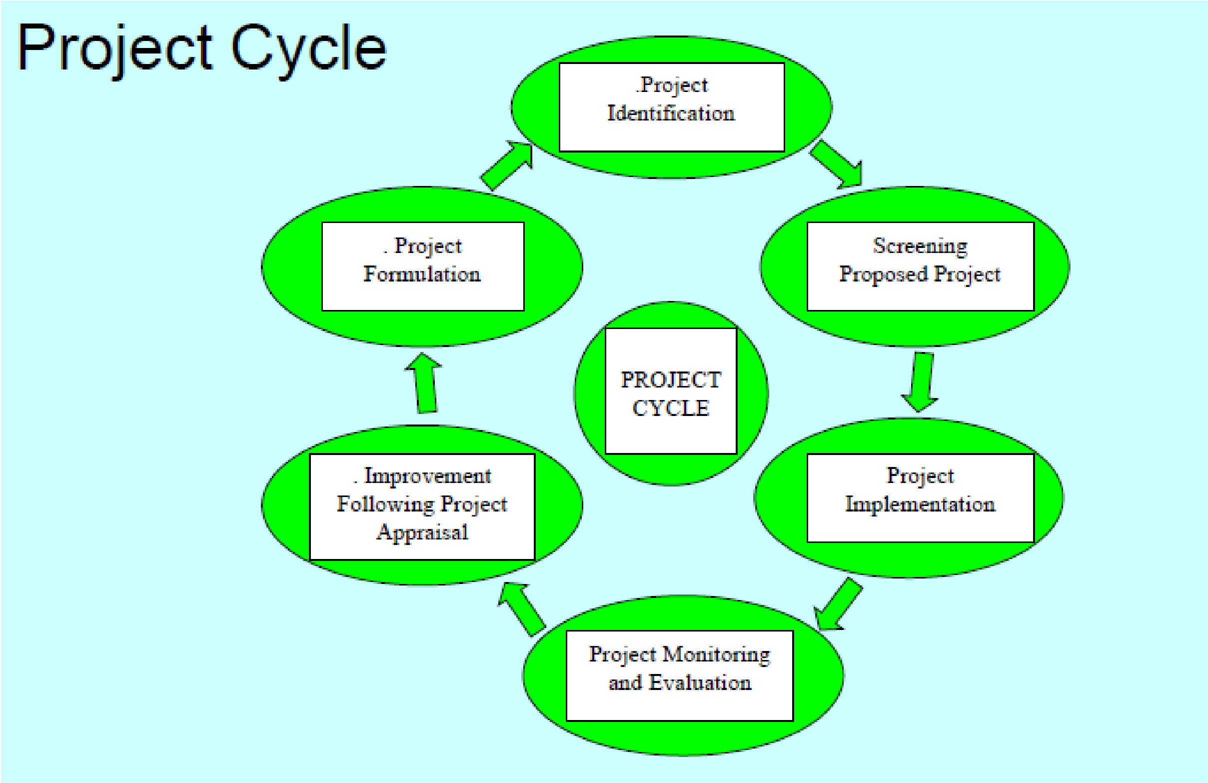
Machinery Fleet of Leached Ore Storage Facilities Construction

Non-Road 2018 Vehicle Type	HP	Tier	No. of Vehicles	Stages
Dump Truck	450	TIER II	50	Overburden Removal, Loading & Hauling
Water boxer	190	TIER II	4	Water Spray
Excavator	1260	TIER II	9	Overburden Removal, Loading & Hauling
~~Excavator~~	1260	TIER II	9	Overburden Removal, Loading & Hauling

Leached Ore Storage Facility Construction Parameters

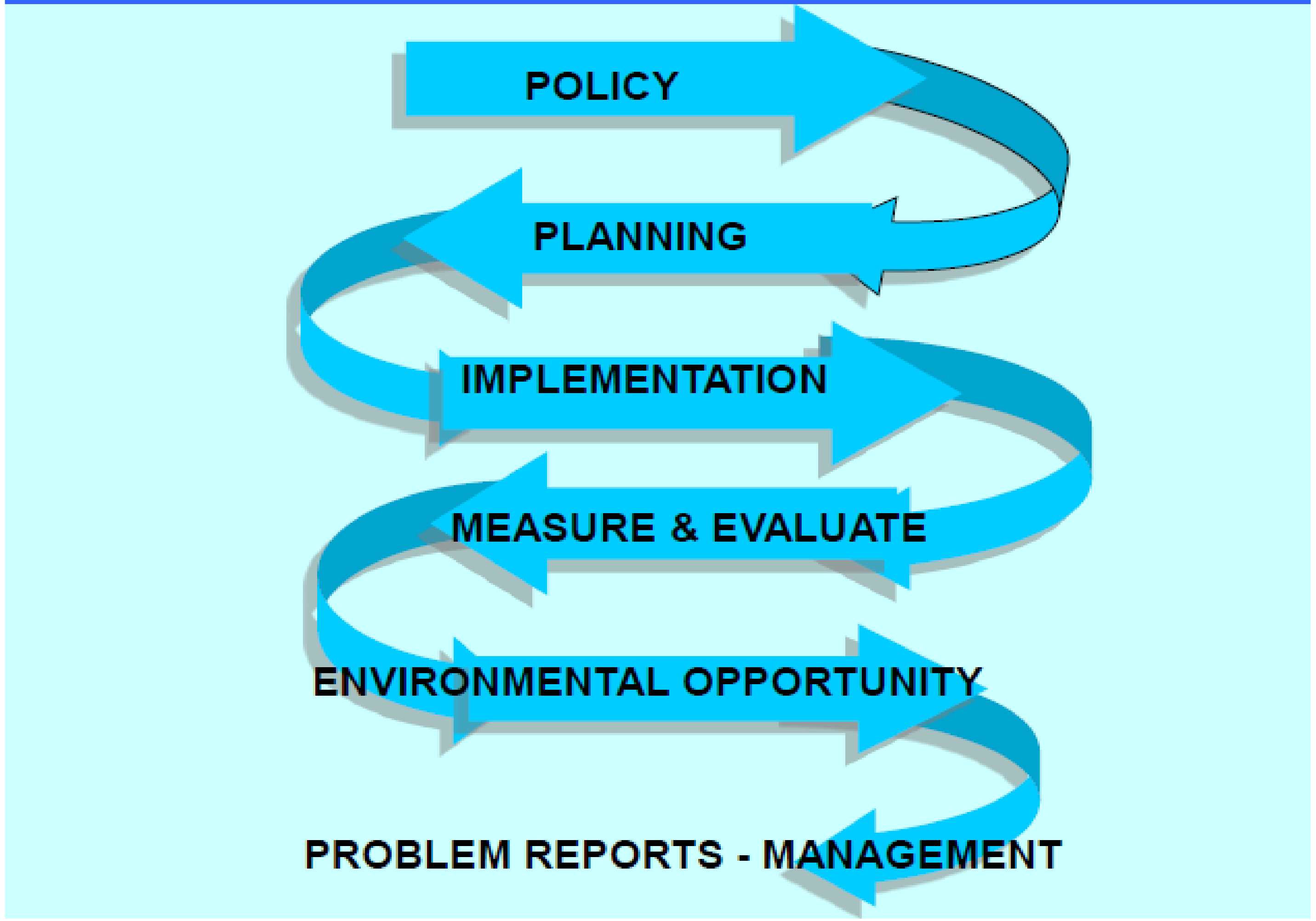
Parameter	Value	Units
Waste rock average density	1.60	t/m3
Surface	230	ha
Surface	2,300,000	m2
Leached ore capacity	344	Mt
Leached ore density	1.80	t/m3
Leached ore capacity	190,000,000	m3
Waste rock surface	801	m3
Waste rock surface conveyor	5,600,000	m3
Total volume of rock removed	5,860,500	m3
Total mass of rock removed	8,950,000	t
Total waste rock extracted/Leached ore ratio	0.0260	t/t
Area/Leached ore mass ratio	0.0066	m2/t

Environmental Management System For Mining Project



Proposed Management Model for Project Life Cycle for Sabetaung and Kyisintaung

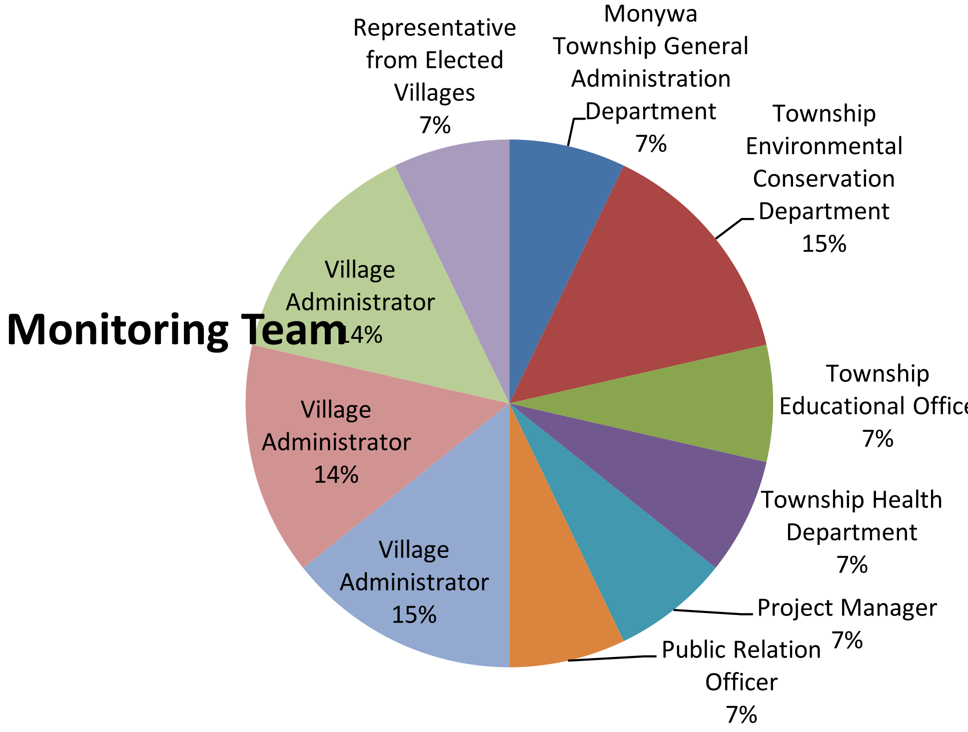
Strategic Environmental Management System



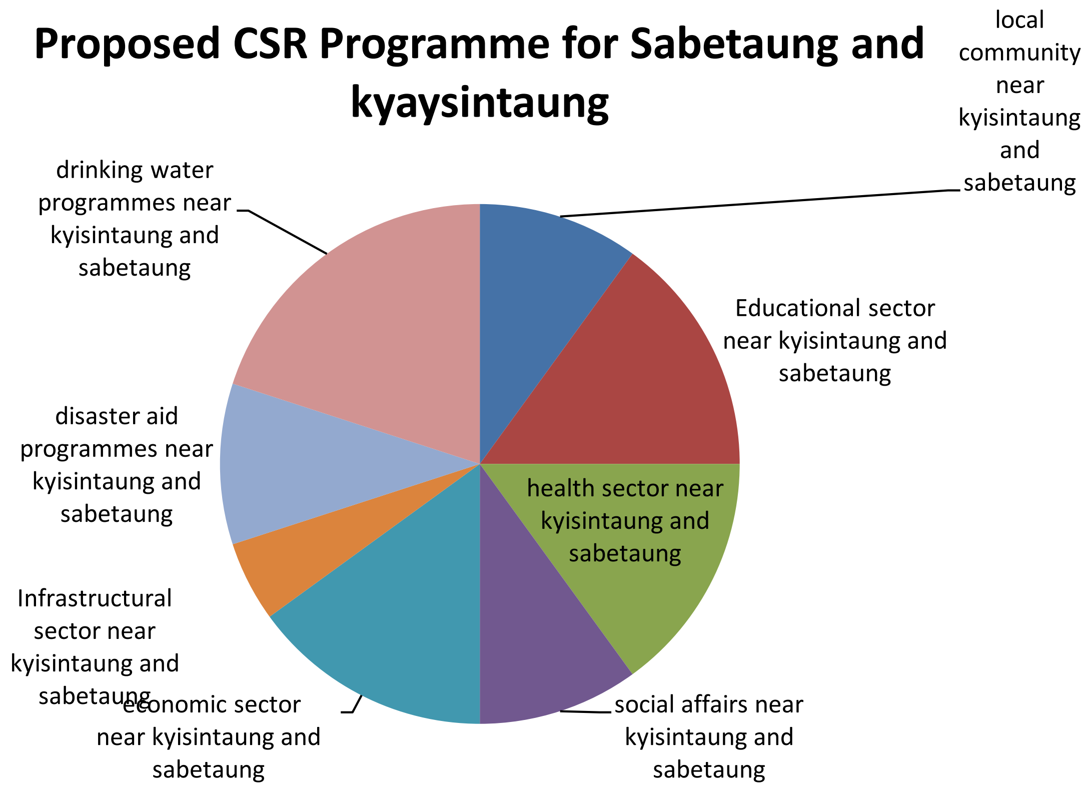
Proposed Strategic Environmental Management Planning Model for Sabetaung and Kyaysintaung Mining Enterprise

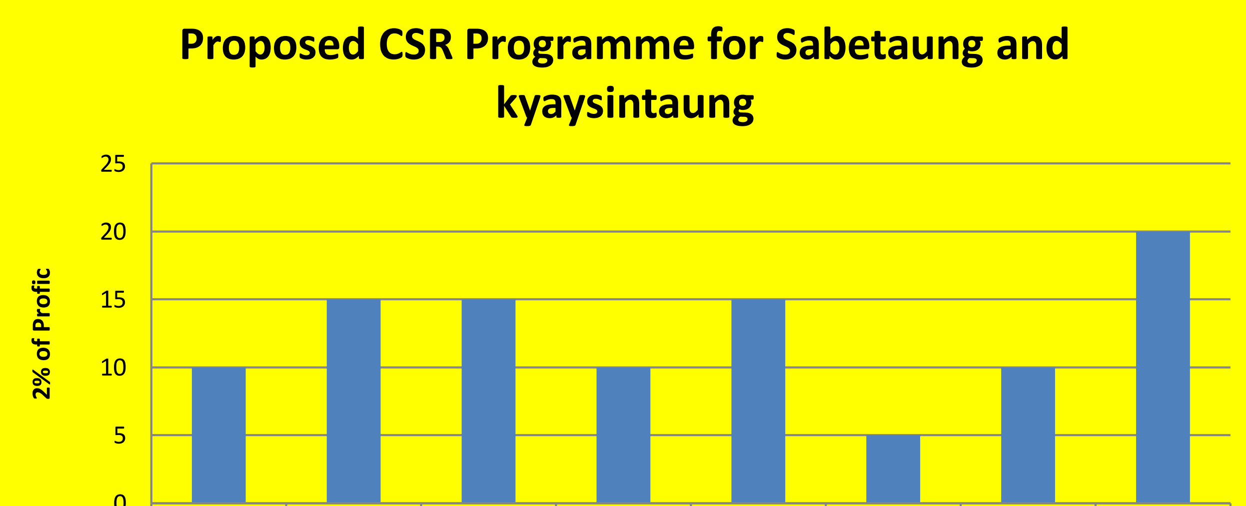
Environmental Monitoring Team

Sr.	Representative	Number
	Monywa Township Governmental Departments	
1	Monywa Township General Administration Department	1
2	Township Environmental Conservation Department	2
3	Township Educational Office	1
4	Township Health Department	1
	Project Management	
1	Project Manager	1
2	Public Relation Officer	1
	Local Community	
1	Village Administrator	2
2	Village Administrator	2
2	Village Administrator	2
4	Representative from Elected Villages	1
	Proposed Total Monitoring Team Members	14



Proposed CSR Programme for Sabetaung and Kyaysintaung





	local community near kyisintaung and sabetaung	Educational sector near kyisintaung and sabetaung	health sector near kyisintaung and sabetaung	social affairs near kyisintaung and sabetaung	economic sector near kyisintaung and sabetaung	Infrastructural sector near kyisintaung and sabetaung	disaster aid programmes near kyisintaung and sabetaung	drinking water programmes near kyisintaung and sabetaung
Series1	10	15	15	10	15	5	10	20

Environmental Concerns from Mine Exploration

Action	Affected Environment	Environmental Concerns
CONSTRUCTION ACTIVITIES		
Camp, road, airstrip, drill pad and staging area construction Line cutting Topsoil removal	Soils and Geology Water Quality Vegetation Fish and Wildlife Land Use Air Quality Cultural Noise and Vibration Aesthetics Health and Safety	Erosion and Sedimentation Modification of streams and rivers due to crossings Spills Deforestation and loss or disturbance of habitat Fire Equipment emissions and fugitive dust Cultural and heritage site disturbance Noise and vibration from construction activities Aesthetic/visual impacts Health and safety of workers transported to the site, using equipment and working in inhospitable environments
EXPLORATORY PROGRAMS		
Geophysical surveys Reconnaissance Mapping and Sampling Aerial photography	Water Quality Vegetation Fish and Wildlife	Erosion and sedimentation from off-road vehicle use Impacts on vegetation from off-road vehicle use Disturbance of wildlife from surface and airborne surveys
Trenching, pitting and drilling to collect samples	Soils and Geology Water Quality Vegetation Fish and Wildlife Land Use Air Quality Cultural Noise and Vibration Aesthetics Health and Safety	Erosion and sedimentation Metals leaching into surface water and groundwater Spills or leaks from mud pits Groundwater contamination from drilling fluids Deforestation and loss or disturbance of habitat Scarring of land in remote locations Equipment emissions and fugitive dust Cultural and heritage site disturbance

Action	Affected Environment	Environmental Concerns
Transportation	Water Quality Air Quality Health and Safety	Spills Emissions from vehicles and fugitive dust Transportation accidents
CAMP ACTIVITIES		
Camp operation	Fish and Wildlife	Animals attracted to garbage and food waste Migratory patterns, breeding/nesting behavior affected by presence of humans and noise from helicopters, planes and drill rigs Increased hunting and fishing (food for workers)
Solid and human waste Disposal	Water Quality Aquatic Biota	Water quality degradation Depletion of aquatic biota from spills
Fuel storage and handling	Water Quality Aquatic Biota	Water quality degradation from spills Depletion of aquatic biota
Water supply	Water Quantity	Depletion of nearby water sources
Energy production	Air Quality	Emissions from generators
Transportation	Water Quality Air Quality Health and Safety	Spills Emissions from vehicles and fugitive dust Transportation accidents

Environmental Concerns from Mine Development

Action	Affected Environment	Environmental Concerns
CONSTRUCTION ACTIVITIES		
Construction of buildings, workshops, processing plant, and permanent camp	Soils and Geology Water Quality Vegetation Fish and Wildlife Land Use Air Quality Cultural Noise and Vibration Aesthetics Health and Safety	Erosion and sedimentation Spills Deforestation and loss of habitat Fire Equipment emissions and fugitive dust Cultural and heritage site disturbance Noise and vibration from construction activities Aesthetic/visual impacts Health and safety of workers transported to the site, using equipment and working in inhospitable environments
Construction of site access roads and power lines	Soils and Geology Water Quality Vegetation Fish and Wildlife Land Use Air Quality Cultural Noise and Vibration Aesthetics	Erosion and sedimentation Modification of streams and rivers due to crossings Acid generation from exposed sulfide materials Spills Deforestation and loss or disturbance of habitat Increased road access in remote areas may lead to: - Increased fishing/hunting, stressing populations - Human invasion of previously inaccessible areas Fire Equipment emissions and fugitive dust Cultural and heritage site disturbance Noise and vibration from construction

Action	Affected Environment	Environmental Concerns
TRANSPORTATION		
Operation of vehicles and equipment	Water Quality Air Quality Health and Safety	Stream crossings Vehicle emissions and fugitive dust Transportation accident
Fuel and chemical transportation, handling, and storage	Water Quality Air Quality Health and Safety	Spills and stream crossings Potential releases of volatile organic compounds and hazardous substances Transportation accidents
MINE PREPARATION		
Site preparation (topsoil and overburden removal)	Soils and Geology Water Quality Vegetation Fish and Wildlife	Erosion and sediment from site as well as waste dump areas Acid generation from exposed sulfide materials at site and at waste dump areas and metals leaching into surface water and ground water Modification of drainage patterns, streams and rivers Deforestation and loss or disturbance of habitat Disruption and dislocation local wildlife and migratory wildlife
Drainage control	Water Quality Water Quantity	Erosion and sedimentation Modification of drainage patterns, streams and rivers Changes in flood patterns
Initial dewatering	Water Quality Water Quantity	Increased total dissolved solids and potentially trace metals Increased volumes of water to surface streams Downstream erosion and changes in stream morphology and floodplains due to increased volume

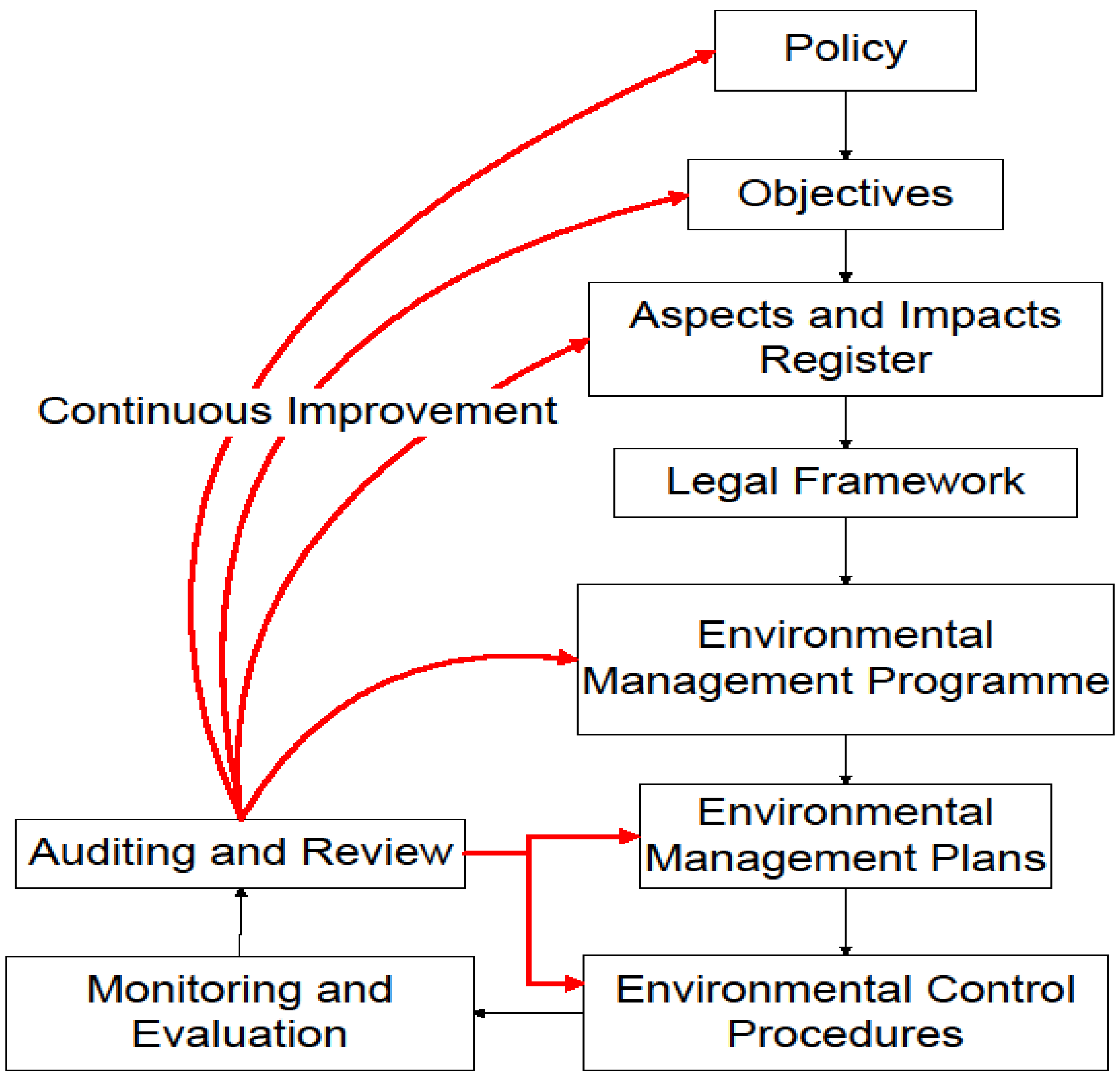
Solid and human waste Disposal	Water Quality Aquatic Biota
Fuel storage	Water Quality Aquatic Biota
Water supply	Water Quantity
Energy production	Air Quality
Transportation	Water Quality Air Quality Health and Safety

Environmental Concerns from Mine Operation

Action	Affected Environment	Environmental Concerns
MINING ACTIVITIES		
Land disturbance from any type of mine involving excavation or dredging	Soils and Geology Water Quality Water Quantity Vegetation Fish and Wildlife Land Use Air Quality Cultural Noise and Vibration Aesthetics Health and Safety	Erosion and sedimentation including increased streambed erosion Spills/overflows from ponds during storm events or electricity failures Degradation of groundwater and surface water quality Lowering of water table, reduced well production, decreased stream, seep and spring flows Deforestation and loss of habitat Disruption of migration routes and nesting/breeding activities Areas made unproductive for non-mine uses, including fishing in the case of dredging Increased landslide and dam failure potential Equipment emissions and fugitive dust Cultural and heritage sites destruction Traditional uses disrupted Noise and vibration from blasting and other mining activities Open pits, in-stream dredging and other unsightly facilities Health and safety of workers transported to the site, using equipment and working in inhospitable

Action	Affected Environment	Environmental Concerns
Land disturbance from waste disposal from hard rock mining activities including heap leach, waste rock and tailings dam facilities	Soils and Geology Water Quality Water Quantity Vegetation Fish and Wildlife Land Use Cultural Aesthetics Health and Safety	Erosion and sedimentation Spills/overflows from ponds during storm events or electricity failures Cyanide contamination of groundwater and surface water (Metal Mining) Increased potential for trace metals/other contaminants Deforestation and loss of habitat Poisoning of birds and other wildlife Disruption of migration routes/nesting/breeding activities Areas made unproductive for non-mine uses Disturbance or destruction of cultural and heritage sites Traditional uses disrupted Tailings dams and rock waste disposal sites are unsightly Health and safety of workers transported to the site, using equipment and working in inhospitable environments
Mining, power generation, processing, and transport	Air quality	Emissions from vehicles and machinery Fugitive dust Odors
Drainage and dewatering	Water Quality Water Quantity	Increased total dissolve solids and potentially trace metals Increased volumes of water to surface streams

Flow Diagram of Elements within the Environment & Social Management System (ESMS)



Source: The Sustainability Report, MYTCL (2017-2018)

Environmental Management Programs

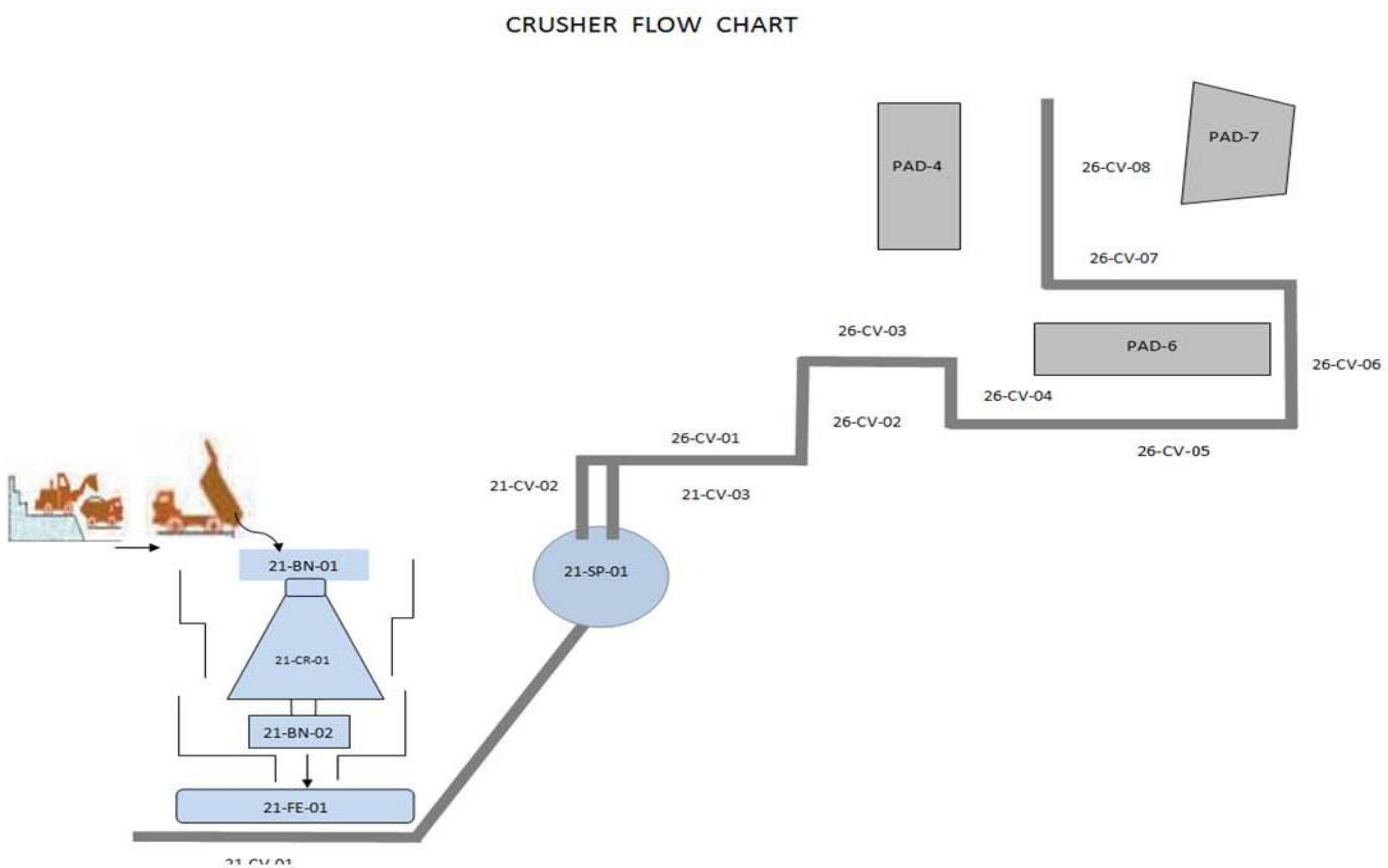
No.	Description of Task	Objective	Target	Target Date	Accountable
1	Environmental Induction, Training & Policies	To ensure that all project personnel understand the key environmental sensitivities of the S&K project	All personnel and contractors to have completed the environmental induction and training	On-going	- QHSE Superintendent. - All department superintendents
2	Environmental Incident reporting	To establish Environmental Incident reporting	To minimize disturbance to the environment and the local community.	On-going	- Environment & Operational Development Manager, - QHSE Superintendent, - All Departments
3	Clearing and ground disturbance	To maintain the abundance of diversity, broad scale geographic distribution and productivity of flora species, ecological communities and fauna habitat through heritage and environmental sites.	Replanting of equivalent areas of degraded land, such as old borrow pits, with the community.	On-going	- Environment & Operational Development Manager, - QHSE Superintendent, - All Departments
4	Air quality	To establish environmental control procedures (ECPs) for construction, operations and closure activities	To keep all air emissions within appropriate regulatory and industry guidelines.	On-going	- Environment & Operational Development Manager, - QHSE Superintendent, - All Departments
5	Hydrocarbon	To define plans/measures for impact mitigation	To prevent the creation of hydrocarbon contaminated sites.	On-going	- Environment & Operational Development Manager, - ES Superintendent, - QHSE Superintendent, - All Departments
6	Non-Hazardous waste	To define plan/measures for impact mitigation	To project workers, local communities' livestock, wildlife and vegetation from adverse impacts due to storage and handling of non-hazardous waste.	On-going	- Environment & Operational Development Manager, - ES Superintendent, - QHSE Superintendent, - All Departments
7	Hazardous materials	To define plan/measures for impact mitigation	To protect worker, local communities, livestock, wildfire and vegetation	On-going	- Environment & Operational Development Manager, - ES Superintendent,

Kyisintaung Ore Reserve Summary

Remaining Ore Reserves Tonnes August 31st 2018						
New Block Model & Design						
Kyisintaung Pit at the end of Aug 2018	Ore	Cu%	Cont.Cu	Waste		Total (Ore+ Waste)
615-295	223,676,629	0.304	679,949			
	223,676,629	0.304	679,949			
615-295				81,919,898	PAF	
				15,856,819	NAF	
				97,776,717		321,453,346
Kyisintaung Pit at the end of Aug 2018	223,676,629	0.304	679,949	97,776,717		321,453,346

Digital Thermometer

Crusher Flow Chart



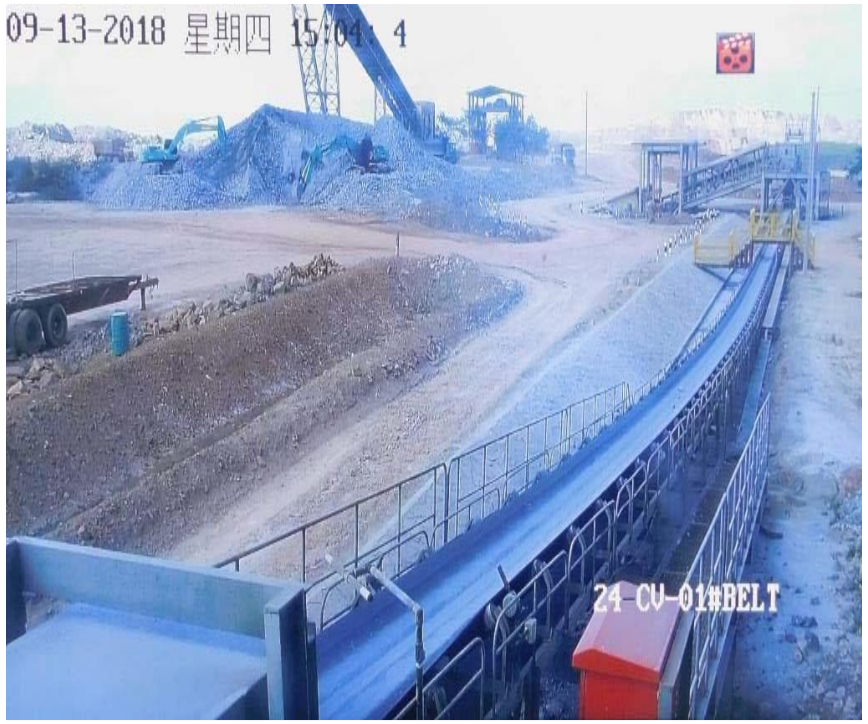
Primary Crusher

Primary Crusher

Primary Crusher Feeder

PC Stock Pile

Stock Pile to Feeders (2 sets)



Conveyor Line

Portable Stacker Conveyor Line System

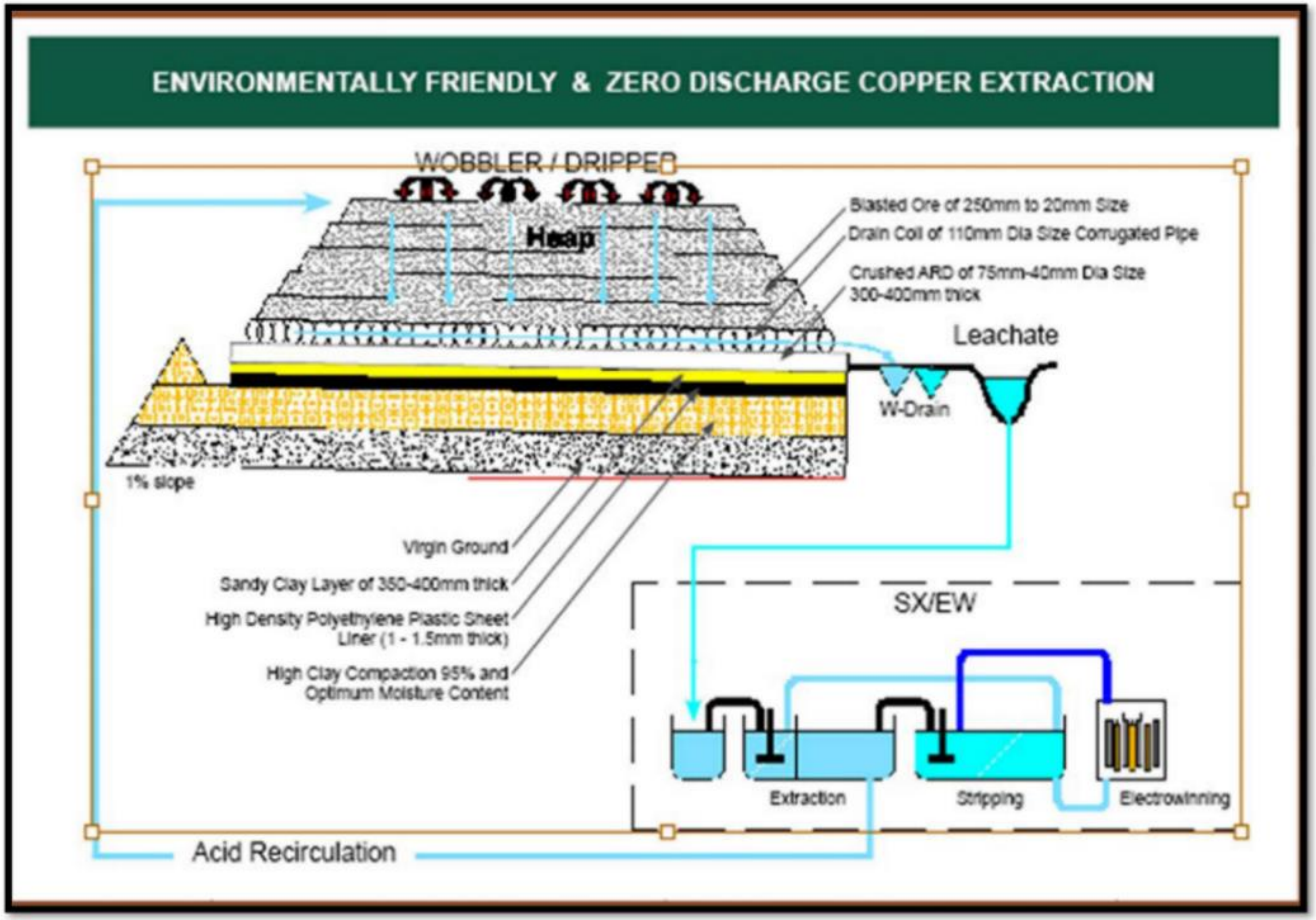
Stacker Operations

Mobile Crusher System

Heap Leaching at Leach Pads 3a & 3b

Heap Leaching at Leach Pads 4 & 6

A Typical Heap Leach Pad at MYTCL



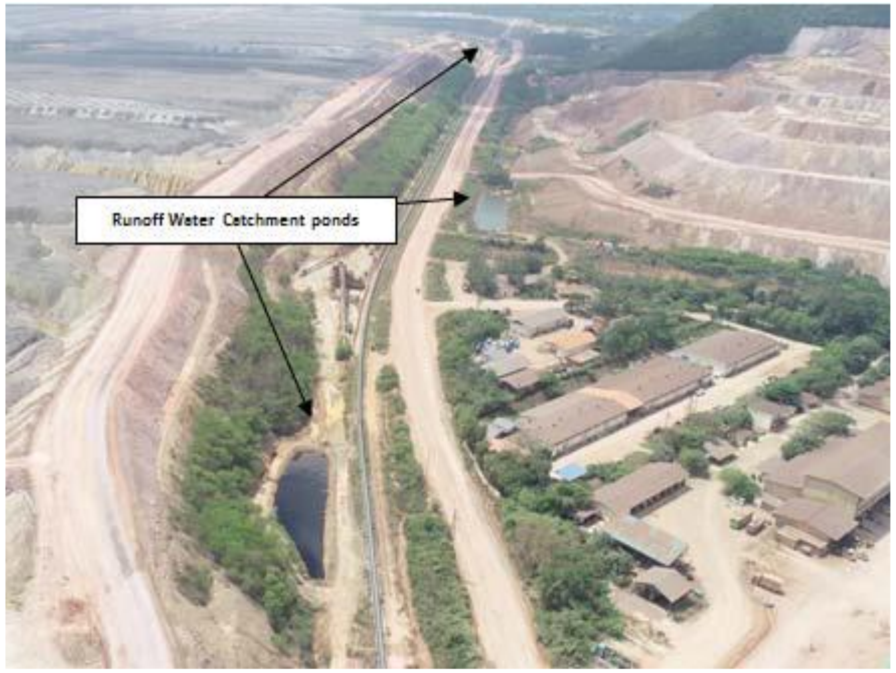
Source: The Sustainability Report (MYTCL), 2016-2017

W-Drain at Pad 4

TH-C Raffinate Pond at Pad 4

Recycling at Tube Wells

Bore-Hole Sampling



Liner Experiencing an Abnormal Condition

HDPE Pond Repairing

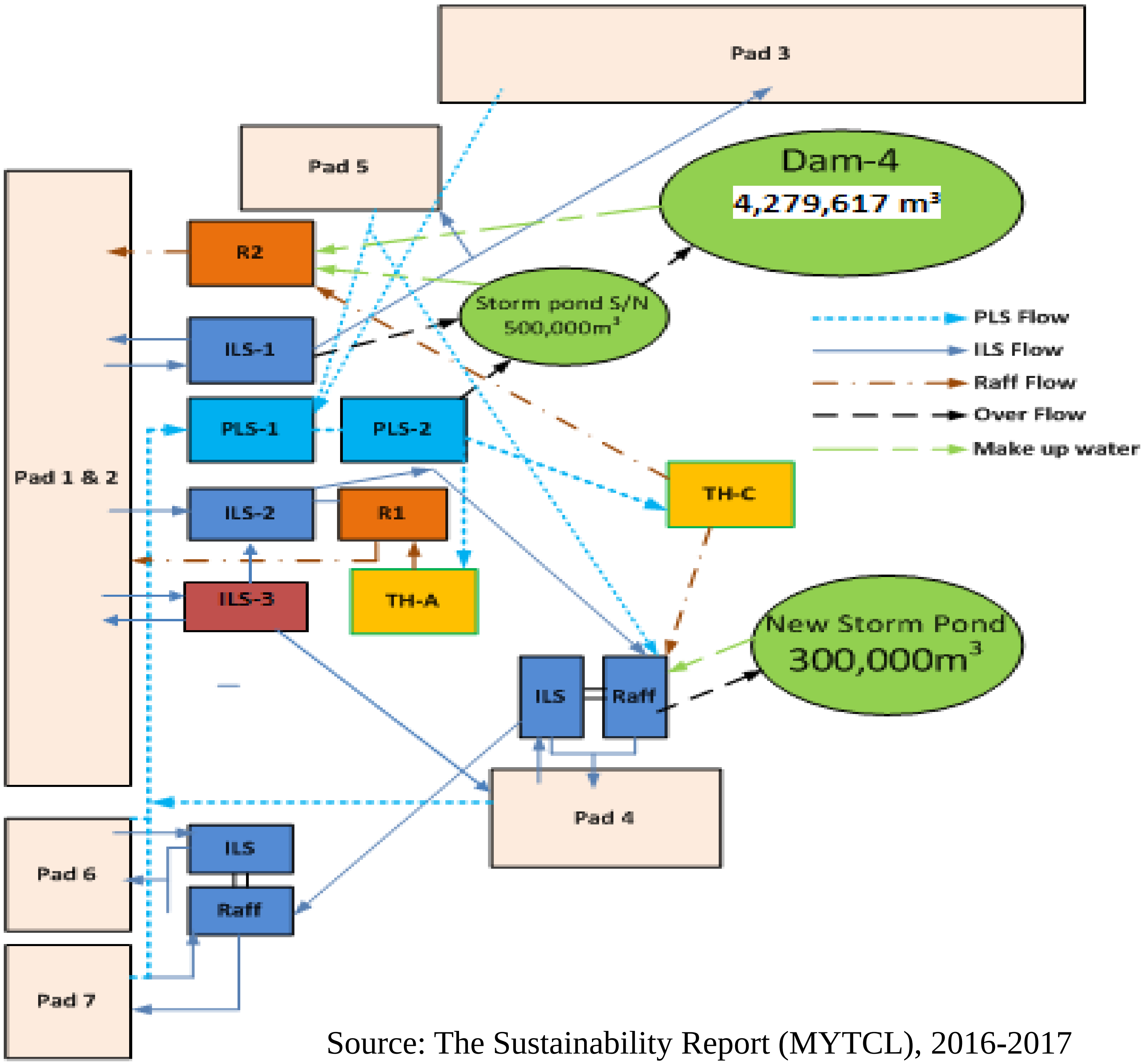
Catchment Ponds at Pads 1 and 2

No	Name of Catchment Pond	Pond Capacity(m3)
1	Overflow recycled pond for Process	338,000
2	Agglomerate recycled pond for Process	200
3	Pad 6 recycled pond for Process	200
4	Take up Tower recycled pond for Process	2,000
5	Pad-3 recycled pond for Process	200
6	Storm Water recycled pond for Process	552,000
7	Screens Fines Tailings Storage Facility (Dam-4) recycled pond for Process	4,280,000
8	Oil Separator pond	5,000
9	Old Wetland pond	512,000
10	Ywatha Wetland pond	9,000

Capacity of Each Ponds

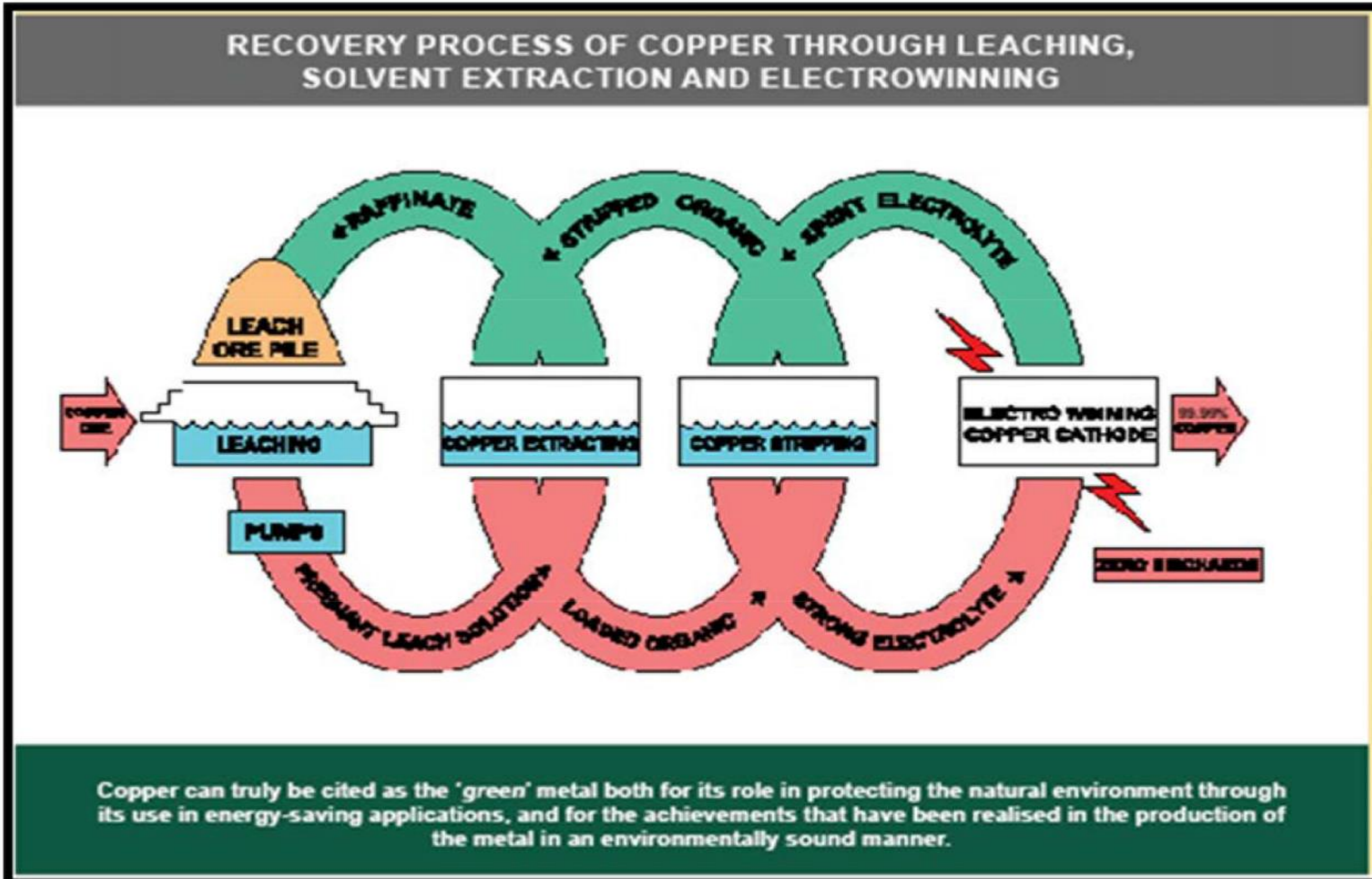
Location of TH-A Pond Systems for Pad 1 and 2

Flow Diagram Among the Pads, Ponds and Tank Houses



Source: The Sustainability Report (MYTCL), 2016-2017

Zero Discharge Diagram



Source: The Sustainability Report (MYTCL), 2017-2018

Waste Type	Disposal Method
• Lead Sludge	• Store in IBC tank and cover up
• Aqueous waste (Lab Waste)	• Recycle to raffinate solution
• Organic waste (Lab Waste)	• Recycle to solution mixer tanks
• Ore waste (Lab Waste)	• Dump on to the heap cell
• Cathode Plates	• Store at storage yard
• Anode Plates	• Store at storage yard
• Crud	• Dump on to the heap cell

Types of Waste from Production Stages and their Disposal Methods

Used Lead Sludge for Recycle

Aqueous Waste Disposal

Crud Cake and Ore Waste Disposal onto Heap Leach Cell

Used Cathode Plates to be Recycled

Used Anode Plates to be Recycled

S&K Mine Site Water Demand and Water Quality Restrictions

Location	Approximate Water Demand (m^3/day)	Water Quality Restriction
Mine Town	1,700	PH 7.0-8.0 TDS <200 mg/L TSS <50 mg/L Cl <500 mg/L
Process Plant	3,300	Portable Water
Crushing Plant/ Other Utilities (Workshop/ Supply/ANFO/23-Cv-03 Line)	5,000	No restriction
TH-B/ MYTCL Expatriate Camp	1,700	PH 7.0-8.0 TDS <200 mg/L TSS <50 mg/L Cl <500 mg/L

Conclusion

- With infrastructure and engineering products and processes becoming increasingly complex, engineers need to integrate consideration of whole-life environmental and social impacts – positive as well as negative – with the mail stream and commercial aspects of their work.
- To become wise use of natural resources, minimum adverse impact and maximum positive impact on people and the environment, Engineers play critical role to collaborate with scientist meeting the sustainable development goals.

References

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THANKS FOR YOUR KIND ATTENSION!