UN Economic Commission for Europe

Expert Group on Resource Classification

DRAFT FOR PUBLIC COMMENT

Guidelines for Application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 for Uranium and Thorium Resources

1. INTRODUCTION

1.1 BACKGROUND

These Guidelines are written to facilitate the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 *incorporating* Specifications for its Application (UNFC-2009) to uranium and thorium resources [1].

As energy resources, uranium and thorium have a special place in "the current and future supply base of fossil energy and minerals"[1], which is the focus of UNFC-2009. For the foreseeable future, both uranium and thorium, and uranium in the immediate future, will make a critical contribution to energy security and low carbon energy production. These Guidelines will assist all those responsible for finding, classifying, quantifying, financing, permitting, mining, and processing these minerals such that they are fit to enter the nuclear fuel cycle.

It will enable them to align the various resource classification systems currently in use for uranium and thorium resource management and reporting, such as the Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA) and International Atomic Energy Agency (IAEA) "Red Book", the Template of the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) and various national systems, in a coherent and consistent manner. Doing this significantly aids the generation, analysis and tracking of "accurate and consistent estimates of […] reserves and resources"[2] of these critical materials. It will also assist in the wider objective of meeting the policy, regulatory and governance objectives, including stakeholder engagement, for the peaceful uses of these materials as set out by IAEA.

1.2 WHY UNFC-2009?

UNFC-2009 is designed to simplify and harmonize a range of resource classification, progression and reporting tools currently in use worldwide, notably for commercial-scale projects. It does so by classifying the range of estimations from pre-competitive regional, order of magnitude and scoping studies all the way through to individual projects at varying levels and stages of economic and operational readiness. Hence, UNFC-2009 can be used by both governments and the private sector. UNFC-2009 classifies resources according to:

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[1] See the Foreword to UNFC-2009
[2] See the Foreword to UNFC-2009

(a) three primary qualitative criteria: their current level of socio-economic viability (E), technical feasibility (F) and geological confidence or uncertainty (G)[3]

(b) their quantitative status according to these criteria as measured by independently verifiable means on a four point scale, of which 3 or 4 is the furthest from and 1 the closest to commercial scale production.

In UNFC-2009 a given project's status is expressed by means of a combined alpha-numeric rating. Hence a profitable working project will be classed E1, F1, G1, 2, 3. A project which satisfies technical feasibility and geological criteria for production but which is not viable economically will be classed E2, F1, G1, 2, 3.

UNFC-2009 is the first such system developed to be applicable both to primary materials, such as mineral resources and reserves, and fossil fuels, notably coal, oil and gas, but also, potentially, renewables, such as hydro-electricity and geothermal and secondary resources, such as tailings and residues. It is able to encompass a wide range of target resource classification procedures, starting from small, geographically focused projects and extending to current state determination of a nation's geological endowment. The outcome is a universal resource management tool, suited to corporate decision-making needs in national and international resource inventories and planning, resource progression and related financial reporting procedures and standards.

Where required, a series of "bridging" documents have been constructed to validate the proposition of universal applicability, as for example, to map coherently to the widely used CRIRSCO Template for minerals and the equivalent resource progression tools for oil and gas. UNFC-2009 is particularly well-suited to reporting projects developed under a "comprehensive extraction" methodology where multiple resources are included in a single, integrated project design and delivery strategy.

1.3 UNFC-2009 AND EXISTING SYSTEMS FOR URANIUM AND THORIUM REPORTING

UNFC-2009 has its origins in the work of the United Nations Economic Commission for Europe (UNECE) towards standardization of resource reporting. The first iteration was published in 1947 for coal, its scope extended to solid fuels and minerals in 1992, which was updated in 1997, which was taken into law in a number of countries in the wake of publication. The scope was extended further to include uranium and oil and gas in 2004. The system was further simplified for multi-commodity application in the most recent iteration, UNFC-2009 [1].

Historically, uranium and thorium deposits worldwide have been most commonly classified and reported according to different mineral resource reporting schemes:

(1) Inter-Governmental: A system developed by the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (NEA) and the International Atomic Energy Agency (IAEA), known as the "Red Book". The NEA-IAEA Red Book [2] consists of a biaxial classification that considers the degree of geological knowledge and the production costs of uranium by cost band. The system was developed for reporting individual, regional, national and international uranium resource estimates primarily at a governmental rather than commercial level. The Red Book has also

[3] For the definitions of these and other key terms see UNFC-2009 Table 1

been used to classify thorium resources.[4] In the context of how such a resource specific reporting tool can also be accommodated within UNFC-2009, the Bridging Document on Nuclear Fuel Resources [ECE/ENERGY/2014/6] provides specifications for reporting uranium and thorium resources and transfer of results between UNFC-2009 and the NEA/IAEA schemes [3].

(2) National: Some countries such as Australia, China, Ukraine and the United States of America, have developed their own classification systems for mineral resources, including uranium and thorium. Mapping of these national systems to UNFC-2009 is provided in this document.

(3) Commercial: A system developed and maintained by the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) Template [4]; the CRIRSCO system is internationally recognized and widely used to classify *in situ* commodity resources of all mineral deposit types. Reports of Exploration Results, Mineral Resources and Mineral Reserves for uranium and thorium deposits prepared under the CRIRSCO family of aligned codes and standards, can be reported equally well using the UNFC-2009 Numerical Codes. How to map data across from CRIRSCO to UNFC-2009 is explained in the "Bridging Document" between the CRIRSCO Template and UNFC-2009, found in Annex III of UNFC-2009 (release 2013).

1.4 A THREE-TIER APPLICATION PROCEDURE

UNFC-2009 is a voluntary system. But where a member state or an operator chooses to use it, the use is expected to comply with its three-tier application procedure which, in common with United Nations documentation of this kind, consists of the following:

(i) Principles (or the high-level framework and governing assumptions from which UNFC-2009 derives);
(ii) Specifications (rules or "shall be" and "should be" statements) which must be followed by governments or enterprises using the tool to report; and
(iii) Guidelines (non-mandatory guidance or "may be" statements) which assists those using UNFC-2009 in optimizing its value both as a management tool internally and as a stakeholder engagement and transparent governance tool externally.

This document belongs to tier iii, Guidelines and must be used in conjunction with the most recent release of UNFC-2009 principles (release 2013), which incorporates the specifications for use of UNFC-2009. As a living document it will be subject to ongoing review and update. Users of these Guidelines are invited to share their experience of using the document with the Expert Group on Resource Classification (the Expert Group).

1.5 SCOPE AND STRUCTURE

The scope and structure of the Guidelines are as follows:

[4] In the past, the NEA/IAEA classification system reported thorium resources in the same way as it reports uranium. Since there is no current major market for thorium, but it is being or could be produced with other, commercially saleable commodities (such as rare earth elements), thorium thus can be reported under UNFC-2009.

- An overview of global nuclear fuel resources and production (uranium and thorium), including current sources of information;
- A description of UNFC-2009 principles and specifications provided through the Bridging Document for Nuclear Fuel Resources to be considered in classification and reporting;
- Mapping of the NEA-IAEA scheme to CRIRSCO and other mineral resource classification systems, the outcome of which is that these existing systems are designated by UNFC-2009 as “aligned systems”;
- Issues to be considered in the application of UNFC-2009 to nuclear fuel resources; and
- Descriptions of factors involved in comprehensive extraction projects for nuclear fuels.

Table 1.
Key terms used in UNFC-2009 and their definitions.

Term	Definition
Aligned System	A classification system that has been aligned with UNFC-2009 as demonstrated by the existence of a Bridging Document that has been endorsed by the Expert Group on Resource Classification.
Bridging Document	A document that explains the relationship between UNFC-2009 and another classification system, including instructions and guidelines on how to classify estimates generated by application of that system using the UNFC-2009 Numerical Codes.
Category	Primary basis for classification using each of the three fundamental Criteria of economic and social viability (related Categories being E1, E2, and E3), field project status and feasibility (related Categories being F1, F2, F3 and F4), and geological knowledge (related Categories being G1, G2, G3 and G4). Definitions of Categories are provided in Annex I to UNFC-2009 [1].
Class(es)	Primary level of resource classification resulting from the combination of a Category from each of the three Criteria (axes).
Complementary Texts	Additional texts to provide mandatory requirements (i.e. Specifications) and further guidance regarding the application of UNFC-2009.
CRIRSCO Template	The CRIRSCO Template of 2013 is the system developed by the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) for solid minerals and, for the purposes of the Specifications Document, includes the reporting codes and standards that are aligned with it.
Criteria	UNFC-2009 utilizes three fundamental Criteria for reserve and resource classification: economic and social viability; field project status and feasibility; and, geological knowledge. These Criteria are each subdivided into Categories and Sub-categories, which are then combined in the form of Classes or Sub-classes.
Evaluator	Person, or persons, performing resource estimation and/or classification.
Exploration Project	A Project that is associated with one or more Potential Deposits (as defined below).

Generic Specifications	Specifications (as documented in the Specifications Document) that apply to the classification of quantities of any commodity using UNFC-2009.
Known Deposit	A deposit that has been demonstrated to exist by direct evidence. More detailed specifications can be found in relevant commodity specific Aligned Systems.
Mapping Document	The output of a comparison between another resource classification system and UNFC-2009, or between that system and existing Aligned Systems, which highlights the similarities and differences between the systems. A Mapping Document can provide the basis for assessing the potential for the other system to become an Aligned System through the development of a Bridging Document.
Numerical Code	Numerical designation of each Class or Sub-class of resource quantity as defined by UNFC-2009. Numerical Codes are always quoted in the same sequence (i.e. E;F;G).
Potential Deposit	A deposit that has not yet been demonstrated to exist by direct evidence (e.g. drilling and/or sampling), but is assessed as potentially existing based primarily on indirect evidence (e.g. surface or airborne geophysical measurements). More detailed specifications can be found in relevant commodity-specific Aligned Systems.
Project	A Project is a defined development or mining operation which provides the basis for economic evaluation and decision-making. In the early stages of evaluation, including exploration, the Project might be defined only in conceptual terms, whereas more mature Projects will be defined in significant detail. Where no development or mining operation can currently be defined for all or part of a deposit, based on existing technology or technology currently under development, all quantities associated with that deposit (or part thereof) are classified in Category F4.
Specifications	Additional details (mandatory rules) as to how a resource classification system is to be applied, supplementing the framework definitions of that system. Generic Specifications provided for UNFC-2009 in this Specifications Document ensure clarity and comparability and are complementary to the commodity-specific requirements included in Aligned Systems, as set out in the relevant Bridging Document.
Specifications Document	Specifications for the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009).
Sub-categories	Optional subdivision of Categories for each of the fundamental Criteria of economic and social viability, field project status and feasibility, and geological knowledge. Definitions of Sub-categories are provided in Annex II to UNFC-2009.
Sub-classes	Optional subdivision of resource classification based on project maturity principles resulting from the combination of Subcategories. Project maturity Sub-classes are discussed further in Annex V of the Specifications Document.

2. OVERVIEW OF NUCLEAR FUEL RESOURCES AND PRODUCTION

2.1 BRIEF SUMMARY OF NUCLEAR FUEL RESOURCES AND PRODUCTION

2.1.1 Nuclear energy

Despite recent declines in electricity demand in some developed countries, overall demand is expected to continue to grow in the next several decades to meet the needs of a growing population, particularly in achieving energy security and sustainable development goals [5]. Since nuclear power plant operation produces competitively priced, baseload electricity that is essentially free of greenhouse gas emissions, and the deployment of nuclear power enhances security of energy supply, it is projected to remain an important component of energy supply.

Nuclear power presently contributes 11 per cent of world electricity requirements. At present (2015), 435 nuclear reactors provide 381 GWe to thirty counties. Further, 65 reactors are under construction with 6.3 GWe installed capacity (http://www.iaea.org/pris/). Installed nuclear capacity is projected to increase from about 375 GWe net at the beginning of 2015 to between about 400 GWe net (low case) and 678 GWe net (high case) by the year 2035. The low case represents growth of about 7% from 2015 nuclear generating capacity, while the high case represents an increase of about 82%. By 2025, low and high case scenario projections estimate increases of 12% and 51% respectively, indicating that significant expansion activities are already underway in several countries [2].

2.1.2 Uranium

Uranium is an element that is widely distributed within the earth's crust. Its principal use is as the primary fuel for nuclear power reactors. Naturally occurring uranium is composed of about 99.3% ^{238}U, 0.7% ^{235}U and traces of ^{234}U. In order to utilize the uranium that is recovered from the ground, it has to be extracted from the ore and converted into a form that can be used in the nuclear fuel cycle.

A deposit of uranium discovered by various exploration techniques is evaluated to determine the amounts of uranium materials that are extractable at specified costs. Uranium resources are the amounts of ore that are estimated to be recoverable at stated costs.

Uranium ore can be extracted through conventional mining by open cut and underground methods. In some cases uranium is recovered as a by-product, for example of copper mining. Mined uranium ores normally are processed by grinding the ore materials to a uniform particle size and then treating the ore to extract the uranium by chemical leaching. The milling process commonly yields dry powder-form material consisting of natural uranium, "yellowcake," which is sold on the uranium market as U_3O_8.

Heap leaching and in-place leaching (also called stope or block leaching) are the other methods used in uranium extraction. Stope/block leaching involves the extraction of uranium from broken ore without removing it from an underground mine, whereas heap leaching involves the use of a leaching facility on the surface once the ore has been mined. Small amounts of uranium are also recovered from mine water treatment and environmental restoration activities.

Over the past two decades, in-situ leach (ISL) mining of uranium, which uses either acid or alkaline solutions to extract the uranium directly from the deposit, has become increasingly important. The uranium dissolving solutions are injected into and recovered from the ore-bearing zone using a system of wells. ISL technology is currently being used to extract uranium only from sandstone deposits. In recent years, mining by ISL has become the dominant method of uranium production.

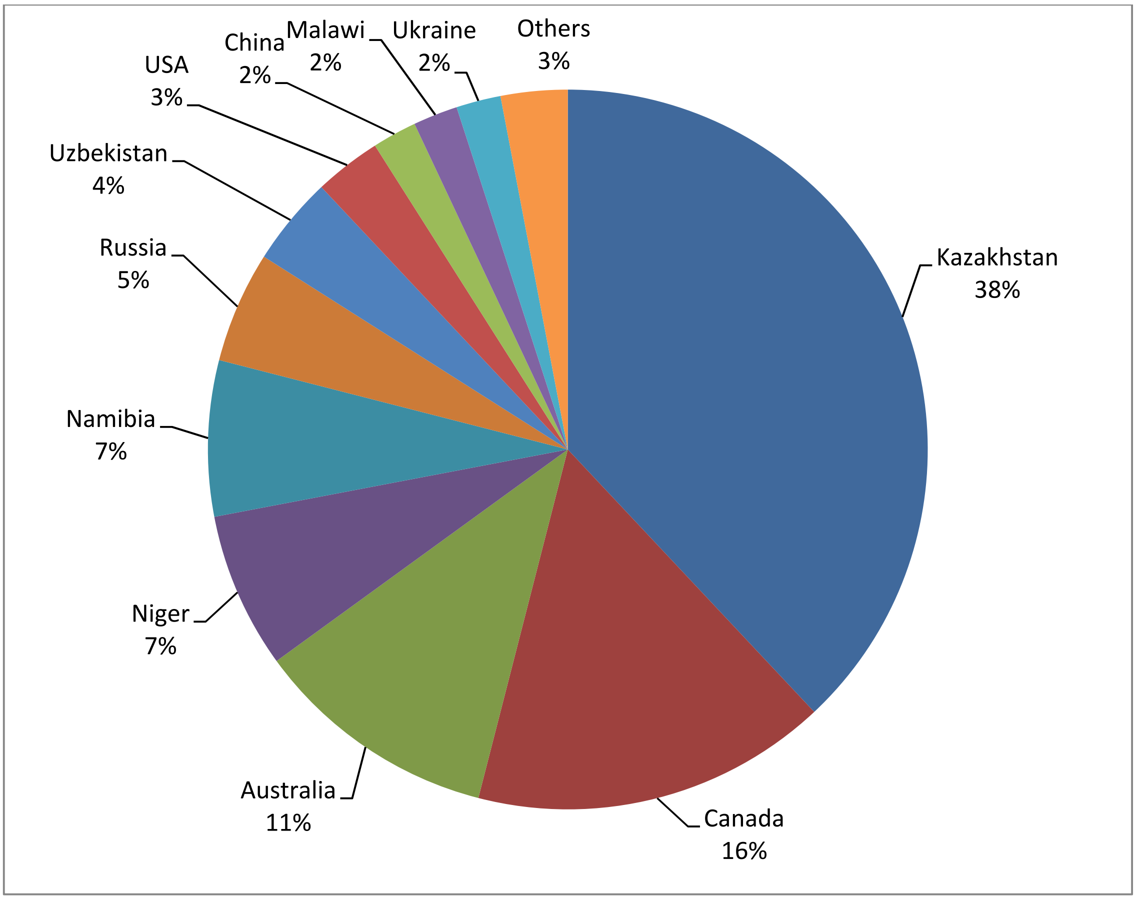
As shown in Table 2, ISL production currently dominates uranium production, largely because of the rapid growth of production in Kazakhstan along with other ISL projects in Australia, China, the Russian Federation, the United States and Uzbekistan. World uranium production by ISL reached 44.9% of total production in 2012, which is approximately 58,816 tU.

Table 2
Percentage distribution of world uranium production by method

Production method	Production in 2013 (%)
ISL	44.9
Underground mining	26.2
Open-pit mining	19.9
Co-product/by-product	6.6
Heap leaching	1.7
Other	0.7
Total	100

In 2012, uranium was produced in 21 different countries [2]. Of these, Germany, Hungary, and France produced small amounts of uranium only as the result of remediation of mines. In 2012, uranium production worldwide was 58,816 tonnes U. Kazakhstan is the world's largest uranium producer with 22,451 tU produced in 2013, followed by Canada with 9,331 tonnes and Australia with 6,350 tonnes in second and third positions, respectively (Figure 1).

Figure 1
World uranium production in 2013

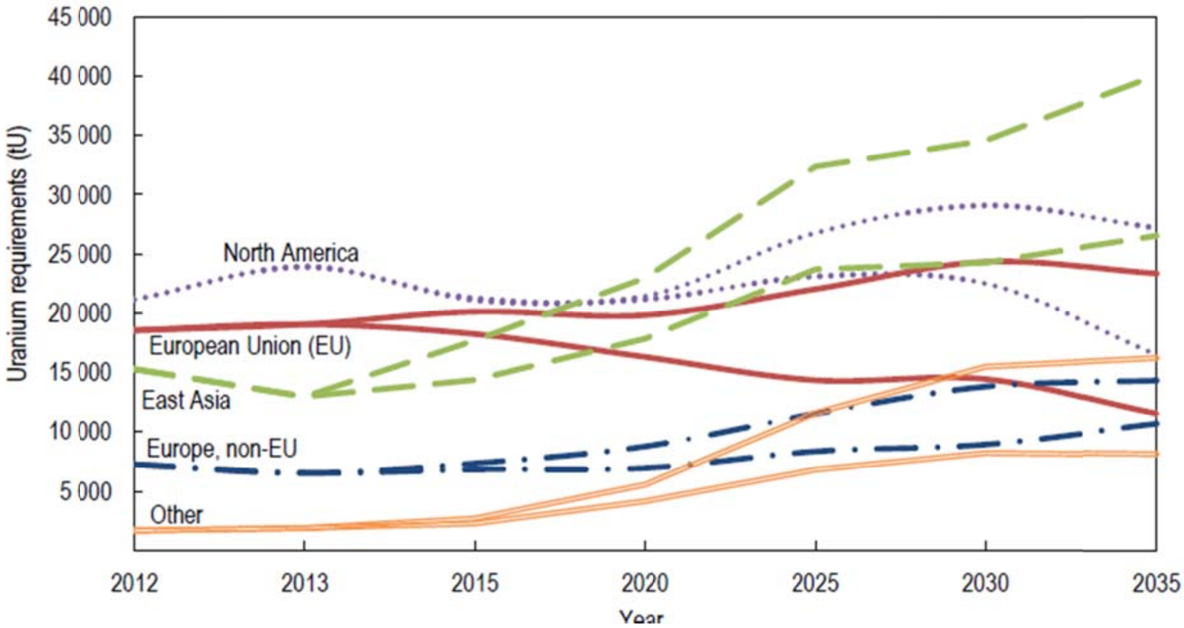


The top five producing countries in 2012 (Kazakhstan, Canada, Australia, Niger and Namibia) accounted for 79% of world production and ten countries, Kazakhstan (36%), Canada

(15%), Australia (12%), Niger (8%), Namibia (8%), the Russian Federation (5%), Uzbekistan (4%), the United States (3%), China (2%) and Malawi (2%) and Ukraine (2%) accounted for 97% of global mine production.

World reactor-related uranium requirements by the year 2035 are projected to increase to a total of between 72,200 tU/yr in the low case and 121,100 tU/yr in the high case, representing increases of about 20% and 105%, respectively, compared with 2013 requirements (Figure 2).

Figure 2
Projected annual reactor-related uranium requirements to 2035 (low and high projections)

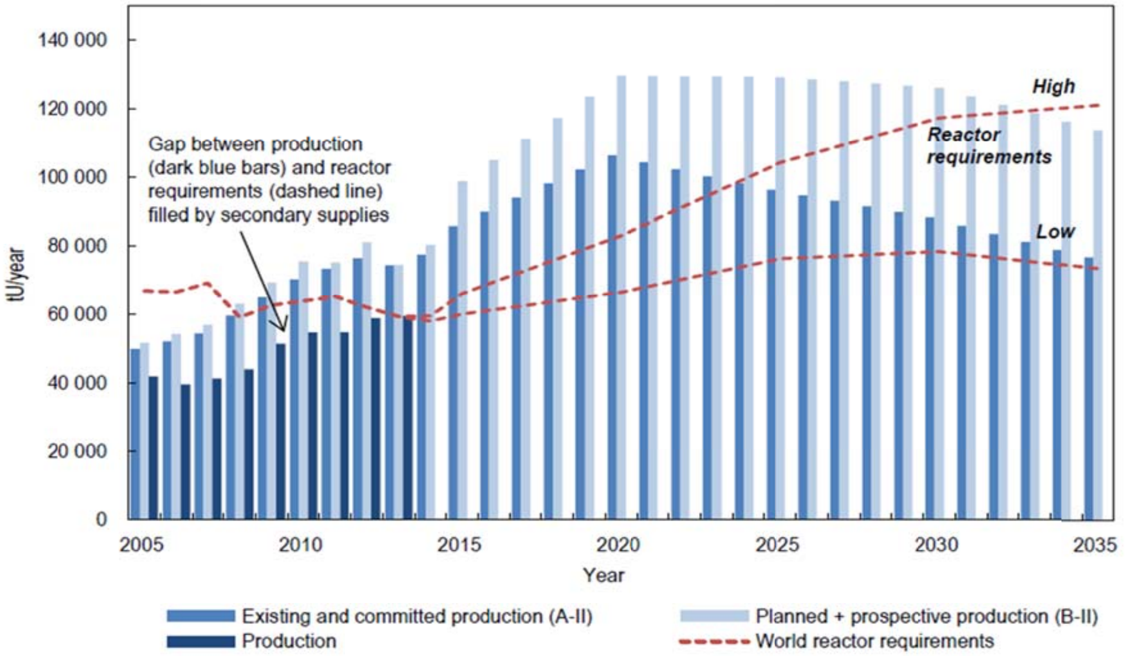


Primary production of uranium over the last few years has satisfied as much as 95% of world requirements. The remainder has been derived from secondary sources, which include stockpiles of natural and enriched uranium, blending down weapons-grade uranium, reprocessing of spent fuel, and the re-enrichment of depleted uranium tails.

As reactor requirements are projected to rise through 2035, an expansion of production capability is also projected to occur (Figure 3). As of 1 January 2013, these expansion plans, if successfully implemented, would cover high case demand requirements throughout much of this period, even without secondary supplies that met anywhere from 5% to 50% of annual requirements between 2000 and 2012.

Some national and international authorities (Australia, the United States and the Euratom Supply Agency (ESA)), publish price indicators to illustrate uranium price trends for both long-term and short term (market spot price) contract arrangements. Beginning in 2002, uranium prices began to increase, eventually rising to levels not seen since the 1980s, then rising more rapidly through 2005 and 2006 with spot prices reaching a peak through 2007 and 2008, then falling off rapidly, recovering somewhat in 2011, and declining in 2012 (Figure 4).

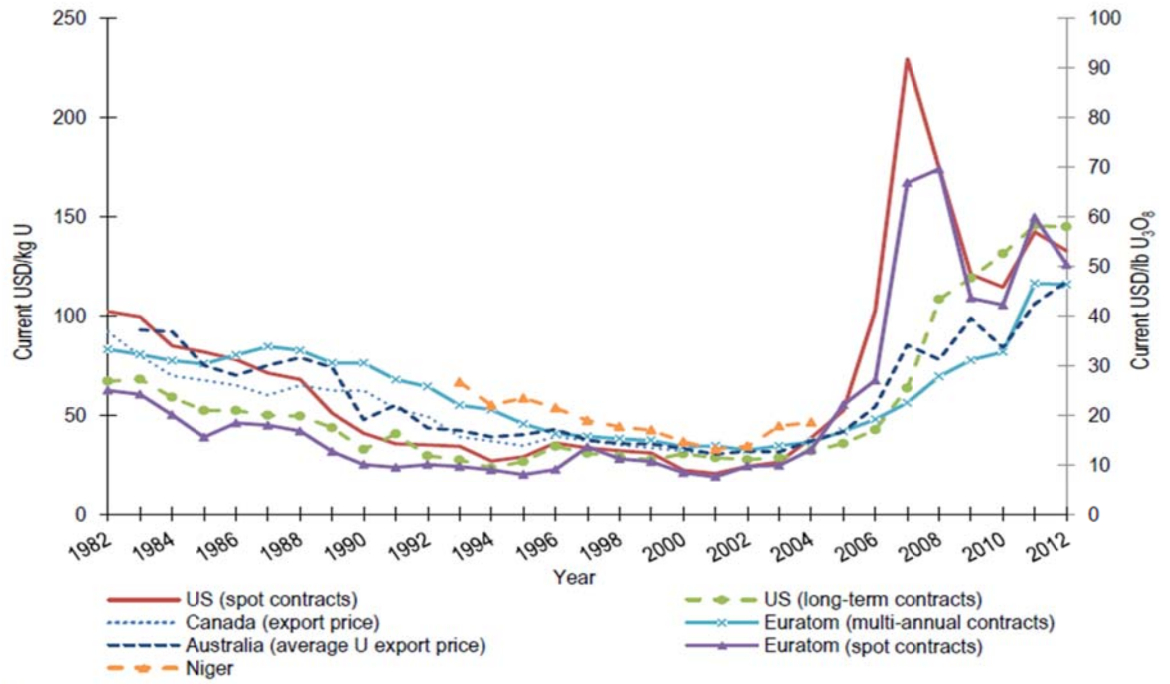
Figure 3
Projected annual world uranium production capability to 2035 compared with projected world reactor requirements



Source: Tables 1.26 and 2.4.

* Includes all existing, committed, planned and prospective production centres supported by RAR and inferred resources recoverable at a cost of <USD 130/kgU.

Figure 4
Uranium price trends



Source: Australia, Canada, Euratom Supply Agency, Niger, and the United States.

1. Euratom prices refer to deliveries during that year under multi-annual contracts.
2. Beginning in 2002, Natural Resources Canada (NRCan) suspended publication of export price pending policy review.

2.1.3 Thorium

Thorium, abundant and widely dispersed, could also be used as a nuclear fuel resource. Most of the largest identified thorium resources were discovered during the exploration of carbonatites and alkaline igneous bodies for uranium, rare earth elements, niobium, phosphate, and titanium. Today, thorium is recovered mainly from the mineral monazite as a by-product of processing heavy-mineral sand deposits for titanium-, zirconium-, or tin-bearing minerals.

The primary source of the world's thorium is the rare-earth and thorium phosphate mineral, monazite. Monazite itself is sometimes recovered as a by-product of processing heavy-mineral sands for titanium and zirconium minerals.

In 2011, OECD/NEA noted an interest in thorium in several countries to use thorium as a nuclear fuel over the last few decades [6]. Basic research and development, as well as operation of reactors with thorium fuel, has been conducted in Canada, Germany, India, Japan, the Russian Federation, the United Kingdom and the United States.

2.2 INFORMATION RESOURCES

2.2.1 NEA/IAEA "Red Book"

Since 1965, with the cooperation of member countries and states, the Organization for Economic Co-Operation and Development (OECD) Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA) has jointly prepared periodic updates (most recently every two years) on world uranium resources, production and demand [2]. These volumes have been informally referred to as the "Red Book". This publication provides a comprehensive overview of current uranium supply and demand, as well as projections into the future (generally for two decades or more). In addition to a global analysis, the report contains detailed reviews of uranium-related developments in Member countries over the two-year reporting period. Each edition of the Red Book contains estimates of uranium resources divided into several categories of assurance of existence and economic attractiveness, along with projections of production capability, installed nuclear capacity and related reactor requirements. Annual statistical data are included on exploration expenditures, uranium production, employment, and levels of uranium stocks.

The 'Red Book' is based on official submissions by NEA and IAEA Member States, as well as secretarial (NEA and IAEA) estimates. Individual country reports provide updated information on recent developments in uranium exploration and development, environmental activities and relevant national uranium policies. The report has become widely recognised in the international nuclear community as a primary reference document for world uranium supply and demand.

In the Red Book, uranium resources are classified according to geological certainty and costs of production. The NEA/IAEA classification scheme as used in the Red Book is described in detail in Chapter 4 of this document. The NEA/IAEA scheme is used to combine resource estimates from a number of different countries into harmonised global figures.

Additionally, IAEA publishes projections of uranium supply over long-term intervals (decades). The analysis is based on current knowledge of uranium resources and production facilities [7].

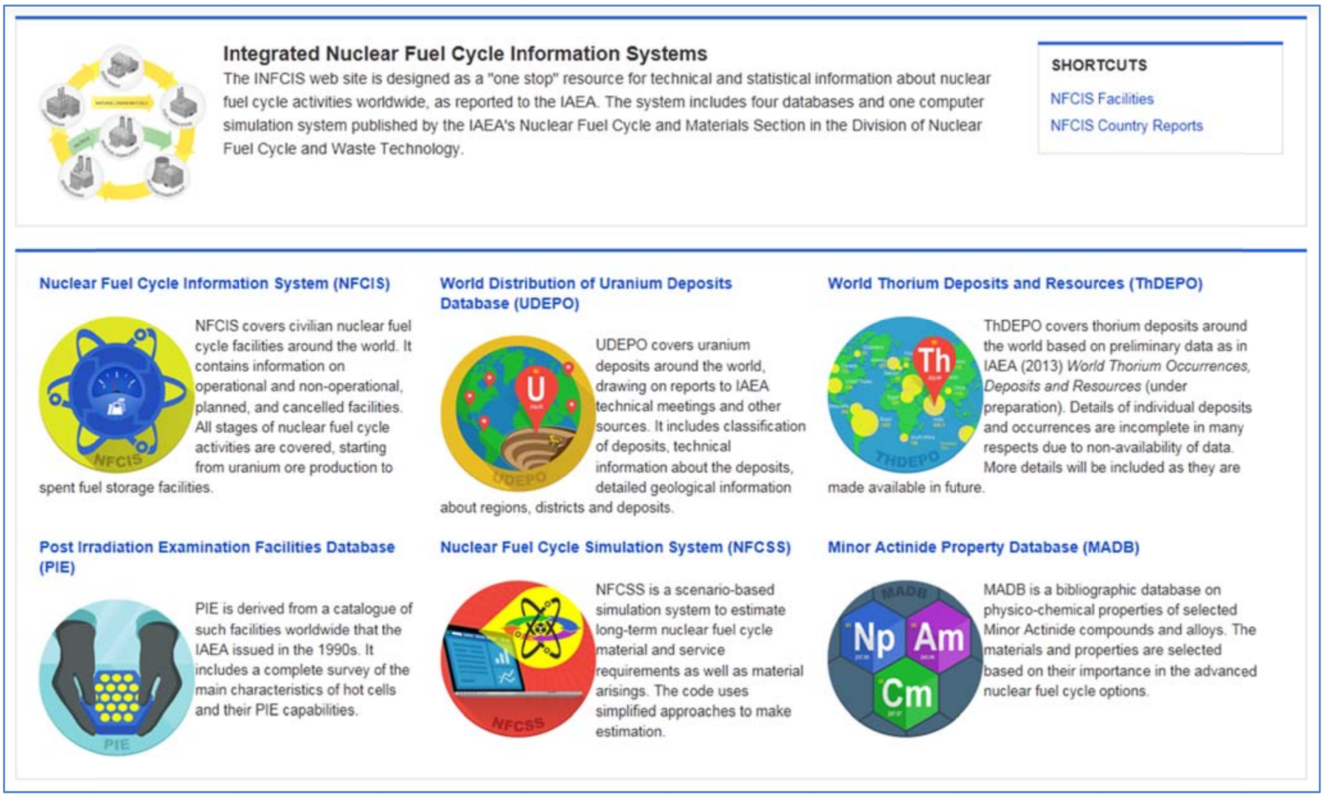
2.2.2 UDEPO and ThDEPO

World Distribution of Uranium Deposits (UDEPO) is a database of uranium deposits, maintained by IAEA, which includes all geographic regions of the world [8]. The database contains information on the classification, geological characteristics, geographical distribution and known and inferred resources in uranium deposits. Currently (2014), the database contains over 1,500 deposit records from more than 70 countries. The long-term intent is that the UDEPO database will be updated through periodic questionnaires to IAEA Member States and regularly held consultancy meetings.

ThDEPO is a database of world thorium deposits and resources that is also maintained by the IAEA [9]. As noted by the IAEA [9]: "While uranium is the main-stay of the present generation of nuclear power plants, with the anticipated steep growth in nuclear energy in the future, it will be necessary to introduce thorium too as a fuel."

UDEPO and ThDEPO are part of IAEA's Integrated Nuclear Fuel Cycle Information Systems (iNFCIS) and can be accessed online at http://infcis.iaea.org (Figure 5).

Figure 5
Screen shot of Integrated Nuclear Fuel Cycle Information Systems



2.2.3 National Sources of Information

Many countries regularly compile estimates of their domestic mineral resources, including uranium (and thorium, rarely) where appropriate. Countries can employ different resource classification schemes to categorize this data, thereby complicating the comparison of resource estimates internationally.

2.2.3.1 United States

Since 1980, mineral resource classification in the United States has been influenced by a resource classification system published that year by the U.S. Bureau of Mines and the U.S. Geological Survey [10]. This document is not a reporting standard (for example for stock exchange purposes), but rather laid the groundwork for defining the terms "resource" and "reserves" in the context of *in situ* mineral and energy deposits; this report further defined several sub-classes within the broad categories of resources and reserves. Subsequent assessments of uranium and thorium resources by the U.S. Bureau of Mines and the U.S. Geological Survey used the terminology and guidelines described in the 1980 classification scheme [10].

The U.S. Energy Information Administration (EIA) periodically reports estimates of uranium reserves in active properties in the United States [11].

The United States also published a recent analysis of world uranium supply and demand [12].

2.2.3.2 Australia

Australia considers its mineral resources as an important component of its wealth. Therefore, a long term perspective of what is likely to be available for mining is considered as a prerequisite for formulating sound policies on resources and land-access.

The Australian national resource stocks are quantified by Geoscience Australia in the annual online publication *Australia's Identified Mineral Resources*, available at http://www.ga.gov.au/scientific-topics/minerals/mineral-resources/aimr. This report provides a comprehensive assessment of national mineral resources, including uranium and thorium resources in the country. The relationships between Australia's national mineral resource classification system and other systems are described by Lambert and others [13].

2.2.3.3 Canada

Minerals and metals are considered fundamental to the Canadian economy, contributing to the country's economic well-being at various points along the value chain, including extraction, processing, and manufacturing, which are key inputs to a wide range of consumer products. Natural Resources Canada periodically produces comprehensive reviews of developments in the minerals and metals industries and publishes the results as commodity reviews. The latest commodity review of uranium resources in Canada was released in 2011 [14].

3. UNITED NATIONS FRAMEWORK CLASSIFICATION 2009

UNFC-2009 is a project-based system that applies to all fossil energy and mineral reserves and resources. It has been designed to meet, to the extent possible, the needs of applications pertaining to energy and mineral studies, resource management functions, corporate business process and financial reporting standards [1].

UNFC-2009 is the only international system that is applicable equally to solid minerals and fluids such as petroleum. Since about half of current world production of uranium is in the form of solutions from in-situ leach (ISL) extraction, it is particularly advantageous to report uranium qualities in this system. Currently UNFC-2009 is being expanded to include renewable energy systems and injection projects, which once operational, will make UNFC-2009 as the only resource classification system in the world that can be applied to all energy resources.

UNFC-2009 applies to quantities of materials located on or below the earth's surface. The classification framework considers quantities of solids or fluids as 'projects', and classifies them in order of its readiness to produce a commodity. Usage of often confusing terms such as 'reserves' and 'resources' are avoided and language independent numerical codes are used to designate different projects.

UNFC-2009 can be divided into:

1. Principles — the classification framework
2. Specifications — the application rules
3. Guidelines — non-mandatory guidance for application

3.1 UNFC-2009 principles

3.1.1 Categories and sub-categories

The fundamental criteria used to classify projects are:

- E: Economic and social viability
- F: Field project status and feasibility
- G: Geological knowledge

There are three E categories and four each for F and G categories, which are all designated by numerical codes. Each of these 11 categories has a definition and supporting explanation.

Categories are the building blocks of the system. The E, F and G axis categories create the three dimensional UNFC-2009 system (Figure 6). Alternatively, a simplified two-dimensional version can also be used (Figure 7).

Categories are sub-divided into sub-categories. There are five E sub-categories and six F sub-categories. There are no sub-categories for E2, F3 and F4 and all of the G categories in the main framework.

Additional F and G sub-categories are provided through the Generic Specification, which can be used in certain situations.

Figure 6
UNFC-2009 Categories

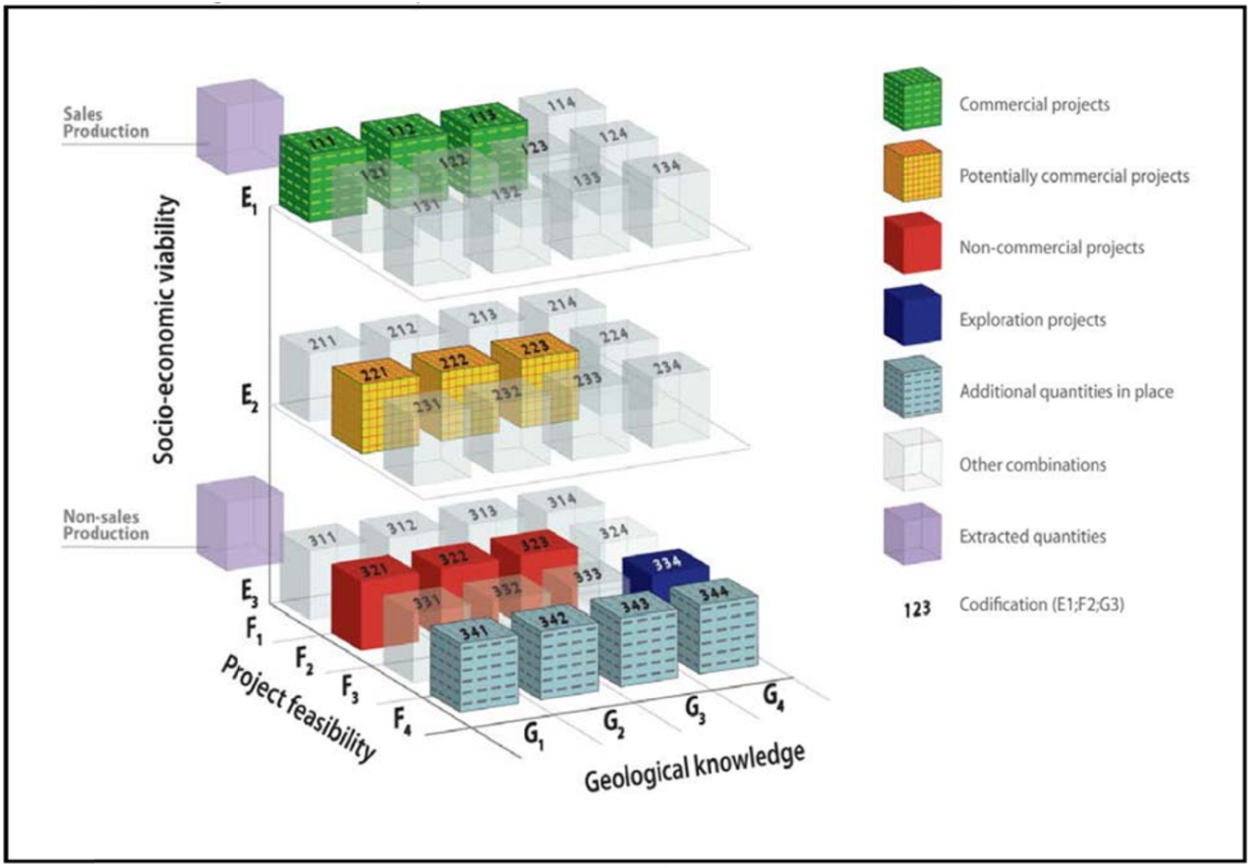


Figure 7
Abbreviated version of UNFC-2009

Total Commodity Initially in Place					
	Extracted	Sales Production			
		Non-Sales Production[a]			
		Class	Categories		
			E	F	G[b]
	Future recovery by commercial development projects or mining operations	Commercial Projects[c]	1	1	1, 2, 3
	Potential future recovery by contingent development projects or mining operations	Potentially Commercial Projects[d]	2[e]	2	1, 2, 3
		Non-Commercial Projects[f]	3	2	1, 2, 3
	Additional quantities in place associated with known deposits[g]		3	4	1, 2, 3
	Potential future recovery by successful exploration activities	Exploration Projects	3	3	4
	Additional quantities in place associated with potential deposits[g]		3	4	4

[a] Future non-sales production is categorized as E3.1. Resources that will be extracted but not sold can exist for all classes of recoverable quantities. They are not shown in the figure.

[b] G categories may be used discretely, particularly when classifying solid minerals and quantities in place, or in cumulative form (e.g. G1+G2), as is commonly applied for recoverable fluids.

[c] Commercial Projects have been confirmed to be technically, economically and socially feasible. Recoverable quantities associated with Commercial Projects are defined in many classification systems as Reserves, but there are some material differences between the specific definitions that are applied within the extractive industries and hence the term is not used here.

[d] Potentially Commercial Projects are expected to be developed in the foreseeable future, in that the quantities are assessed to have reasonable prospects for eventual economic extraction, but technical and/or commercial feasibility has not yet been confirmed. Consequently, not all Potentially Commercial Projects may be developed.

[e] Potentially Commercial Projects may satisfy the requirements for E1.

[f] Non-Commercial Projects include those that are at an early stage of evaluation in addition to those that are considered unlikely to become commercially feasible developments within the foreseeable future.

[g] A portion of these quantities may become recoverable in the future as technological developments occur. Depending on the commodity type and recovery technology (if any) that has already been applied, some or all of these quantities may never be recovered due to physical and/or chemical constraints.

3.1.2 Classes and sub-classes

A unique combination of each of the three criteria will define a class. Numerical codes (in Arabic numerals) are quoted in E;F;G sequence to designate a class. Letters E, F, G can be dropped because they are always quoted in the same sequence.

Sub-categories can also be used to designate classes with more accuracy or designate sub-classes to provide additional level of granularity. UNFC-2009 classes and sub-classes defined by sub-categories are shown in Figure 8.

Figure 8
UNFC-2009 Classes and sub-classes.

<table>
<tr><th colspan="7">UNFC Classes Defined by Categories and Sub-categories</th></tr>
<tr><td rowspan="14">Total Commodity Initially in Place</td><td rowspan="2">Extracted</td><td colspan="5">Sales Production</td></tr>
<tr><td colspan="5">Non-sales Production</td></tr>
<tr><td colspan="2" rowspan="2">Class</td><td rowspan="2">Sub-class</td><td colspan="3">Categories</td></tr>
<tr><td>E</td><td>F</td><td>G</td></tr>
<tr><td rowspan="8">Known Deposit</td><td rowspan="3">Commercial Projects</td><td>On Production</td><td>1</td><td>1.1</td><td>1, 2, 3</td></tr>
<tr><td>Approved for Development</td><td>1</td><td>1.2</td><td>1, 2, 3</td></tr>
<tr><td>Justified for Development</td><td>1</td><td>1.3</td><td>1, 2, 3</td></tr>
<tr><td rowspan="2">Potentially Commercial Projects</td><td>Development Pending</td><td>2[b]</td><td>2.1</td><td>1, 2, 3</td></tr>
<tr><td>Development On Hold</td><td>2</td><td>2.2</td><td>1, 2, 3</td></tr>
<tr><td rowspan="2">Non-Commercial Projects</td><td>Development Unclarified</td><td>3.2</td><td>2.2</td><td>1, 2, 3</td></tr>
<tr><td>Development Not Viable</td><td>3.3</td><td>2.3</td><td>1, 2, 3</td></tr>
<tr><td colspan="2">Additional Quantities in Place</td><td>3.3</td><td>4</td><td>1, 2, 3</td></tr>
<tr><td rowspan="2">Potential Deposit</td><td>Exploration Projects</td><td>[No sub-classes defined][c]</td><td>3.2</td><td>3</td><td>4</td></tr>
<tr><td colspan="2">Additional Quantities in Place</td><td>3.3</td><td>4</td><td>4</td></tr>
</table>

[a] Refer also to the notes for Figure 2 of [1].

[b] Development Pending Projects may satisfy the requirements for E1.

[c] Generic sub-classes have not been defined here, but it is noted that in petroleum the terms Prospect, Lead and Play are commonly adopted.

3.2 Specifications

Specifications are application rules required for consistent application of UNFC-2009. Generic specifications apply for all commodities, such as petroleum, solid minerals or uranium. Individual commodities will have commodity-specific specifications. Commodity-specific specifications for solid minerals are provided through the CRIRSCO Template. Similar commodity-specific specifications for petroleum are provided by the Petroleum Resources Management System of 2007 (PRMS) which has been endorsed by the Society of Petroleum Engineers (SPE), the World Petroleum Council (WPC), the American Association of Petroleum Geologists (AAPG), the Society of Petroleum Evaluation Engineers (SPEE) and the Society of Exploration Geophysicists (SEG). The relationship between UNFC-2009 and the CRIRSCO Template, and between UNFC-2009 and PRMS, is explained in the respective Bridging Documents.

Uranium and thorium quantities are also commonly reported under the NEA/IAEA system. If these resources quantities are reported under UNFC-2009, the Nuclear Fuel Resources Bridging Document and the CRIRSCO Template provide the commodity-specific specifications for uranium and thorium; also the relationships between the NEA/IAEA system and UNFC-2009 are explained in those documents.

When reporting quantities it is necessary to specify which commodity-specific specifications and corresponding Bridging Document have been used.

3.2.1 Generic Specifications

Generic specifications set the minimum standards for reporting under UNFC-2009. Generic specifications are rules that will apply to all commodities. Generic specifications include a set of conditions that are mandatory under any circumstances. The word “shall” is used for all mandatory provisions. When the word “should” is used, the provision is preferred, and when “may” is used, alternatives are equally acceptable.

3.2.1.1 Mandatory provisions

1. Relevant Numerical Code(s) shall always be reported in conjunction with the estimated quantity.
2. The Bridging Document that was used as the basis for the evaluation shall be disclosed in conjunction with the reported quantities.
3. The Effective Date shall be clearly stated in conjunction with the reported quantities. If information becomes available subsequent to the Effective Date, but prior to reporting, that could have significantly changed the estimated quantities as at the Effective Date, the likely effect of this information shall be disclosed.
4. Where estimates for different commodities or product types have been aggregated for reporting purposes, and separate estimates are not provided, the aggregated estimates shall be accompanied by a statement clarifying which commodities or product types have been aggregated and the conversion factor(s) used to render them equivalent for the purposes of aggregation.
5. The reporting basis shall be clearly stated in conjunction with the reported quantities. Where the reported quantities exclude the proportion attributable to the royalty obligation, this shall be disclosed.
6. The Reference Point shall be disclosed in conjunction with the reported quantities. Where the Reference Point is not the point of sale to third parties (or where custody is transferred to the entity’s downstream operations), and such quantities are classified as E1, the information necessary to derive estimated sales quantities shall also be provided.
7. Where extractive activities are suspended, but there are “reasonable prospects for economic extraction and sale in the foreseeable future”, remaining technically recoverable quantities shall be reclassified from E1 to E2. Where “reasonable prospects for economic extraction and

sale in the foreseeable future" cannot be demonstrated, remaining quantities shall be reclassified from E1 to E3.

8. Other than quantities that are classified on the Feasibility axis as F4, all reported quantities shall be limited to those quantities that are potentially recoverable on the basis of existing technology or technology currently under development, and are associated with actual or possible future exploration/development projects or mining operations. If *in situ* quantities are reported and it is expected that the extraction methodology will lead to significant losses and/or grade dilution, this shall be disclosed, e.g. in a footnote. For commodities extracted as fluids, the recovery factor is usually a major uncertainty and hence this should always be taken into account for such projects (F2 and F3) and shall be accommodated using the G-axis Categories.
9. Estimated quantities associated with mining operations or development projects that are classified in different Categories on the Economic or Feasibility axis shall not be aggregated with each other without proper justification and disclosure of the methodology adopted. In all cases, the specific Classes that have been aggregated shall be disclosed in conjunction with the reported quantity (e.g. 111+112+221+222) and a footnote added to highlight the fact that there is a risk that projects that are not classified as E1F1 (Commercial Projects) may not eventually achieve commercial operation.
10. In accordance with the definitions of E1, E2 and E3, economic assumptions shall be based on current market conditions and realistic assumptions of future market conditions. The basis for the assumptions (as opposed to the actual forecast) shall be disclosed.
11. Traditional measurement units that are widely used and accepted for certain commodities will be used; where such units are used for reporting purposes, conversion factors to SI units shall be provided. Where quantities are converted from volume or mass to energy equivalents, or other conversions are applied, the conversion factors shall be disclosed.
12. Estimates of resource quantities shall be documented in sufficient detail that would allow an independent evaluator or auditor to clearly understand the basis for estimation of the reported quantities and their classification.

3.2.1.2 Preferred provisions

1. The evaluation should take into account all data and information available to the evaluator prior to the Effective Date.
2. Estimated quantities should be reported separately for each commodity or significant product type that will be sold, used, transferred or disposed of separately.
3. For commodities extracted as fluids, the recovery factor is usually a major uncertainty and hence this should always be taken into account for such projects (F2 and F3) and shall be accommodated using the G-axis Categories.
4. Where estimated quantities have been aggregated from multiple projects, consideration should be given to sub-dividing the aggregated totals by deposit type and by location (e.g. offshore *versus* onshore).
5. Except where constrained by regulation, assumptions of future market conditions should reflect the view of either: (a) The organization responsible for the evaluation; (b) The view of a competent person or independent evaluator; or, (c) An externally published independent view, which is considered to be a reasonable forecast of future market conditions.

3.2.1.3 Provisions where alternatives are equally acceptable

1. Where a specification for the same issue exists in the Aligned System, and it fully meets the requirements of the generic specification defined below, that specification may be adopted.
2. The defined classes and sub-classes of UNFC-2009 may be used as supplementary terminology.
3. Reported quantities may be those quantities attributable to the mine/development project as a whole, or may reflect the proportion of those quantities that is attributable to the reporting

entity's economic interest in the mining operation or development project. The reported quantities may include the proportion attributable to the royalty obligation.

4. The Reference Point may be the commodity sales point from the extraction and processing operation or it may be an intermediate stage, such as pre-processing (if required), in which case the reported quantities would not take into account processing losses.
5. Where it is considered appropriate or helpful to sub-classify projects to reflect different levels of project maturity, based on the current status of the project, the optional Sub-classes may be adopted for reporting purposes.
6. For solid minerals projects where the ultimate extraction methodology has yet to be confirmed (E2F2), *in situ* quantities may be reported, provided that there are "reasonable prospects for economic extraction and sale" of all such quantities in the foreseeable future.
7. In some situations, it may be helpful to sub-classify Exploration Projects on the basis of their level of maturity.
8. Where it is considered appropriate or helpful to use labels in addition to the numerical codes for a range of estimates for a specific development project or mining operation, the terms "Low Estimate", "Best Estimate" and "High Estimate" may be used to correspond to quantities that are classified on the Geological axis as G1, G1+G2 and G1+G2+G3 respectively.
9. In some situations, it may be helpful to sub-classify Exploration Projects on the basis of their level of maturity.
10. In some situations, it may be helpful to sub-classify Additional Quantities in Place on the basis of the current state of technological developments.

3.3 COMMODITY-SPECIFIC SPECIFICATIONS/GUIDELINES

3.3.1 Solid minerals

Commodity-specific specifications for solid minerals are provided through the CRIRSCO Template [4] (www.crirsco.com). The relationship between UNFC-2009 and the CRIRSCO Template is explained in the "Bridging Document Between the CRIRSCO Template and UNFC-2009" (refer to Annex III (p. 31) of UNFC-2009). Along with the Generic Specifications, these provide the foundation and keystones for consistent application of UNFC-2009 for solid minerals including uranium and thorium.

3.3.1.1 CRIRSCO Template for solid minerals, including uranium and thorium

The CRIRSCO Template was developed as the international standard for the reporting of Exploration Targets, Mineral Resources and Mineral Reserves for solid mineral deposits. It is in turn based on a number of national or regional reporting standards that are compatible and consistent with each other and the Template, and whose authors contributed to the development of the Template that represents current international best practice for Public Reports by companies.

The Template is focussed on establishing and maintaining consistent and appropriate standards for Public Reports (as defined by CRIRSCO) and hence does not address all mineralisation that may be relevant for other purposes, such as national inventories or internal use. Consequently, full application of UNFC-2009 for solid minerals can extend beyond the classes explicitly defined in the Template.

CRIRSCO Commodity Specific Specifications (clauses) for Mineral Resource (UNFC 2,2,1-3), Mineral Reserve (UNFC 1,1,1&2) and Exploration Target (UNFC 3.2,3,4) are compiled under sections 5.3.2, 5.3.3 and 5.3.4. Commodity Specific Specifications are compiled in standard text and specification guidance is shown in italics.

3.3.1.1.1 Mineral Resource/ Potentially Commercial Project/Identified Resource

An Identified Resource (Reasonably Assured Resources (RAR) and Inferred Resources (IR)) under the NEA/IAEA system corresponds to a CRIRSCO Mineral Resource and Potentially Commercial Project under UNFC, when economic and project feasibility considerations meet CRIRSCO and UNFC criteria.

A Mineral Resource defined under the CRIRSCO Template, and an Identified Resource with "Prospective status" under NEA/IAEA, correspond to UNFC Categories E2 and F2. Optionally, the CRIRSCO and NEA/IAEA estimates may be further sub-classified on the F axis into UNFC "Development Pending" (F2.1) or UNFC Development on Hold" (F2.2) subclasses (Chapter 4, Figure 12).

CRIRSCO Commodity Specific Specifications for a Mineral Resource and UNFC Potentially Commercial Project are defined by the following CRIRSCO clauses (November 2013):

Clause 21 - A ***<u>Mineral Resource</u>*** (UNFC 2,2,1-3) is a concentration or occurrence of solid material of economic interest in or on the Earth's crust in such form, grade or quality and quantity that there are reasonable prospects for eventual economic extraction.

The location, quantity, grade or quality, continuity and other geological characteristics of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge, including sampling.

Mineral Resources are subdivided, in order of increasing geological confidence into Inferred (UNFC 2, 2.1and 2.2, 3), Indicated (UNFC 2, 2.1and 2.2, 2) and Measured categories (UNFC 2, 2.1 and 2.2, 1) (see Figure 2–Figure III.2, page 33 of UNFC-2009) [1].

Portions of a mineral deposit that do not have reasonable prospects for eventual economic extraction must not be included in a Mineral Resource.

The term 'Mineral Resource' covers mineralisation, including dumps and tailings, which has been identified and estimated through exploration and sampling and within which Mineral Reserves may be defined by the consideration and application of Modifying Factors.

The term 'reasonable prospects for eventual economic extraction' implies a judgement (albeit preliminary) by the Competent Person in respect of the technical and economic factors likely to influence the prospect of economic extraction, including the approximate mining parameters. In other words, a Mineral Resource is not an inventory of all mineralisation drilled or sampled regardless of cut-off grade, likely mining dimensions, location or continuity. It is a realistic inventory of mineralisation which, under assumed and justifiable technical and economic conditions, might, in whole or in part, become economically extractable.

Any material assumptions made in determining the 'reasonable prospects for eventual economic extraction' should be clearly stated in the Public Report.

Interpretation of the word 'eventual' in this context may vary depending on the commodity or mineral involved. For example, for some coal, iron ore, bauxite and other bulk minerals or commodities, it may be reasonable to envisage 'eventual economic extraction' as covering time periods in excess of 50 years. However for many gold deposits, application of the concept would normally be restricted to perhaps 10 to 15 years, and frequently to much shorter periods of time.

Any adjustment made to the data for the purpose of making the Mineral Resource estimate, for example by cutting or factoring grades, should be clearly stated and described in the Public Report.

Certain reports (e.g. inventory reports, exploration reports to government and other similar reports not intended primarily for providing information for investment purposes) may require full disclosure of all mineralisation, including some material that does not have reasonable prospects for eventual economic extraction. Such estimates of mineralisation would not qualify as Mineral Resources or Mineral Reserves under the Template.

Clause 22 **-** An ***Inferred Mineral Resource*** (UNFC 2,2.1&2.2,3) is that part of a Mineral Resource for which quantity and grade or quality are estimated on the basis of limited geological evidence and sampling. Geological evidence is sufficient to imply but not verify geological and grade or quality continuity.

An Inferred Resource has a lower level of confidence than that applying to an Indicated Mineral Resource and must not be converted to a Mineral Reserve. It is reasonably expected that the majority of Inferred Mineral Resources could be upgraded to Indicated Mineral Resources with continued exploration. An Inferred Mineral Resource has a lower level of confidence than that applying to an Indicated Mineral Resource.

The Inferred category is intended to cover situations where a mineral concentration or occurrence has been identified and limited measurements and sampling completed, but where the data are insufficient to allow the geological and/or grade continuity to be confidently interpreted. Commonly, it would be reasonable to expect that the majority of Inferred Mineral Resources would upgrade to Indicated Mineral Resources with continued exploration. However, due to the uncertainty of Inferred Mineral resources, it should not be assumed that such upgrading will always occur.

Confidence in the estimate is usually not sufficient to allow the results of the application of technical and economic parameters to be used for detailed planning. For this reason, there is no direct link from an Inferred Resource to any category of Mineral Reserves (see Figure 11). [Figure III.1 of UNFC-2009, page 32]

Caution should be exercised if this category is considered in technical and economic studies.

Clause 23 **-** An ***Indicated Mineral Resource*** (UNFC 2,2.1&2.2,2) is that part of a Mineral Resource for which quantity, grade or quality, densities, shape and physical characteristics are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit.

Geological evidence is derived from adequately detailed and reliable exploration, sampling and testing, and is sufficient to assume geological and grade or quality continuity between points of observation.

An Indicated Mineral Resource has a lower level of confidence than that applying to a Measured Mineral Resource and may only be converted to a Probable Mineral Reserve.

An Indicated Mineral Resource has a lower level of confidence than that applying to a Measured Mineral Resource, but has a higher level of confidence than that applying to an Inferred Mineral Resource.

Mineralisation may be classified as an Indicated Mineral Resource when the nature, quality, amount and distribution of data are such as to allow confident interpretation of the geological framework and to assume continuity of mineralisation.

Confidence in the estimate is sufficient to allow the application of technical and economic parameters, and to enable an evaluation of economic viability.

Clause 24 - A ***Measured Mineral Resource*** (UNFC 2,2.1&2.2,1) is that part of a Mineral Resource for which quantity, grade or quality, densities, shape, and physical characteristics are estimated with confidence sufficient to allow the application of Modifying Factors to support detailed mine planning and final evaluation of the economic viability of the deposit.

Geological evidence is derived from detailed and reliable exploration, sampling and testing and is sufficient to confirm geological and grade or quality continuity between points of observation.

A Measured Mineral Resource has a higher level of confidence than that applying to either an Indicated Mineral Resource or an Inferred Mineral Resource. It may be converted to a Proved Mineral Reserve or to a Probable Mineral Reserve.

Mineralisation may be classified as a Measured Mineral Resource when the nature, quality, amount and distribution of data are such as to leave no reasonable doubt, in the opinion of the Competent Person determining the Mineral Resource, that the tonnage and grade of the mineralisation can be estimated to within close limits, and that any variation from the estimate would be unlikely to significantly affect potential economic viability.

This category requires a high level of confidence in, and understanding of, the geology and the controls of the mineral deposit.

Confidence in the estimate is sufficient to allow the application of technical and economic parameters and to enable an evaluation of economic viability with a high level of confidence.

Clause 25 - The choice of the appropriate category of Mineral Resource depends upon the quantity, distribution and quality of data available and the level of confidence that attaches to those data. The appropriate Mineral Resource category must be determined by a Competent Person or Persons.

Mineral Resource classification is a matter for skilled judgement and Competent Persons should take into account those items in Table 1 [of the CRIRSCO Template] that relate to confidence in Mineral Resource estimation.

In deciding between Measured Mineral Resources and Indicated Mineral Resources, Competent Persons may find it useful to consider, in addition to the phrases in the two definitions relating to geological and grade continuity in Clauses 21 and 22, the phrase in the guideline to the definition for Measured Mineral Resources: '....any variation from the estimate would be unlikely to significantly affect potential economic viability'.

In deciding between Indicated Mineral Resources and Inferred Mineral Resources, Competent Persons may wish to take into account, in addition to the phrases in the two definitions in Clauses 20 and 21 [of the CRIRSCO Template] relating to geological and grade continuity, the guideline to the definition for Indicated Mineral Resources: 'Confidence in the estimate is sufficient to allow the application of technical and economic parameters and to enable an evaluation of economic viability.', which contrasts with the guideline to the definition for Inferred Mineral Resources: 'Confidence in the estimate of Inferred Mineral Resources is usually not sufficient to allow the results of the application of technical and economic parameters to be used for detailed planning' and 'Caution should be exercised if this category is considered in technical and economic studies'.

The Competent Person should take into consideration issues of the style of mineralisation, scale and cut-off grade when assessing geological and grade continuity.

Clause 26 **-** Mineral Resource estimates are not precise calculations, being dependent on the interpretation of limited information on the location, shape and continuity of the occurrence and on the available sampling results. Reporting of tonnage and grade figures should reflect the relative uncertainty of the estimate by rounding off to appropriately significant figures and, in the case of Inferred Mineral Resources, by qualification with terms such as 'approximately'.

In most situations, rounding to the second significant figure should be sufficient. For example 10,863,000 tonnes at 8.23 per cent should be stated as 11 million tonnes at 8.2 per cent. There will be occasions, however, where rounding to the first significant figure may be necessary in order to convey properly the uncertainties in estimation.

This would usually be the case with Inferred Mineral Resources.

To emphasise the imprecise nature of a Mineral Resource estimate, the final result should always be referred to as an estimate not a calculation.

Competent Persons are encouraged, where appropriate, to discuss the relative accuracy and/or confidence of the Mineral Resource estimates. The statement should specify whether it relates to global (whole of resource) or local estimates (a subset of the resource for which the accuracy and/or confidence might differ from the whole of the resource), and, if local, state the relevant tonnage or volume. Where a statement of the relative accuracy and/or confidence is not possible, a qualitative discussion of the uncertainties should be provided (refer to Table 1 of the CRIRSCO Template).

3.3.1.1.2 Mineral Reserves/Commercial Project/Reasonably Assured Resources

A Mineral Reserve, defined under the CRIRSCO Template, corresponds to a Commercial Project under UNFC-2009 and a Reasonably Assured Resource under NEA/IAEA (Chapter 4, Figure 12). Mineral Reserves defined under the CRIRSCO Template are subdivided into Proved and Probable categories, which correspond to UNFC Categories G1 and G2. Since the NEA/IAEA Classification does not subdivide Reasonably Assured Resources on geological confidence, UNFC-2009 G1 and G2 categories, and corresponding CRIRSCO Proved and Probable Mineral Reserve classes, are aggregated under NEA/IAEA.

CRIRSCO Commodity Specific Specifications for a Mineral Reserve and UNFC-2009 Commercial Project are defined by the following CRIRSCO Template clauses (November 2013):

Clause 30 **-** A ***<u>Mineral Reserve</u>*** (UNFC 1,1,1&2) is the economically mineable part of a Measured and/or Indicated Mineral Resource.

It includes diluting materials and allowances for losses, which may occur when the material is mined or extracted and is defined by studies at Pre-Feasibility or Feasibility level as appropriate to include application of Modifying Factors.

Such studies demonstrate that, at the time of reporting, extraction could reasonably be justified.

The reference point at which Reserves are defined, usually the point where the ore is delivered to the processing plant, must be stated. It is important that, in all situations where the reference point is different, such as for a saleable product, a clarifying statement is included to ensure that the reader is fully informed as to what is being reported.

Mineral Reserves are those portions of Mineral Resources which, after the application of all mining factors, result in an estimated tonnage and grade which, in the opinion of the Competent

Person making the estimates, can be the basis of a viable project, after taking account of all relevant Modifying Factors

In reporting Mineral Reserves, information on estimated mineral processing recovery factors is very important, and should always be included in Public Reports.

The term 'economically mineable' implies that extraction of the Mineral Reserve has been demonstrated to be viable under reasonable financial assumptions. What constitutes the term 'realistically assumed' will vary with the type of deposit, the level of study that has been carried out and the financial criteria of the individual company. For this reason, there can be no fixed definition for the term 'economically mineable'. However, it is expected that companies will attempt to achieve an acceptable return on capital invested, and that returns to investors in the project will be competitive with alternative investments of comparable risk.

In order to achieve the required level of confidence in the Mineral Resources, all of the modifying factors studies to Pre-Feasibility or Feasibility level as appropriate will have been carried out prior to determination of the Mineral Reserves. The study will have determined a mine plan that is technically achievable and economically viable and from which the Mineral Reserves can be derived.

The term 'Mineral Reserves' need not necessarily signify that extraction facilities are in place or operative, or that all necessary approvals or sales contracts have been received. It does signify that there are reasonable expectations of such approvals or contracts. The Competent Person should consider the materiality of any unresolved matter that is dependent on a third party on which extraction is contingent.

Any adjustment made to the data for the purpose of making the Mineral Reserve estimate, for example by cutting or factoring grades, should be clearly stated and described in the Public Report.

It should be noted that the Template does not imply that an economic operation should have Proved Mineral Reserves. Situations may arise where Probable Mineral Reserves alone may be sufficient to justify extraction, as for example with some alluvial tin, diamond or gold deposits. This is a matter for judgement by the Competent Person.

Clause 31 - A ***<u>Probable Mineral Reserve</u>*** (UNFC-2009 1, 1.1 to 1.3, 2) is the economically mineable part of an Indicated, and in some circumstances, a Measured Mineral Resource.

The confidence in the Modifying Factors applying to a Probable Mineral Reserve is lower than that applying to a Proved Mineral Reserve.

A Probable Mineral Reserve has a lower level of confidence than a Proved Mineral Reserve but is of sufficient quality to serve as the basis for a decision on the development of the deposit.

Clause 32 - A ***<u>Proved Mineral Reserve</u>*** (UNFC-2009 1, 1.1 to 1.3, 1) is the economically mineable part of a Measured Mineral Resource. A Proved Mineral Reserve implies a high degree of confidence in the Modifying Factors.

A Proved Mineral Reserve represents the highest confidence category of reserve estimate.

The style of mineralisation or other factors could mean that Proved Mineral Reserves are not achievable in some deposits. Competent Persons should be aware of the consequences of declaring material of the highest confidence category before satisfying themselves that all of the relevant resource parameters and Modifying Factors have been established at a similarly high level of confidence.

Clause 33 - The choice of the appropriate category of Mineral Reserve is determined primarily by the relevant level of confidence in the Mineral Resource and after considering any uncertainties in the modifying factors. Allocation of the appropriate category must be made by the Competent Person.

The Template provides for a direct relationship between Indicated Mineral Resources and Probable Mineral Reserves and between Measured Mineral Resources and Proved Mineral Reserves (Fig. 1). In other words, the level of geological confidence for Probable Mineral Reserves is similar to that required for the determination of Indicated Mineral Resources. The level of geological confidence for Proved Mineral Reserves is similar to that required for the determination of Measured Mineral Resources. Inferred Mineral Resources are always additional to Mineral Reserves.

The Template also provides for a two-way relationship between Measured Mineral Resources and Probable Mineral Reserves. This is to cover a situation where uncertainties associated with any of the Modifying Factors considered when converting Mineral Resources to Mineral Reserves may result in there being a lower degree of confidence in the Mineral Reserves than in the corresponding Mineral Resources. Such a conversion would not imply a reduction in the level of geological knowledge or confidence.

A Probable Mineral Reserve derived from a Measured Mineral Resource may be converted to a Proved Mineral Reserve if the uncertainties in the Modifying Factors are removed. No amount of confidence in the Modifying Factors for conversion of a Mineral Resource to a Mineral Reserve can override the upper level of confidence that exists in the Mineral Resource. Under no circumstances can an Indicated Mineral Resource be converted directly to a Proved Mineral Reserve (see Figure 1).

Application of the category of Proved Mineral Reserves implies the highest degree of confidence in the estimate, with consequent expectations in the minds of the readers of the report. These expectations should be borne in mind when categorising a Mineral Resource as Measured.

Refer also to the guidelines in Clause 25 [of the CRIRSCO Template] regarding classification of Mineral Resources.

Clause 34 - Mineral Reserve estimates are not precise calculations. Reporting of tonnage and grade figures should reflect the relative uncertainty of the estimate by rounding off to appropriately significant figures. Refer also to Clause 26.

To emphasise the imprecise nature of a Mineral Reserve, the final result should always be referred to as an estimate not a calculation.

Competent Persons are encouraged, where appropriate, to discuss the relative accuracy and/or confidence of the Mineral Reserve estimates. The statement should specify whether it relates to global (whole of reserve) or local estimates (a subset of the reserve for which the accuracy and/or confidence might differ from the whole of the reserve), and, if local, state the relevant tonnage or volume. Where a statement of the relative accuracy and/or confidence is not possible, a qualitative discussion of the uncertainties should be provided (refer to Table 1 and to the Guidelines for Clause 24).

Since the reporting of a CRIRSCO Mineral Reserve and UNFC Commercial Project, are conditional on the application of Modifying Factors and the preparation of a minimum Prefeasibility Study, CRIRSCO Commodity Specific Specifications for Modifying Factors and Prefeasibility Study are defined by the following CRIRSCO clauses (November 2013) :

Clause 12 - Modifying Factors are considerations used to convert Mineral Resources to Mineral Reserves. These include, but are not restricted to, mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social and governmental factors.

Clause 38 **-** A ***Pre-Feasibility Study*** is a comprehensive study of a range of options for the technical and economic viability of a mineral project that has advanced to a stage where a preferred mining method, in the case of underground mining, or the pit configuration, in the case of an open pit, is established and an effective method of mineral processing is determined. It includes a financial analysis based on reasonable assumptions on the Modifying Factors and the evaluation of any other relevant factors that are sufficient for a Competent Person, acting reasonably, to determine if all or part of the Mineral Resource may be converted to a Mineral Reserve at the time of reporting. A Pre-Feasibility Study is at a lower confidence level than a Feasibility Study.

3.3.1.1.3 Exploration Results, Exploration Targets/Exploration, Project/Undiscovered Resources

Exploration Results and Exploration Targets defined under the CRIRSCO Template, generally correspond to an Exploration Project under UNFC-2009 and Undiscovered Resources under NEA/IAEA (Chapter 4, Figure 12).

Under the CRIRSCO Template, when exploration activities have taken place but are insufficiently advanced to estimate a Mineral Resource, the exploration findings may be publically disclosed as Exploration Results and Exploration Targets. Exploration Results are insufficient to justify the public disclosure of a volume, tonnes, grade or quality of mineralization and cannot be stated as Mineral Resource.

CRIRSCO Commodity Specific Specifications for Exploration Targets and Exploration Results are defined by the following CRIRSCO Template clauses (November 2013):

Clause 17 **-** An **Exploration Target** (UNFC-2009 3.2,3,4) is a statement or estimate of the exploration potential of a mineral deposit in a defined geological setting where the statement or estimate, quoted as a range of tonnes and a range of grade or quality, relates to mineralisation for which there has been insufficient exploration to estimate Mineral Resources.

Clause 18 **- Exploration Results** include data and information generated by mineral exploration programmes that might be of use to investors but which do not form part of a declaration of Mineral Resources or Mineral Reserves.

This is common in the early stages of exploration when the quantity of data available is generally not sufficient to allow any reasonable estimates of tonnage and grade to be made. Examples include discovery outcrops, single drill hole intercepts or the results of geophysical surveys.

CRIRSCO Commodity Specific Specifications for a Competent Person are defined by the following CRIRSCO clause (November 2013):

Clause 11 **-** A **Competent Person** is a minerals industry professional with appropriate membership class in a recognised Professional Organisation with enforceable disciplinary processes including the powers to suspend or expel a member.

A Competent Person must have a minimum of five years relevant experience in the style of mineralisation or type of deposit under consideration and in the activity which that person is undertaking.

If the Competent Person is preparing a report on Exploration Results, the relevant experience must be in exploration. If the Competent Person is estimating, or supervising the estimation of Mineral Resources, the relevant experience must be in the estimation, assessment and evaluation of Mineral Resources. If the Competent Person is estimating, or supervising the estimation of Mineral Reserves, the relevant experience must be in the estimation, assessment, evaluation and economic extraction of Mineral Reserves.

The key qualifier in the definition of a Competent Person is the word `relevant'. Determination of what constitutes relevant experience can be a difficult area and common sense has to be exercised. For example, in estimating Mineral Resources for vein gold mineralisation, experience in a high-nugget, vein-type mineralisation such as tin, uranium etc. will probably be relevant whereas experience in massive base metal deposits may not be. As a second example, to qualify as a Competent Person in the estimation of Mineral Reserves for alluvial gold deposits, considerable (probably at least five years) experience in the evaluation and economic extraction of this type of mineralisation would be needed. This is due to the characteristics of gold in alluvial systems, the particle sizing of the host sediment, and the low grades involved. Experience with placer deposits containing minerals other than gold may not necessarily provide appropriate relevant experience.

The key word 'relevant' also means that it is not always necessary for a person to have five years' experience in each and every type of deposit in order to act as a Competent Person if that person has relevant experience in other deposit types. For example, a person with (say) 20 years' experience in estimating Mineral Resources for a variety of metalliferous hard-rock deposit types may not require five years specific experience in (say) porphyry copper deposits in order to act as a Competent Person. Relevant experience in the other deposit types could count towards the required experience in relation to porphyry copper deposits.

In addition to experience in the style of mineralisation, a Competent Person taking responsibility for the compilation of Exploration Results or Mineral Resource estimates should have sufficient experience in the sampling and analytical techniques relevant to the deposit under consideration to be aware of problems which could affect the reliability of data. Some appreciation of extraction and processing techniques applicable to that deposit type is also important.

As a general guide, persons being called upon to act as Competent Persons should be clearly satisfied in their own minds that they could face their peers and demonstrate competence in the commodity, type of deposit and situation under consideration. If doubt exists, the person should either seek opinions from appropriately experienced colleagues or should decline to act as a Competent Person. Estimation of Mineral Resources may be a team effort (for example, involving one person or team collecting the data and another person or team preparing the estimate).

Estimation of Mineral Reserves is very commonly a team effort involving several technical disciplines. It is recommended that, where there is a clear division of responsibility within a team, each Competent Person and his or her contribution should be identified, and responsibility accepted for that particular contribution. If only one Competent Person signs the Mineral Resource or Mineral Reserve documentation, that person is responsible and accountable for the whole of the documentation under the Template. It is important in this situation that the Competent Person accepting overall responsibility for a Mineral Resource or Mineral Reserve estimate and supporting documentation prepared in whole or in part by others, is satisfied that the work of the other contributors is acceptable.

Complaints made in respect of the professional work of a Competent Person will be dealt with under the disciplinary procedures of the National professional organisation to which the Competent Person belongs. Such procedures may vary from country to country, but international agreements between National Reporting Organisations through the 'ROPO' (Recognised Overseas Professional Organisation) system are encouraged to standardise Competent Person practices where possible.

3.3.2 Petroleum

SPE has provided commodity-specific specifications via the Petroleum Resources Management System of 2007 (PRMS). The relationship between UNFC-2009 and PRMS is explained in the "Bridging Document Between the PRMS and UNFC-2009" (refer to Annex IV (p. 37) of

UNFC-2009). Along with the Generic Specifications, these commodity-specific specifications provide the foundation and keystones for consistent application of UNFC-2009 for petroleum.

The definitions and guidelines of PRMS are designed to provide a common reference for the international petroleum industry, including national reporting and regulatory disclosure agencies, and to support petroleum project and portfolio management requirements. They are intended to improve clarity in global communications regarding petroleum resources.

3.3.3 Nuclear Fuel Resources

Raw materials for nuclear fuel, uranium and thorium, can be reported under the CRIRSCO Template (see 3.3.1) and the Organisation of Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA)/International Atomic Energy Agency (IAEA) resource reporting system (NEA/IAEA system). The relationship between UNFC-2009 and NEA/IAEA scheme is explained in the “Bridging Document between the Organisation of Economic Co-operation and Development Nuclear Energy Agency/International Atomic Energy Agency Uranium Classification and UNFC-2009”. Along with the UNFC-2009 Generic Specifications, these instructions and guidelines provide the foundation and keystones for consistent application of UNFC-2009 for the reporting of uranium and thorium resources.

3.4 RELATIONSHIPS BETWEEN SYSTEMS

A bridging document explains the relationship between UNFC-2009 and another classification system, including instructions and guidelines on how to classify estimates generated by application of that system using the UNFC-2009 Numerical Codes. An aligned system is a classification system that has been aligned with UNFC-2009, as demonstrated by the existence of a bridging document that has been endorsed by the Expert Group on Resource Classification (the Expert Group). The CRIRSCO Template and the NEA/IAEA system are aligned systems of UNFC-2009.

A mapping document is the output of a comparison between another resource classification system and UNFC-2009, or between that system and existing Aligned Systems, which highlights the similarities and differences between the systems. A Mapping Document can provide the basis for assessing the potential for the other system to become an Aligned System through the development of a Bridging Document.

In this report, mapping between NEA/IAEA system and the CRIRSCO Template is provided. Some other examples of possible mappings between UNFC-2009 and other systems are also discussed. These mappings demonstrate the potential for the systems to become aligned systems; however, an ERGC approved bridging document will be required if any of these systems are to be deemed aligned systems.

4. NEA/IAEA CLASSIFICATION

4.1 NEA/IAEA Classification Scheme

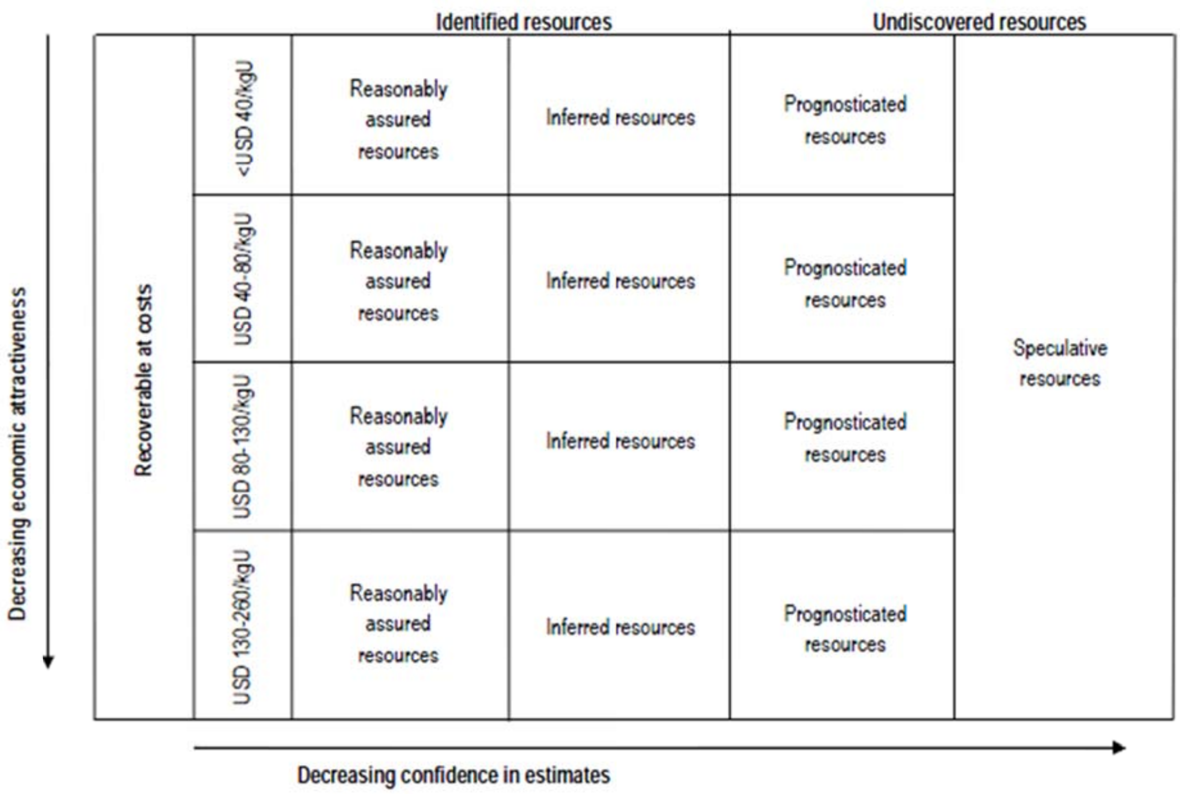
In the mid-1960s, NEA and IAEA began the publication of a report entitled: "Uranium – Resources, Production and Demand". The report, commonly known as the "Red Book", has been published at roughly two-year intervals. The report has become widely recognized in the international nuclear community as a primary reference document for world uranium supply and demand. Each edition of the "Red Book" contains estimates of uranium resources divided into several categories of assurance of existence and economic attractiveness, along with projections of production capability, installed nuclear capacity and related reactor requirements [2].

Uranium resources are broadly classified as either conventional or unconventional. Conventional resources are those that have an established history of production where uranium is a primary product, co-product or an important by-product. Unconventional resources are very low-grade uranium resources from which the uranium is only recoverable as a minor product of developing and processing a mineral ore.

Uranium resources are classified according to geological certainty and costs of production. Figure 9 illustrates the inter-relationship between the different resource categories. The horizontal axis expresses the level of confidence about the actual existence of a given tonnage based on varying degrees of geological knowledge. The vertical axis expresses the economic feasibility of exploitation separated into cost categories.

Conventional uranium and thorium resources are sub-divided according to different confidence levels of occurrence, into Identified Resources and Undiscovered Resources. Identified Resources are further sub-divided into Reasonably Assured Resources (RAR) and Inferred Resources (IR). Undiscovered Resources are sub-divided into Prognosticated Resources (PR) and Speculative Resources (SR).

Figure 9
NEA/IAEA classification scheme for uranium resources



4.1.1 Identified Resources

Identified resources (RAR and IR) refer to uranium deposits delineated by sufficient direct measurement to conduct pre-feasibility studies, and in some cases feasibility studies. For Reasonably Assured Resources (RAR), high confidence in estimates of grade and tonnage are generally compatible with standards for making the decision to proceed with development of the project. Inferred Resources (IR) are not defined with a high a degree of confidence and generally require further direct measurement prior to making a decision to develop the project.

Reasonably Assured Resources (RAR) refers to uranium that occurs in known mineral deposits of delineated size, grade and configuration such that the quantities which could be recovered within the given production cost ranges with currently proven mining and processing technology, can be specified. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of deposit characteristics. Reasonably assured resources have a high assurance of existence. Unless otherwise noted, RAR are expressed in terms of quantities of uranium recoverable from mineable ore (see recoverable resources).

Inferred Resources (IR) refers to uranium, in addition to RAR, that is inferred to occur based on direct geological evidence, in extensions of well-explored deposits, or in deposits in which geological continuity has been established but where specific data, including measurements of the deposits, and knowledge of the deposit's characteristics, are considered to be inadequate to classify the resource as RAR. Estimates of tonnage, grade and cost of further delineation and recovery are based on such sampling as is available and on knowledge of the deposit characteristics as determined in the best known parts of the deposit or in similar deposits. Less reliance can be placed on the estimates in this category than on those for RAR. Unless otherwise noted, inferred resources are expressed in terms of quantities of uranium recoverable from mineable ore (see recoverable resources).

4.1.2 Recoverable Resources

RAR and IR estimates are expressed in terms of recoverable tonnes of uranium, i.e. quantities of uranium recoverable from mineable ore, as opposed to quantities contained in mineable ore, or quantities *in situ*, i.e. not taking into account mining and milling losses. Therefore both expected mining and ore processing losses have been deducted in most cases.

4.1.2 Undiscovered Resources

Undiscovered Resources (Prognosticated Resources and Speculative Resources) refer to resources that are expected to exist based on geological knowledge of previously discovered deposits, regional geological mapping and other geological data sources.

Prognosticated resources (PR) refers to uranium, in addition to inferred resources, that is expected to occur in deposits for which the evidence is mainly indirect and which are believed to exist in well-defined geological trends or areas of mineralisation with known deposits. Estimates of tonnage, grade and cost of discovery, delineation and recovery are based primarily on knowledge of deposit characteristics in known deposits within the respective trends or areas and on such sampling, geological, geophysical or geochemical evidence as may be available. Less reliance can be placed on the estimates in this category than on those for inferred resources. Prognosticated resources are normally expressed in terms of uranium contained in mineable ore, i.e. *in situ* quantities.

Speculative resources (SR) refer to uranium, in addition to prognosticated resources, that is thought to exist, mostly on the basis of indirect evidence and geological extrapolations, in deposits discoverable with existing exploration techniques. The location of deposits envisaged in this category could generally be specified only as being somewhere within a given region or geological trend. As the term implies, the existence and size of such resources are speculative. SR are normally expressed in terms of uranium contained in mineable ore, i.e. *in situ* quantities.

4.1.3 Cost categories

The cost categories, in United States dollars (USD), used in this report are defined as: <USD 40/kgU, <USD 80/kgU, <USD 130/kgU and <USD 260/kgU. All resource categories are defined in terms of costs of uranium recovered at the ore processing plant.

When estimating the cost of production for assigning resources within these cost categories, account has been taken of the following costs:

- the direct costs of mining, transporting and processing the uranium ore;
- the costs of associated environmental and waste management during and after mining;
- the costs of maintaining non-operating production units where applicable;
- in the case of ongoing projects, those capital costs that remain non-amortised;
- the capital cost of providing new production units where applicable, including the cost of financing;
- indirect costs such as office overheads, taxes and royalties where applicable;
- future exploration and development costs wherever required for further ore delineation to the stage where it is ready to be mined;
- sunk costs are not normally taken into consideration.

The cost categories, in United States Dollars (USD), currently used in the NEA/IAEA classification are shown in Figure 9. Quantities reported in UNFC-2009 do not have any correspondence with cost categories of the NEA/IAEA classification.

4.1.4 Production terminology

The NEA/IAEA “Red Book” [2] uses production terminology for uranium reporting. A production centre is a production unit consisting of one or more ore processing plants, as well as one or more associated mines and uranium resources that are tributary to these facilities. For the purpose of describing production centres, they have been divided into four classes, as follows:

- **Existing** production centres are those that currently exist in operational condition; this category also includes plants that are closed but could be readily brought back into operation.
- **Committed** production centres are those under construction or firmly committed for construction.
- **Planned** production centres are those for which feasibility studies are either completed or under way, but construction commitments have not yet been made. This class also includes plants that are closed and would require substantial expenditures to bring back into operation.
- **Prospective** production centres are those that could be supported by tributary Reasonably Assured Resources and Inferred Resources, but for which construction plans have not yet been made.

4.2 Nuclear Fuel Resources Bridging Document

If uranium and thorium quantities are reported using UNFC-2009, then either the CRIRSCO or the Nuclear Fuel Resources (NFR) Bridging Document can be used [ECE/ENERGY/2014/6].

“Bridging Document between the Organisation of Economic Co-operation and Development Nuclear Energy Agency/International Atomic Energy Agency Uranium Classification and UNFC-2009” [3] was approved by EGRC and endorsed by the Committee on Sustainable Energy in 2014. This makes the NEA/IAEA Uranium Classification an aligned system. Definitions of resource categories provided in the “Red Book” are the commodity-specific specifications for reporting uranium and thorium quantities in UNFC-2009.

While reporting uranium and thorium quantities, the bridging document used and the commodity-specific specifications applied shall be disclosed.

The transfer of NEA/IAEA uranium and thorium quantities for individual deposits into UNFC-2009 also requires the application of Production Terminology (Figure 10).

4.3 Mapping of the NEA/IAEA Uranium Classification, UNFC-2009 and the CRIRSCO Template

4.3.1 Background

UNFC-2009 is designed to provide a standardized system for creating an inventory of naturally occurring petroleum and solid minerals reserves and resources contained on or within the earth's crust. A key aspect of such a system is that it must align with established and widely- used classifications in order to have broad application, e.g. as a high-level umbrella system. Such a system also requires sufficient guidelines to ensure consistency in the allocation of quantities within this framework.

UNFC-2009 is a project-based system that applies to all fossil energy and mineral reserves and resources. It has been designed to meet, to the extent possible, the needs of applications pertaining to energy and mineral studies, resource management functions, corporate business process and financial reporting standards.

The NEA/IAEA scheme was developed for reporting individual, regional, national and international uranium/thorium resource estimates. Uranium/thorium resources are classified according to geological certainty and costs of production (Figure 9 – NEA/IAEA scheme). The scheme is used to combine resource estimates from a number of different countries into harmonized global figures.

CRIRSCO (Committee for Mineral Reserves International Reporting Standards) [4], was formed in 1994 under the auspices of the Council of Mining and Metallurgical Institutes (CMMI), is a grouping of representatives of organisations that are responsible for developing mineral reporting codes and guidelines in Australasia (JORC), Canada (CIM), Chile (National Committee), Europe (National Committee PERC), South Africa (SAMREC), Russia (NAEN) and the USA (SME). The combined value of mining companies listed on the stock exchanges of these countries accounts for more than 80% of the listed capital of the mining industry. The CRIRSCO Template is the international standard for the public reporting of Exploration Results, Mineral Resources and Mineral Reserves for mineral deposits including uranium and thorium deposits. The basic framework on which the Template and the standards aligned to it are based is shown in Figure 11.

Some of the major reporting standards under the CRIRSCO family are:

- The Canadian classification system (**National Instrument 43-101**) is a part of Canadian securities law and is a national standard of detailed rules and guidelines for reporting information on mineral properties owned or explored by companies that report their results to Canadian stock exchanges [15].
- The Australasian Joint Ore Reserves Committee Code (**JORC Code**) is another recognized standard system for reporting mineral resource deposits and ore reserves. It was developed for consistent reporting of mineral resource projects by publicly listed companies in Australia and New Zealand. As explained in its website [16]: "The JORC Code provides a mandatory system for the classification of minerals Exploration Results, Mineral Resources and Ore Reserves according to the levels of confidence in geological knowledge and technical and economic considerations in Public Reports."
- The South African Code for the Reporting of Mineral Resources and Mineral Reserves (**SAMREC Code**) sets out minimum standards, recommendations and guidelines for public reporting of exploration results, mineral resources and mineral reserves in South Africa [17]. The SAMREC code was first issued in 2000, revised as recently as 2009, and was being newly refined in 2013 and 2014 [17].

Figure 10
Mapping of NEA/IAEA Uranium Resource Categories to UNFC-2009 Classes and Sub-classes

UNFC-2009 Classification					NEA/IAEA Classification		
UNFC Classes and Sub-classes		UNFC Categories					
Class	Sub-Class	E	F	G	IAEA-NEA Categories		Status
Commercial Projects	On Production	1	1.1	1, 2	Identified Resources	Reasonably Assured Resources (RAR)	Existing
	Approved for Development	1	1.2	1, 2			Committed
	Justified for Development	1	1.3	1, 2			Planned
Potentially Commercial Projects	Development Pending	2	2.1	1, 2, 3	Identified Resources	RAR, IR*	Prospective
	Development On Hold	2	2.2	1, 2, 3		RAR, IR*	
Non-commercial Projects	Development Unclarified	3.2	2.2	1, 2, 3	Identified Resources	RAR, IR*	Unclarified
	Development Not Viable	3.3	2.3	1, 2, 3		RAR, IR*	Not Viable
Exploration Projects		3.2	3.1	4	Undiscovered Resources	Prognosticated Resources	
		3.2	3.2, 3.3	4		Speculative Resources	

IR* = Inferred Resources

4.3.2. Mapping between UNFC-2009, CRIRSCO Template and NEA/IAEA system

The high-level framework of UNFC-2009 is provided by the definitions of E, F and G categories [1].

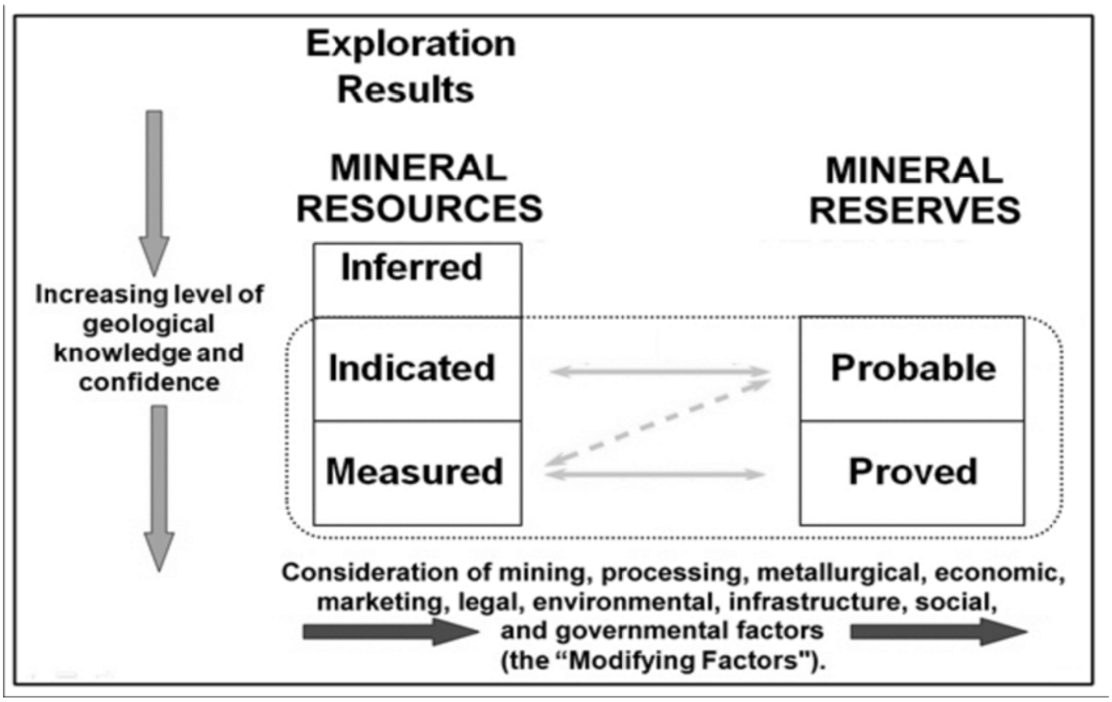
The specifications for solid minerals have been provided through the CRIRSCO Template. The relationship between UNFC-2009 and the CRIRSCO Template is explained in a Bridging Document (see Annex III in [1]).

Subsequently, the rules for application of UNFC-2009 uranium/thorium resources, as used by the Member States of NEA and IAEA, have been provided through “Bridging Document between the Organisation of Economic Co-operation and Development Nuclear Energy Agency/International Atomic Energy Agency Uranium Classification and UNFC-2009” (ECE/ENERGY/GE.3/2014/L.1). The alignment in this case has been made by a direct bridging of NEA/IAEA system to UNFC-2009 and complying with all UNFC-2009 definitions, generic specifications and CRIRSCO commodity specific specifications (Figure 12).

Many companies in different countries report uranium/thorium resources in the CRIRSCO Template. UNFC-2009 provides an excellent opportunity to understand the relationship between the NEA/IAEA Classification and CRIRSCO Template in a broad manner.

As many countries use their own diverse systems, which are approximately mapped to NEA/IAEA Classification, this mapping to CRIRSCO does not necessarily mean that each of the national system is fully in alignment with the CRIRSCO system. The mapping of NEA/IAEA Classification to the more granular UNFC-2009, through the CRIRSCO Template, may be treated with the same confidence as a bridging that exists between two aligned systems.

Figure 11
General Relationship between Exploration Target (Exploration Results), Mineral Resources and Mineral Reserves, as set out in the CRIRSCO Template



4.3.3 Mapping of CRIRSCO Mineral Reserves to NEA/IAEA Reasonably Assured Resources

A Mineral Reserve, defined under the CRIRSCO Template, corresponds to a Commercial Project under UNFC and a Reasonably Assured Resource under NEA/IAEA (Figure 12).

Under the CRIRSCO Template and UNFC system Mineral Reserves and estimates on Commercial Projects, may be compiled as quantities delivered to the process plant (tonnage and grade or quality), or as saleable product (tonnage and quality). Most metal deposits disclose Mineral Reserves at a “plant feed” reference point while most industrial mineral, coal, uranium and thorium reserves are reported as “saleable product”. The Competent Person must clearly state the “reference point” used to prepare the estimate. Under the NEA/IAEA system, Reasonably Assured Resource estimates are always expressed in terms of recoverable tonnes of uranium or thorium (“saleable product”). When results are transferred from either the UNFC or CRIRSCO into the NEA/IAEA system the transfer must account for any change in reference point which may occur.

A Mineral Reserve, defined under the CRIRSCO Template and Reasonably Assured Resource under NEA/IAEA, always correspond to UNFC Categories E1 and F1. Optionally, Mineral Reserves may be further sub-classified on the F axis into F1.1, F1.2 or F1.3, which correspond to “Existing”, “Committed” or “Planned” production centres under NEA/IAEA and “On Production (E1F1.1)”, “Approved for Development”(E1F1.2) and “Justified for Development” (E1F1.3) under

UNFC-2009. Mineral Reserves defined under the CRIRSCO Template are subdivided into Proved and Probable categories, which correspond to UNFC Categories G1 and G2. Since NEA/IAEA Classification does not subdivide Reasonably Assured Resources based on geologic confidence, UNFC G1, and G2 categories and corresponding CRIRSCO Proved and Probable Mineral Reserve classes are aggregated under NEA/IAEA (Figure 12).

Figure 12
Mapping of UNFC-2009, CRIRSCO Template and NEA/IAEA Classification

UNFC-2009 Classification					CRIRSCO Template		NEA/IAEA Classification		
UNFC Classes and Sub-classes		UNFC Categories			CRIRSCO Classes and Sub-classes				
Class	Sub-Class	E	F	G	Class	Sub-Class	IAEA-NEA Categories		Status
Commercial Projects	On Production	1	1.1	1	Mineral Reserves	Proved	Reasonably Assured Resources (RAR)		Existing
				2		Probable			
	Approved for Development	1	1.2	1		Proved			Committed
				2		Probable			
	Justified for Development	1	1.3	1		Proved			Planned
				2		Probable			
Potentially Commercial Projects	Development Pending	2	2.1	1	Mineral Resources	Measured	Identified Resources	RAR	Prospective
				2		Indicated			
				3		Inferred		IR*	
	Development On Hold	2	2.2	1		Measured		RAR	
				2		Indicated			
				3		Inferred		IR*	
Non-commercial Projects	Development Unclarified	3.2	2.2	1,2, 3	Inventory (not defined in Template)	Development Unclarified (not defined in Template)	Identified Resources RAR IR*		Unclarified
	Development Not Viable	3.3	2.3	1,2, 3		Not Viable (not defined in Template)			Not Viable
Exploration Projects		3.2	3.1	4	Exploration Target		Undiscovered Resources	Prognosticated Resources	
		3.2	3.2, 3.3	4				Speculative Resources	

*IR - Inferred Resources

4.3.4 Mapping of CRIRSCO Mineral Resources to NEA/IAEA Identified Resources

A Mineral Resource, defined under the CRIRSCO Template, corresponds to a Potentially Commercial Project under UNFC. An Identified Resource (RAR & IR) under the NEA/IAEA system corresponds to CRIRSCO Mineral Resource and Potentially Commercial Project under UNFC, when economics considerations meet CRIRSCO and UNFC criteria.

The CRIRSCO Template defines a Mineral Resource as a "concentration or occurrence of solid material of economic interest in or on the Earth's crust in such form, grade or quality and quantity that there are reasonable prospects for eventual economic extraction".

Although consideration must be given to mining, processing, metallurgical, economic, marketing, legal, infrastructure, environmental, social and governmental factors (the Modifying Factors) to justify "reasonable prospects for eventual economic extraction", Mineral Resource estimates do not typically include theoretical adjustments for mining, dilution or plant recovery. These adjustments are applied to Mineral Reserves after significant engineering has been completed. The UNFC system allows estimates on Potentially Commercial Projects to be prepared as *in situ* basis, quantities, plant feed (tonnage and grade or quality), or as saleable product (tonnage and quality), as long as the "reference point" is stated.

Under the NEA/IAEA system, Identified Resources are always expressed in terms of recoverable tonnes of uranium or thorium ("saleable product"). When results are transferred between the three systems the transfer must accommodate changes in "reference point".

A Mineral Resource defined under the CRIRSCO Template, and aN Identified Resource with "Prospective status" under NEA/IAEA, correspond to UNFC Categories E2 and F2. Optionally, the CRIRSCO and NEA/IAEA estimates may be further sub-classified on the F axis into UNFC-2009 "Development Pending" (F2.1) or UNFC-2009 "Development on Hold" (F2.2) subclasses (Figure 12).

In the NEA/IAEA Classification , quantities of Identified Resources (Reasonably Assured Resources plus Inferred Resources) shall correspond to UNFC-2009 requirements of E2 F2 where:

(a) project activities are on-going to justify development in the foreseeable future (Sub-categories E2, F2.1); or

(b) are on hold and/or where justification as a commercial development may be subject to significant delay. This shall correspond to "Prospective" production centre status (Sub-categories E2, F2.2).

Mineral Resources defined under the CRIRSCO Template are subdivided into Measured, Indicated and Inferred categories, which correspond to UNFC-2009 Categories G1, G2 and G3. Since NEA/IAEA Classification does not further subdivide RAR based on geologic confidence, UNFC-2009 G1 and G2 categories, and corresponding CRIRSCO Measured and Indicated Mineral Resource classes, are aggregated under NEA/IAEA (RAR). Inferred Resources under the NEA/IAEA scheme and Inferred Mineral Resources under the CRIRSCO Template correspond to G3 (Figure 12).

4.3.5 Conversion of Mineral Resources to Mineral Reserves

Conversion of CRIRSCO Mineral Resources to Mineral Reserves requires technical studies of at least pre-feasibility level to demonstrate that mining, processing, metallurgical, economic, marketing, legal, environmental, infrastructure, environmental, social and governmental factors (the Modifying Factors) have been adequately addressed and the project yields a positive financial return. In UNFC-2009, this requirement is also reflected in the definitions of the E1 and F1 Categories.

The Competent Person(s) may elect to convert Measured Mineral Resources to Probable Mineral Reserves if the confidence in the Modifying Factors is lower than that applied to a Proven Mineral Reserve. Indicated Mineral Resources can be converted to Probable Reserves. Inferred Resources shall not be converted to Mineral Reserves.

4.3.6 Reporting of Mineral Reserves and Mineral Resources: Inclusive versus Exclusive

The CRIRSCO Template allows Mineral Resources to be reported inclusive of, or exclusive of, Mineral Reserves as long as the approach used is clearly disclosed. Similar to CRIRSCO, UNFC-2009, also allow classes to be aggregated, if the approach is documented explicitly (e.g. 111+221). In contrast, the NEA/IAEA system only reports categories exclusive of each other. Special care should be taken to avoid double counting when transferring results between systems.

4.3.7 Mapping "Inventory"

In the CRIRSCO Template, where adequate geological studies have been carried out but preliminary assessment of the Modifying Factors indicates that the project does not have "reasonable prospects for eventual economic extraction", the mineralization is frequently classified as "inventory" and is not converted to a Mineral Resource. "Inventory" is not a defined term in the Template, and such quantities may not be disclosed in a Public Report. These quantities are classified in UNFC-2009 as either: 9a) E3F2 where the quantities are technically recoverable but are not expected to become economically viable in the foreseeable future (Sub-categories E3.3, F2.3) or (b) where economically viability cannot yet be determined due to insufficient information (Sub-categories E3.2, F2.2), or (c) E3F4 where no technically viable development project or mining operation can be identified (Sub-category E3.3).

In the NEA/IAEA Classification, quantities of Identified Resources shall correspond to UNFC-2009 requirements of E3 and F2.2 or F2.3, where the quantities are technically recoverable; however (a) economically viability cannot yet be determined due to insufficient information (sub-categories E3.2, F2.2) or (b) the resources are not expected to become economically viable in the very distant future (sub-categories E3.3, F2.3). The production centre status may be unclarified for these quantities.

4.3.8 Mapping Exploration Targets / Exploration Results

Exploration Results and Exploration Targets defined under the CRIRSCO Template generally correspond to an Exploration Project under UNFC and as Undiscovered Resources under NEA/IAEA. Under the CRIRSCO Template, when exploration activities have taken place but are insufficiently advanced to estimate a Mineral Resource, the exploration findings may be publically disclosed as Exploration Results and Exploration Targets. Exploration Results are insufficient to justify the public disclosure of a volume, tonnes, grade or quality of mineralization and cannot be stated as Mineral Resource.

However, when UNFC-2009 is used for other purposes, estimated quantities would be classified as E3F3 where the quantities are technically recoverable (Sub-categories E3.2, F3), or as E3F4 where no technically viable development project or mining operation can be identified (Sub-category E3.3).

Under NEA/IAEA Classification, the UNFC class Exploration Project, is subdivided into two categories of Undiscovered Resources (Prognosticated Resources and Speculative Resources). In UNFC-2009, the quantities estimated for Undiscovered Resources can correspond to E3, F3 and G4. Both Prognosticated and Speculative Resources require significant amounts of exploration before their existence can be confirmed and grades and tonnages of discovered resources can be defined. Additional sub-classification into Prognosticated Resources and Speculative Resources can be aided by Generic Specifications (see Generic specification "Classification of quantities associated with Exploration Projects", ECE Energy Series No. 42) [1].

4.3.9 Minimum standards

Note that the E and F Categories set minimum standards for the UNFC-2009 Classes. For example, a Potentially Commercial Project (Development Pending in Figure 12) must be at least E2 and F2, but it could be also E1F2 or E2F1.

4.4 Mapping to other systems

The definitions used in the NEA/IAEA system are not strictly comparable as the criteria used in the various systems are not identical. “Grey zones” in correlation are therefore unavoidable, particularly as the resources become less assured. Nonetheless, Figure 13 presents a reasonable approximation of the comparability of terms.

Figure 13
Approximate correlation of terms used in major resources classification systems

<table>
<tr><td></td><td colspan="3">Identified resources</td><td colspan="3">Undiscovered resources</td></tr>
<tr><td>NEA/IAEA</td><td colspan="2">Reasonably assured</td><td>Inferred</td><td>Prognosticated</td><td colspan="2">Speculative</td></tr>
<tr><td rowspan="2">Australia</td><td colspan="2">Demonstrated</td><td rowspan="2">Inferred</td><td colspan="3" rowspan="2">Undiscovered</td></tr>
<tr><td>Measured</td><td>Indicated</td></tr>
<tr><td>Canada (NRCan)</td><td>Measured</td><td>Indicated</td><td>Inferred</td><td>Prognosticated</td><td colspan="2">Speculative</td></tr>
<tr><td>United States (DOE)</td><td colspan="2">Reasonably assured</td><td colspan="2">Estimated additional</td><td colspan="2">Speculative</td></tr>
<tr><td>Russian Federation, Kazakhstan, Ukraine, Uzbekistan</td><td>A + B</td><td>C1</td><td>C2</td><td>P1</td><td>P2</td><td>P3</td></tr>
</table>

From a UNFC-2009 perspective, mapping is the output of a comparison between another resource classification system and UNFC-2009, or between that system and existing Aligned Systems, which highlights their similarities and differences. Mapping of a system to UNFC-2009 can therefore provide a basis for comparison not only between the two systems being compared, but also with other aligned systems, such as the NEA/IAEA system. Examples for preliminary mapping of different national systems to UNFC-2009 are provided below. It may be noted that these mappings are work in progress, and therefore will evolve as understanding of the inter-relationships are better understood through testing.

4.4.1 Mapping to USGS system

The U.S. Geological Survey (USGS) collects information about the quantity and quality of all mineral resources. In 1976, the USGS and the U.S. Bureau of Mines developed a common classification and nomenclature, which was published as USGS Bulletin 1450–A—“Principles of the Mineral Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Survey” [10]. Experience with this resource classification system showed that some changes were necessary in order to make it more workable in practice and more useful in long-term planning. Therefore, representatives of the USGS and the U.S. Bureau of Mines collaborated to revise Bulletin 1450–A. Their work was published in 1980 as USGS Circular 831—“Principles of a Resource/Reserve Classification for Minerals.”

Long-term public and commercial planning must be based on the probability of discovering new deposits, on developing economic extraction processes for currently unworkable deposits, and on knowing which resources are immediately available. Thus, resources must be continuously reassessed in the light of new geologic knowledge, of progress in science and technology, and of shifts in economic and political conditions. To best serve these planning needs, known resources are classified from two standpoints: (1) purely geologic or physical/chemical characteristics—such as grade, quality, tonnage, thickness, and depth—of the material in place; and (2) profitability analyses based on costs of extracting and marketing the material in a given economy at a given time. The former constitutes important objective scientific information about the resource and a relatively unchanging foundation upon which the latter more valuable economic delineation can be based. The revised classification system and mapping to UNFC-2009, is shown graphically in Figure 14. Mapping to UNFC-2009 is modified from the mapping shown in [12].

Figure 14
USGS Classification (black font) with mapping to UNFC-2009 (in red font)

CUMMULATIVE PRODUCTION	**IDENTIFIED RESOURCES**			**UNDISCOVERED RESOURCES**
	Demonstrated		**Inferred**	**Probability Range**
	Measured	**Indicated**		**Hypothetical (or) Speculative**
ECONOMIC	**Reserves** **Commercial Projects** **E1F1G1**	**Reserves** **Commercial Projects** **E1F1G2**	**Inferred Reserves** **Commercial Projects** **E1F1G3**	
MARGINALLY ECONOMIC	**Marginal Reserves** **Potentially Commercial Projects** **E2F2G1**	**Marginal Reserves** **Potentially Commercial Projects** **E2F2G2**	**Inferred Marginal Reserves** **Potentially Commercial Projects** **E2F2G3**	**Exploration Projects** **E3F3G4**
SUBECONOMIC	**Demonstrated sub-economic Resources** **Non-Commercial Projects** **E3F2G1**	**Demonstrated sub-economic Resources** **Non-Commercial Projects** **E3F2G2**	**Inferred sub-economic Resources** **Non-Commercial Projects** **E3F2G3**	

Other Occurrences	**Included nonconventional and low-grade materials**

4.4.2 Mapping to Geoscience Australia system

The mineral resource classification system used for Australia's national inventory is based on two general criteria:

- the geological certainty of the existence of the mineral resource, and
- the economic feasibility of its extraction over the long term.

In 1975, Australia (through the Bureau of Mineral Resources, which has evolved to become Geoscience Australia) adopted, with minor changes, the McKelvey resource classification system used in the United States [10] by the then U.S. Bureau of Mines and the United States Geological Survey (USGS). Australia's national system remains comparable with the current USGS system, as published in its Mineral Commodity Summaries.

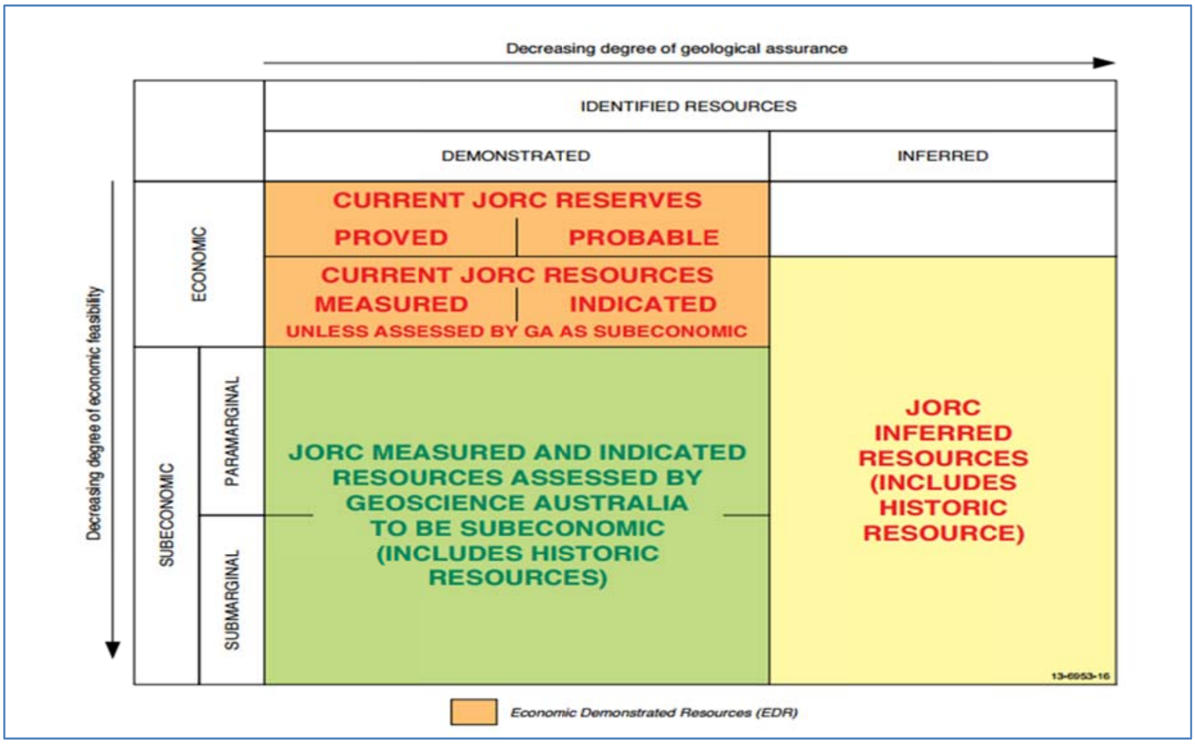
Companies listed on the Australian Securities Exchange are required to report publicly on ore reserves and mineral resources under their control, using the Joint Ore Reserves Committee (JORC) Code (see http://www.jorc.org/) [16]. This system has also evolved from the McKelvey system, so the national system and JORC Code are compatible. Data reported for individual deposits by mining companies are compiled in Geoscience Australia's national mineral resources database and used in the preparation of the annual national assessments of Australia's mineral resources. Estimating the total amount of each commodity likely to be available for mining in the long term is not a precise science. For mineral commodities, the long-term perspective takes account of the following:

- JORC Code Reserves will all be mined, but they only provide a short term view of what is likely to be available for mining.
- Most current JORC Code Measured and Indicated Resources are also likely to be mined.
- Some current JORC Code Inferred Resources will also be transferred to Measured Resources and Indicated Resources and Reserves.
- New discoveries will add to the resource inventory.

The national system for classification of Australia's identified mineral resources is illustrated in Figure 15. It classifies Identified (known) Mineral Resources according to two parameters, the degree of geological assurance and the degree of economic feasibility of exploitation. The former takes account of information on quantity (tonnage) and grade while the latter takes account of economic factors such as commodity prices, operating costs, capital costs, and discount rates.

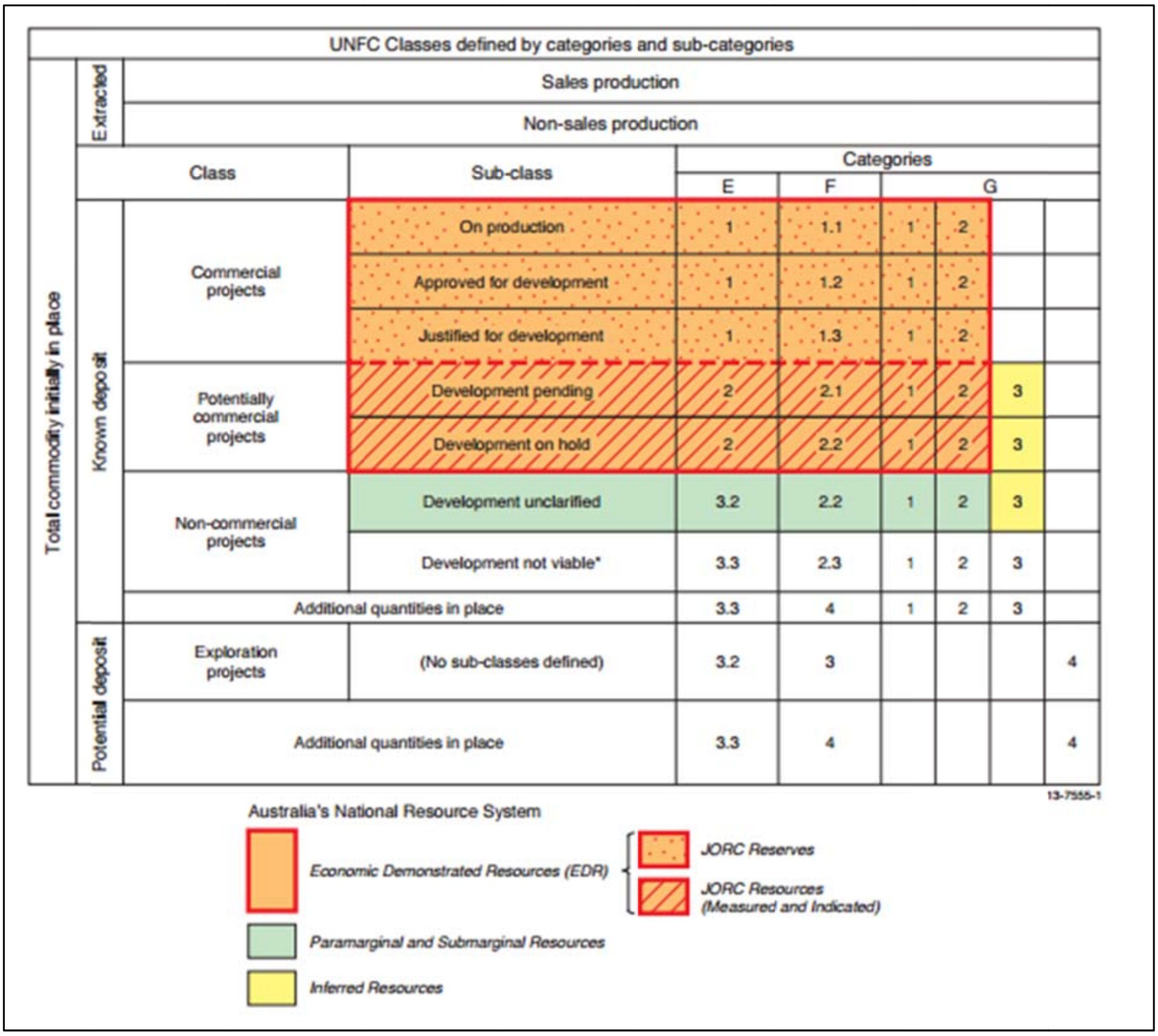
Resources are classified in accordance with economic circumstances at the time of estimation. Resources that are not available for development at the time of classification because of legal and/or land access factors are classified without regard to such factors, because circumstances could change in the future. However, wherever possible, the amount of resource affected by these factors is stated. Because of its specific use in the JORC Code, the term 'Reserve' is not used in the national inventory, where the highest category is 'Economic Demonstrated Resources' (EDR, Figure 16). In essence, EDR combines the JORC Code categories 'Proved Reserves', Probable Reserves', plus 'Measured Resources' and 'Indicated Resources', as shown in Figure 16. This is considered to provide a reasonable and objective estimate of what is likely to be available for mining in the long term.

Figure 15
Australia's national mineral resource classification system and its correlation with JORC Code mineral resource categories



Australia's national inventory of mineral resources has been mapped to UNFC-2009 (Figure 16) [13].

Figure 16
Correlation of Australia's national mineral resource classification system with UNFC-2009



As discussed previously (Figure 15), Geoscience Australia's EDR comprises JORC Reserves and JORC Resources where:

- the JORC Reserves component of EDR correlates with the UNFC's class of 'Commercial Projects' (as defined by mineral resource categories 111 and 112 in Figure 16); and
- the JORC Resources component correlates with 'Potentially Commercial Projects' (as defined by categories 221 and 222).
- Australia's national Subeconomic Resources (Paramarginal and Submarginal) correlate with a subclass of UNFC's 'Non-Commercial Projects' (categories 3.2; 2.3; 1,2).
- Geoscience Australia's Inferred Resources are identified by the UNFC geological criterion G3 and is defined by 223.

UNFC-2009's mineral resource classes under 'Potential Deposits' comprise Exploration Results under the JORC Code and various types of quantitative estimates of undiscovered mineral resources that are not currently assessed under Geoscience Australia's national mineral resource system.

4.4.3 Mapping to Ukraine national classification system

Ukraine was the country to implement UNFC of 1997 at the state level in 1997 [18]. Ukraine also developed a universal classification adapted to all types of mineral resources (coal, oil, gas, non-metallic products, solid minerals, and groundwater). The relevant guidelines have been issued in Ukraine to apply the "Classification of Mineral Reserves and Resources of the State Subsoil Fund" to all types of minerals. This classification was approved by Resolution No. 432 of the Cabinet of Ministers of Ukraine dated May 5, 1997. This classification stipulates the principles of calculation, economic-geological evaluation and public accounting of mineral quantities according to their level of commercial value, degree of geological exploration and technical and economic studies. The guidelines also include preparedness of explored mineral deposits for commercial development and the basic criteria for quantitative estimation.

The national classification of Ukraine sub-divide resources based on three basic criteria (Table 3):
- Commercial value
- Degrees of technical and economic investigation
- Geological exploration

The State Subsoil Fund of Mineral Deposits includes quantities of uranium of Metasomatite and Sandstone types. The balance reserves of Metasomatite type is sub-divided in cost categories of less than $40/kg and less than $80/Kg and off-balance reserves include more than$80/Kg. The off-balance reserves of Sandstone type include cost category of less than $40/Kg. Quantities of uranium in other geological types are attributed to those with undetermined commercial value.

Table 3
National classification of Ukraine: Subdivision of Mineral Reserves and Resources

Commercial Value	**Degree of technical and economic investigation**	**Degree of geological exploration**	**Class code**
1. Balance reserves	EGE-1	Explored (proved) reserves	111
	EGE-2	Explored (proved) reserves	121
	EGE-2	Prospected (probable) reserves	122
2. Conditionally balance and off-balance reserves	EGE-1	Explored (Proved) reserves	211
	EGE-2	Explored (Proved) reserves	221
	EGE-2	Prospected (probable) reserves	222
3. Commercial value undetermined	EGE-3	Prospected (probable) reserves	332
	EGE-3	Prospective resources	333
	EGE-3	Prospective resources	334

Note:

Mineral Reserves – Quantity (volumes) of minerals, calculated within discovered (identified) mineral deposits of which fitness for commercial use has been proved in terms of quantity, quality and mode of occurrence of mineral.

Explored (proved) reserves – Volumes of minerals explored with completeness sufficient to develop projects for mining and processing facilities; Prospected (probable) reserves – Volumes of minerals explored with completeness sufficient to determine the commercial value of a field or site.

Prospected (probable) reserves – Volumes of minerals explored with the completeness sufficient to determine the commercial value of the field in general or site thereof.

Mineral Resources – Quantity (volumes) of minerals of a specific geologic-production type, determined (estimated) as potential for identification beyond discovered field, but within productive areas with known mineral deposits of the same geologic-production type or within prospective areas, where there are no commercial fields discovered yet.

Prospective resources – Quantitatively consider the possibility of discovering new fields (deposits) of a specific geologic-production type, the existence of which is justified by the positive evaluation of mineral shows, geophysical, geochemical and other anomalies, the nature and prospectivity of which have been proved, within productive areas with known mineral deposits of the same geologic-productive type.

EGE-1 (Detailed economic-geological evaluation), of an explored field shall be carried out to determine the cost-effectiveness level of the production activities of a mining enterprise being created or reconstructed, and the expediency of investment in the activities related to design and construction.

EGE-2 (Preliminary economic-geological evaluation), of a mineral field (deposit) shall be carried out to determine the expediency of its commercial development and investment in the activities related to its exploration and survey and preparation for exploration.

EGE-3 (Initial economic-geological evaluation) is carried out to justify the expediency of investment in the prospecting and exploration activities on sites, prospective for discovering mineral deposits.

Balance reserves – Includes reserves, the extraction and utilization of which, at the time of estimation, according to calculations, are cost-effective, with state-of-the –art equipment and technology of extraction and processing of minerals, ensuring the compliance with requirements for rational, complex use of minerals and environmental protection.

Conditionally balance reserves – Includes reserves, the effectiveness of the extraction and utilization of which, at the time of estimation, cannot be unambiguously determined, as well as that meet the requirements (conditions) for balance reserves, but cannot be utilized at the time of estimation for various reasons.

Off-balance reserves – Includes reserves, the extraction and utilization of which are economically inexpedient, but they can become an object of commercial value in the future.

Commercial value undetermined – Reserves and resources for which initial economic-geological evaluation has been only performed based on possible technological and economic input data.

The mapping of the Ukrainian Classification of Mineral Reserves and Resources to UNFC-2009 is shown in Table 4.

Table 4
Mapping of Ukrainian Classification to UNFC-2009; modified from [18]

Commercial value category	**Technical and economic examination category**		**Geological investigation category**	**Class code**	**UNFC-2009 categories**	**UNFC-2009 Class**
1. Balance reserves (1..)	EGE-1 (.1.) Producible and approved for development		Explored reserves (..1)	111 (Proved)	E1;F1,G1,2	Commercial Projects
	EGE-2 (.2.) Proved for development		Prospected reserves (..2)	121 (Probable)		
				122 (Probable)		
2. Conditionally balance and off-balance reserves (2..)	Pending development	EGE-1(.1.)	Explored reserves (..1)	211	E2;F2;G1,2	Potentially Commercial Projects
				221		
		EGE-2 (.2.)	Prospected reserves (..2)	222		
3. Commercial value not defined (3..)	Development not clarified	EGE-3(.3)	Explored reserves (..1)	331	E3;F2;G1,2	Non-commercial projects
			Prospected reserves (..2)	332		
			Prospective resources (..3)	333	E3;F3;G4	Exploration projects
			Prognostic resources (..4)	334		

4.4.4 Mapping to China National System

The China Mineral Reserves and Resources Classification System (CMRRCS) for solid minerals was established in 1999 [19, 20]. It was formulated on the basis of the principles of UNFC-1997. Both these systems use E, F, G axes (see Table 5). As shown in Table 5, CMRRCS has 16 categories.

A high-level mapping of UNFC-1997 to UNFC-2009 is available [21]. The UNFC–2009 category definitions reflect general principles rather than more specific and detailed requirements of UNFC–1997, such as the existence of a specific type of report. In most cases, but not all, the intention is that the two definitions are aligned in terms of level of knowledge and/or confidence.

Mapping of E, F and G categories are shown in Tables 6, 7 and 8. In general, it can be demonstrated that this is no material change in UNFC-1997 and UNFC-2009 categories.

However, mapping of E, F and G on an individual basis do not have a one-to-one correspondence between CMRRCS and UNFC-2009 (Table 9). Hence, mapping has been done on the basis of giving precedence to E category, where E1, E2 and E3 maps directly to CMRRCS 1, 2 and 3, respectively. CMRRCS 2M and 2S (denoting Marginal Economic and Sub-Marginal Economic) are mapped directly to UNFC-2009 sub-classes of E2F2.1 and E2F2.2.

Table 5
China Mineral Reserves and Resources Classification System (CMRRCS) for solid minerals

Economic Viability	Geological Study			
	Identified mineral resources			Potential mineral resources
	Measured	**Indicated**	**Inferred**	**Prognostic**
Economic	**Minable reserve（111）**			
	Basic reserve（11lb）			
	Pre-minable reserve（121）	**Pre-minable reserve（122）**		
	Basic reserve（12lb）	**Basic reserve（122b）**		
Marginal Economic	**Basic reserve（2M11）**			
	Basic reserve（2M21）	**Basic reserve（2M22）**		
Sub-Marginal Economic	**Resource（2S11）**			
	Resource（2S21）	**Resource（2S22）**		
Intrinsically Economic	**Resource（331）**	**Resource（332）**	**Resource（333)**	**Resource（334）**

Note: 1) the first number represents economic viability, where 1=economic, 2M= Marginal Economic; 2S=Sub-Marginal Economic; 3= Intrinsically Economic. 2) the second number represents status of project feasibility study, where 1= feasibility study; 2=pre-feasibility study. 3= Scoping study; 3) the third number represents geologic study, where 1=measured; 2=indicated; 3=inferred; 4=prognostic. 4) b=minable reserve with no consideration of mining losses.

Table 6
Mapping of E axis of UNFC-1997 and UNFC-2009

UNFC-1997	UNFC-2009	Discussion
1	E1	No material change, other than being based on principles rather than a specific (defined) type of report.
2M 2S	E2	No material change unless 2M and 2S include quantities that are not expected to become economically viable in foreseeable future. These now would have to be classified as E3 (UNFC-2009)
3	E3	No material change, since 3 (CNS) would be consistent with: “economic viability of extraction cannot yet be determined due to insufficient information” E3 (UNFC-2009) also includes uneconomic quantities and those that will be extracted but not sold.

Table 7
Mapping of F axis

UNFC-1997	UNFC-2009	Discussion
1	F1	F1 (UNFC-2009) is based on the principle of having undertaken sufficient detailed studies have been completed to demonstrate that the project can proceed. Also includes quantities where extraction is currently taking place; or, implementation of the development project or mining operation is underway.
2	F2	No material change, other than being based on principles rather than a specific (defined) type of report.
3	F3	No material change, other than being based on principles rather than a specific (defined) type of report.
N.A.	F4	New category in UNFC-2009 for *in situ* (in-place) quantities that will not be extracted by any currently defined development project or mining operation.

Table 8
Mapping of G axis

UNFC-1997	UNFC-2009	Discussion
1	G1	No material change provided that the level of geological knowledge and confidence is of high level.
2	G2	No material change provided that the level of geological knowledge and confidence is of moderate level.
3	G3	No material change provided that the level of geological knowledge and confidence is of low level.
4	G4	No material change. Although the UNFC 2009 definitions are written so that they can be applied at the level of an individual deposit (even at the exploration stage, as is commonly done in the petroleum sector), they may also be applied at a regional scale to document resource potential for a geological province, for example. Such applications are discussed in the Specifications to UNFC 2009.

Mapping of the F category of CMRRCS has considerable overlaps with the respective categories of UNFC-2009. This could be only resolved on the basis of EF combinations of the 16 CMRRCS classes.

The mappings of G axis categories are relatively straight forward.

The mapping of CMRRCS to UNFC-2009 classification is shown in Tables 9 and 10.

It can be seen that while mapping of CMRRCS classes to UNFC-2009 Classes is quite straight forward, mapping of UNFC-2009 sub-classes in most cases is not defined. Although use of sub-cases is an optional feature of UNFC-2009, it could be highly useful for certain situations. Transfer of quantities from CMRRCS to UNFC-2009 sub-classes will require application of UNFC-2009 principles and specifications on a project by project basis.

Table 9
Mapping of CMRRCS to UNFC-2009 Categories

No.		CMRRCS			UNFC-2009		
		E	F	G	E	F	G
1	Economic Measured Minable reserve	1	1	1	1	1	1
2	Economic Measured Basic reserve	1	1	1b*	1	1	1
3	Economic Measured Pre-minable reserve	1	2	1	1	1.2, 1.3	1
4	Economic Measured Basic reserve	1	2	1b*	1	1.2; 1.3	1
5	Economic Indicated Pre-minable reserve	1	2	2	1	1.2; 1.3	2
6	Economic Indicated Basic reserve	1	2	2b*	1	1.2; 1.3	2
7	Marginal Economic Measured Basic Reserve	2M	1	1	2	2.1	1
8	Marginal Economic Measured Basic Reserve	2M	2	1	2	2.1	1
9	Marginal Economic Indicated Basic Reserve	2M	2	2	2	2.1	2
10	Sub-Marginal Economic Measured Basic reserve	2S	1	1	2	2.2	1
11	Sub-Marginal Economic Measured Basic reserve	2S	2	1	2	2.2	1
12	Sub-Marginal Economic Indicated Basic reserve	2S	2	2	2	2.2	2
13	Intrinsically Economic Measured Resource	3	3	1	3.2, 3.3	2.2; 2.3	1
14	Intrinsically Economic Indicated Resource	3	3	2	3.2, 3.3	2.2; 2.3	2
15	Intrinsically Economic Inferred Resource	3	3	3	3.2, 3.3	2.2;2.3	3
16	Intrinsically Economic Prognostic Resource	3	3	4	3.2	3	4

* When transferring to UNFC-2009, should be adjusted to recoverable quantities.

Table 10
Mapping of CMRRCS to NEA/IAEA uranium resource Categories and UNFC-2009 Classes

UNFC-2009 Classification					NEA/IAEA Classification			CMRRCS
UNFC Classes and Sub-classes		UNFC Categories						
Class	Sub-Class	E	F	G	IAEA-NEA Categories		Status	
Commercial Projects	On Production	1	1.1	1, 2	Reasonably Assured Resources (RAR)		Existing	111 111b 121 121b 122 122b
	Approved for Development	1	1.2	1, 2			Committed	
	Justified for Development	1	1.3	1, 2			Planned	
Potentially Commercial Projects	Development Pending	2	2.1	1, 2, 3	Identified Resources	RAR IR*	Prospective	2M11 2M21 2M22
	Development On Hold	2	2.2	1, 2, 3		RAR IR*		2S11 2S21 2S22
Non-commercial Projects	Development Unclarified	3.2	2.2	1,2,3	Identified Resources RAR IR*		Unclarified	331 332 333
	Development Not Viable	3.3	2.3	1,2,3			Not Viable	
Exploration Projects		3.2	3.1	4	Undiscovered Resources	Prognosticated Resources		334
		3.2	3.2, 3.3	4		Speculative Resources		

Note: See Table 5 for details of CMRRCS classes

5. APPLICATION OF UNFC-2009 FOR NUCLEAR FUEL RESOURCES

5.1 POLICY, REGULATIONS AND GOVERNANCE

5.1.1 Peaceful Uses

The IAEA rationale and vision for the peaceful uses of nuclear energy defines that: "Any use of nuclear energy should be beneficial, responsible and sustainable, with due regard to the protection of people and the environment, non-proliferation, and security" [22]. The basic principles on which nuclear energy systems should be based to help meet growing global energy needs include uses that are: (1) beneficial; (2) responsible and (3) sustainable.

IAEA further has defined the criteria necessary to satisfy these basic principles of peaceful use when applied to the classification and beneficial use of uranium resources in the generation of energy [23]. These are as follows:

- Benefits: Uranium resources are characterized utilizing best practices that contribute to long term management of the uranium production cycle. An understanding of the availability of nuclear fuel resources[5] is essential for the planning and development of all aspects of the utilization of the nuclear fuel cycle. This involves the following activities:
  - Classification of uranium deposits
  - Updated information on world uranium resources
  - Analysing uranium supply and demand for postulated nuclear power growth scenarios
- Transparency: Information on natural uranium technologies, good practices across the uranium production cycle, and on the associated risks and benefits is distributed and discussed, engaging stakeholders and the general public.
- Protection of People and the Environment: Effective legislation, regulation, monitoring and technological provisions are developed and implemented for the protection of people and the environment at all stages of the uranium production cycle.
- Security: Nuclear security measures are addressed and implemented during all stages of the uranium production cycle.
- Non-Proliferation: Non-proliferation requirements and procedures regarding mining and milling operations are implemented as required by the additional protocol in IAEA Member States, where applicable.
- Long Term Commitment: Evaluation of the supply of uranium includes assessments of long term supply and availability.
- Resource Efficiency: Uranium recovery processes continue to develop in ways that are increasingly efficient, effective and economic.
- Continual Improvement: The uranium production industry continually benefits from and incorporates changes through lessons learned and information exchange.

5.1.2 Project Licensing and Operation

In operating mining and processing projects, according to the criteria for sustainable development the following policy, legal and regulatory considerations may apply [24]:

- Stable national government
- A coherent and transparent licensing strategy based on a well-founded understanding of all components of licensing, a balanced and well-coordinated legal and engineering team, clear delineation of roles and responsibilities as between government and the operator and a clear time-line

[5] Natural uranium and thorium are the basic raw materials for fuels for nuclear reactors. The present generation of nuclear reactors uses mostly uranium raw material for fuel fabrication. The statements in this section on uranium raw materials and resources are generally also applicable to thorium. The uranium production cycle covers mining and milling, including mine and mill remediation.

- Stakeholder engagement
- An reasonable royalty scheme allowing the government to receive payments for the depletion of mineral resources
- Appropriate land use planning and legislation
- Complementary mining laws, permitting the rent or lease of the mine site and associated lands
- Fair resolution of any consequences for land ownership and/or use whether in heavily populated areas of where population displacement may be a serious social issues
- Appropriate regulations concerning uranium mining and processing both as a NORM industry and in regard to radiation protection and environmental protection objectives, whether at federal, provincial/state or tribal levels. Under modern mining regimes the responsibility for identifying and correcting health and safety hazards in the workplace is shared among all parties involved – employers, contractors, owners, supervisors and workers. National laws are enforced by a workplace regulator that independently inspects, reviews, records and promotes workplace safety [25]. International safety standards provide support for States in meeting their obligations under general principles of international law, such as those relating to environmental protection. International safety standards also promote and assure confidence in safety and facilitate international commerce and trade [26].
- Environmental regulations, which may have a material effect on the economics of the operations and the timing of project development. A successful uranium and thorium recovery Increasing globalization of the mining industry is leading to greater uniformity of a range of regulatory controls. This is especially true for environmental standards and regulations. Adoption of similar environmental standards reflects policies based on science as well as recognition that in a competitive world economy, objective, uniform standards promote development and international competitiveness.

5.1.3 Legislation framework for sustainability and environmental protection

Legislation must provide protection to the environment and to local communities, considering both current operations and the longer term, including post mine closure. Environmental assessment legislation is necessary and must be framed in a manner to allow all interested parties, in particular people and communities close to a proposed mine site, an opportunity to comment on and influence the direction of the proposed development.

Most companies now routinely anticipate and plan for the most stringent environmental controls and apply them uniformly around the world. The increased emphasis on sustainability is also leading to more formal consideration of social impacts. Currently this is most visible through provisions for stakeholder input and the public review process. Different mining and milling situations, as represented by different deposit types and mining methods, will be capable of supporting different levels of regulatory controls.

5.1.4 Human resources

It is necessary but not sufficient simply to have policy and legal structures in place. Governments should also staff necessary agencies (particularly environmental and occupational health and safety agencies) with competent, properly trained personnel and ensure that they have sufficient resources to carry out necessary inspections and enforcement.

5.1.5 Transparency and flexibility

An important part of the governance system is transparency. This requirement for transparency applies equally to both government and industry. For regulators transparency is important as it gives other stakeholders such as communities, landholders, and civil society, confidence that all aspects of sustainability are being considered during approval and subsequent regulation of an operation. Where regulators do not allow for transparency in their actions, there is a risk that stakeholders will perceive they are working in collusion with industry. Regulators will need to understand where flexibility is permissible in order to provide the optimum in economic development, environmental protection, and social benefits [24].

5.1.6 International safeguards

Due to the potential use of uranium in nuclear weapons programmes, uranium production is subject to an additional set of constraints not applied to other mineral developments. The IAEA was created to allow countries with nuclear technology to share it with other countries in return for an agreement not to use that technology for weapons development. As a result, international trade in uranium requires that parties agree to IAEA safeguards [24].

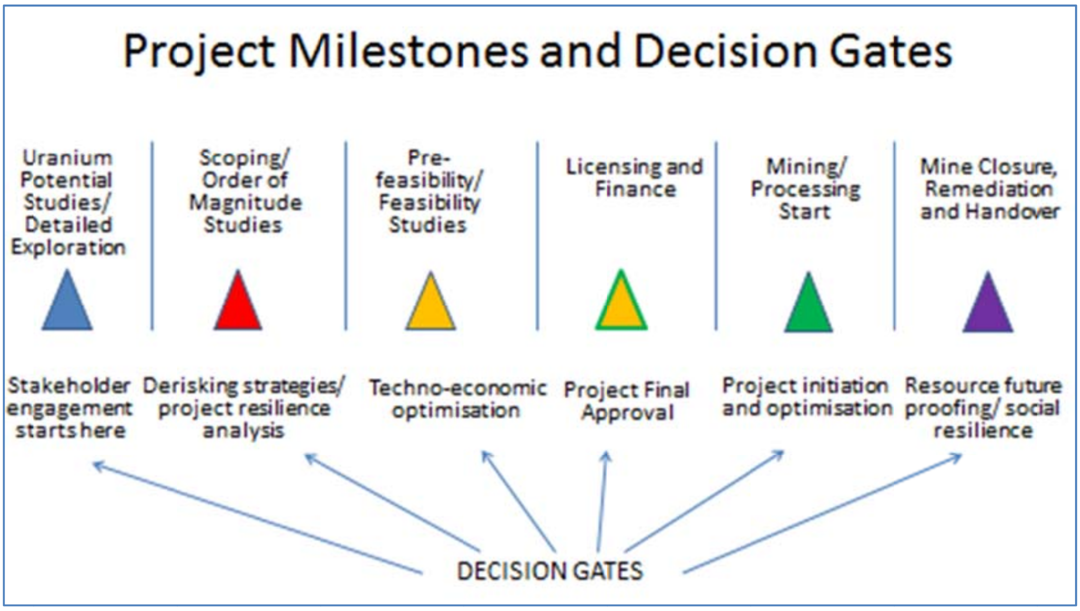
Safeguards on uranium mining and milling facilities consist of verifying the activities declared by the State and the absence of undeclared activities through the implementation of an additional protocol (AP) [27]. Detailed nuclear material accountancy at such facilities is not required by an AP nor by a comprehensive safeguards agreement [28], unless the source material has reached "a composition and purity suitable for fuel fabrication or for being isotopically enriched". Allowing safeguards verification under an AP at mining and milling facilities would help to ensure that all mining and milling operations comply with IAEA safeguards requirements [23].

Some countries also require bilateral agreements between the producing country and the customer country. The safeguards system requires accounting for all the uranium transferred between countries and between facilities within countries, with periodic physical inspections to verify accountability records [24].

5.2 MILESTONES AND DECISION GATES

The adoption of milestone and decision-gate approach to supporting uranium mining and processing projects can facilitate smooth project planning and operation across the full project life-cycle including eventual closure, decommissioning and site handover. The methodology aligns with the UNFC criteria, geological knowledge, project feasibility, socio-economic viability focused on key milestones in a project life. A prerequisite of successful application of the model is a thorough needs and gap analysis. Based on the conclusions of the gap analysis capacity-building and resource deployment is targeted to a specific milestone rather than attempting to cover the whole life-cycle at once. The desired outcome is a progressive strengthening of policy and regulatory frameworks achieved at a pace that a government can sustain, especially in a country where there is little or no familiarity with the demands of designing, licensing and operating a uranium mining and milling project (Figure 17). Of these milestones the fulcrum is the (pre-) feasibility study. Once passed, the selected control points effectively allow decision-makers to monitor overall preparedness in the mining and processing life cycle and to apply decision gates to each critical control point in the project life-cycle.

Figure 17.
Milestones and Decision Gates in the Uranium Mining and Processing Life-Cycle



Because the milestones are generic in nature the methodology can be used by a wide range of mining and mineral processing projects, meaning that the return on investment can be much broader than simply from the uranium sector. Significant qualitative improvements and cost savings can be effected across a project life-cycle by focusing attention in a similar manner on a small group of control points. A particular feature of the method is the "one up/ one down" approach to project teamwork, communications and documentation in the life-cycle. The owners of and stakeholders in any given milestone must have a good understanding of, and close working relationship with, their counterparts responsible for a) the milestone that precedes theirs ("one up" and b) the one that follows theirs ("one down"). That way the risk of losing key institutional knowledge and project momentum between the stages in the project life-cycle is much reduced.

5.3 Application of CRIRSCO Commodity-Specific Specifications

"Commodity-specific specifications for solid minerals" adopted by UNFC-2009 are provided through the CRIRSCO Template [4]. The relationship between UNFC-2009 and the CRIRSCO Template is explained in in the "Bridging Document Between the CRIRSCO Template and UNFC-2009" (see Annex III, page 31 of UNFC-2009) [1]. CRIRSCO Commodity Specific specifications for Mineral Resource, Mineral Reserve and Exploration Results are compiled in proceeding section 3.3.1.1.

5.4 SOCIO-ECONOMIC VIABILITY

5.4.1 Application of E categories

UNFC-2009 defines E1, E2 and E3 based on economic viability of the project. It may be noted that the phrase "economically viable" encompasses economic (in the narrow sense) plus other relevant "market conditions", and includes consideration of prices, costs, legal/fiscal framework, environmental, social and all other non-technical factors that could directly impact the viability of a development project. In classifying estimated quantities that may be extracted in the future from a development project or mining operation, the E-axis Categories are explicitly defined to include both environmental and social issues that may be relevant to the commercial viability of such a venture, in addition to economic, legal and other non-technical factors.

In particular, the identification and consideration at the time of the estimate of all known environmental or social impediments or barriers to the project during its entire life cycle is recognized as an integral part of the project assessment. The presence of environmental or social impediments can prevent a project from proceeding or it can lead to the suspension or termination of activities in an existing operation.

The Economic axis Categories encompass all non-technical issues that could directly impact the viability of a project, including commodity prices, operating costs, legal/fiscal framework, environmental regulations and known environmental or social impediments or barriers. Any one of these issues could prevent a new project from proceeding (and hence quantities would be classified as E2 or E3, as appropriate), or it could lead to the suspension or termination of extractive activities in an existing operation. Where extractive activities are suspended, but there are “reasonable prospects for economic extraction and sale in the foreseeable future”, remaining technically recoverable quantities shall be reclassified from E1 to E2. Where “reasonable prospects for economic extraction and sale in the foreseeable future” cannot be demonstrated, remaining quantities shall be reclassified from E1 to E3.

Sub-categories E1 and E3 can be used define projects more accurately. For example, if uranium production is done for national programmes, and when cost of production is assumed to be higher the market prices, E1.2 category may be applied. But it should be noted that there is no obligation to make such a distinction in any reporting (the use of sub-categories is optional).

Thorium currently has minor commercial applications. It is considered as a potential fuel for present and future generation nuclear reactors [29]. Presently, thorium is being produced as a by-product of mining and processing other mineral commodities, such as rare earth elements; at some operations thorium minerals are stockpiled for future use. Provided that thorium is stored in a manner in which it remains available for future commercial sale, it may be assigned to E3.2 or E3.3 (and subsequently moved to E2 and E1 once a large scale commercial market emerges for thorium as a nuclear reactor fuel).

5.4.2 Foreseeable future

As elaborated in Generic Specification H, the distinction between quantities that are classified on the Economic axis as E1, E2 or E3 is based on the phrase “reasonable prospects for economic extraction and sale in the foreseeable future”. The definition of “foreseeable future” can vary depending on the commodity and hence more detailed specifications can be found in relevant commodity-specific systems that have been aligned with UNFC-2009.

IAEA’s International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) has developed a set of basic principles, user requirements and criteria together with an assessment method, which taken together, comprise the INPRO methodology, for the evaluation of a national or global nuclear energy system in regard of its long term sustainability. INPRO methodology area of environmental impact by depletion of resources [30] consists of the basic principle that seeks to assure that the nuclear energy system (NES) will be capable of contributing to the energy needs in the 21st century while making efficient use of non-renewable resources that it needs for construction, operation and decommissioning. The first user requirement of this methodology, which is pertinent to discussion here, seeks to confirm that the NES assessed will not run out of resources such as fissile and fertile material and other non-renewable materials during its lifetime. The operator of the NES is asked to confirm that sufficient resources of fissile/fertile material and other key materials are available during the intended lifetime of the system. The various criteria under this requirement seek confirmation of availability of natural uranium and thorium for 100 years from now.

In line with the requirement as above, INPRO’s collaborative project (CP) called Global Architecture of Innovative Nuclear Energy Systems based on thermal and fast reactors including a closed fuel cycle (GAINS) [31] studies the demand for uranium resources by possible nuclear energy systems (NES) until the end of the 21st century.

IAEA's Analysis of uranium supply to 2050 looks in the availability of uranium over 50 years. The "Red Book" on the other hand, based on official submissions from different countries looks into the demand and supply of uranium into a medium-term of 25 years from now. The latest edition of the "Red Book" provides projections up to 2035.

5.4.3 Social licence to operate

Since the beginning of this century, the concept of the social licence to operate (SLO) has gained significantly in both clarity and adoption [32]. The SLO has an intangible aspect, the unwritten but well-respected process a mining and processing project has to undergo, and continue, of winning and keeping the acceptance of the communities most directly affected by a given project, along with its many direct and indirect stakeholders.

How this process is conducted will vary from project to project and community to community; but a key to its success is finding a realistic but equitable distribution of benefits between shareholders and stakeholders. This process is increasingly critical to the E axis of resource progression under UNFC 2009, and hence critical to a project's overall success.

The SLO, once agreed, defines the point of equilibrium in the negotiation [33], the moment that marks a stable relationship between investment in capital expenditure (CAPEX) and equivalent investment in social capital (SOCEX). If this equilibrium is achieved both parties benefit, making the project sustainable for the longer term. As the mining and processing industry is now increasingly aware, success in the negotiation is more likely to be SOCEX than CAPEX dependent. Hence from the outset, the prospective operator, and its owners, need to be aware what social capital will be required to execute a project, starting with the definition of what "community dividend" must be targeted to make the project sustainable across up to four generations of the same community [34]. A dependable community dividend is a key measure of the ongoing capacity of a project to deliver benefits throughout its life-cycle, a means by which the communities engaging in the project can see a perspective for sustainability even after the project has finished.

Social capital is a function of the relationship between a community's needs, the technology available to it, and its culture [35]. Social capital is effectively compromised if an operator seeks simply to purchase approval by the wrong kind of incentive. But a project obviously cannot survive on social capital alone. Sustainable businesses that depend on maintaining this point of equilibrium must show measurable financial, social and environmental benefits throughout the project's life cycle [36]. This is what is termed as the Triple Bottom Line (TBL). Making the TBL work in a mining and processing project in an operationally sustainable manner requires three complementary strategies, one for each component of the TBL:

- Techno-economic – Efficiency in operations
- Social – Social licence to operate
- Environmental – Reduce the footprint

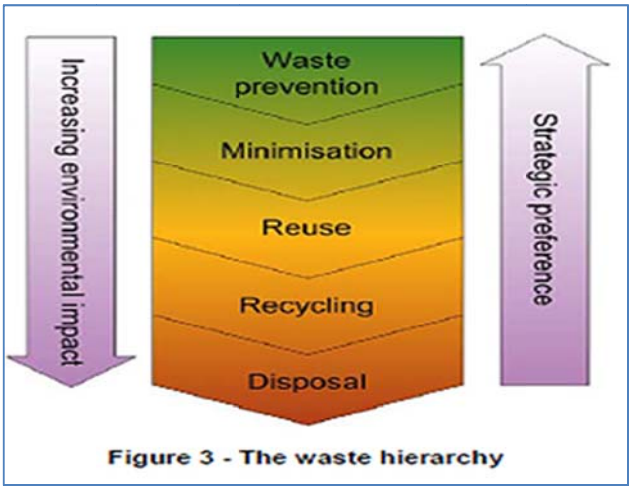
A key performance indicator may be found at the point of convergence between the social and environmental namely the approach to waste. The discredited "sink industry" model of mining and processing, with some justification portrays the industry as one that focuses solely on profit with no regard either to the social or the environmental consequences.

Investment should result in increased, self-sustaining social capital, based on capacity building, infrastructure development and long-term community/operator partnership. Success may be manifest in such outcomes as technology transfer and technology spill-over. The investment must also result in internationally recognized health and safety standards. Equitable distribution of benefits between community and operator short and longer term should reflect evolving stakeholder needs and cultures [37].

5.4.4 Environmental and social impact assessment

The concept of an environmental and social impact assessment (ESIA) for any project has gained acceptance in project planning and licensing, to the extent that it is increasingly mandatory in countries around the world. Central to an ESIA is the policy on waste, whether focused on prevention, or its management [38]. Dealing with wastes is best conducted according to a "hierarchy" of options (Figure 18) of which indefinite disposal is the least favoured [39].

Figure 18
The European Union Waste Hierarchy



By contrast, reuse, recycling and the recovery of energy from wastes has now become central to the project life-cycle. In this new model, provision for "end of life" (EoL) requirements, some of which, such as progressive remediation, run in parallel with the project must be included in the project financials, including a care and maintenance plan with associated financial resources, for any residues or tailing left behind. An effective plan for waste, with, as a vision, "zero waste" as the outcome meets the expectation of Fundamental Safety Principle 7 [26, 40] according to which no legacy problem should be left of subsequent generations than can be dealt with in the current generation. Hence the waste plan may be the key to unlocking the social licence and hence to mitigate one of the key financial risks that any long-term project may face, its rejection by its local community and stakeholders [41].

5.4.5 Radiation protection

The ALARA principle for worker radiation protection requires that exposure to risks arising from radiation needs to be kept as low as reasonably achievable, with social and economic factors being taken into account [42, 43, 44, 45]. In addition, there is an absolute limit to the allowable exposure of any one individual, regardless of the benefit to society as a whole. Often, the ALARA principle is wrongly viewed as mandating that concentrations of a constituent in the discharge shall be as low as achievable [46].

5.4.6 Closure and remediation

The issue of closure, decommissioning and remediation requires careful consideration [47, 48]. The mining industry has many examples of abandoned sites that continue to have adverse environmental impacts many years after shutdown. Appropriate planning from the outset can avoid these problems by creating long term plans for final disposal of wastes and return of the site to a safe condition that minimizes restrictions on future use. In some countries closure plans are required as part of the initial licensing process. Plans for long term containment of radioactive wastes are essential. Legislation should ensure that sites are properly remediated and can be handed back to the government. Today, in most jurisdictions, best practice requires a company to provide from the outset of a project a financial instrument of some type (bank guarantee, bond, trust fund, etc.). This is to ensure that costs for remediation and subsequent ongoing monitoring and potential remedial and maintenance work can be met without additional costs to the state, especially if a mining company should cease operations unexpectedly or suffer financial failure.

Many stakeholders are concerned about the environmental and socio-economic impacts of uranium mining project well beyond the active time of the mine. A comprehensive life-cycle management approach is needed in order to ensure the sustainability of the project.

5.5 PROJECT FEASIBILITY

5.5.1 Application of F categories

UNFC-2009 is a project-based system, therefore careful consideration as all stages will have to be given to the project feasibility criteria.

Identified Resources (RAR and IR) estimates are expressed in terms of recoverable tonnes of uranium—quantities of uranium recoverable from mineable ore—as opposed to quantities of uranium contained in mineable ore or quantities *in situ*, which does not take into account mining and milling losses. Other than quantities that are classified as F4, all reported quantities shall be limited to those quantities that are potentially recoverable on the basis of existing technology or technology currently under development, and are associated with actual or possible future exploration/development projects or mining operations.

5.5.2 Recovery factors

The recoverability factors that may be applied in conceptual levels studies can be derived from the "Red Book" guidance in this respect (Table 11).

Table 11
Overall recovery factor based on projected mining and processing methods

Mining and milling method	Overall recovery factor (%)
Open-pit mining with conventional milling	80
Underground mining with conventional milling	75
ISL (acid)	75
ISL (alkaline)	70
Heap leaching	70
Block and stope leaching	75
Co-product or by-product	65
Unspecified method	75

For uranium and thorium projects where the ultimate extraction methodology has yet to be confirmed (E2F2), *in situ* quantities may be reported, provided that there are "reasonable prospects for economic extraction and sale" of all such quantities in the foreseeable future. If *in situ* quantities are reported and it is expected that the extraction methodology will lead to significant losses and/or grade dilution, this shall be disclosed, e.g. in a footnote.

For uranium production from ISL projects, the recovery factor is usually a major uncertainty and hence this should always be taken into account for such projects (F2 and F3) and shall be accommodated using the G-axis Categories.

In the absence of any consideration of potential economic recoverability, all reported quantities shall be classified as F4. Undiscovered Resources (PR and SR) estimates are expressed in terms of uranium contained in mineable ore; that is, in-situ quantities. However, such quantities must still be "potentially recoverable" in order to be designated F3.

5.5.3 Technological development

In some situations, it may be helpful to sub-classify Additional Quantities in Place on the basis of the current state of technological developments. As provided in Generic Specifications S, these quantities can be sub-classified as F4.1, F4.2 and F4.3 based on an assessment of the uranium or thorium recovery technology that could be available in future. This could have important implications for comprehensive extraction projects (see Chapter 6).

5.5.4 Level of maturity for exploration projects

Sub-categories for F1 and F2 can be used for more accurate designation of the projects. In some situations, it may be helpful to sub-classify Exploration Projects on the basis of their level of maturity using F3 sub-categories. Generic Specifications R provides the rules for this.

5.5.5 Detailed studies

To designate a project as F1, sufficiently detailed studies have to be completed to demonstrate the feasibility of extraction. 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, thus the term GO, NO-GO decision. 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.

After a potentially viable uranium deposit has been identified, it is normal to conduct a feasibility study to determine whether or not the deposit can be developed economically. The feasibility study usually entails definition of the ore reserves and design of a method for recovering the uranium. The capital, operating, and decommissioning costs are estimated and compared with the projected revenue generated by the sale of the product. To properly conduct this assessment, it is important to do a preliminary environmental baseline study and to estimate the potential impacts of the project on the local environment. Coupled with this is the need to examine the regulatory requirements that may be imposed upon the development.

Mitigation of undesirable environmental impacts and stringent regulatory requirements could significantly affect the economics of a project. It is important to assess these factors before proceeding too far with the development. The environmental information needed for the feasibility study is similar to that required for an environmental impact statement, but at a lesser level of detail. From an environmental perspective, the feasibility study needs only to consider those issues that could have serious economic impacts on the project.

The feasibility study must accurately and completely describe the proposed project. The mining method, process equipment, infrastructure details and all other facets of the project must be totally resolved and designed in detail. If this definition is lacking, cost over-runs will inevitably occur. The feasibility study must also present evidence to the potential investor that the proposed process will actually work. Proposed mining methods and costs, and mill recovery and cost projections must be accurate and supported by adequate test work and studies [49].

It is common to progress through a series of three or four studies of increasing accuracy and cost before construction of a project starts. The study phases can be briefly defined as follows:

- Scoping study/Order of magnitude studies / Pre-evaluation: First economic study carried out with minimum requirements and by comparison with similar existing operations, more advanced projects, or using general cost curves.
- Pre-feasibility study: Economic study based on more specific data for the actual deposit.
- Feasibility study: Final detailed study at the end of which a decision to proceed with or defer construction can be taken.

5.6 GEOLOGICAL KNOWLEDGE

5.6.1 Measurement of uranium

Gamma ray techniques are commonly used to measure the gamma radiation from radioactive daughter isotopes produced from decay of U-238. Consequently, the uranium determination can be inaccurate due to the natural disequilibrium between uranium and its daughter isotopes. It is therefore important to specify the disequilibrium when gamma ray techniques are used. Prompt Fission Neutron (PFN) techniques on the other hand provide a direct measure of uranium and these measurements are not affected by natural disequilibrium.

5.6.2 Geologic type of deposits

Geological types of uranium deposits have an important being not only on the confidence of estimates, but also in the socio-economics and feasibility of extraction. IAEA defines 15 major geological types of deposits which may be considered when describing projects.

1. Sandstone
2. Proterozoic unconformity
3. Polymetallic Fe-oxide breccia complex
4. Paleo-quartz-pebble conglomerate
5. Granite-related
6. Metamorphite
7. Intrusive
8. Volcanic-related
9. Metasomatic
10. Surficial
11. Carbonate
12. Collapse breccia-type
13. Phosphate
14. Lignite and coal
15. Black shale.

Major geological types of thorium deposits which may be used are:

1. Alkaline/peralkaline
2. Carbonatite
3. Metamorphic
4. Vein
5. Placer
6. Other types.

5.6.3 Confidence levels for G1, G2 and G3

The level of confidence for quantities that are classified on the Geological axis as G1, G2 and G3 is defined as “high”, “medium” and “low”, respectively. These are not specified more precisely at a generic level because there are fundamental differences between the approaches that are appropriate for commodities extracted. In the case of uranium and thorium, these specifications will depend on type of the deposit and other geological and structural factors. For more guidance see [50].

5.6.4 Considerations for G4

Undiscovered Resources (Prognosticated Resources and Speculative Resources) refer to resources that are expected to exist based on geological knowledge of previously discovered deposits, regional geological mapping and other geological data sources. In UNFC-2009, the quantities estimated for Undiscovered Resources can correspond to E3, F3 and G4. Both Prognosticated and Speculative Resources require significant exploration before their existence can be confirmed and grades and tonnages of discovered resources can be defined. In some situations, it may be helpful to express a range of uncertainty for quantities that are classified on the Geological axis as G4 into G4.1, G4.2 and G4.3. (See Generic Specification P).

Additional sub-classification into Prognosticated Resources and Speculative Resources can be achieved through use of Generic Specification R, where F3.1 shall correspond to Prognosticated Resources and F3.2 and 3.3 to Speculative Resources.

5.7 IN-SITU LEACH (ISL) PRODUCTION

The extraction of uranium using in-situ leaching (ISL) is a well-established process, comprising some 46% of current (2013) global production of uranium.

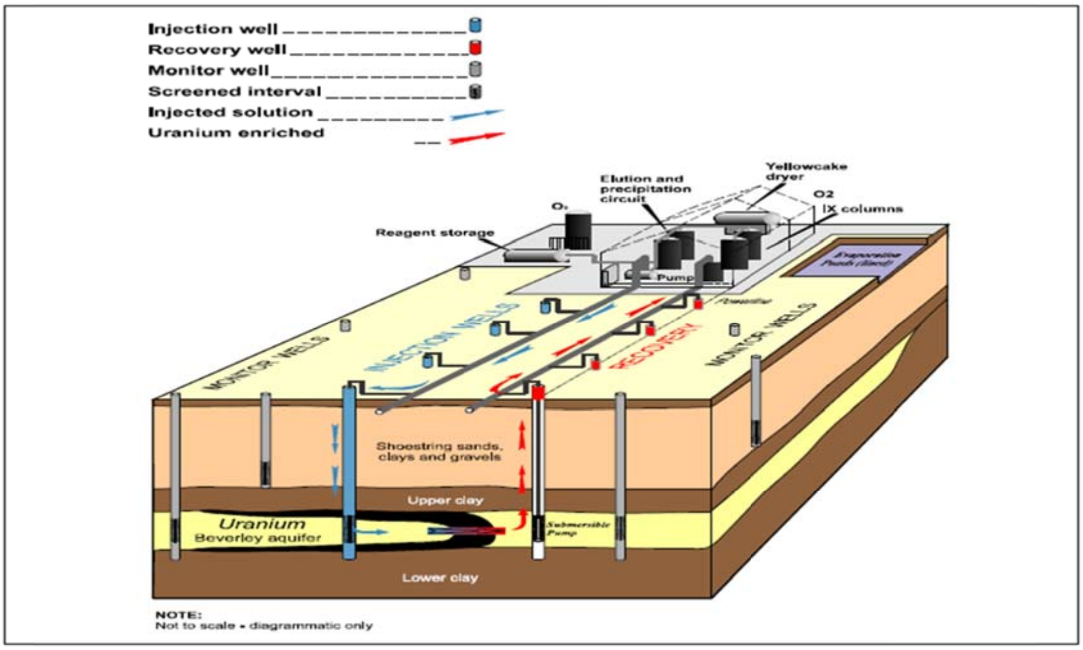
In this method, uranium from sandstone is extracted using chemical solutions and recovered from solutions at the surface. ISL extraction is conducted by injecting a suitable uranium-dissolving leach solution (acid, alkaline or carbonate dioxide-oxygen solution) into the ore zone below the water table thereby oxidising, complexing, and mobilizing the uranium; then recovering the pregnant solutions through production wells, and finally pumping the uranium bearing solution to the surface for further processing (Figure 19) . This process is sometimes referred to as *in situ* recovery (ISR).

ISL production technology is specifically suitable for sandstone type uranium deposits located in water saturated permeable rocks [51, 52, 53]. Important factors that are required to be considered are:

- Grade and geometry of mineralisation are estimated with accuracy sufficient for supporting ISL operations
- If grade is estimated using the gamma logging technique secular disequilibrium should be studied and reported
- Permeability of the mineralized zone
- Hydrological confinement of the mineralized zone
- Amenability of the uranium minerals to dissolution by weak acid or alkaline solutions.
- Rate of the in-situ dissolution of the uranium minerals
- Groundwater flow
- Aquifer salinity.

While the end-product is a solid mineral, the extraction process is, in many ways, much closer to that of an oil and gas operation. In particular, the key difference between traditional mining techniques and ISL is the fact that it is a fluid that is produced at the surface and the uranium content of that fluid is a major uncertainty in the extraction process, even where the *in situ* tonnage and grade may be fairly well defined. Specifically, the recovery efficiency of the project, i.e. the proportion of uranium within the produced fluid relative to the estimated *in situ* quantity, may be much more uncertain (and significantly lower) than is generally the case when using traditional mining techniques for solid minerals.

Figure 19.
Schematic processing model, *In Situ* Leach production. From [51].



The recovery can be estimated by detailed studies including:

- Core drilling and detailed assays to compare with gamma ray probe results or PFN tool results
- Petrology studies
- Bench-scale laboratory testing of bulk samples
- Pump testing of well field

ISL field leach trials provide more reliable, large scale tests of recovery. In addition, these trails also provide important data on the hydrology and permeability of the sands which host mineralisation. These tests may be a strict requirement in the detailed studies for ISL projects.

For most ISL operations, overall uranium recovery factors are commonly of the order of 60-70%. Higher recovery factors are commonly reported for ISL operations in Kazakhstan. For ISL operations, it is difficult to evaluate depletion of quantities and, consequently, remaining quantities at a given point in time. This is because ISL recoveries are a composite of both *in situ* leaching and processing losses. While the processing losses can be independently estimated as tonnage into the plant versus production, the details of the local *in situ* extraction are more difficult to estimate. An approximation of remaining quantities can be made by subtracting the year on year production from the initial resource estimates, but this takes no account of uneven *in situ* recovery which may influence the potential economic extraction of the remaining material. For classifying any part of the deposit as E1 F1, detailed studies will have included detailed ISL field leach trials to estimate the expected recovery factor.

Since Identified Resources (RAR and IR) estimates are expressed in terms of recoverable tonnes of uranium/thorium, these already incorporate both mining and milling losses (i.e. the recovery efficiency of the extraction project and the processing recovery factor) and hence fully satisfy the definition of the G-axis categories, which designate the level of confidence in both the geological knowledge and potential recoverability. While the reference point must always be stated (UNFC-2009, Specification F), this approach also addresses the requirements of UNFC-2009, Specification J, with regard to commodities extracted as fluids.

5.8 REFERENCE POINT

Uranium and thorium quantities are usually reported at sale point from an extraction and processing operation. The final product for uranium usually is “yellow cake”. ASTM standard specification for uranium ore concentrate is available [54]. Quantities may be reported in tonnes of uranium metal rather than pounds of U_3O_8 (contained in tonnes of ore), which is a common practice in company public reporting.

5.9 CLASSIFICATION WORKFLOWS

When transferring quantities from an Aligned System to NEA/IAEA Classification any of the following workflows may be easily adopted:

- CRIRSCO → UNFC-2009 → NEA/IAEA Classification
- CRIRSCO → NEA/IAEA Classification
- Aligned System (eg. National Classification) → UNFC-2009 → NEA/IAEA Classification
- Aligned System (eg. National Classification) and CRIRSCO → UNFC-2009 → NEA/IAEA Classification

For transferring from an Aligned System which could be less granular to UNFC-2009, full adherence of UNFC-2009 principles and specifications will have to be ensured. Note that the E and F Categories set minimum standards for the UNFC-2009 Classes.

The transfer of NEA/IAEA uranium and thorium quantities for individual deposits into UNFC-2009 also requires the application of Production Terminology (see section 4.2), UNFC-2009 generic specifications, and commodity-specific CRIRSCO specifications. The transfer must account for any change in reference point which may occur.

Special care should be taken to avoid double counting when transferring results between systems (see section 4.3.6).

6. COMPREHENSIVE EXTRACTION PROJECTS

6.1. Unconventional uranium resources

Conventional resources are defined as resources from which uranium is recoverable as a primary product, a co-product or a significant by-product. Unconventional resources are resources from which uranium is only recoverable as a minor by-product, such as uranium associated with phosphate rocks, non-ferrous ores, peralkaline intrusions and carbonatite, black shale and coal-lignite [2]. Most of the unconventional uranium resources currently reported includes these uranium deposit types:

- Intrusive plutonic
- Polymetallic iron-oxide breccia complex
- Coal/lignite
- Phosphate
- Black shale.

Apart from these deposit types, re-processing of previous tailings, waste water, and residues (such as coal ash) can also be a source of unconventional uranium. Historically, significant quantities of uranium have been produced from phosphates, as a by-product of fertilizer production. During 1954 to 1962, about 17 150 tU were recovered in the United States from phosphate rocks in Florida with production focused on military needs; a second wave of US production (1970s to 1990s) was largely for civil nuclear power production. As much as 40 000 tU were also recovered from processing marine organic deposits (essentially concentrations of ancient fish bones) in Kazakhstan. In the 1990s, the price of uranium dropped to a level that made these operations uneconomic and most of these plants were shut down. Those that were operating in the United States were decommissioned and demolished.

Gold tailing projects in South Africa are another source that contributed uranium production considerably in the past, which continues to date, though at reduced levels.

Seawater has long been regarded as a possible source of uranium due to the large amount of contained uranium (over 4 billion tU) and its almost inexhaustible nature. However, because of the low concentration of uranium in seawater (3-4 parts per billion), developing a cost-effective method of extraction remains a challenge. Research on uranium recovery from seawater was carried out in Germany, Italy, Japan, the United Kingdom and the United States from the 1950s through the 1980s and more recently in Japan and the United States.

Since 2007, a combination of expectations of rising medium-term demand and sustainability issue has stimulated investigation of a variety of projects, extraction technologies and business models on the part of both governments and commercial entities. The potential to expand the unconventional uranium quantities is strongly tied to the ability to bring it into production. This will depend on market conditions, notably for the commercial recovery of the primary commodities, since these determine the underlying economics of by-product uranium recovery. Secondly, changing policy can affect by-product recovery, notably to require uranium and other critical resources such as rare earth elements to be extracted for strategic and sustainability reasons rather than on a commercial basis. Policy drivers might include the need to enhance the security of uranium supply to the national nuclear fuel cycle or to reap the environmental benefits of extracting uranium from various ores, rather than let it remain in the processing residues.

If uranium prices reach long-term levels in excess of USD 260/kgU (USD 100/lb U_3O_8), and/or improvements are made in reducing mining and processing costs, by-product recovery of uranium from unconventional resources could become commercially viable, even without the policy change noted above. A hybrid situation (market and policy driven scenario) may, however, be the most sustainable scenario over the long term. The need to combine fuel security to the utility company with commercial viability to the mining company, and to align these requirements with the equally significant role of other critical materials, could drive new business models.

6.2 Comprehensive Extraction

The term “comprehensive extraction” has been use since the early 1990s to describe methodologies that can maximize returns from mining and processing especially from low-grade, depleted and other non-commercial ore bodies [55]. This has both opportunistic and sustainability aspects. On the opportunistic side, the nature of sedimentary basins containing energy resources is such that a number of different energy resources are commonly collocated, such as uranium, phosphates, rare earths elements, oil, gas, and coal. Managing these resources in an integrated, multi-target manner is likely to achieve considerably higher aggregate recovery rates than a management strategy that targets only a single resource and effectively treats all other resources as if they were contaminants or wastes.

On the sustainability side, the premise is simpler: once a decision is made to break ground, there is an ethical imperative to maximise the return from that activity in conformity with the well-established fundamentals of sustainable development. These fundamentals are driven by the need for each project to make a balanced contribution to food, energy and water (FEW) security. In consequence, there is a strong case for considering adherence to comprehensive extraction as in and of itself a sustainable development indicator.

There is of course a strong economic case for opportunistic comprehensive extraction, for example in regard to uranium, as shown by the quantities of uranium available as a co- or by-product of other mineral resources, many associated with sedimentary basins that contain energy resources.

Available uranium resources from phosphates alone are estimated at nearly double the tonnages from conventional resources. This insight sits at the heart of the Brazilian Santa Quiteria project, which has a single flow sheet for the production of 500,000 t/yr diammonium phosphate and 1500 t/yr yellowcake from the same complex uranium/phosphate deposit.

Once the prospect is opened up of recovering more than one resource of value from a single mining and processing option (the idea of being “comprehensive”), a complementary process is initiated which opens up the question of what exactly “extraction” is itself. Mining companies, such as KAZATOMPROM are now explicitly engaging with “smart mining” practices, rethinking the fundamentals of mining and processing in highly innovative, sustainable ways [56].

Emerging economies tend to be influenced ethically as well by policies of sustainability and resource conservation that have favoured the emergence of the comprehensive extraction approach. The premise of comprehensive extraction is that if you propose to mine at all, or to extract oil and gas, it is better when you disturb the ground to do so only once. This approach is the more attractive given the increasing difficulty all extractive projects have in winning, and keeping, a social licence to operate.

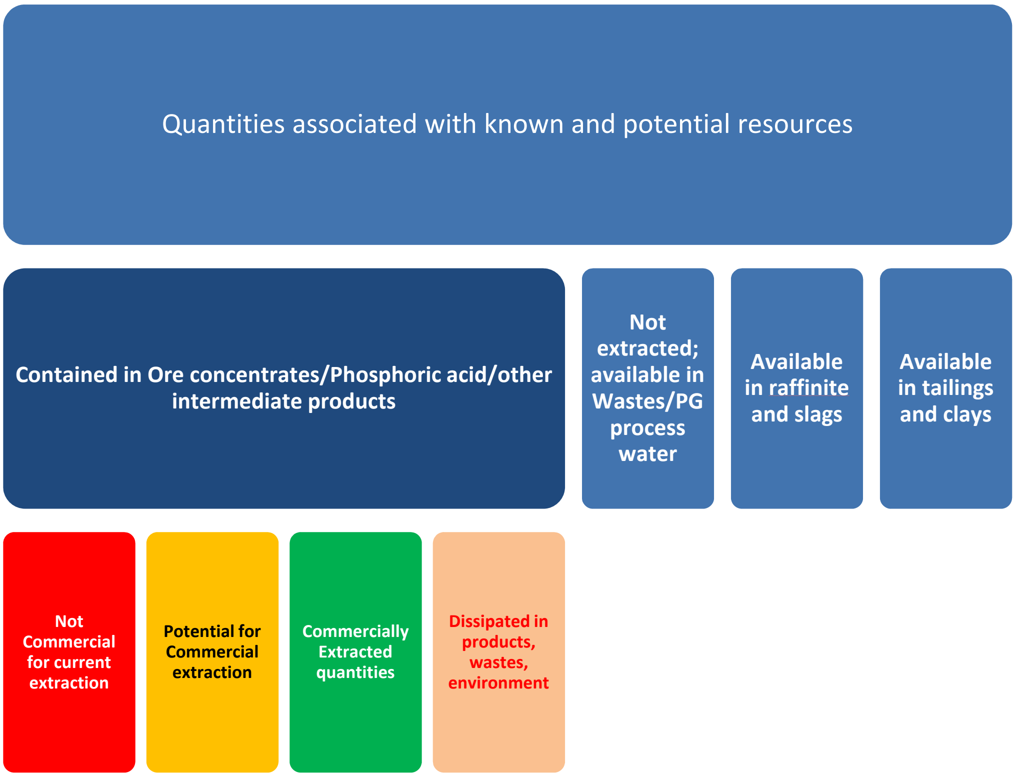
Comprehensive extraction seeks to maximize the returns from mining by a strategic, long-term approach to resource extraction and processing rather than focusing on a single commodity. This has implications for the way resources are assessed, for the sequence in which they are mined and the methods by which they are extracted. One outcome from the comprehensive approach is the emergence of concepts such as “energy basin management” [57] where the resources of a sedimentary basin that might include coal, oil and gas, uranium, phosphates and rare earths are managed as a single complex resource rather than as a competing set of target minerals.

In line with both the opportunistic and ethical drivers, comprehensive has the following operational objectives:

- Disturb the ground only once during mining and extraction, optimising returns from all the resources in an ore body, not just a single target mineral
- Manage all resources from a given site or deposit, both individually and in combination, across the whole life-cycle
- Integrate primary and secondary resource management for resource conservation and waste prevention
- Foster flow-sheet modifications, and innovative, and if necessary, disruptive technologies and business to achieve sustained triple bottom line returns
- Foster reuse, recycling and new product development (ie., from recycling tailings or residues) in line with the waste hierarchy
- Leave zero waste at the end of the project life-cycle, thus eliminating long-term negative externalities
- Base any mineral resource project life-cycle plan on finding the New Point of Equilibrium between the interests of Stockholders and Stakeholders, expressed in the form of a social licence and measured in TBL financial, social and environmental returns
- Future-proof mineral resources through pro-active life-cycle management, including recovery and recycling, as a key sustainable development outcome
- Build and sustain human resource capability (social capital) by
  - net positive contribution to Food Energy and Water security (FEW)
  - education and training.

Applying these principles to UNFC-2009-based resource progression has significant consequences in classifying the projects, as shown in Figure 20.

Figure 20
Classification of comprehensive extraction projects using UNFC-2009.



To illustrate Figure 20, one of the compelling examples is how a Naturally Occurring Radioactive Materials (NORM) industry "waste" has in recent years been transformed into a major, multi-use resource is phosphogypsum. Phosphogypsum (PG) is the co-product with phosphoric acid of the "wet process" manufacture of phosphate fertilisers. In the wet process phosphate rock is digested with sulphuric acid to create phosphoric acid (P_2O_5) and calcium sulphate, also known as phosphogypsum. For every tonne of P_2O_5 there are 5 tonnes of PG, meaning that currently some 150 million tonnes per year are produced.

As another example of comprehensive extraction, in Finland the Talvivaara Mining Company (http://www.talvivaara.com/) has constructed a processing plant, in collaboration with Cameco Corporation, to recover uranium as a by-product from the processing of its zinc-nickel-cobalt-copper deposits. They predict annual production of 350 t uranium/year as by-product recovery from their black schist ore, which averages 16 to 18 parts per million uranium content.

Because of the way it redefines the nature of resources *per se* comprehensive extraction has also found support at a policy level in the context of increasing concern at shortages of supplies of "critical" minerals. Inevitably the definition of what is, and is not, a critical mineral is both contested and subject to temporal, local and regional variation. But this theory has made the prospect of reintroducing uranium extraction facilities at phosphate plants, but also facilities for capturing other minerals such as rare earth elements (REE) or thorium, culturally more acceptable. A further, highly significant attraction of "comprehensive extraction" of uranium as a by- or co-product [58] is the environmental benefit; because mining takes place only once every tonne of uranium that can be extracted this way offsets uranium that has to be extracted by conventional mining.

6.3 Assessment and classification of comprehensive extraction projects

The assessment of uranium from unconventional resources in UNFC-2009 should give equal considerations for both the market and policy driven factors. If the case of phosphates is taken as an example in the market scenario, phosphate deposits will only be processed commercially when it is intrinsically economically viable to do so. Hence, the phosphate market acts as the determining factor of how much uranium can even theoretically be extracted from phosphate resources. In the policy-driven scenario, the value of other recoverable elements will be added by various means, such as long-term government contracts, to the overall economic evaluation. Governments could also place a premium on securing the supply of nuclear fuel, especially where this can come from national resources, thereby eliminating dependency on third parties. In some countries, uranium extraction from phosphates could perhaps be mandated.

For assessment and classification of comprehensive extraction projects, a bottoms-up approach could be useful. As shown in Figure 20, global quantities of uranium, thorium, REE or other commodities associated with comprehensive extraction projects may be classified as E3 F4 G4 if no development project or extraction operation has been identified. In this case, quantities can be reported as in-situ that will not be extracted by any currently defined development project or mining operation. Some of these quantities may subsequently become recoverable in the future due to the development of new technology.

When a conceptual study or very preliminary studies can indicate the need for further data acquisition to confirm the viability of the extraction project and the existence of the deposit in such form, quality and quantity that the feasibility of extraction can be evaluated, the projects can be designated as E3 F3 G4 or as an Exploration Project.

If preliminary studies are under taken, which demonstrate the existence of a deposit in such a form, quality and quantity that the feasibility of extraction by a defined extraction project (at least in broad terms) can be evaluated, but project activities are on hold and/or commercial development may be subject to significant delay, the project can be classified as E3 F2.2 or 2.3 G1, 2 or 3. Further studies may be required to confirm the feasibility of extraction. Such projects can be classified as Non-Commercial Projects.

If project activities are ongoing to justify development in the foreseeable future, E2 F2.1 G1,2,3 can be applied and the project classified as a Potentially Commercial Project.

If the feasibility of extraction by a defined extraction project has been confirmed it can be classified as E1 F1 G1,2,3 and designated as a Commercial Project. Sufficiently detailed studies will have to be completed to demonstrate the feasibility of extraction. Projects where the implementation is underway or where extraction is currently taking place also fall under this class.

One important factor in the feasibility studies will be demonstration of the fact that extraction of the by-product(s) will not have a deleterious impact on the extraction of the primary product.

Major aspects of assessment comprehensive extraction projects are summarized as:

1. Socio-economic criteria – Policy driven factors in relation to mineral conservation, environment and social returns; Market factors and assumptions with regard to the primary product (s) and by-product(s).
2. Project feasibility – Technological options for by-product recovery without deleterious effects to the primary commodity extraction process.
3. Geological knowledge – Geological confidence of estimates will have to be well clarified.

7. CONCLUSIONS

This Guidelines document was created in order to:

- Facilitate the easy application of UNFC-2009 to uranium and thorium resources and/or
- Guide the transfer of existing uranium or thorium resource data from other resource classification schemes into UNFC-2009.
- Assist those responsible for classifying uranium or thorium resources for the purposes of quantifying, financing, permitting, mining, and processing to the point where the product is in a form to enter the nuclear fuel cycle.
- Enable users to see the alignments between the various resource classification systems currently in use for uranium and thorium resource management and reporting, such as the NEA-IAEA "Red Book", CRIRSCO, and various national systems, in a coherent and consistent manner.

The scope and structure of this Guideline document includes:

- An overview of global nuclear fuel resources and production (uranium and thorium), including current sources of information;
- A description of UNFC-2009 principles and specifications, provided through the Bridging Document for Nuclear Fuel Resources, which are to be considered in classification and reporting;
- Mapping of the NEA-IAEA scheme to CRIRSCO and other mineral resource classification systems, which are the existing systems designated by UNFC as "aligned systems";
- Multiple issues to be considered in the application of UNFC-2009 to nuclear fuel resources; and
- Discussion of the concepts and factors involved in comprehensive extraction projects for nuclear fuels.

It must be emphasized that the proper application of the guidelines requires the following three accompanying publications in hand:

1) The document *United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources (UNFC-2009)* [1], which outlines the UNFC-2009 principles —the high-level framework of the UNFC-2009 classification scheme;
2) The Generic UNFC-2009 and CRIRSCO commodity-specific specifications—the mandatory rules for the application of UNFC-2009, which ensures consistency in its use [1];
3) The Bridging Document for Nuclear Fuel Resources [3].

Uranium will continue to make a critical contribution to energy security and low carbon energy production in the future, and potentially it will be accompanied by thorium-based nuclear power in the foreseeable future. Thus, there will be a constant need to systematically categorize and account for nuclear fuel resources for a wide variety of purposes at an equally wide range of levels.

The careful application of the specifications outlined in UNFC-2009, with assistance provided by this Guidelines document, provides a simple but powerful tool for classifying uranium and thorium resources. The authors hope that this Guidelines document will guide easy application of UNFC-2009, a system currently in use worldwide with increasing global support for its use in multiple venues.

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ABBREVIATIONS

CIM	Canadian Institute of Mining, Metallurgy and Petroleum
CRIRSCO	Committee for Mineral Reserves International Reporting Standards
IAEA	International Atomic Energy Agency
JORC	Australasian Joint Ore Reserves Committee
kgU	Kilograms of uranium
NEA	Nuclear Energy Agency of the Organisation for Economic Co-operation and Development
PRMS	Petroleum Resources Management System of 2007
REE	Rare earth elements
SAMREC	South African Code for the Reporting of Mineral Resources and Mineral Reserves
TREO	Total rare earth elements in oxide form
tU	Metric tons (tonnes) of uranium
ThDEPO	World Distribution of Thorium Deposits (database maintained by the IAEA)
U	Uranium
UDEPO	World Distribution of Uranium Deposits (database maintained by the IAEA)
UNECE	United Nations Economic Commission for Europe
UNFC-2009	United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009
USD	United States dollars

GLOSSARY OF TERMS

NEA/IAEA CLASSIFICATION TERMS

Term	**Definition**
Committed production centre	Production centre that is either under construction or is firmly committed for construction (see Production centre).
Conventional resources	Uranium / thorium resources are broadly classified as either conventional or unconventional. Conventional resources are those that have an established history of production where uranium is a primary product, co-product or an important by-product (e.g. from the mining of copper and gold) (see Unconventional resources).
Existing production centre	Production centre that currently exists in operational condition; this includes those plants which that are closed down but which could be readily brought back into operation (see Production centre).
Identified resources	Identified resources include reasonably assured resources and inferred resources (see Reasonably assured resources; Inferred resources)
Inferred resources	In addition to reasonably assured resources, Uranium/thorium inferred to occur i) based on direct geological evidence, ii) in extensions of well-explored deposits, or iii) in deposits in which geological continuity has been established but where specific data, including measurements of the deposits, and knowledge of the deposits' characteristics, are considered to be inadequate to classify the resource as reasonably assured resources. Estimates of tonnage, grade and cost of further delineation and recovery are based on such sampling as is available and on knowledge of the deposit characteristics as determined in the best-known parts of the deposit or in similar deposits. Less reliance can be placed on the estimates in this category than on those for reasonably assured resources. Unless otherwise noted, inferred resources are expressed in terms of quantities of uranium/thorium recoverable from mineable ore (see Reasonably assured resources; Recoverable resources).
Planned production centre	Production centre for which feasibility studies are either completed or under way, but for which construction commitments have not yet been made. This class includes those plants that are closed which but would require substantial expenditures to bring them back into operation (see Production centre).
Production centre	A production unit consisting of one or more ore processing plants, as well as one or more associated mines and uranium/thorium resources that are tributary to these facilities. Production centres are divided into four classes; see i) Existing production centre; ii) Committed production centre; iii) Planned production centre; iv) Prospective production centre).
Prognosticated resources	In addition to inferred resources, Uranium/thorium, expected to occur in deposits for which the evidence is mainly indirect and which are believed to exist in well-defined geological trends or areas of mineralisation with known deposits. Estimates of tonnage, grade and cost of discovery, delineation and recovery are based primarily on knowledge of deposit characteristics in known deposits within the respective trends or areas and on such sampling, geological, geophysical or geochemical evidence as may be available. Less reliance can be placed on the estimates in this category than on those for inferred resources. Prognosticated resources are normally expressed in terms of uranium/thorium contained in mineable ore, i.e. *in situ* quantities.

Term	**Definition**
Prospective production centre	Production centre that could be supported by tributary Reasonably assured resources and Inferred resources, i.e. “Identified resources”, but for which construction plans have not been made as yet (see Production centre).
Reasonably assured resources	Uranium/thorium that occurs in known mineral deposits of delineated size, grade and configuration such that the quantities which could be recovered within the given production cost ranges with currently proven mining and processing technology, can be specified. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of deposit characteristics. Reasonably assured resources have a high assurance of existence. Unless otherwise noted, Reasonably assured resources are expressed in terms of quantities of uranium/thorium recoverable from mineable ore (see Recoverable resources).
Recoverable resources	Estimates of Reasonably assured resources and Inferred resources are expressed in terms of recoverable tonnes of uranium/thorium, i.e. quantities of uranium/thorium recoverable from mineable ore, as opposed to quantities contained in mineable ore, or quantities *in situ*, i.e., not taking into account mining and milling losses. Therefore in most cases both expected mining and ore processing losses have been deducted .
Speculative resources	Speculative Uranium/thorium resources, in addition to Prognosticated resources, are mostly on the basis of indirect evidence and geological extrapolations, in deposits that can be discovered with existing exploration techniques. The location of deposits envisaged in this category could generally be specified only as being within a given region or geological trend. As the term implies, the existence and size of such resources are speculative. Speculative resources are normally expressed in terms of uranium/thorium contained in mineable ore, i.e. *in situ* quantities (see Prognosticated resources).
Unconventional resources	Uranium resources are broadly classified as either conventional or unconventional. Very low-grade resources or those deposits from which uranium is only recoverable as a minor by-product are considered unconventional resources (see Conventional resources).
Undiscovered resources	Undiscovered resources include Prognosticated resources and Speculative resources (see Prognosticated resources; Speculative resources).

CRIRSCO TERMS

CRIRSCO Term	Definition
Public Reports	Public Reports are reports prepared for the purpose of informing investors or potential investors and their advisers on Exploration Results, Mineral Resources or Mineral Reserves. They include, but are not limited to annual and quarterly company reports, press releases, information memoranda, technical papers, website postings and public presentations.
Competent Person	A Competent Person is a minerals industry professional who is a member of a professional body with an enforceable disciplinary processes including the powers to suspend or expel a member. A Competent Person must have a minimum of five years relevant experience in the style of mineralisation or type of deposit under consideration and in the activity which that person is undertaking.
Modifying Factors	Modifying Factors are considerations used to convert Mineral Resources to Mineral Reserves. These include, but are not restricted to, mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social and governmental factors.
Exploration Target	An Exploration Target is a statement or estimate of the exploration potential of a mineral deposit in a defined geological setting where the statement or estimate, quoted as a range of tonnes and a range of grade or quality, relates to mineralisation for which there has been insufficient exploration to estimate Mineral Resources.
Exploration Results	Exploration Results include data and information generated by mineral exploration programmes that might be of use to investors but which do not form part of a declaration of Mineral Resources or Mineral Reserves.
Mineral Resource	A Mineral Resource is a concentration or occurrence of solid material of economic interest in or on the Earth's crust in such form, grade or quality and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade or quality, continuity and other geological characteristics of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge, including sampling.
Inferred Mineral Resource	An Inferred Mineral Resource is that part of a Mineral Resource for which quantity and grade or quality are estimated on the basis of limited geological evidence and sampling. Geological evidence is sufficient to imply but not verify geological and grade or quality continuity. An Inferred Resource has a lower level of confidence than that applying to an Indicated Mineral Resource and must not be converted to a Mineral Reserve. It is reasonably expected that the majority of Inferred Mineral Resources could be upgraded to Indicated Mineral Resources with continued exploration.

CRIRSCO Term	Definition
Indicated Mineral Resource	An Indicated Mineral Resource is that part of a Mineral Resource for which quantity, grade or quality, densities, shape and physical characteristics are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit. Geological evidence is derived from adequately detailed and reliable exploration, sampling and testing and is sufficient to assume geological and grade or quality continuity between points of observation. An Indicated Mineral Resource has a lower level of confidence than that applying to a Measured Mineral Resource and may only be converted to a Probable Mineral Reserve.
Measured Mineral Resource	A Measured Mineral Resource is that part of a Mineral Resource for which quantity, grade or quality, densities, shape, and physical characteristics are estimated with confidence sufficient to allow the application of Modifying Factors to support detailed mine planning and final evaluation of the economic viability of the deposit. Geological evidence is derived from detailed and reliable exploration, sampling and testing and is sufficient to confirm geological and grade or quality continuity between points of observation. A Measured Mineral Resource has a higher level of confidence than that applying to either an Indicated Mineral Resource or an Inferred Mineral Resource. It may be converted to a Proved Mineral Reserve or to a Probable Mineral Reserve.
Mineral Reserve	A Mineral Reserve is the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined or extracted and is defined by studies at Pre-Feasibility or Feasibility level as appropriate that include application of Modifying Factors. Such studies demonstrate that, at the time of reporting, extraction could reasonably be justified. The reference point at which Reserves are defined, usually the point where the ore is delivered to the processing plant, must be stated. It is important that, in all situations where the reference point is different, such as for a saleable product, a clarifying statement is included to ensure that the reader is fully informed as to what is being reported.
Probable Mineral Reserve	A Probable Mineral Reserve is the economically mineable part of an Indicated, and in some circumstances, a Measured Mineral Resource. The confidence in the Modifying Factors applying to a Probable Mineral Reserve is lower than that applying to a Proved Mineral Reserve.
Proved Mineral Reserve	A Proved Mineral Reserve is the economically mineable part of a Measured Mineral Resource. A Proved Mineral Reserve implies a high degree of confidence in the Modifying Factors.

CRIRSCO Term	Definition
Pre-Feasibility Study	A Pre-Feasibility Study is a comprehensive study of a range of options for the technical and economic viability of a mineral project that has advanced to a stage where a preferred mining method, in the case of underground mining, or the pit configuration, in the case of an open pit, is established and an effective method of mineral processing is determined. It includes a financial analysis based on reasonable assumptions on the Modifying Factors and the evaluation of any other relevant factors which are sufficient for a Competent Person, acting reasonably, to determine if all or part of the Mineral Resource may be converted to a Mineral Reserve at the time of reporting. A Pre-Feasibility Study is at a lower confidence level than a Feasibility Study.
Feasibility Study	A Feasibility Study is a comprehensive technical and economic study of the selected development option for a mineral project that includes appropriately detailed assessments of applicable Modifying Factors together with any other relevant operational factors and detailed financial analysis that are necessary to demonstrate at the time of reporting that extraction is reasonably justified (economically mineable). The results of the study may reasonably serve as the basis for a final decision by a proponent or financial institution to proceed with, or finance, the development of the project. The confidence level of the study will be higher than that of a Pre-Feasibility Study.