Theory to Practice:
The Scope, Purpose and Practice of
Prefeasibility Studies for
Critical Resources in the
Era of Sustainable Development

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Expert Working Group
U 4G
The PFS Menu

1. Context
2. Scope
3. Purpose
4. Practice
1. Context

Sustainable development
THE SUSTAINABLE DEVELOPMENT CYCLE


“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

– the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and

– the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.”
The Cycle of Needs and Limitations
Triple Bottom Line (TBL)

- Introduced by John Elkington, 1994 in California Business Review\(^1\)
- Direct response to the Brundtland/ Sustainability agenda – becomes an enterprise obligation
- Three variables must all apply to enterprise or organisational performance:
  - Economic/ financial
  - Social
  - Environmental
- Derived from John Nash’s Nobel prize-winning cooperative game theory – the win/win \(^2\)

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2. Scope

Aligning core “TBL” Principles with Sustainability
Raising the IAEA Dividend
Scope:

- TBL 1 - Social licence to operate (SLO) (**social**)
- TBL 2 - Comprehensive extraction (CX) (**techno-economic**)
- TBL 3 - Zero waste (OW) (**environmental**)

Diagram:

- SLO (1)
- CX (2)
- OW (3) (Zero Waste)

The triangle represents the Sustainable TBL.
Safety and Sustainability

• A strong mutual dependency has been identified between the objectives of HSE and sustainable development goals, such as the sustainable management and use of critical mineral resources.

• A practice cannot be described as sustainable that is not also safe.
3. Purpose

An equitable, realistic, sustainable equilibrium of benefits for stockholders and stakeholders
The Cycle of Needs and Limitations

THE SUSTAINABLE DEVELOPMENT CYCLE

Needs

Social

Technological

Environmental

PFS

Pathfinding

Sustainable Development
Pathways

= new business models

= new, compelling resource narratives...

= Future-proofing critical resources ...

= Waste as definition of last resort...
What do we mean by U “mining”?
“Solid” mining

Uranium mineral (yellow) in Granite

Uranium mineral (yellow) in Granite

Uranium mineral (yellow) in El-Hammat

NMA, Egypt
THE SUSTAINABLE DEVELOPMENT CYCLE

“Liquid” mining

URAM 2014
THE SUSTAINABLE DEVELOPMENT CYCLE

Yellowcake
Waste or Resource?
EoL or Futureproofing?
Learning New Competencies:
Future-proofing the national mines


Core PFS “TBL” Objectives - New Business Models

The PFS

• De-risked financials/ ROI (protects lender/ investor)
• Stable, equitable, long-term partnerships with stakeholders
• Reduced risk of project-related social conflicts/ conflict-free supply chain/ compliance with EITI objectives
• Positive contribution to / reduced impact on health, culture and heritage
• Equitable balance of economic and environmental interest, eg new, NORM industry specific regulation (U, P, oil and gas, REE etc)
1. Project – Nature and Objectives
   1.1 Project background
   1.2 Project Team
   1.3 Business Case
   1.4 Advisory Committee/ Experts
   1.5 Major Stakeholders
   1.6 Partners
   1.7 High-level Road Map with Major Milestones, Timeline, Life-cycle
   1.8 Sustainable Development Objectives and Dependencies

2. Present State Analysis (People, Process, Purpose)
   2.1 Laboratory and Pilot Studies / Status within the Halder Project Development Model
      2.1.1 Fundamental process chemistry
      2.1.2 Results and findings from scaled-up experiments
      2.1.3 Pilot Plant Operations
      2.1.4 Project Formulation (High Level Summary)
   2.2 Existing Facilities
      2.1.1 Buildings and Infrastructure
      2.1.2 Technology
      2.1.3 Consumables
      2.1.4 Environment
   2.3 Human Resources and Social Infrastructure
   2.4 Mineral Projects
      2.4.1 UNFC resources
      2.4.2 CRIRSCO or Equivalent
      2.4.3 Resource description and CX Opportunities
         2.4.3.1 Phosphates (a. Economic grade; b. Low-grade)
         2.4.3.2 Phosphogypsum stacks
         2.4.3.3 Heavy mineral sands
         2.4.3.4 Granites
         2.4.3.5 Other sources [including residues]
      2.4.4 Critical materials – policies and priorities
      2.4.5 Waste hierarchy – zero footprint (wastes and emissions)
   2.5 Gap Analysis
   2.6 Change Drivers
      2.6.1 Economic/ Financial
      2.6.2 Social
      2.6.3 Environmental
   2.7 Desired Outcomes/ Triple Bottom Line Returns
      2.7.1 Economic
      2.7.2 Social
      2.7.3 Environmental
   2.8 Sustainable Development and Performance Indicators
      2.8.1 [Proposed] Sustainable Development Framework
      2.8.2 Metrics and indicators

3. Proposed Future Facilities (Structures) including planning and building regulations
   3.1 Site Location and Justification [Greenfield or Brownfield]
   3.2 Operational Context within which Site Works including Physical Infrastructure, Roads, Utilities, Communications and Regulatory Framework.
   3.3 Site Master Plan, Location of Buildings, Facilities and Major Structures
   3.4 Preparation and Development of Additional Facilities (if required)
   3.5 Engineering Infrastructure and Materials of Construction
   3.6 Permits and Licences

4. Architectural and Construction Requirements
   4.1 Mechanisms / Constraints for Defining Calculating Space Requirements
5. Health, Safety and Environment .................................................................
  5.1 All hazards approach (biological, chemical, physical, radiological)/ risk and exposure pathways
  5.2 Culture of safety [ISO 18000] and associated training and oversight
  5.3 Environmental Impact Assessment
    5.3.1 Environmental Safety Case
    5.3.2 Environmental Management Plan
    5.3.3 Permits and Licences
  5.4 Standard Operating Procedures
  5.5 Lead and Lag Indicators
  5.6 PPE
  5.7 Fire prevention and emergency procedures
  5.8 Noise and Vibration Protection
  5.9 Safety Stakeholders
  5.10 Inspections and Audits

6. Emissions, residues and Wastes ...........................................................
  6.1 The Waste Hierarchy / Zero Emissions and Discharges
    Characterisation of waste streams and emissions
    Application of Waste Hierarchy across Project Life-cycle................................
  6.2 Prevention
  6.3 Minimisation
  6.4 Reuse
  6.5 Recycling
  6.6 Disposal/Discharge
  6.7 Added value options
  6.8 Permits and Licences

7. Utilities, Roads, Engineering Support, Infrastructure ...........................
  7.1 Electric Power Supply,
    7.1.1 Power Generation Equipment,
    7.1.2 Electric Lighting,
    7.1.3 Controls Systems
    7.1.4 Communications
    7.1.5 Alarms, Signaling
  7.2 Water Supply and Sewage
  7.3 Roads and Transportation
  7.4 Engineering Dependencies

8. Technical Specifications............................
  8.1 General Information, including Process and Equipment Selection Criteria
    8.1.1 Production Capacity and Operating Assumptions
    8.1.2 Licences, patents, uses of third party intellectual property
  8.2 Raw Materials/ Feedstocks
  8.3 Energy
  8.4 Reagents/ Solvents
  8.5 Consumables / Coefficients
  8.6 Process Description and Flowsheet
  8.7 Layout – Block Diagrams
  8.8 6 line Equipment List
  8.9 Human Resources including detailed Job Descriptions
8.10 Process controls
8.11 Maintenance and upkeep
8.12 End of Life (EOL) Plan

9. Market Analysis
9.1 Supply Analysis (including key assumptions)
  9.1.1 Domestic
  9.1.2 International
9.2 Demand Analysis (including key assumptions)
  9.2.1 Domestic
    - Volume
    - Price
  9.2.2 International
    - Volume
    - Price
9.3 Competitors/ Market Resilience
9.4 Market Risks
9.5 Supply chain / raw materials and other inputs
9.6 Transport and distribution
9.7 Taxes

10. Financial Assessment and Investment Requirements
10.1 Analysis of Financial Standing of Project Initiator, its Capacity to Implement Project including
    Strategic [Business] Plan
10.2 Capital Costs (CAPEX) (Mapped to Length of Expected Loan/ Investment)
    10.2.1 Reasonable/ Realistic Case
    10.2.2 Pessimistic Case
10.3 Operating Costs (OPEX) (Mapped to Length of Expected Loan/ Investment)
    10.3.1 Reasonable/ Realistic Case
    10.3.2 Pessimistic Case
10.4 Working Capital and Cash Flow
10.5 Internal Rate of Return/ Return on Investment
10.6 Permits and Licences
10.7 Off-take agreements, Contracts,
10.8 Bonds and Special Provisions
10.9 Life-cycle Analysis

11. Costs of Construction including Timelines/ Drawdown Requirements/ Contingencies

12. Cross-cutting Issues and Requirements

13. Regulatory and Licensing Requirements

14. Project Risks
14.1 Operational and Technical
14.2 Environmental
14.3 Financial and Economic
14.4 Social
14.5 Political and Regulatory
NORM-industry specific regulation

• Equitable balance of environmental, occupational and economic interests...
• Evidence-based
• Graded approach
4. Practice

Into the world of co- and by-product U
Have Your Yellowcake and Eat It?
What do I see?
Single Mineral or Complex Resource? ...
How conventional do I feel?...
Comprehensive extraction

• Disturb the ground once: extract maximum benefits
• All the useful materials should be extracted from the ore
• Mine/ by-products “future proofed” (closed system, successive life-cycles)
• By-products and residues (re)used
• Waste streams minimised/ legacy costs greatly reduced
  eg U, REE extraction from phosphates, base-metal ores etc
EXAMPLE: SANTA QUITERIA, BRAZIL, U AND P PROJECT
FLOWCHART

- Phosphate Mining
  - Phosphate Beneficiation
  - Phosphoric Acid Production
    - Uranium Recovery
      - Thorium Removal
      - Uranium Ore Concentrate
    - Sulphur
      - Sulphuric Acid Production
        - Fertilizers (MAP, DAP...)
        - Animal Feed Salt (DCP)
Definitional Uncertainty – “conventional” and “unconventional” resources

• the distinction between conventional and unconventional is harder and harder to defend ... As defined in the Red Book text attached conventional U may include sources of U as a by-product if the quantity is "important" or "significant"

• in the light of conventional mining activities often having very low grades (and hence are now being taken out of production) the distinction based on undefined "importance" does not really hold at either a quantitative level or a taxonomic level

• Reported at UNECE/ UNFC meeting April 2014 that the US SEC is now discouraging use of the distinction.
THE SUSTAINABLE DEVELOPMENT NARRATIVE

Unconventional U

<table>
<thead>
<tr>
<th>Source</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Shale</td>
<td>1,199,086</td>
</tr>
<tr>
<td>Lignite</td>
<td>313,685</td>
</tr>
<tr>
<td>Phosphates</td>
<td>12,894,830</td>
</tr>
<tr>
<td>Other</td>
<td>234,137</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14,641,738</strong></td>
</tr>
</tbody>
</table>

UDEPO, 2012
Kazakhstan – energy basin with U and hydrocarbons

Possible link between oil & gas and uranium, with associated migration of gas along faults, tectonic control of the localisation of roll fronts...

Jaireth et al. 2008
What do I mean by waste?
Lose it?
Kazakhstan

Cotton Growth and Yield (up to 200-300% increase over 3 years, (ICARDA))

AFA Technical Conference, July 9-11, 2012
Hilton: Jeff Grove
Rationale – Rethinking “Waste”

- Projects for managing any waste in isolation from the processes that generate them are running against the policy objectives of the waste hierarchy (e.g., EU Waste Framework Directive, 1975; US Non-Hazardous Waste Management Hierarchy)
  - disposal as the last, and least desirable of the management options
  - projects showing signs of “not performing well when undertaken purely as waste management tasks”
Waste Hierarchy

• progressive / step-wise transformation of waste to resource, with a hierarchy of waste itself premised as
  – i. prevention (or transformation to resource),
  – ii. minimisation,
  – iii. reuse;
  – iv. recycling,
  – v. disposal.
Resource data

• Reliability
• Transparency
• Currency
• Degree of criticality
Comprehensive extraction lifecycle

Accurate and transparent management of essential materials throughout the lifecycle

IAEA
A New U?

• Uranium has lived in a world apart since its sudden promotion to prime asset in the military sphere. It has struggled since 1945 to tell its elemental story as a source of clean, reliable energy and has let itself down in the past with poor mining practices (Rum Jungle) and inept management of nuclear power facilities. It has often chosen isolation over engagement.

• But there is a new, much older story to tell, and that story is now coming out, led from the major emerging economies, the “BRICS” not from the developed world.

• URAM 2014 might just be looked back on as the day that page in uranium’s history was turned, turned by, or perhaps on behalf of, those to whom energy security, access and affordability is a compelling, life-defining need.
SAFETY + SUSTAINABLE PRACTICES = SOCIAL LICENCE

• Safety – a “social/ organizational” concept
• Sustainability – critically dependent on TBL “techno-economic feasibility” (how to do things affordably well)
• Resulting in assurance of “the environment's ability to meet present and future needs”

Outcome = “Social Licence”
= The New Sustainable Equilibrium between Stockholders and Stakeholders
SECURE THE “FEW”

- Food security
- Energy security
- Water security

“SUSTAIN THE MANY”
U 4G

Smart mine
Green U
Fuel security
Clean, safe, affordable energy
Social capital
MRP DASHBOARD: MILESTONE-DRIVEN, INTEGRATED SOCIAL LICENCE AND CAPACITY-BUILDING

Feedback/ Lessons Learned

PFS in Practice – the UPSAT
Contribution to the Mkuju River Project = IAEA Dividend

Map milestones and competencies into an activity matrix
Thank you!

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