

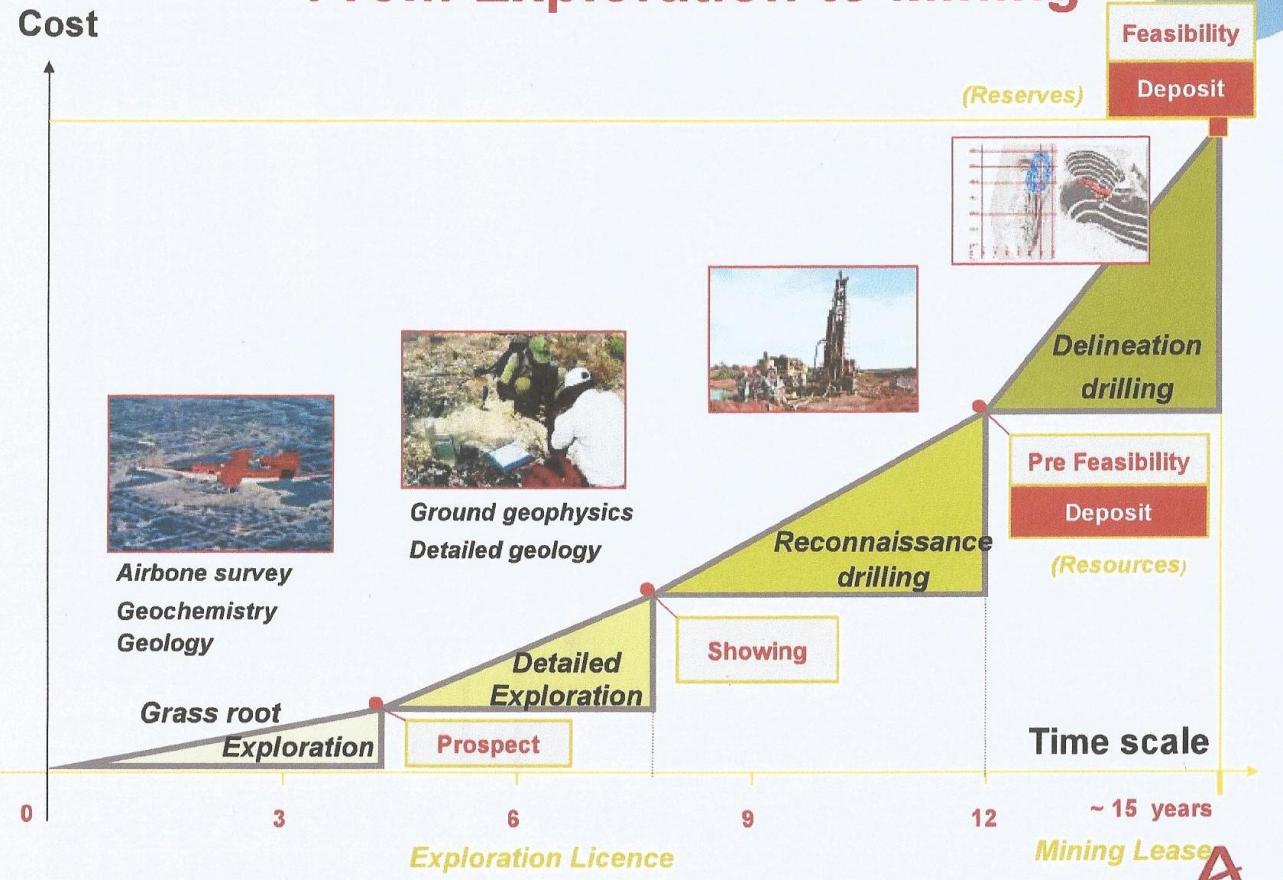


Feasibility studies

Uranium exploration, development and eventual production, form a series of progressive and logical steps. Each step is part of a progression of activities with the objective of obtaining new or additional information from which a crucial decision is to be made. This decision is either to proceed with the project or to stop it.

Evaluation of the viability of the project must be carried at the various stages of the project development. Any delays in stopping a nonviable project will normally result in unnecessary or wasteful expenditure of resources that could have been spent on other projects which offer a better potential.

From Exploration to Mining



Verifying the viability of a mining operation project

Before the exploitation of a deposit, it is necessary to **verify the technical and economic viability of the mine**. A number of questions must be addressed:

Will exploitation be profitable, given the expected market price of uranium?

Has the best method for extracting and processing the ore been chosen ? A test phase (the “pilot” phase) is always carried out to make sure this is the case.

What will the impact be on the environment and on the life of local communities during and after exploitation?

Feasibility Study

A mining feasibility study is an evaluation of a proposed mining project to determine whether the mineral resource can be mined economically.

There are three types of feasibility study used in mining, conceptual, preliminary feasibility and detailed feasibility.

- Conceptual
- Preliminary feasibility
- Detailed feasibility

Conceptual feasibility study

It is intended to indicate the general merit of a uranium source or deposit.

It is often used to prioritize several potential exploration targets so that resources can be focused on the most promising.

It must be done as soon as the exploration team has the feeling that they have discovered or intersected something which could be a minable deposit.

The pre-evaluation can also be used to reject projects that have little or no value.

Conceptual feasibility study

Conceptual feasibility studies (sometimes referred to as "scoping studies") are an initial financial appraisal of an indicated mineral resource.

Depending on the size of the project an order of magnitude study may be carried out by a single individual.

It will involve a preliminary mine plan, and are the basis for determining whether to proceed forward with an exploration program, and more detailed engineering work.

Order of magnitude studies are developed copying plans and factoring known costs from existing projects completed elsewhere and are accurate to within 40-50%.

Conceptual feasibility study

First economic study is carried out

- with minimum requirements
- by comparison with similar existing operations,
more advanced projects.

Conceptual feasibility study

The pre-evaluation process includes a preliminary selection of mining and processing methods based on knowledge of the uranium source.

This is followed by factored estimates of the project capital and operating costs, and an initial economic evaluation using realistic marketing/price data.

Conceptual feasibility study

The requirements for a pre-evaluation are

- Geology of the potential deposit
- Preliminary estimates for the tonnage and grade of the deposit
- Mining considerations
- Some ideas of the mineralogy or chemistry
- An appreciation of the demand for the product and its market price,
- An appreciation of the local infrastructure and geography.

Conceptual feasibility study

Geological information:

- size, geometry and depth of the ore zone,
- grade, its variability (heterogeneity of the deposit), radioactive disequilibrium,
- mineralogy of the ore, including those of the associated elements,
- mineralogy of the gangue materials,
- physical properties of the host and adjacent rocks (grain size, density, massive, semi-consolidated, fractured, friable, porosity, permeability, impermeability of the inclosing rocks, etc.),
- hydrogeological information,
- available exploration data that can be used as baseline information for environmental impact studies (regional and detailed radiometric, and geochemical survey data).

Conceptual feasibility study

Mining Considerations.

The factors to be considered during mine design are:

- *The morphology of the orebody.*
- *The mining method*
- *The ground conditions*
- *The water inflow which will show, if it is necessary, to dewater with external wells or to use pumps from within the mine workings.*
- *The radioactivity level calculated from the value of the grade. The ventilation of the mine will be designed accordingly.*

Conceptual feasibility study

Milling considerations:

The main factors determining the process selection are the grade, tonnage, local geology and mineralogy.

Guidelines for the selection of a process include:

- *Any earlier uranium operations in the general area or in the same geological setting should be used as a guide.*
- *Permeable, lower grade deposits sandwiched between impermeable strata may be suitable for in situ leaching.*
- *Lower grade material (less than 2 kg U/t) containing readily leached uranium might be best treated by heap leaching.*
- *Large, higher grade orebodies (more than 2 kg U/t) are probably best treated by grinding and leaching. Acid or alkaline leaching systems can be selected after initial tests and studies. In an initial assessment, it can be assumed that alkaline leaching will be preferable only if the CO₂ content of the ore is greater than 5%.*

Conceptual feasibility study

UNFC Classification

F: 3

Conceptual feasibility study

Conclusion

At the conclusion of a pre-evaluation study, it should be decided whether the project should proceed into the next phase or be aborted. Thus a go or no-go decision.

The possibility to "revisit" the project should be kept open since some of the parameters used in pre-evaluation may change with time. A change of metal price, for example, may modify cut-off grade, hence possible increase of the minable resources that might reverse the no-go situation to go. A new process or mining techniques can also modify the outcome of a pre-evaluation study.

Preliminary Feasibility

Preliminary feasibility studies are more detailed than conceptual studies.

A preliminary feasibility study is used in due diligence work, determining whether to proceed with a detailed feasibility study and as a "reality check" to determine areas within the project that require more attention.

Preliminary feasibility studies are done by factoring known unit costs and by estimating gross dimensions or quantities once conceptual or preliminary engineering and mine design has been completed.

Preliminary feasibility studies are completed by a small group of multi-disciplined technical individuals and have an accuracy within 20-30%.

Preliminary Feasibility

The prefeasibility is undertaken when a go decision has been taken at the end of the preevaluation.

At this stage of the procedure, we know that the project under study has some chance to be an economic one and that additional money can reasonably be spent in order to have a better understanding of the project and to improve the accuracy of the cost estimates and other key financial factors.

Preliminary Feasibility

Resource information

Probably one of the most important parameter in any mineral feasibility study is the existence of a minable reserve or resource.

The most valuable information is generally generated from the systematic drilling programme which objective is to define the likely ore characteristic, grade, geometry and limit of the mineralized body

Preliminary Feasibility

Mining and geotechnical information

The required mining and geotechnical data are similar to those required during the pre-evaluation stage. The quality of the information will have to be better, more representative and reliable.

Data include:

Rock mechanics

Rock density

Water content

Radioactivity

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Preliminary Feasibility

Metallurgical information

A pre-feasibility study of a potential mine requires completion of sufficient bench scale metallurgical testworks to determine a preliminary process flowsheet.

The testworks must be performed on samples that are representative of the entire orebody. The following metallurgical tests should be performed:

- *Complete analysis of ore (U, Th, V, Mo, S, CO₂, Au, major elements.)*
- *Ore sorting tests*
- *Bond work index tests*
- *Preliminary acid and alkaline leach tests*
- *Preliminary liquid-solid separation tests*
- *Preliminary IX and SX tests*
- *Effluent treatment experiments*
- *Acid generation tests on tailings and waste rock*

Preliminary Feasibility

Infrastructure

To develop meaningful project costs, the infrastructure requirements must be carefully defined. Important information that must be available includes:

- *project location*
- *information on land ownership, royalty arrangements, etc.*
- *local mapping*
- *climatic data*
- *preliminary alignments for any new roads*
- *preliminary tailings dam site selection and quantities*
- *environmental requirements of area*
- *preliminary data concerning on-site office, shop and laboratory requirements*
- *airstrip and camp requirements*

Preliminary Feasibility

Waste management and environmental consideration

Compliance with the regulations requires the expenditure of both capital and operating costs.

Effort should also be made to obtain or, if necessary, create a baseline information of the natural environment before actual mining and processing start.

A good baseline information on the natural radioactivity level of the area as well complete geochemical information will be needed at the rehabilitation stage

Preliminary Feasibility

PROJECT SCHEDULE

An estimate of the time required to complete the project should be made during the prefeasibility study. This schedule is required as part of the cash flow analysis. At the pre-feasibility stage, the analysis of the schedule will necessarily be limited. Key items on the schedule include:

- *commitment to proceed to feasibility stage*
- *completion of testwork and other studies*
- *feasibility study*
- *financing*
- *environmental permitting and licensing requirements*
- *commitment to construct*
- *mine development*
- *equipment procurement and delivery*
- *on-site construction*
- *seasonal constraints (shipping windows, winter works, rainy season, etc.)*
- *commissioning*

Preliminary Feasibility

CAPITAL AND OPERATING COSTS

Project capital cost

To evaluate the project, it must be subjected to capital cost estimating procedures. For a prefeasibility study, the development of the costs will include the following components:

- *Land acquisition cost*
- *Mine development*
- *Building*
- *Equipment supply costs*
- *Equipment installation costs*
- *Instrumentation*
- *Electrical*
- *Infrastructure costs*
- *Indirect construction costs*
- *Engineering, procurement and construction management*
- *Contingency*

Preliminary Feasibility

CAPITAL AND OPERATING COSTS

Operating cost

The main components of the pre-feasibility operating cost estimate are :

- *Operating labour costs*
- *Supply costs*
- *Power costs*
- *Infrastructure costs*
- *Administration costs*
- *Head office costs*

Preliminary Feasibility

UNFC Classification

F: 2

Feasibility studies

The final measurement of the project viability is assessed in the Feasibility Study.

If the Feasibility Study shows that the project can profitably produce uranium at the current market price, the project will probably proceed to detailed design and construction.

A detailed feasibility study will be the basis for capital appropriation, and will provide the budget figures for the project.

Detailed feasibility studies require a significant amount of formal engineering work, are accurate to within 10-15% and can cost between 0.5 -1.5% of the total estimated project cost

Detailed Feasibility

A detailed feasibility study will be the basis for capital appropriation, and will provide the budget figures for the project.

Detailed feasibility studies require a significant amount of formal engineering work, are accurate to within 10-15% and can cost between 0.5 -1.5% of the total estimated project cost.

STEPS FOR A FEASIBILITY STUDY

1. Geology and Resource
2. Mine design and Mineable Reserve
3. Metallurgy and process facility
4. Tailings disposal
5. Infrastructure development
6. Power supply
7. Water supply
8. Environmental impacts
9. Other key parameters: Support facilities, maintenance, transport cost of man and material, labor cost, site access, social impacts
10. Cost estimation: capital and operating cost
11. Financial Evaluation: The total cost and expenses are looked against the expected revenue gained from the selling of final products and by-products.
12. Sensitivity Analysis: A sensitivity analysis is then carried out to determine the impact of variation in metal price, operating cost, metal recovery, metal grade, and capital cost on the overall project NPV and IRR values.

The viability of the mine project is established by all these stages and if based on these considerations if mine is feasible, then the next stage of actual development occurs.

Ulaanbaatar August 2016

FEASIBILITY STUDY

UNFC Classification

F: 1

Feasibility studies: Data requirements

Item	Conceptual feasibility	Pre-Feasibility	Feasibility
Site/Infrastructure			
Location	Assumed	Approximately defined	Finalized
Plant area	Assumed	Approximately defined	Finalized
Map and surveys	None	If available	Detailed
Soil and foundation tests	None	None	Essential
Power supply	Assumed	Type defined	Detailed
Access roads	Assumed	Approximate length	Final alignment
Camp/townsite	Assumed	Approximate size	Finalized
Site visit by project team	Recommended	Recommended	Several
Orebody			
Reserve category	Assumed	Indicated	Proven/Probable
Bulk sampling	None	Possible	Essential
Mine			
Production rate	Assumed	Preliminary	Finalized
Mining method	Assumed	Conceptual	Finalized
Mine layout	None	Preliminary	Detailed
Equipment selection	Assumed	Preliminary	Quotations
Rock mechanics	Some recommended	Some recommended	Essential
Test mining	None	Probable	Probable

Feasibility studies: Data requirements

Item	Conceptual feasibility	Pre-Feasibility	Feasibility
Process Plant			
Plant throughput	Assumed	Preliminary	Finalized
Bench lab tests	Recommended	Initial	Detailed
Pilot plant tests	None	None	Probably
Process flowsheet	Assumed	Preliminary	Frozen
Equipment sizing	Assumed	Preliminary	Final
General arrangements	Area only	Preliminary	Final
Piping, instrumentation	None	None	P&ID and layout
Electrical	None	None	Detailed
Concrete and steel	None	None	Detailed
Tailings Environment			
Tailings design	Assumed	Assumed	Defined
Decommissioning plans	Assumed	Assumed	Defined
Effluent treatment plant	None	None	Completed
Baseline study	Assumed	Assumed	Finalized
Environmental impact statement	None	None	Complete
Permits	None	None	Submitted Applied for

Feasibility studies: Data requirements

Item	Conceptual feasibility	Pre-Feasibility	Feasibility
Capital Costs			
Estimate type	Factored	Preliminary	Very Detailed
Equipment costs	Factored	Budget quotes	Firm quotes
Installation costs	Factored	Prelim. \$/h & h	Contract \$ & h
Transport costs	Assumed	Allowance	Quotations
Civil costs	Factored	Area basis	QTO & bid
Building and structures	Factored	Volume basis	QTO & bid
Piping-in plant	Factored	% installed equip.	Partial QTO
Piping-off site	Factored	Preliminary estim	QTO & bid
Instrumentation	Factored	% installed equip.	QTO & bid
Electrical	Factored	% installed equip.	QTO & bid
Construction indirect	Factored	% direct costs	Estimated
Contingency	Factored	% direct costs	Estimated
Operating Costs			
Staff level	Assumed	Preliminary list	Detailed list
Labour rates	Assumed	Assumed	Prelim. Contract
Supplies consumed	Assumed	From lab. Data	From lab data
Supply prices	Assumed	Assumed / quotes	Firm quotes
Power consumed	Assumed	Preliminary	Detailed estimate
Power cost/unit	Assumed	Estimated	Firm quote
Marketing costs	Allowance	Assumed	Studied
Head office costs	Allowance	Allowance	Detailed est.

Feasibility studies: Data requirements

Item	Conceptual feasibility	Pre-Feasibility	Feasibility
Project Schedule	Assumed	General	Detailed
Economic Analysis			
Taxation	Assumed	Preliminary Study	Detailed
Revenue/markets	Preliminary	Firm	Firm
Discounted cash flow	Very Preliminary	Preliminary	Detailed

Feasibility Studies: Phase Parameters

Type of Study	Concept	Pre-feasibility	Feasibility
Objectives	Generate a range of options	Examine all options Select 1 option for feasibility	Optimise the selected option Make a decision on mine development
Database(s)	Limited. Mostly assumed	Bigger. Mostly assessed	Large to very large. Calculated
Resources	Inferred	Indicated	Measured
Reserves	No	Probable	Proven
Accuracy	+/- 30% to +/- 60 %	+/- 20% to +/-25%	+/-10% to +/-15%
Typical duration	2-9 months	9-13 months	12-24 months
Cost (US\$)	50k – 200k	200k – 1 000k	500k – 5 000k
Staffing	2-6	5-20	15-50

Feasibility studies

IAEA-TECDOC-885

Steps for preparing uranium production feasibility studies: A guidebook



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Thank You

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