Optimizing quality of information in RAw MAterial data collection across Europe

Deliverable 1.5
Good practice guidelines for harmonisation of resource and reserve data

Title of the project:	Optimizing quality of information in RAw MAterial data collection across Europe - ORAMA
Grant Agreement number:	776517
Funding Scheme:	H2020 – SC5-15-2017 – CSA
Start date:	01.12.2017
Duration:	24 months
Document title:	Deliverable 1.5: Good practice guidelines for harmonisation of resource and reserve data
Work Package:	1
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Date of delivery:	08/11/2019
Dissemination level:	PU[1]
Reviewed by:	
Status of the document:	**Final**
Document location:	Tiimeri: Documents / Deliverables
Project web site:	http://www.orama-h2020.eu

[1] PU=public, PP= Restricted to other programme participants (including the Commission Services), RE= Restricted to a group specified by the consortium (including the Commission Services), CO= Confidential, only for members of the consortium (including the Commission Services)

Publishable abstract

The EU is highly dependent on mineral raw materials, which are essential for European industries, jobs and growth. Part of the strategy for assessing issues on security of supply of raw materials is to improve the quality and harmonisation of raw materials data. This is essential not just for investigating supply vulnerability at the European level, but also for facilitating information sharing at different levels within the EU. A key requirement of this data is to understand the resource potential of Europe, by evaluating known 'geological stocks' of raw materials using statistics for mineral resources and reserves.

This document aims to provide background information as to the issues around the difficulties to date in compiling a harmonised dataset for primary mineral reserve and resource data in Europe, such as data being complied in a variety of non-comparable systems. It then aims to provide a potential solution to the lack of harmonised data at a European level via the use of the United Nations Framework Classification (UNFC) system as a standard way of classifying mineral resources. This document is designed to act as guidance note to how and why UNFC should be used in Europe. For recommendations as to how to implement UNFC in Europe, and how other data types can be harmonised, please refer to D1.2 and D6.6 of the ORAMA project.

Use of the UNFC overcomes the issue of multiple non-comparable resource and reserve reporting codes and standards in use across Europe by producing data that is harmonised at the EU level. It is not suggested that individual countries should change their current systems of working, many of which have a legal foundation. At the national level, all countries would be able to continue with other systems of reporting to suit their internal purposes, but when figures are reported to a central point for EU level compilation (e.g., European Minerals Yearbook), and in order for them to be consistent and comparable, they would need to be converted to a harmonised system such as the UNFC.

A simplified guide to the use of the UNFC is presented here, along with a range of case studies from European countries that have worked towards producing a harmonised reserve and resource dataset using the UNFC.

It is hoped that these resources can act to provide organisations, such as geological surveys and national statistical agencies, who are responsible for the collation of mineral statistical data at a national level, with the required tools to convert existing data to the UNFC for the compilation of pan-European resource and reserve estimates.

A range of separate training materials and worked examples has also been developed alongside this report to enable the use of the UNFC. These are listed within this report and are available from the ORAMA website (https://orama-h2020.eu/).

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Abbreviations and acronyms

BGS	British Geological Survey
CRIRSCO	Committee for Mineral Reserves International Reporting Standards
EGS	EuroGeoSurveys
EU	European Union
EURMKB	European Union Raw Materials Knowledge Base
GeoZS	Geological Survey of Slovenia
GIS	Geographical Information System
GTK	Geological Survey of Finland
INSPIRE	Infrastructure for Spatial Information in the European Community
JORC	Joint Ore Reserves Committee
MBFSZ	Mining and Geological Survey of Hungary
MREG	Mineral Resources Expert Group (from EuroGeoSurveys)
NAEN	Russian Code for the Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves
NGU	Geological Survey of Norway
PERC	Pan-European Reserves and Resources Reporting Committee
RMIS	Raw Materials Information System (from EC DG JRC)
SPE-PRMS	Society of Petroleum Engineers - Petroleum Resource Management System
TUKES	Finnish Safety and Chemicals Agency
UNECE	United Nations Economic Commission for Europe
UNECE EGRC	United Nations Economic Commission for Europe - Expert Group on Resource Classification
UNFC	United Nations Framework Classification for Resources
UNRMS	United Nations Resource Management System (the successor of the UNFC from the second half of 2018).
USGS	United States Geological Survey.

1 Introduction and background to statistical data for mineral resources and reserves in Europe

The aim of the ORAMA project is to improve the provision of raw materials information across Europe, for all data types, for both primary and secondary raw materials. These type of data are critical for informing long term planning for industrial strategy and raw materials supply

Many aspects of how data provision can be improved and how national level data can be harmonised at a European level have been outlined in the ORAMA deliverables D1.1 and D1.2 for primary raw materials and in D2.1 and D2.2 for secondary raw materials. This deliverable report deals with the specific issue of harmonisation of data pertaining to mineral resources (and, where appropriate, to reserves). This particular subject has been singled out as it has been identified in other H2020 projects, such as Minerals4EU and Minventory, as a major concern hindering the provision of important minerals data. These data are required in order to support the planning and decision making required to ensure the sustainable supply of raw materials. This issue was considered in detail by the Minventory project, which produced a roadmap of how harmonisation of mineral resource data can be achieved. This roadmap and the Minventory project are discussed in more detail in D1.2. The Minerals4EU project attempted to compile an inventory of mineral resources and reserves across Europe, for the first time. Although this project succeeded in compiling a wealth of data at a national level for many European countries, no pan-European totals could be calculated for the reasons discussed below. This prompted further discussion to determine how a consistent, internationally recognised system of reporting for these data could be implemented across Europe.

The European Commission has specifically requested pan-European resource and reserve statistics. However, these currently cannot be provided because these data are collected using different systems of reporting with varying levels of detail and confidence. Consequently the available data are not directly comparable and cannot be aggregated. This report aims to explore the issues around different standards of reporting mineral resource information and recommends that the United Nations Framework Classification (UNFC) would be a method for producing harmonised figures and should be adopted for pan-European reporting. This will require tools to bridge existing data, that are reported in other systems, to the UNFC. This report provides case studies from different countries for a range of different data to show how this can be achieved.

Training material and technical guidance

Alongside this document, the ORAMA project has also produced a host of training material and technical guidance that is designed to aid with the conversion of different codes and standards to the UNFC and enable data providers to understand and make set use of the UNFC when compiling statistical data on mineral resources. These documents formed the basis of a webinar designed to facilitate the use of the UNFC, and is available as a recording here: https://orama-h2020.eu/

This training material and technical guidance comprises:

- D1.5.1 Technical Guidance Note: United Nations Framework Classification (UNFC). This is a brief document outlying the basic principles of the UNFC.
- D1.5.2 Technical Guidance Note: Bridging document between CRIRSCO and United Nations Framework Classification (UNFC). This is a concise guide to how CRIRSCO-compliant resource codes can be bridged across to UNFC.

- D1.5.3 Technical Guidance Note: Decision flow tools for classifying resource data according to the United Nations Framework Classification (UNFC). These are a series of decision-flow tools, one for each of the UNFC axes and one for bridging between CRIRSCO and UNFC, that go step by step through the decision making process when classifying resources.
- D1.5.4 Technical Guidance Note: Practical Exercises in Reporting Resource and Reserve Data according to the United Nations Framework Classification (UNFC). These are a series of practical exercises on classifying different types of resource data according to UNFC.
- D1.5.5 Technical Guidance Note: Worked example for conversion of UK polyhalite resource data to UNFC. This is a worked example of how data for polyhalite resources in the UK have been converted to UNFC.
- D1.5.6 Technical Guidance Note: Worked example for conversion of Spanish copper resource data to UNFC. This is a worked example showing how the geological survey of Spain (IGME) has converted their mineral resource database to UNFC.
- D1.5.7 Technical guidance note: Raw materials import reliance and associated data uncertainties. This document highlights issues around the use of PRM production and trade data for commodity specific studies, using the example of how import reliance is calculated at an EU or country level and what this means for PRM supply.
- D1.5.8 Technical guidance note: The challenge of assessing European raw material resources − insights from data availability and quality. This is document explaining the issues, difficulties and data gaps regarding European critical raw materials data and what this means for data collection for critical raw materials.
- D1.5.9 Technical guidance note: A minerals inventory for the UK, for 2019, using the United Nations Framework Classification system. This is a worked example showing how a country, like the UK, with no systematic collection of resource data, can create a resource inventory using UNFC.
- D1.5.10 Technical guidance note: Country summaries for national legal and regulatory frameworks for resource and reserve data. This is a summary for individual EU countries regarding how and if figures for resources and reserves are reported on a national basis and if any attempts have been made to harmonise with other classification systems.

2 Mineral reserve and resource codes

How mineral resources and reserves are defined is the key issue for harmonisation. Different systems, codes and standards of resource reporting all use different definitions; these differences can often be subtle but can have significant implications on the data reported. A comprehensive review of different types of systems of reporting, their definitions, background and purpose can be found in the Minventory final deliverable[2]. To minimise repetition, only a brief summary of the definitions and different reporting systems are given here.

[2] Parker, D, Petavratzi, E, Mankelow, J, Waugh, R, and Bertrand, G. 2015. Minventory: EU raw materials statistics on resources and reserves. European Commission.
https://ec.europa.eu/docsroom/documents/10224/attachments/1/translations/en/renditions/pdf

A commonly used definition is that a mineral resource is a natural concentration of material in such form and quantity that economic extraction of a commodity is potentially feasible[3,4]. Reserves are that part of an identified resource that could be economically extracted at the time of the assessment, taking into account the 'modifying factors' (these will vary by reporting system but could include, for example, the issuance of mining and environmental permits, the establishment of legal ownership or royalty agreements, etc.). Consequently mineral resources and reserves are of fundamental importance to the global mining industry because they identify deposits that are currently economically and legally extractable (reserves) and those where economic and legal extraction of a commodity is potentially feasible (resources).

Reserves can be regarded as working inventories at a particular point in time, determined by numerous variables including discovery and extraction rates, technologies for extraction, processing and use, and various political, legal, economic and social factors that influence their accessibility. As a result of their dynamic nature and the inherent uncertainties in global and national totals, published reserve estimates should not be regarded as reliable indicators of the future availability of mineral commodities[6,5].

The size of mineral resources and reserves are critically dependent on the commodity price prevailing at a particular time. If the commodity price rises, then a greater proportion of the deposits containing that mineral will become economically profitable to extract and these could be added to the figures for resources (providing there are no other factors to prevent this). Conversely, if the commodity price falls, then some deposits previously considered as resources may become uneconomic and these would no longer be included within that term.

The various reporting systems set out minimum standards, recommendations and guidelines for the public reporting of exploration results, mineral resources and ore reserves. For example, in Australia companies listed on the Australian Securities Exchange are required to use the code of the JORC. Companies that report their results on stock exchanges in Canada are required to follow the rules and guidelines of National Instrument (NI) 43-101. Various professional bodies have worked hard to harmonise definitions and reporting standards but substantial differences remain between many commonly used systems of reporting[6].

Different jurisdictions have very different ways of measuring and reporting mineral resources and reserves. For example, there are the many international standards that use the CRIRSCO[3] template (Committee for Mineral Reserves International Reporting Standards). This is a grouping of representatives of organisations that are responsible for developing mineral reporting codes and guidelines. These comprise:

- Joint Ore Reserves Committee (JORC) Code (Australia)
- Canadian Institute of Mining (CIM) Code (Canada)
- Certification Code for Exploration Prospects, Mineral Resources and Ore Reserves (Chile)

[3] CRIRSCO. 2016. Committee for Mineral Reserves International Reporting Standards. [cited June 2016]. http://www.crirsco.com/welcome.asp

[4] US Geological Survey. 2018. Mineral Commodity Summaries 2018. (Reston, VA)

[5] P. A. J. Lusty, and A. G. Gunn. 2015. Challenges to global mineral resource security and options for future supply. 265–276 in *Ore Deposits in an Evolving Earth*. McDonald, I (editor). Special Publications 393. (London: Geological Society.)

[6] P. C. F. Crowson. 2011. Mineral reserves and future minerals availability. *Mineral Economics*, Vol. 24, 1-6.

- South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (SAMREC) Code (South Africa)
- Society for Mining, Metallurgy and Exploration (SME) Guide (United States)
- Russian Code for the Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves (NAEN Code) (post 2011) (Russia)
- Pan European Reserves and Resources Reporting Committee (PERC) Reporting Standard (Europe)
- National Resources and Reserves Reporting Committee (UMREK Code) (Turkey)
- Indonesian Committee for Mineral Reserves (KCMI Code) (Indonesia)
- Mongolian Resource Committee Code (MRC Code)(Mongolia)
- The Code of the Republic Kazakhstan subsoil and subsoil use (KAZRC) (Kazakhstan)
- Comisión Colombiana de Recursos y Reservas Mineras (CCRR) (Columbia)
- Guide for Reporting Exploration Results, Mineral Resources, and Mineral Reserves (CBBR) (Brazil)

More details of these reporting standards can be found at http://crirsco.com/national.asp.

There are also many European countries that use their own resource code. This is commonly for use in national resource management as opposed to financial or stock exchange reporting, which frequently require use of a CRIRSCO-compliant code. In many cases, these National Reporting Codes are adapted from CRIRSCO-compliant codes, but in others they have been developed independently. A detailed description of the resource codes used by individual European countries can be found ORAMA deliverable D1.5.10.

In addition, there is also the United Nations Framework Classification (UNFC), a method of classifying mineral resources developed by the UN. This classification scheme is aimed to be used at a national level to build global energy and mineral studies, analyse government policies, plan industrial processes and allocate capital efficiently. The UNFC has been designed to be an interoperable scheme between different commodities such as petroleum, minerals, renewable energy, nuclear fuel and anthropogenic resources.

3 The Issues facing statistical data for mineral resources and reserves in Europe

Europe is highly dependent on mineral raw materials, which are essential for European industries, jobs and growth. Part of the strategy to ensure security of supply of mineral raw materials is to improve the quality and harmonisation of statistical data. This is essential not just for investigating supply vulnerability at the European level, but also for facilitating information sharing at different levels within Europe. A key requirement is to understand the resource potential of Europe, by evaluating known ‘geological stocks’ of mineral raw materials using statistics for resources and reserves. Without some level of interoperability for mineral raw materials data between different European countries, it is very difficult to compare data, to assess the quantities and locations of mineral resources across Europe and to develop a coherent industrial strategy and raw materials policy.

A significant amount of work was undertaken by the Minerals4EU[7] project in collecting figures for mineral resources and reserves from official sources across the European countries. This was the first time that statistics on mineral resources and reserves were collected at the European level and they became publicly available through the electronic European Minerals Yearbook. However, it is apparent that no pan-European resource and reserve estimates can be obtained from those numbers due to serious issues relating to data availability, quality and harmonisation.

The main issues with using the Minerals4EU dataset for this purpose are:

1. For many countries, there are either no data or data for only certain commodities.
2. Data were compiled according to a wide variety of systems of reporting across the Europe. A total of 19 different reporting systems were used in data collected by Minerals4EU and more are known to exist that were not reported. These codes are not comparable and the data cannot be summed.
3. Some countries use their own unique national reporting systems, while others use a number of different codes.
4. The ages of the datasets vary considerably. Some are undated 'historical' estimates, while others are modern estimates based on current international reporting systems.

The fundamental issues with the resource data from the Minerals4EU project is illustrated in Figure 1. This shows the large array of different reporting schemes and classification systems for one commodity, gold. Each separate coloured box in Figure 1 represents a reported data point that uses the same definition. Although there may be established methods to bridge between some of the codes and classifications listed in the diagram, no effort has been made to convert between them. For some data points, there are no examples of how data can be bridged across to other internationally recognised ways of reporting, such as UNFC or CRIRSCO.

Any national or pan-European totals that could be derived from summing reserve and resource estimates obtained by these projects would be incomplete and fundamentally flawed. Furthermore, they would provide no indication of the current availability of a commodity within Europe nor of the potential for future discovery. They would be incompatible with the global resource and reserve data published annually by the USGS with which they would inevitably be compared to provide an indication of their significance relative to those in the rest of the world. It is also important to note that the reserve estimates published by the USGS do not always meet the specified ideal situation such that the information would be derived from "comprehensive evaluations that apply the same criteria to deposits in different geographic areas and report the results by country" [4] as set out by the USGS.

The inability to easily produce reliable statistics about resources and reserves of raw materials is a major concern for the European Commission. Some level of agreement on which of the internationally recognised systems of reporting should be adopted at a pan-European level is essential for improving the situation. Procedures for data collection and accessibility at specified time intervals are also required to ensure consistent and continuous reporting

[7] Minerals Intelligence Network for Europe. 2016. http://www.minerals4eu.eu/

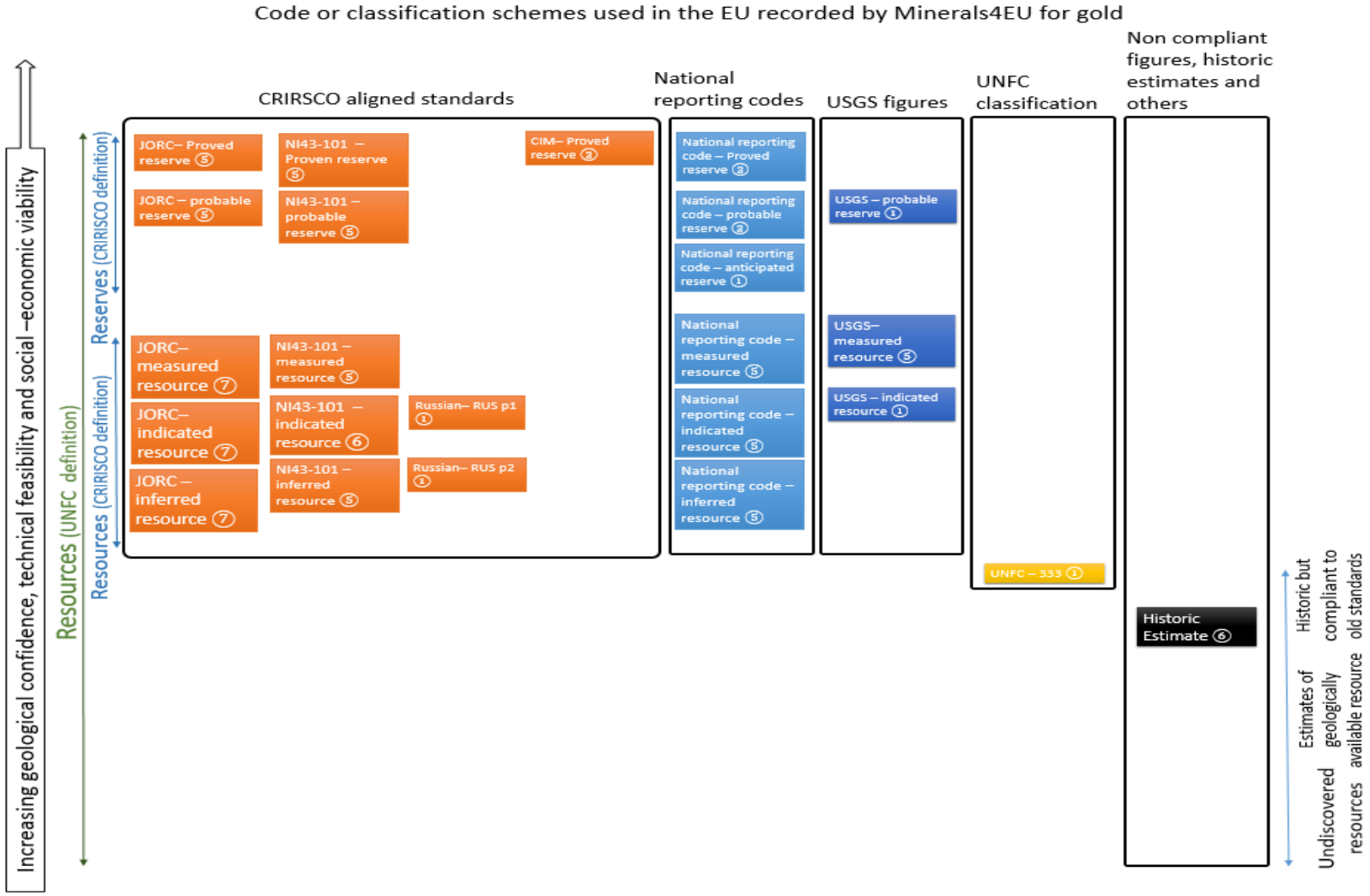


Figure 1: Codes and classification schemes used in Europe recorded by Minerals4EU for gold. Text indicates: name of code, standard or classification scheme used for reporting, number encircled and box size indicates the number of figures reported using this for the Minerals 4EU project.

4 Potential solutions for harmonisation of European resource and reserve data

One solution to the issue of multiple non-comparable resources and reserves reporting codes and standards in use across the Europe would be harmonisation of resources and reserves data at the European level. It is not suggested that individual countries should change their currents systems of working, many of which have a legal foundation. At the national level, all countries would be able to continue with other systems of reporting to suit their internal purposes, but when figures are reported to a central point for European-level compilation (e.g., the electronic European Minerals Yearbook) they would need to be converted to a harmonised system in order for them to be consistent and comparable. This approach has been described in the Minventory project final report[2] (Figure 2) and was also recommended in the Minerals4EU deliverable 4.3 report[8].

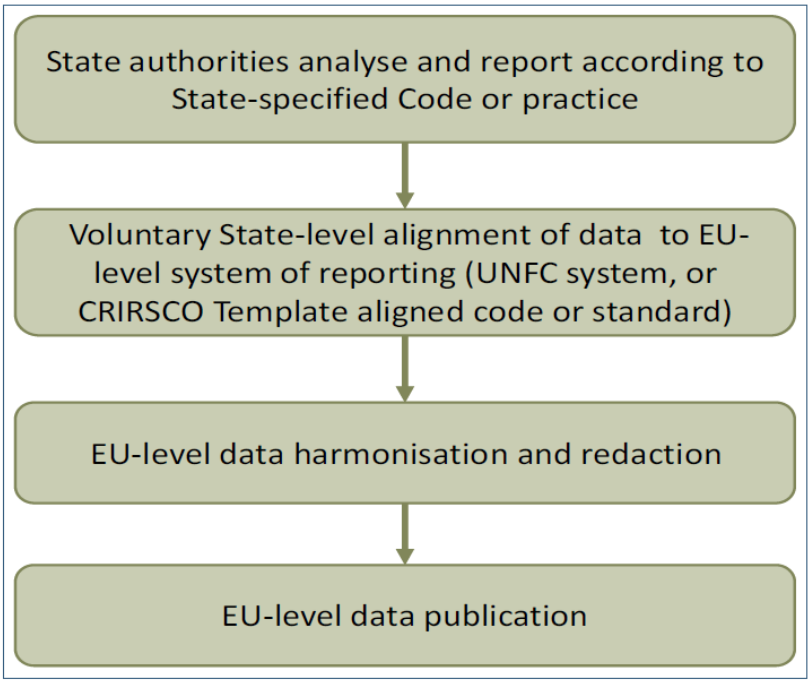


Figure 2: A potential road map for resource data harmonisation outlined by the Minventory project for data harmonisation, source: Minventory final report.

It is acknowledged that this will require clear guidance and instructional documents to enable the transposition of existing data to agreed systems. These sorts of documents have been referred to as mapping or bridging documents by previous projects, the term 'bridging document' has been used here for clarity. Training of appropriate personnel to enable this to be done at a national level is also essential.

The use of a single system of reporting should be agreed by the European nations in order to move forward with the European-level harmonisation of mineral resources and reserves statistical data. The chosen system of reporting should be internationally recognised, widely accepted across Europe, be fit for purpose for national reporting and have the capacity for other reporting standards and codes to be bridged to it. There are two routes that fit these criteria,

[8] Brown, T, and Petavratzi, E. 2015. Report on the availability of mineral statistics. Minerals 4EU WP4 Deliverable 4.3. https://vyvi-some2.vy-verkko.fi/gtk/Minerals4EU/Deliverables

systems of reporting adhering to the CRIRSCO template, or the adoption of the UNFC classification framework. There are a number of notable differences between the two routes, as discussed in the following sections.

CRIRSCO Template

The Committee for Mineral Reserves International Reporting Standards (CRIRSCO) is an advisory body (without legal authority) set up to promote the best practice in the international public reporting of Mineral Exploration Results, Mineral Resources and Mineral Reserves. An International reporting template (the CRIRSCO Template) was released in July 2006 and an update was published in 2013[9]. This template is advisory and intended to be used as a model for development of new reporting codes, and alignment of existing ones, in for potential new members. CRIRSCO-aligned codes are organised according to the classification in Figure 3, which splits categories into mineral reserves, mineral resources and exploration results. The CRIRSCO family of codes has been designed specifically for the reporting of results to stock exchanges to ensure a consistent standard is applied to protect investors. As a result of this, any 'reserves' or 'resources' stated are economic entities that have a realistic chance of being extracted in the future.

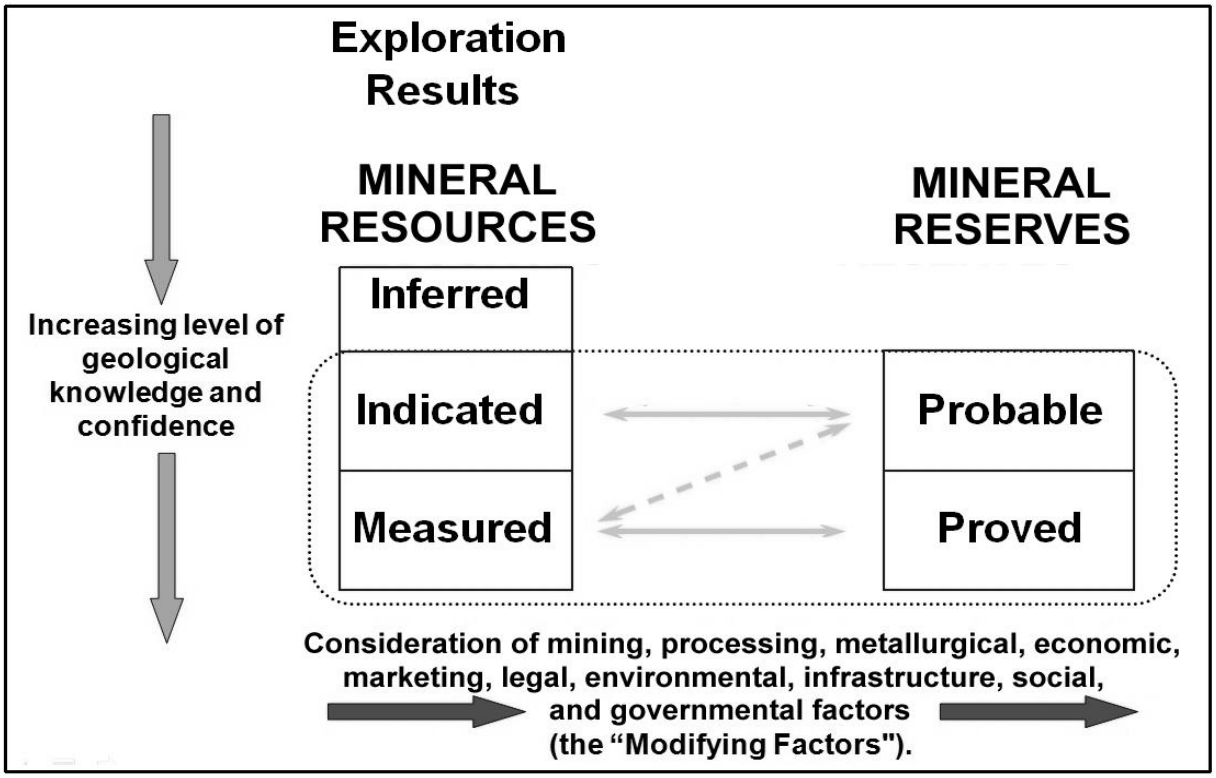


Figure 3: The CRIRISCO classification scheme, source: CRIRISCO, modified from McKelvey, V.E., 1972. Mineral Resource Estimates and Public Policy. American Scientist, 60(1), pp. 32-40.

[9] CRIRSCO. 2013. International reporting template for the public reporting of exploration results, mineral resources and mineral reserves.
http://www.crirsco.com/templates/international_reporting_template_november_2013.pdf

CRIRSCO summary:

Advantages (for regional, national, and continental scale reporting)

- Widely used by industry
- A lot of data are available that adheres to the CRIRSCO template (from industry)
- Individual codes (PERC, JORC etc...) are clearly defined standards and backed by professional bodies
- Confidence is given to any reported figures by the need for a 'competent person' whose qualifications are clearly defined in the standard
- The modified McKelvey diagram is a very clear way of conveying to non-experts the levels of confidence for different categories

Disadvantages (for regional, national, and continental scale reporting)

- CRIRSCO is not designed for the purpose of national- or continent-scale strategic planning or policy making. It is designed for public reporting and to help protect investors. As such, it cannot take into account all that needs to be considered for national level reporting.
- There is no provision to record anything that is not currently economic. As a result, this is a 5–10 year snapshot of what is economic to extract or will be in the near future. It does not take into account known but poorly defined deposits or anything that is not currently worked due to environmental or economic constraints. This is not a true representation of the total mineral inventory.
- The requirements for a 'competent person' are quite onerous and discourage many organisations
- It is less frequently used for many construction or industrial minerals or by private companies.
- Any work done by governments and geological surveys will most likely not adhere to the CRIRSCO template because it mostly relates to early-stage exploration and pre-competitive research.

UNFC

The United Nations Framework Classification (UNFC) for Fossil Energy and Mineral Resources (UN, 2010) is a global classification system developed under a mandate from the UN Economic and Social Council and serviced by the Expert Group on Resource Classification (EGRC) of the United Nations Economic Commission for Europe (UNECE). The UNFC is a flexible classification system that is capable of meeting the requirements for application at national, industrial and institutional level, as well as to be successfully used for international communication and trans-national assessments. It should be emphasised that UNFC is a *classification* and not a full reporting standard. It provides no guidance on data quality or validation, or on methods or formats of reporting.

In the UNFC system, quantities are classified using a numerical coding scheme for three fundamental criteria: economic and social viability (E); field project status and feasibility (F); and uncertainty, mostly related to geological knowledge (G). Combinations of these criteria can be displayed and visualized in three dimensions (Figure 4) or reduced to two dimensional presentations (Figure 5).

The UNFC system has been designed to create mineral inventories in harmonised ways that can be easily combined across regions and national borders for the purpose of developing mineral policies and planning. Unlike the CRIRISCO template, the UNFC can accommodate resources that are not economic to extract under current market conditions. The UNFC system does not use the term 'reserves', rather all categories are considered 'resources'.

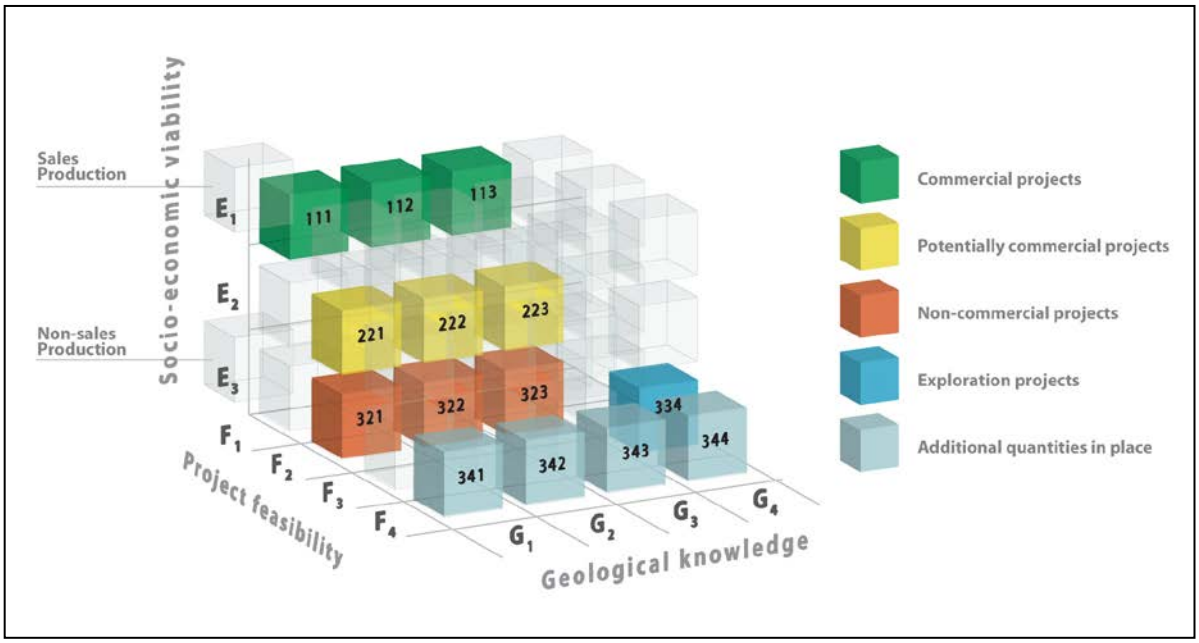


Figure 4: The UNFC classification system, source: http://www.unece.org/energy/se/reserves.html.

UNFC summary

Advantages (for regional, national, and continental scale reporting)

- It is easy to compare a wide range of commodities using UNFC, including minerals, petroleum, renewable energy sources, water, etc.
- UNFC has been designed for national- or continent-scale reporting and has the flexibility to accommodate a wide range of different types of information.
- UNFC can accommodate 'uneconomic' and 'undiscovered' resources, including early stage exploration, giving a full picture of known mineral stocks.
- A bridging document has been prepared between CRIRSCO and UNFC.
- Work has already been completed that bridges some national codes to UNFC.
- It is already being used for mineral resource inventories in some countries – e.g., Hungary, Finland, Ukraine, Romania – and possibly Norway in the near future.
- Backed by the UN – internationally recognised.
- Although competency to report using the UNFC framework is required, this is not an essential requirement (i.e., the UNFC is not a certifying body). As a result it is more readily accessed by geological surveys.

Disadvantages (for regional, national, and continental scale reporting)

- UNFC is a classification that does not include any rules governing public reporting of estimates. It is not, therefore, accepted for reporting on any stock exchanges and consequently is unlikely to be taken up by large publically-listed companies.

- Many companies do not report data to UNFC and their data will need to be bridged across (but this is possible if they report in accordance with the CRIRSCO template as a bridging document already exists).
- The three axes approach makes it appear complicated – this can be an issue if trying to communicate with policy makers or encouraging others to adopt it. But 2D representations are also possible.
- Bridging from CRIRSCO to UNFC is not always a one-to-one association but a one-to-many association, i.e., a single category in CRIRSCO may bridge to two categories in UNFC. More information may, therefore, be required at the deposit level to be sure it is correctly classified.

5 Using UNFC

On account of its flexibility, together with the fact it has been designed to be used at a national level, and is already being used or considered for use in several European countries, UNFC appears to be the best tool for harmonisation. The three axes and block diagram representation (Figure 4) can appear to be complex and difficult to understand. It is, therefore, simpler to consider the classification system in two dimensions (Figure 5).

Total Commodity Initially in Place	Extracted	Sales Production / Non-Sales Production			
		Class	Categories		
			E	F	G
	Future recovery by commercial development projects or mining operations	Commercial Projects	1	1	1, 2, 3
	Potential future recovery by contingent development projects or mining operations	Potentially Commercial Projects	2	2	1, 2, 3
		Non-Commercial Projects	3	2	1, 2, 3
	Additional quantities in place associated with known deposits		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		3	4	4

Figure 5: Abbreviated version of UNFC-2009, showing the primary classes. Source: Adapted from UNFC (www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/unfc2009/UNFC2009_ES39_e.pdf).

This shows the range of codes that are possible for some typical stages of the lifecycle of a minerals project. However, the flexibility of the UNFC system means that other combinations of codes are possible to suit the individual circumstances. Each project, or data point for

resources, needs to be considered in turn and its place on each axis considered separately, because many have individual properties, which may affect the UNFC classification.

The UNFC axes

The simplest way to use the UNFC classification is to consider each of the three axes in turn. The E axis encompasses factors that influence economic and social viability. These can include the legal and fiscal framework in the jurisdiction where the resource is located, environmental factors, the social acceptability of mineral extraction and other factors of a non-technical nature (which would be covered by the F axis). An explanation of the different E axis categories is given in Figure 6.

An example of E1 would be an operating mine, E2 may be a mine that is not yet operational but where a feasibility study has been completed, while E3 covers resources which may be too small to be economic, or deposits at an early stage of exploration with unproven economics or that may be unviable due to environmental constraints. The E axis may be the most difficult for geological surveys to assess. They may require additional help when considering economic and social aspects if the relevant expertise is not available in house.

Category	Definition [a]	Supporting Explanation [b]
E1	Extraction and sale has been confirmed to be economically viable.[c]	Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions. All necessary approvals/contracts have been confirmed or there are reasonable expectations that all such approvals/contracts will be obtained within a reasonable timeframe. Economic viability is not affected by short-term adverse market conditions provided that longer-term forecasts remain positive.
E2	Extraction and sale is expected to become economically viable in the foreseeable future.[c]	Extraction and sale has not yet been confirmed to be economic but, on the basis of realistic assumptions of future market conditions, there are reasonable prospects for economic extraction and sale in the foreseeable future.
E3	Extraction and sale is not expected to become economically viable in the foreseeable future or evaluation is at too early a stage to determine economic viability.[c]	On the basis of realistic assumptions of future market conditions, it is currently considered that there are not reasonable prospects for economic extraction and sale in the foreseeable future; or, economic viability of extraction cannot yet be determined due to insufficient information (e.g. during the exploration phase).Also included are quantities that are forecast to be extracted, but which will not be available for sale.

a the term “extraction” is equivalent to “production” when applied to petroleum.
b the term “deposit” is equivalent to “accumulation” or “pool” when applied to petroleum.
c 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.

Figure 6: Explanation for the UNFC E axis. Source: adapted from UNFC.

The F axis considers the technical feasibility of a project. This differs from the E axis in that it assesses the confidence in technical aspects of project development, such as processing technology, the maturity of exploration, and the commitments required, such as extra

infrastructure necessary for development. The definitions and explanation for the F axis are given in Figure 7.

Category	Definition	Supporting Explanation
F1	Feasibility of extraction by a defined development project or mining operation has been confirmed.	Extraction is currently taking place; or, implementation of the development project or mining operation is underway; or, sufficiently detailed studies have been completed to demonstrate the feasibility of extraction by implementing a defined development project or mining operation.
F2	Feasibility of extraction by a defined development project or mining operation is subject to further evaluation.	Preliminary studies demonstrate the existence of a deposit in such form, quality and quantity that the feasibility of extraction by a defined (at least in broad terms) development project or mining operation can be evaluated. Further data acquisition and/or studies may be required to confirm the feasibility of extraction.
F3	Feasibility of extraction by a defined development project or mining operation cannot be evaluated due to limited technical data.	Very preliminary studies (e.g. during the exploration phase), which may be based on a defined (at least in conceptual terms) development project or mining operation, indicate the need for further data acquisition in order to confirm the existence of a deposit in such form, quality and quantity that the feasibility of extraction can be evaluated.
F4	No development project or mining operation has been identified.	In situ (in-place) quantities that will not be extracted by any currently defined development project or mining operation.

Figure 7: Explanation for the UNFC F axis. Source: adapted from UNFC.

The G axis considers confidence in geological knowledge. This will cover the stage of exploration, the quantities of samples taken, the amount of drilling carried out and/or the overall geological knowledge and complexity of the project or resource area. The definitions and explanations of the G axis are shown in Figure 8.

G1 relates to deposits that have been extensively studied with detailed local scale investigations that allow detailed geological models to be built with a high degree of confidence. This includes, for example, projects that are in production, that have been in production or are at an advanced stage of development.

As the G axis numbering increases, the level of confidence in the geological knowledge decreases. There is no precise definition of what is meant by high, medium and low levels of confidence in the UNFC. Furthermore, the nature and amount of data required will be dependent on the deposit type and geological situation. This is discussed further in section 9. The G4 category is for resources where there is little actual geological knowledge of a deposit. This will include deposits inferred from regional geological mapping, geophysical or geochemical data, predictive modelling, poorly constrained historic estimates and early stage exploration.

Category	Definition	Supporting Explanation
G1	Quantities associated with a known deposit that can be estimated with a high level of confidence.	For in situ (in-place) quantities, and for recoverable estimates of fossil energy and mineral resources that are extracted as solids, quantities are typically categorised discretely, where each discrete estimate reflects the level of geological knowledge and confidence associated with a specific part of the deposit. The estimates are categorised as G1, G2 and/or G3 as appropriate. For recoverable estimates of fossil energy and mineral resources that are extracted as fluids, their mobile nature generally precludes assigning recoverable quantities to discrete parts of an accumulation. Recoverable quantities should be evaluated on the basis of the impact of the development scheme on the accumulation as a whole and are usually categorised on the basis of three scenarios or outcomes that are equivalent to G1, G1+G2 and G1+G2+G3.
G2	Quantities associated with a known deposit that can be estimated with a moderate level of confidence.	
G3	Quantities associated with a known deposit that can be estimated with a low level of confidence.	
G4	Estimated quantities associated with a potential deposit, based primarily on indirect evidence.	Quantities that are estimated during the exploration phase are subject to a substantial range of uncertainty as well as a major risk that no development project or mining operation may subsequently be implemented to extract the estimated quantities. Where a single estimate is provided, it should be the expected outcome but, where possible, a full range of uncertainty in the size of the potential deposit should be documented (e.g. in the form of a probability distribution). In addition, it is recommended that the chance (probability) that the potential deposit will become a deposit of any commercial significance is also documented.

Figure 8: Explanation for the UNFC G axis. Source: adapted from UNFC.

The E and F axis can also be further divided into sub-codes, which differentiate between specific stages in the development of a project. For example, such sub-codes may be useful if government subsidies can make a deposit economic or if capital funding has been invested but production is not yet underway. It should be noted, that for use in a resource management system, the use of sub-codes is essential to properly assess the status of a project.

6 Bridging, between different codes and classifications

Various documents, known as 'bridging documents,' exist to convert between different systems of defining resources, which have been developed by governments and the minerals industry to enable comparisons. However, not all commonly used definitions have bridging documents, as shown in Figure 9. This highlights that resource harmonisation can be a very challenging task.

The process of bridging between codes is complex due to the difference in national resource codes as well as the inherent complexities surrounding geological, technical, environmental and socio-economic factors at individual sites. Therefore, the most appropriate body to convert data

is the owner of national resource data (normally the national geological survey) as they will have the most experience and understanding of their data and mining industry.

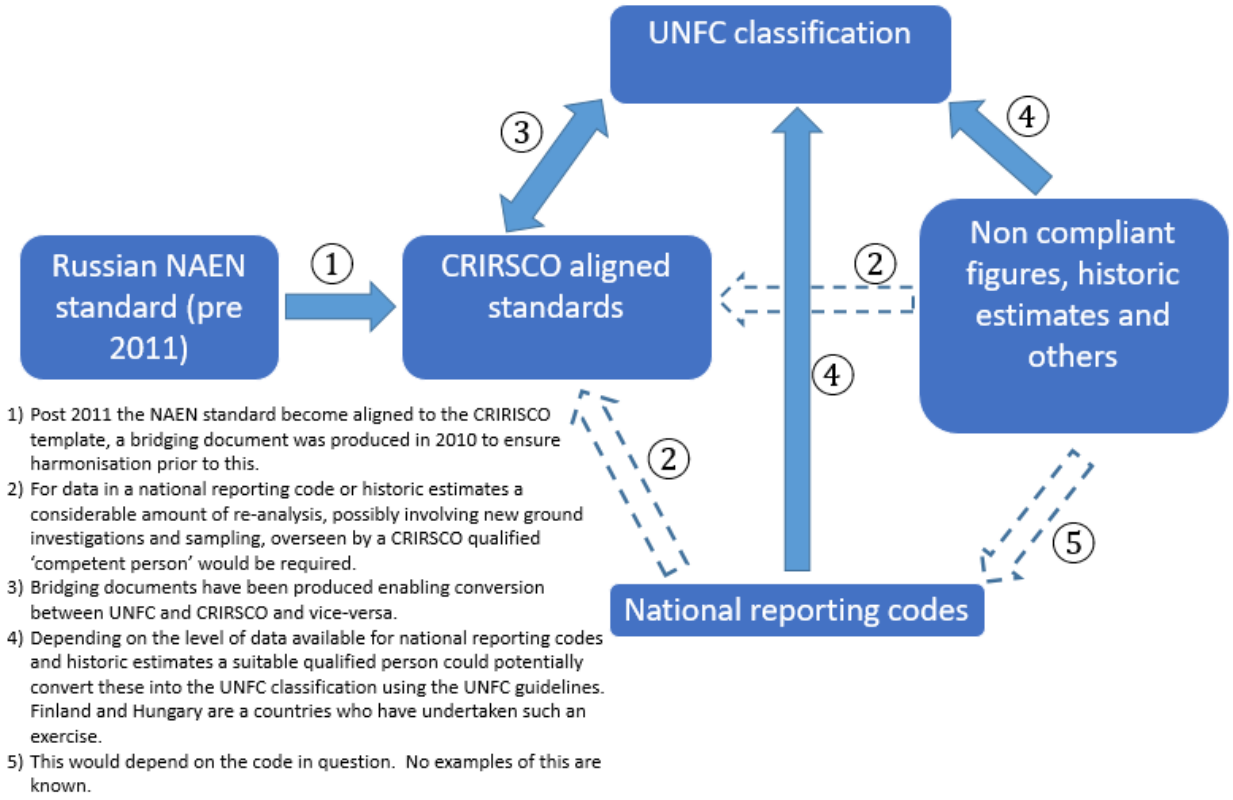


Figure 9: Bridging documents between different reporting codes and classifications. Solid arrows indicate existing bridging documents, dotted arrows indicate where bridging may be possible but little or no official documents exist.

Bridging between UNFC and CRIRSCO

Both the UN and CRIRSCO have undertaken substantial work to develop a bridging document between the CRIRSCO template reporting standards and the classification systems employed by the UNFC. As a result, there is a clear set of rules that can be followed to effectively bridge one to the other[10]. Although it must be noted that the individual circumstances of specific deposits always need to be taken into account. Hence, a 'one size fits all' approach may not always work and each project needs to be considered on its own merits. The detailed bridging instructions can be found in the UNFC guidance document[11] and specific case studies and examples can be found in associated case studies[12] which go into great detail about the specific circumstances that users may encounter for different types of projects. Examples of how

[10] UNECE. 2015. Revised annex iii bridging document between the CRIRSCO template and UNFC-2009. http://www.crirsco.com/docs/Revised_CRIRSCO_Template_UNFC_Bridging_Document.pdf
[11] United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) https://www.unece.org/energy/se/unfc_2009.html
[12] S. Henley. CRIRSCO-UNFC 2009 mapping Solid Minerals Case Studies. http://www.crirsco.com/news_items/mapping_solid_minerals_case_studies-SHenley.pdf

CRIRSCO template figures have been bridged to UNFC are provided in section 8, which contains several case studies that have compiled statistics for mineral resources on a national level using UNFC.

The simple bridging between CRIRSCO and UNFC is outlined in Figure 10, taken from the UNFC guidance document. This shows relatively simple one-to-one relationships between categories in either system. Although it should be noted that in many cases 'proved' and 'probable' reserves are combined, as are 'measured,' 'indicated' and 'inferred' resources, in these cases the specific location of the data point on the G axis is uncertain and a combination of G axis codes may be required, e.g. G1+G2.This can result in a on to many relationship where one CRIRISCO code could be one of several UNFC codes, here extra information is required to properly classify.

CRIRSCO Template		UNFC-2009 "minimum" Categories			UNFC-2009 Class
Mineral Reserve	Proved	E1	F1	G1	Commercial Projects
	Probable			G2	
Mineral Resource	Measured	E2	F2	G1	Potentially Commercial Projects
	Indicated			G2	
	Inferred			G3	
Exploration Results		E3	F3	G4	Exploration Projects

Figure 10: Bridging between UNFC and CRIRSCO. The minimum categories refer to the fact that these set minimum standards, i.e. a mineral reserve must be at least E2 and F2, but it may be E1F2 or E2F1 Source: UNFC.

Another way of visualising the basic bridging of the two systems is shown in Figure 11.

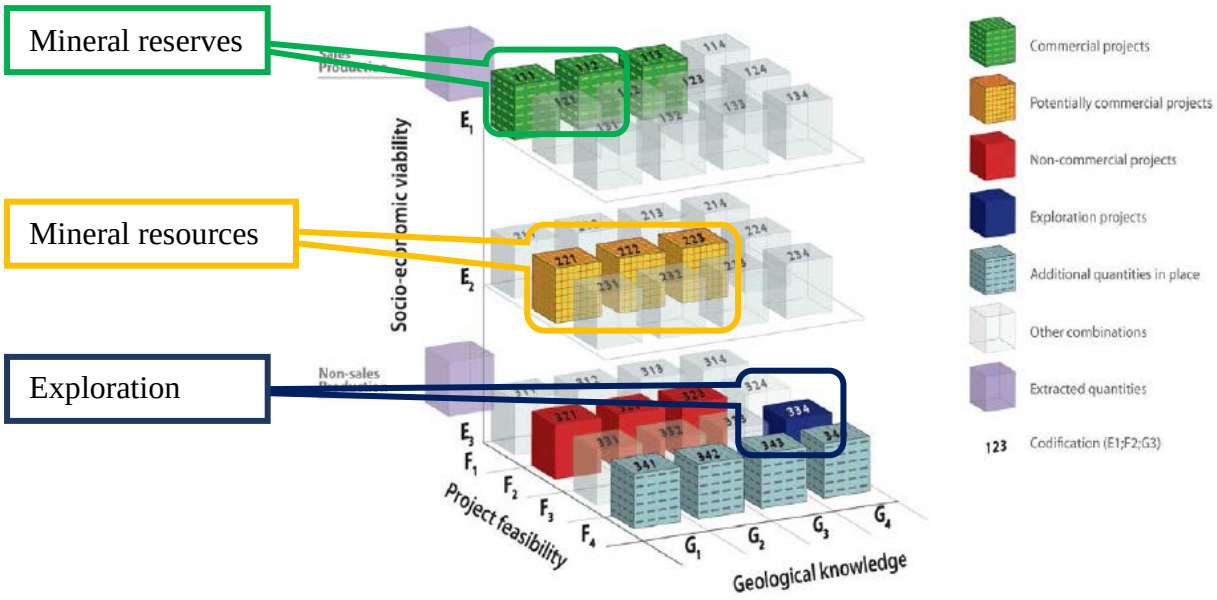


Figure 11: Bridging between UNFC and CRIRSCO. Source UNFC.

Figure 11 also shows the many possible resource types (especially non-commercial resources) that can be covered by the UNFC but are not covered by CRIRSCO codes. This needs to be carefully considered as if only CRIRSCO figures are used a full dataset of resource stocks as defined by UNFC will not be possible.

It is also important to note when bridging between CRIRSCO and UNFC, if figures for reserves are included in those for resources (reporting often states whether resources are exclusive or inclusive of material used to estimate reserves). These two must always be separated to avoid double counting.

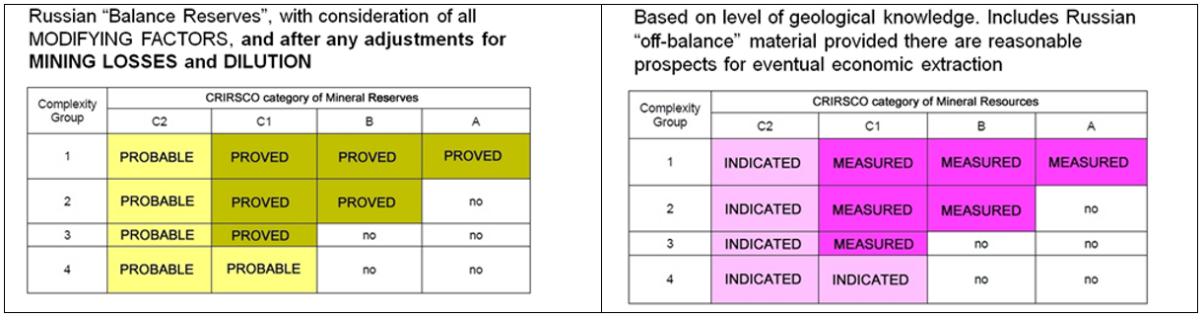
Bridging between UNFC and the Russian system

The Russian code, or NAEN code, has been aligned with the CRIRSCO template since 2011. As such, the NAEN code incorporates the principles, terminology and definitions of the CRIRSCO template whilst retaining many of the principles behind the superseded Russian State System. Due to its alignment to CRIRSCO, the existing bridging document from CRIRSCO to UNFC can be used to bridge between NAEN to UNFC.

Within Europe, many central and eastern European counties use a derivation of the older, non-CRIRSCO-aligned Russian State System. There is a bridging document that can be used to convert Russian State classification categories to CRIRSCO[13] and from there the CRIRSCO-UNFC bridging document discussed in section 8 can be used. The basic principles of bridging between some of the concepts in the Russian System and CRIRSCO are shown in Figure 12. This shows the concept of ‘balance reserves’ and ‘off balance’ material. These refer

[13] GKZ and CRIRSCO. Guidelines on Alignment of Russian minerals reporting standards and the CRIRSCO Template. 2010. http://www.vmine.net/PERC/russia/conversion_guidelines_2010_9.pdf

respectively to material that can be reported after approval by the relevant state body and is proven to be economically recoverable, and material that is uneconomic, for reasons such as they are below agreed cut-off grades, inaccessible by current mining methods or processing technologies.



Russian "Balance Reserves", with consideration of all MODIFYING FACTORS, **and after any adjustments for MINING LOSSES and DILUTION**

Complexity Group	CRIRSCO category of Mineral Reserves			
	C2	C1	B	A
1	PROBABLE	PROVED	PROVED	PROVED
2	PROBABLE	PROVED	PROVED	no
3	PROBABLE	PROVED	no	no
4	PROBABLE	PROBABLE	no	no

Based on level of geological knowledge. Includes Russian "off-balance" material provided there are reasonable prospects for eventual economic extraction

Complexity Group	CRIRSCO category of Mineral Resources			
	C2	C1	B	A
1	INDICATED	MEASURED	MEASURED	MEASURED
2	INDICATED	MEASURED	MEASURED	no
3	INDICATED	MEASURED	no	no
4	INDICATED	INDICATED	no	no

Figure 12: Conversion of the Russian State Committee on Reserves (GKZ) system to CRIRSCO mineral resources and reserves system (Source: S. Henley, 2010[14]). Note that the CRIRSCO categories refer to the coloured boxes not the A, B, C1 and C2 categories.

Another term used by the Russian State system which is not simply transferable to the CRIRSCO template are 'Prognostic resources': these are estimates based on inferred geological data. The category of P3 in particular does not translate to the CRIRSCO template as these represent the potential possibility of discovery of a mineral deposit based on regional survey work. The P3 would, however, bridge to the UNFC category of 334. There is currently, however, no official guidance of bridging between the old (GKZ) Russian system and UNFC.

Further details of how individual countries use a system based on the Russian State system can be found in section 8. This includes several case studies of how individual countries bridged their existing data to UNFC.

7 UNFC as a tool for harmonisation

As discussed above, UNFC is the only commonly used, internationally recognised, system that can incorporate something close to the concept of 'all there is' in terms of mineral resources and can, therefore, provide a relatively complete picture of mineral stocks. The majority of other internationally recognised systems cannot accommodate uneconomic and undiscovered resources, including early stage exploration and historical estimates. For commercial development, the concept of 'all there is', sometimes referred to as the 'ultimate recoverable resource', is unnecessary, and perhaps even unhelpful, because it is not required for stock markets or investors. However, it is important to know more broadly what the ultimate recoverable resources are likely to be when considering longer-term minerals planning and industrial strategy on a national or continental scale. However, it should be recognised that, even though UNFC may be able to accommodate this kind of data, for many countries such data has not previously been collected and may not currently exist in any format. An absence of data does not necessarily mean an absence of resources. These issues are further explained in section 8.

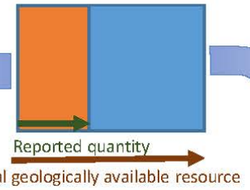
[14] S. Henley. 2010. Reporting Russian reserves and resources for international markets. Presentation for CRIRSCO and ICMM. https://www.slideshare.net/silicondale/russiacrirsco-june-2010

As discussed in section 6, the UNFC is also a useful system to use because several bridging documents already exist between UNFC and other codes and standards, including many examples of national resource codes (see section 8). In addition, although competency to report using the UNFC framework is required, this is not an essential requirement (UNFC is not a certifying body, unlike CRIRSCO family codes) and as a result it is potentially more easily assessed by geological surveys.

The following hypothetical example (Figure 13 and following text) is provided to summarise the challenges of harmonising resource data in Europe discussed above and to highlight how UNFC can help with harmonisation. This uses a theoretically identical deposit located in three different countries that utilise three different systems of reporting.

For none of these countries does the reported 'resource' represent "all there is". If you add these together the figure of 120,000 tonnes is meaningless.

Country A



Country A uses JORC

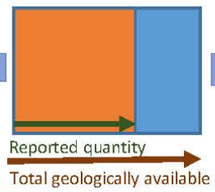
For this deposit there is just one sub-category with an 'inferred' resource

Amounting to 20,000 t

The 'inferred resource maps to UNFC using a 'bridging' document.

But what about the rest of the deposit?
We know it exists but there is no place for it within JORC
UNFC provides us with somewhere for it.

Country B



Country B uses a National Reporting Code

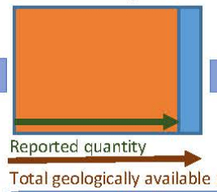
For this deposit there is just one sub-division of 'resource'

Amounting to 40,000 t

Depending on the current status of the deposit, UNFC provides a range of categories to reflect what is known. This could be sub-divided between two categories.

But what about the rest of the deposit?
We know it exists but there is no place for it within this national reporting code
UNFC provides us with somewhere for it.

Country C



Country C does not have a Reporting code, but has 'historical estimates' of resources

Amounting to 60,000 t

Additional information would be needed to sub-divide an historical estimate between the different UNFC categories (as indeed it would if it was translated into any code). However there are a range of categories which provides the necessary flexibility.

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

Figure 13: How UNFC can help in harmonisation

By using the UNFC, the three resource figures in the example of Figure 13, which were previously incompatible, can be compared in a consistent manner. This allows aggregated totals for separate categories under UNFC to be produced (Figure 14).

UNFC category	Description	Country A	Country B	Country C
222	Potentially commercial project	20,000	20,000	20,000
343	Additional quantities in place associated with known deposits	20,000	20,000	20,000
344	Additional quantities in place associated with potential deposits	20,000 + 10,000	20,000 + 10,000	20,000 + 10,000

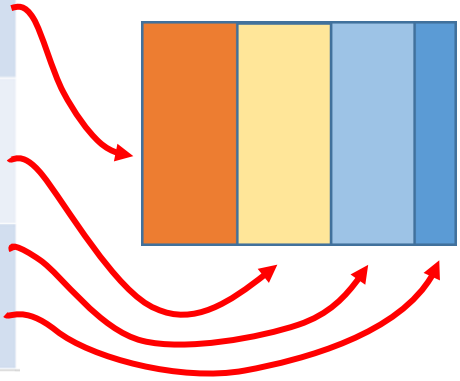


Figure 14: International comparison using UNFC.

Data gaps in European reserve and resource data

An important point to consider when using the UNFC as a tool for harmonisation are gaps in the data. The UNFC provides a flexible and adaptable tool for defining resources, by including categories for everything from well-constrained stocks of material currently being extracted, to deposits that have low confidence in their location, properties, or technical and economic feasibility to be extracted. Although for an accurate full inventory of resources, and for use in a resource management system, it is important to include the lower confidence, sub-economic resources, it should be noted that these data are not commonly available. Such data may include resource figures derived from probabilistic modelling on a regional level[15] or by using historic estimates that do not conform to any modern standards or by extrapolating from regional mapping, geochemical or geophysical spatial data.

If the data source is from a CRIRSCO-compliant system of reporting, it cannot take into account non-economic resources, although there is a category for ‘exploration results’. However, this category is intended for use with data such as grades and drill-core intercepts rather than tonnages. If using the Russian system, or a national code derived from the Russian system, the ‘Prognostic resource’ categories 2 and 3 cover these low-confidence resource categories but such data may not always be calculated by national geological surveys or other organisations conducting resource assessments.

The vast majority of available resource data will relate to working or closed mineral operations. These will be provided by the minerals industry through financial or regulatory reporting, but as a result there may be very little data for resources that are currently uneconomic, or for which the extractive industry is not actively exploring. However, an absence of data does not mean resources are absent, and these data gaps must be clearly identified. National geological surveys

[15] USGS. 2018. Probabilistic mineral assessment research & development, project summary. https://minerals.usgs.gov/west/projects/probminassmnt.htm

may be able to fill some of these gaps using their expert knowledge and wealth of historical data.

8 National resource and reserve reporting in Europe

Detailed descriptions of the reserve and resource reporting procedures in different European countries can be found in D1.5.10, Technical Guidance Note: Country summaries for national legal and regulatory frameworks for resource and reserve data. This gives details of the codes, standards and classification schemes used, the legal and regulatory framework, the level of data availability, existing harmonisation work and any recommendations for further harmonisation.

By understanding existing practices in individual European countries it is hoped that current approaches to harmonisation can be shared and gaps in bridging documents from national schemes to internationally recognised schemes can be identified.

Generally, there are two broad positions regarding national collection of resources and reserve data: (a) a country may have some form of resource management system, or legislation that specifies a specific code or standard to be used when reporting on resources and reserves; or (b) a country will have no specific systems (and often no resource management system). In the latter example public companies that operate in that country will use whatever code they are required to by the stock exchange where they are registered (e.g., the CRIRSCO-compliant JORC or NI 43-101). However, if they are privately owned then no data may be publically available and any data that are collected may not conform to any recognised code or standard. Examples of such countries include the UK, France and Italy. In these cases, the data may not exist unless obtained from publically owned companies or unless the national geological survey takes an active role in mineral exploration. This absence of data needs to be appreciated before issues over harmonisation can be addressed.

Amongst the countries that have a national resource code within Europe, there is an even split between: (a) some derived from the Russian code, for example Hungary, Slovenia and Croatia; (b) a unique national code, such as Austria or Lithuania; and (c) a code compliant with the CRIRSCO template, such as Norway, Finland and Sweden (Table 1; Figure 15). In these countries, some form of resource management system is in place and the minerals industry will often have a legal obligation to report figures to a national body. As a result, if some form of bridging document is developed for figures from these national codes, the data can be translated into internationally recognised systems, such as CRIRSCO and UNFC (however it must be noted that in many cases the non-commercial projects, exploration projects and undiscovered resources, as defined by the UNFC, are not routinely collected as discussed in section 7).

There are also examples of national schemes that are not directly related to internationally recognised ones, for example Slovakia. Elsewhere, responsibility to collect these data does not lie at a national level but a state level, for example in Germany. In these examples, there are major barriers to the creation of national datasets, before harmonisation across national borders can be considered.

Country	Reporting code	Comments
Austria	National (Other)	ÖNORM G 1050
Belgium	None	
Bulgaria	National (Russian, or based on Russian)	
Croatia	National (Russian, or based on Russian)	
Cyprus	National (Other)	
Czech Republic	National (Russian, or based on Russian)	
Denmark	None	In Greenland, data are reported in accordance with CRIRSCO codes such as JORC and NI 43-101
Estonia	National (CRIRSCO)	*Estonia Mineral Resource Classification System* (aligned to PERC)
Finland	National (CRIRSCO)	*Fennoscandia Review Board Standard* (aligned to PERC, JORC, etc.)
Germany	National (Other)	Each federal state has its own regional code
Greece	National (Other)	
Hungary	National (Russian, or based on Russian)	Most commonly used system of reporting
Ireland	None	Companies must report data in line with a CRIRSCO code such as PERC or JORC
Italy	None	
Latvia	National (Russian, or based on Russian)	
Lithuania	National (based on UNFC)	Aligned to UNFC
Luxembourg	None	
Malta	National (Other)	
Netherlands	None	
Norway	National (CRIRSCO)	*Fennoscandia Review Board Standard* (aligned to PERC, JORC, etc.)
Poland	National (Russian, or based on Russian)	*Polish National Reporting Code* (aligned to UNFC)
Portugal	None	
Romania	National (Russian)/UNFC	Since 1998, resource and reserve data in Romania have been reported in line with UNFC
Slovakia	National (Other)	
Slovenia	National (Russian, or based on Russian)	
Spain	None	
Sweden	National (CRIRSCO)	*Fennoscandia Review Board Standard* (aligned to PERC, JORC, etc.)
United Kingdom	None	

Table 1: National resource reporting codes in countries covered by the ORAMA project.

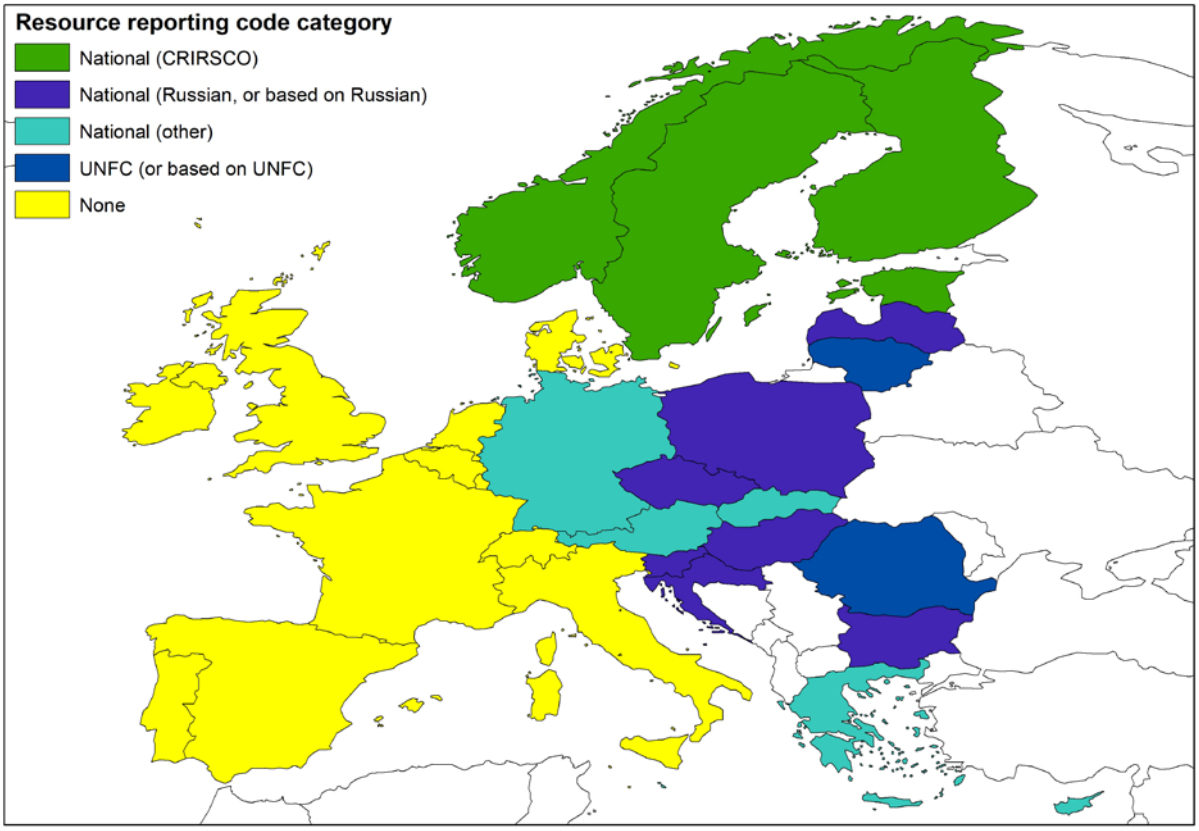


Figure 15: Simplified national resource reporting codes in countries covered by the ORAMA project.

National case studies

As outlined in the previous section it can be very helpful to consider the framework in which a specific country sits before attempting to bridge across to the UNFC for harmonisation purposes. A well-structured dataset with clear definitions will be comparatively straightforward to harmonise with the UNFC and other classification schemes. In contrast, datasets that are fragmented and have loose definitions, such as in the UK, and commonly rely on historical data, can be very challenging. This section contains a number of case studies of national projects to bridge country- or region-specific data to the UNFC. These cover the wide range of examples discussed above and can be used as good practice examples and learning experiences for bridging between new datasets.

Case studies from countries with a national reporting code

Hungary

In order to achieve the modernisation of the national mineral resources inventory, the predecessors of the Mining and Geological Survey of Hungary (MBFSZ) started a research project in 2013. During the last 5 years, the project members have analysed the mineral resources classification systems applied in practice and the reporting standards and codes based on these classifications (UNFC-2009, CRIRSCO-aligned standards, SPE-PRMS (Society of Petroleum Engineers Petroleum Resource Management System) and Australian Geothermal Reporting Code). The Survey has organised several consultations with professional

organisations and companies to discuss the recently used Hungarian and internationally applied definitions and methods in order to make an agreement about the common ground and application. A set of case studies covering all mineral deposit types (metallic ores, coal, non-metallic minerals, hydrocarbon, geothermal energy, carbon capture and storage) has been carried out to test the conversion algorithms.

The principles and elements of the SPE-PRMS that are aligned with the UNFC were integrated into the Hungarian Mining Law in 2017. This was based on stakeholder consultation between the representatives of oil and gas companies and the MBSZ (Mining and Geological Survey of Hungary) and the experts of the Hungarian Geological Society (MBSZ was integrated into MBFSZ in 2017).

Several case studies were been carried out in the project mentioned above. Here the classification of non-metallic resources in Zala County is presented. In Zala County, there are approximately 600 million m^3 of non-metallic mineral resources according to the national inventory of 1 January 2015; mainly building stones and organic sediments (Figure 16).

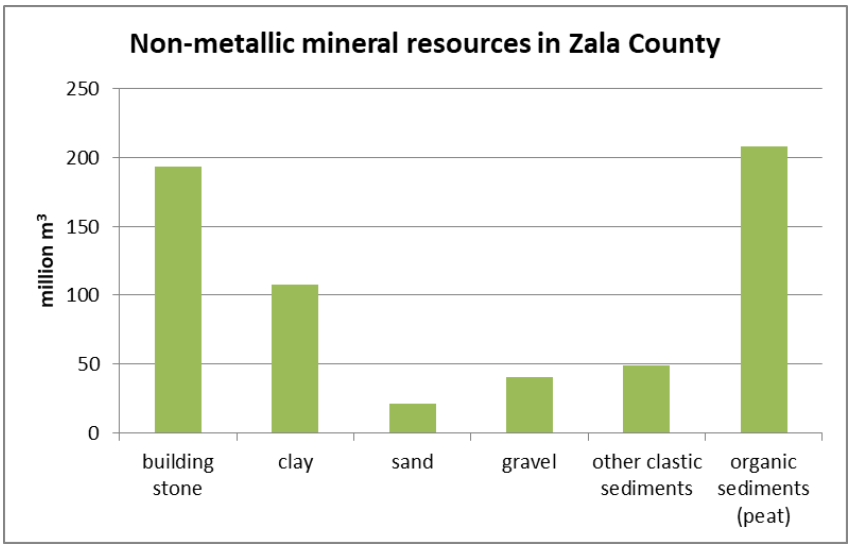


Figure 16: Non-metallic mineral resources in Zala County, Hungary.

Mineral resources are registered in the Hungarian national mineral resource inventory based on the reports of mining operators according to the "Russian" classification system. For resource conversion, the following information has been used:

- The status of the mine or quarry (active, pending, abandoned, unoccupied explored area);
- Resource category (A, B, C1 or C2; in case of non-metallic resources categories A and B are merged into A+B);
- *In situ* mineral resource quantity;
- A 'complexity group' is also necessary to be defined, as is explained below. However, it is not registered in the Hungarian non-metallic mineral resources inventory so it has been estimated.

Complexity is one of the most important differences between the Russian-type national system and international systems. Complexity is designed to support the mineral resource management

blocks that make up the productive part of the deposit and considers the homogeneity of the deposit that needs to be taken into consideration for a specific volume. These blocks are approximately equivalent to 'domains' that are often used for geostatistical analyses of resources in CRIRSCO-compliant codes. These blocks may be separated tectonically or may differ by quality. Resources can be calculated for these blocks and separation may also be interpreted by the need for different mining operations. Deposits may be classified into 3, 4 or 5 classes depending on national or regional practices. Generally, below 50 blocks/km^2 can be considered as a deposit of low complexity (relatively homogeneous), whereas over 100 blocks/km^2 a deposit can be considered as a complex one (heterogeneous).

The conversion algorithm used in this case study (Figure 17) is based on the GKZ to CRIRSCO bridging document and consists of 3 steps:

1. Category C1 is divided into two parts based on complexity group.
2. Categories A+B and less complex C1 are converted into Measured Resources whereas the more complex C1 and C2 go into Indicated Resources.
3. The status of the mine is examined: in case of an active mine or quarry, all modifying factors had been considered so the resources can be converted into reserves.

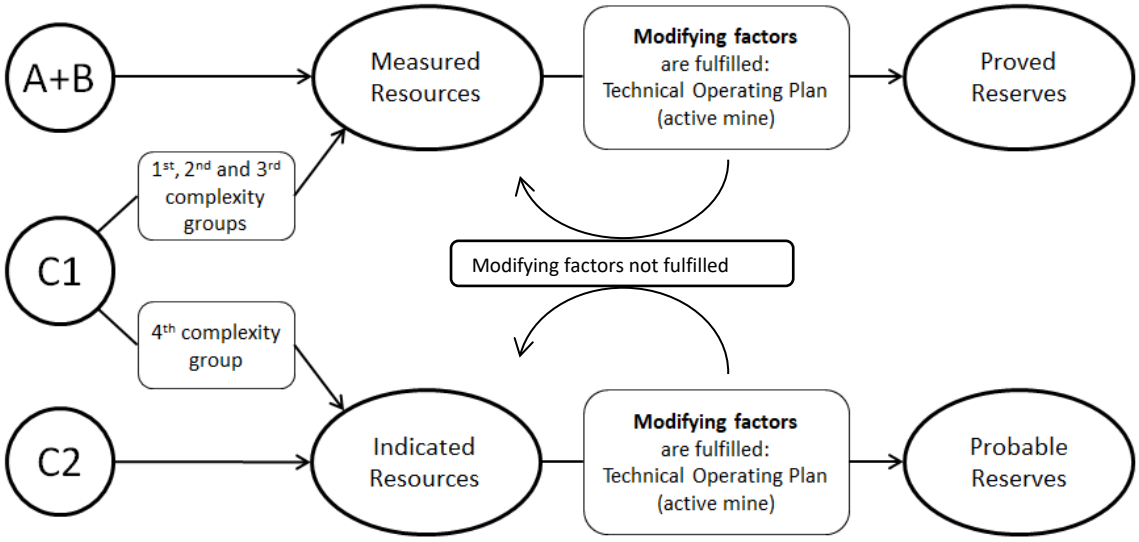


Figure 17. Conversion algorithm between the national (Russian type) and international systems including the CRIRSCO type reporting codes and the UN classification framework.

UNFC classes can be determined based on UNFC–CRIRSCO bridging document (UNECE 2013). Figure 18 compares the mineral resources according to the original, CRIRSCO, and UNFC classification systems. Classes A+B represent a high level of geological knowledge (maximum 20 % uncertainty). C1 has 35 % uncertainty and C2 has 60 % uncertainty in the calculation of the volume of the resource. The D categories (D1, D2 and D3) are not indicated in Figure 18 because these poorly known resources are the topics of potential assessments. However, lesser known resources can also be interpreted as Inferred Resources or Exploration Results that may be harmonised with the UNFC classes 223 and 334, respectively.

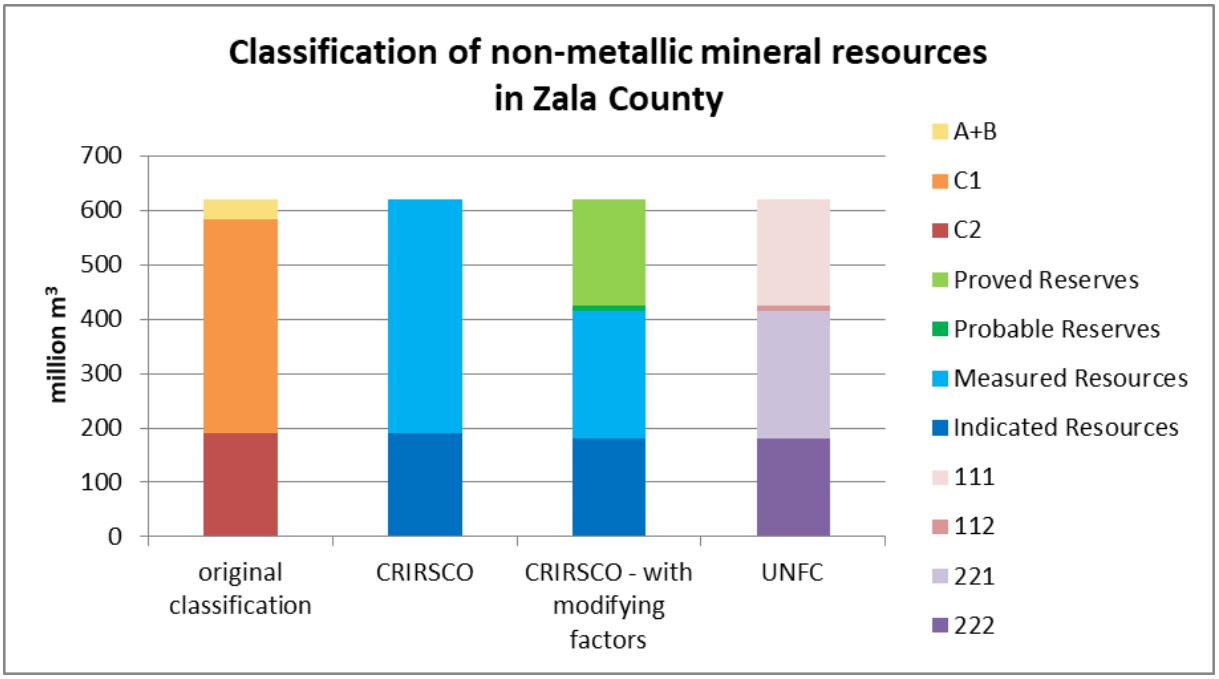


Figure 18: Original, CRIRSCO and UNFC classification of non-metallic mineral resources in Zala County

Slovenia

In Slovenia, there is a national "Commission for Determining Mineral Reserves and Resources". All minerals are in state ownership. Concessioners are obligated to report annually to the ministry responsible for mining (at present, Ministry for Infrastructure). Annual reporting forms include the following data:

- Volume of extracted mineral commodities (tonnes or m^3)
- Degraded area (ha)
- Reserves/resources in situ (m^3).

Mineral commodity data are collected by:

- "Public Mining Service" organised within the Geological Survey, on behalf of the ministry responsible for mining, (National MR Database and Mining Registry Book) and
- "Commission for determining mineral reserves and resources" on a national level.

The Slovenian national classification is derived from the Russian mineral classification. Resources and reserves are divided into three classes: 1) economic, 2) potentially economic, and 3) non-economic. Each of these classes is further sub-divided into the following categories: A, B, C1 (which are classes as "reserves"), and C2 (classed as "resources"). The same reporting system is used for all types of mineral commodities including aggregates, because all types of minerals are in state ownership and managed by the state.

Only mineral resources and reserves inside 'mining areas' and 'exploration areas' with granted mining rights and/or exploration permits are classified (as stated in the Report on classification on reserves and resources) and defined by the national Commission for determining mineral reserves.

The Geological Survey of Slovenia (GeoZS) was involved in the Minerals4EU project. In order to incorporate the data into the Minerals yearbook created by Minerasl4EU, Slovenian mineral data were transformed from the national classification into the UNECE-2009 classification (Figure 19). Because the resource and reserve data for individual deposits are not public, the data reported to Minerals4EU were summarised for each type of mineral resource and reserve (e.g., crushed stone - limestone) at a national level.

fundamental characterization	economic efficiency	categories (national classification)	UNFC E_{axis}	UNFC F_{axis}	UNFC G_{axis}
economic	proved reserves	A, B, C_1, C_2	1	1	1, 2, 3
potentially economic		A, B, C_1, C_2	2	2	1, 2 , 3
non-economic	measured resources	A, B, C_1, C_2	3	2	1, 2, 3

Figure 19: Overview of simplified transformation of the Slovenian national classification into UNFC

However, only those UNFC-2009 categories (marked yellow in Figure 20) have been used, as these can be transformed from the existing national mineral classification. For the rest of the categories, the balancing of mineral data will have to be generated separately.

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

Figure 20: Categories from UNFC used for transformation

Therefore, the model for the transformation of statistical data from the national mineral classification to the UNFC in Slovenia was developed. As such, it is suitable for annual reporting of mineral statistics into EU data platforms.

It should be noted that the Slovenian transformation model cannot be used for other ESEE (East and South East Europe) countries (using national classifications based on Russian system) because each country has its own version of the classification system.

Poland

The Polish Geological Institute (PGI) has compiled a detailed case study converting the Polish classification system to the UNFC in their publication 'The Mineral Resources of Poland'[16]. This outlines in detail how the Polish classification system can be bridged across to the UNFC and explores some of the issues such as the lack of a definition for 'reserves' in the Polish system.

This case study shows the difficulties in converting data between two systems that, although they share many basic principles, have many substantial differences. For example, the Polish system is hierarchical and higher-level categories will include figures from lower level ones, as opposed to UNFC in which no one category is included within another. Despite such barriers, a robust system for bridging between the two classifications systems has been developed, and the PGI is able to publish an inventory of their national mineral resources using UNFC.

The Polish classification system splits resources into D (inferred resources, with a possible error greater than 40 %), C2 (inferred resources, with a possible error less than 40 %), C1 (indicated resources), B (measured resources, with a possible error less than 20 %), and A (measured resources, with a possible error less than 10 %). Detail of how these categories bridge across to UNFC are shown in Table 2 and Figure 21.

[16] POLISH GEOLOGICAL INSTITUTE. 2017. Mineral Resources of Poland. (Warsaw). http://geoportal.pgi.gov.pl/css/surowce/images/2017/pdf/mineral_resources_of_poland_2017.pdf

Polish classification	UNFC-2009		
	Geological documentation		Mineral deposit development plan
	Deposits licensed for mining	Deposits not licensed for mining (beyond concession areas)	
Resources perspective D_2 prognostic D_1	Resources 344 334		
Anticipated economic resources D, C_2 C_1 A+B	Resources 223, 233 222, 232 221, 231		
Anticipated sub-economic resources D, C_2 C_1 A+B	Resources 323, 333 322, 332 321, 331		
Sub-economic resources D, C_2 C_1 A+B			Resources 313, 323 312, 322 311, 321
Economic resources D, C_2 C_1 A+B			Resources 213 212 211
Extractable resources D, C_2 C_1 A+B			Resources ("economic") 113, 123 112, 122 111, 121
Reserves C_2 C_1 A+B			

Table 2: A comparison of the Polish classification system and UNFC-2009. Source: NIEĆ M. 2010. International classifications of mineral resources [in Polish]. Mining and Geoengineering (Górn. Geoinż.), 34, 3: 33–49.

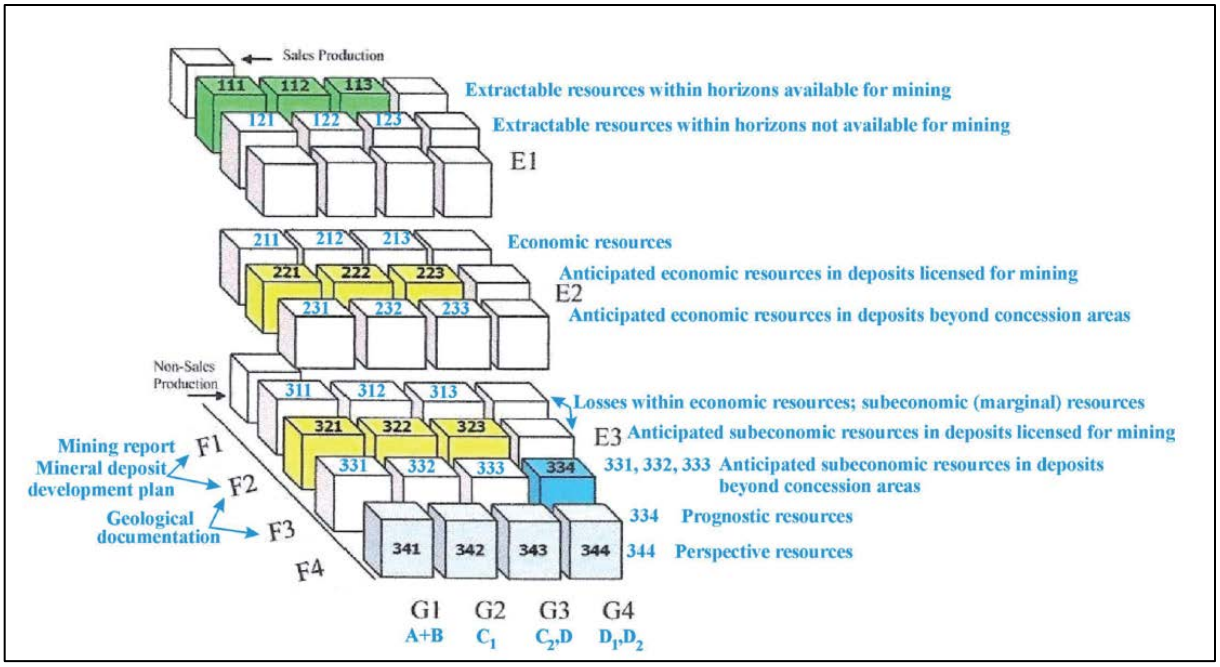


Figure 21: Ties between the Polish and international (UNFC-2009) classification systems. Source: NIEĆ M. 2009. Polish and United Nations Framework Classification of resources (UNFC) – similarities and differences [in Polish]. Open Cast Mining (Górn. Odkryw.) 50, 2/3: 50–57. Text in blue relates to the Polish classification system.

The Nordic countries UNFC work

A team from the Geological Surveys of Finland (GTK), Norway (NGU) and Sweden (SGU), the Swedish Association of Mines, Minerals and Metal Producers (SveMin), and Petronavit a.s., have worked on the application of the UNFC for mineral resources in Finland, Norway and Sweden. The group has presented the "Draft guidance for the application of the UNFC for mineral resources in Finland, Norway and Sweden"[17]. The purpose of the document is to provide guidance on the application of the UNFC incorporating Specifications for its Application (as set out in ECE Energy Series No. 42), to mineral resources in Finland, Norway and Sweden.

The draft document is intended to assist in producing UNFC inventories and support the users by clarifying how UNFC can be used to facilitate policy and strategy formulation, Government resource management, industry business processes, and capital allocation, the four principal areas of application of the UNFC. By using the full UNFC inventory in conjunction with the underlying project information, the classification provides a system that can be used for data collection, standardisation, aggregation and cross-comparison, thus facilitating the management of extractive activities across multiple temporal and spatial scales.

Part of the motivation has been to explore how the application of the UNFC will provide a better harmonisation of mineral resource data across projects from uncertain, reconnaissance stage, and under-explored prospects to well characterized and well assessed resources and reserves.

The industry-recognised reporting standards are mostly employed in developing or on-going mining projects and are required only for listed companies. These industry standards are not used, nor intended to be used, comprehensively, and are therefore not suitable tools for comparing and aggregating resource, and potential resource, inventories.

Norway

In Norway, the Geological Survey of Norway (NGU) has modernised and reclassified the national mineral deposits databases according to INSPIRE. In this work, NGU has introduced an INSPIRE-compliant nomenclature for mineral occurrence types using the terms: occurrence, prospect, deposit. Mineral deposits have been reassessed and reclassified from a qualitative scale of significance to a more quantitative economic value or public importance assessment scale based on criteria, such as *in situ* value, volume, location, quality, national supply, etc. As a result, the deposits are now classified according to public significance and are classified as: international, national, regional, local importance, not important, or not assessed. The Norwegian Directorate of Mining can intervene if deposits of international, national or regional importance are affected by competing land use, such as infrastructure, nature conservation or other types of land use.

NGU delivers much of this data as a map service. The service is continually updated and new maps of mineral resources created. These maps include both deposits previously registered in the database as points, as well as newly defined areas for prospects, deposits and provinces. Although this reclassification does not adhere to UNFC, the use of the INSPIRE standards will greatly aid in data harmonisation, and data collected as part of this database can be used for further classification.

[17] Draft guidance for the application of the UNFC for mineral resources in Finland, Norway and Sweden. 2017. https://www.unece.org/index.php?id=45992

A separate study has taken information from the mineral deposit database for sand and gravel deposits and attempted to classify deposits according to the UNFC. This study looks specifically at the Forsand municipality in Rogaland County in south west Norway, where NGU has registered several large and minor gravel deposits. NGU has assessed the significance of the deposit as described above, and published the data through the NGU resource database.

In addition, Rogaland County has published a resource management plan for the region where areas are given variable prioritisations. In this management plan, different issues are considered and prioritised, such as areas protected by natural diversity or cultural heritage, areas protected for agriculture or protected due to the presence of important resources. Based on the regional plan, the local municipality of Forsand has made specific plans for the areas around the deposits. The largest deposit, named Forsand, is subdivided into zones where some are protected due to natural diversity, some are extraction areas, other are possible future extraction areas, and some of the zones are used for agriculture. In Norway, the Directorate of Mining (DMF) is the authority for giving concession for extraction. DMF has given concession for extraction to two producers and two more have applied for concession in the Forsand gravel resource.

As a basis for the classification, NGU used the UNFC-2009, the "Nordic document": "A guidance for the application of the UNFC-2009 for mineral resources in Finland, Norway and Sweden", as well as an internal NGU guidance document to ensure that the different geologists performing the UNFC-classification have a common understanding of what the different UNFC categories represent. NGU has used information from various sources (Data from NGU's resource database, applications to DMF for mining concession, local municipality area plans and the regional plan for resource management) to employ the UNFC classification to sand and gravel resource in the Forsand municipality (including spatial information and metadata). The areas are defined in the regional plan and are assessed one by one in this study, as shown in Figure 22. NGU's volume estimates are based on probable thickness of the resource (G1 – 90 % probability of given thickness, G2 – 50 % probability of given thickness. G3 25 % probability of the given thickness). Table 3 shows the details according to the UNFC classification.

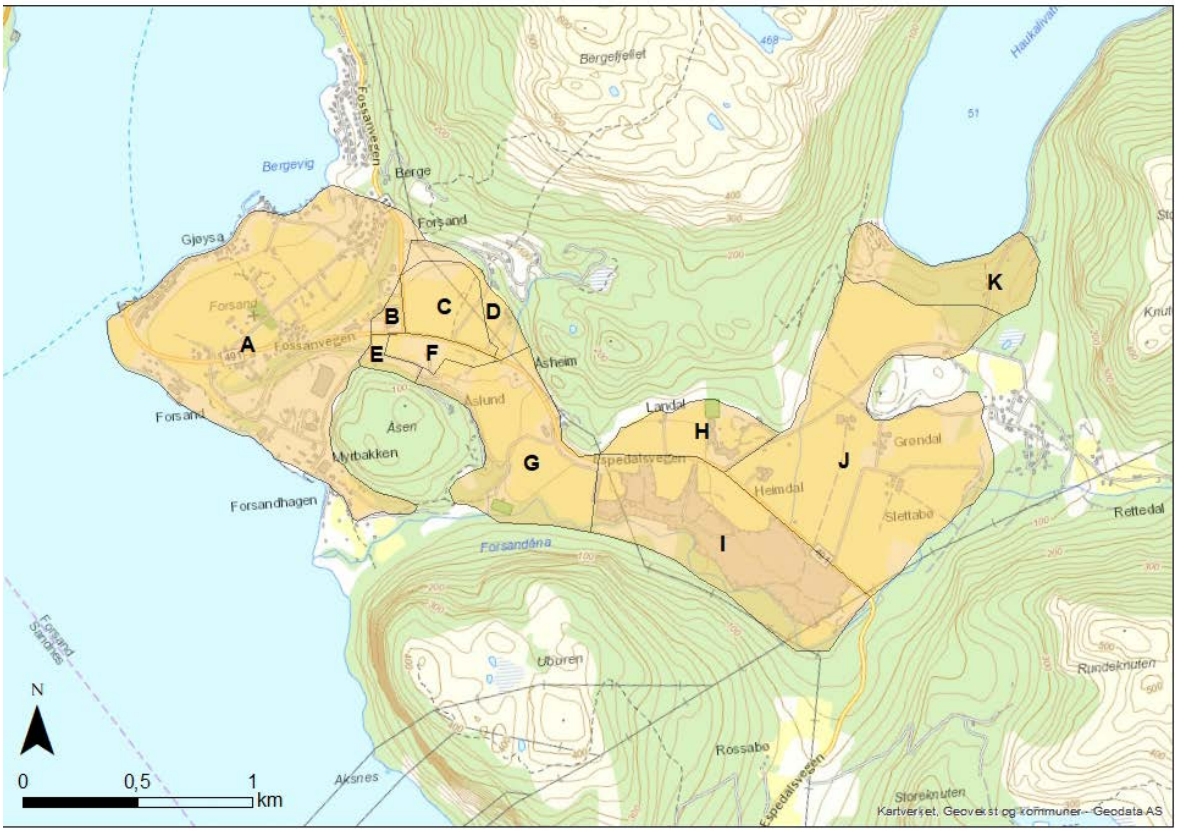


Figure 22: The study area with the various different resource zones, defined by the regional municipality, labelled and A-K for this study. Each zone is classified separately.

AREA	Name of areas	Comments	Area	G-axis			F-axis	E-axis
				G1 (m3)*	G2 (m3)*	G3 (m3)*		
			m2	Thickness 8 m	Thickness 10 m	Thickness 25 m		
A	Forsand - built-up area	Built-up area, area for extraction not included in regional plan	992 000			24 800 000	F4	E3.2
B	Vest A – Ryggjen / Langheim	Built-up area, area for extraction not included in regional plan	20 600	164 800	41 200	309 000	F4	E3.2
C	Vest B – Hestamoen	Future extraction area in regional plan, local area plan for extraction, application for mining concession sent	117 000	936 000	234 000	1 755 000	F1.2	E1.1
D		Future extraction area in regional plan, local area plan for extraction	60 000	480 000	120 000	900 000	F2.3	E2
E	Part of Vest C – Gøysamyra	Future extraction area in regional plan, local area plan for extraction, application for mining consession sent	24 000	192 000	48 000	360 000	F1.2	E1.1
F	Vest D + part of Vest C – Bergekrossen	Resouce in production	47 000	376 000	94 000	705 000	F1.1	E1.1
G	LNF farming	Local plan for agriculture, nature and outdoor recreation	339 000	2 712 000	678 000	5 085 000	F4	E3.2
H	Mindtre A - Landal prehistorical village	Area with protection of historical cultural monuments	136 000	1 088 000	272 000	2 040 000	F4	E3.2
I	Midtre B og Øst B – Forandmoen / Gnr 41, Bnr 3 & 26	Resource in production	505 000	4 040 000	1 010 000	7 575 000	F1.1	E1.1
J	Øst A – LNF farming	Local plan for agriculture, nature and outdoor recreation	850 000	6 800 000	1 700 000	12 750 000	F3	E2
K	Vassryggen - LNF nature protection	Area with protection according to the nature diversity act, nature conservation	190 000			4 750 000	F4	E3.2

* based on volume estimates and probability

Table 3 UNFC classification for the Forsand deposit, Norway. Red cells are sterilized areas, where production is not possible, orange areas not sterilized, have no planned production but production is not prevented. The green cells are areas with production, and no other area conflicts. Areas A to K refers to Figure 22.

This study shows how a combination of different governmental documents can be used to perform UNFC-classification for a deposit. In this area, NGU was fortunate to have documents at different municipal levels and a comprehensive regional plan. For other areas or municipalities, this will not be the case. The main discussion in this study has been whether

quantities for G1 and G2 should be estimated for the sterilized areas, blocked by housing and infrastructure or by protected nature or culture conservation.

Finland

GTK has conducted persistent mineral exploration and bedrock mapping in Finland leading to an excellent understanding of the location and size of many of the country's mineral deposits. GTK's current mineral potential mapping approach is more reconnaissance to prospecting stage exploration to attract further investments in ore-potential areas. In this context, the UNFC provides a neutral framework for reporting resources and a mechanism for reporting early stage exploration results to disseminate geological information for industry and society.

Mining Decree (28.6.2012/391) states that when reporting exploration results under an Exploration permit in a study area, an internationally recognised standard has to be followed. However, the mining law does not specify which code to use. International exploration and mining companies operating in Finland follow the CRIRSCO template and prepare the public reports under the company-specific reporting codes. The most common reporting standards being used in Finland are the Australasian Code (JORC Code) and Canadian National Instrument 43-101 (see Figure 18). There is no national standard reporting code for Finland.

GTK decided in 2014 that the UNFC will be implemented and a few case studies have been undertaken (e.g., Kiviniemi Sc, Mäkärä Au, Virtasalmi Cu). In these case studies, deposits have been classified according to the UNFC for demonstration purposes and formal reporting is ongoing for these. GTK is currently participating in the Mintell4EU project in which one objective is to make a UNFC report for one of these case studies.

Before the UNFC classification of all mineral resources and reserves of Finland can be made, there needs to be a common understanding of the criteria of classification. Criteria cannot change by deposit, commodity or time and they have to be comparable with other countries. Work on the criteria of classification is ongoing, draft guidance has been prepared by the Nordic Project and work continues in GeoERA-funded Mintel4EU project. Based on the criteria, GTK needs to create consistent practice with regards to how to classify new and historical mineral resources. The CRIRSCO template could provide basic information for this work, but the final classification will be according to the UNFC.

Due to a large amount of non-compliant resource estimates (Figure 23) the harmonisation of the whole dataset according to the UNFC will be challenging. These non-compliant resource estimates can be based on sparse geological data with a low level of confidence or systematically explored targets with a high data density. Non-compliant resource estimates cannot be bridged to UNFC before the deposit data is inspected and classified by persons with expertise. Currently, non-compliant resource estimates will be problematic in terms of providing data. A temporary solution could be that all of these deposits will be classified as "Additional quantities in place" (344) until further knowledge has been obtained.

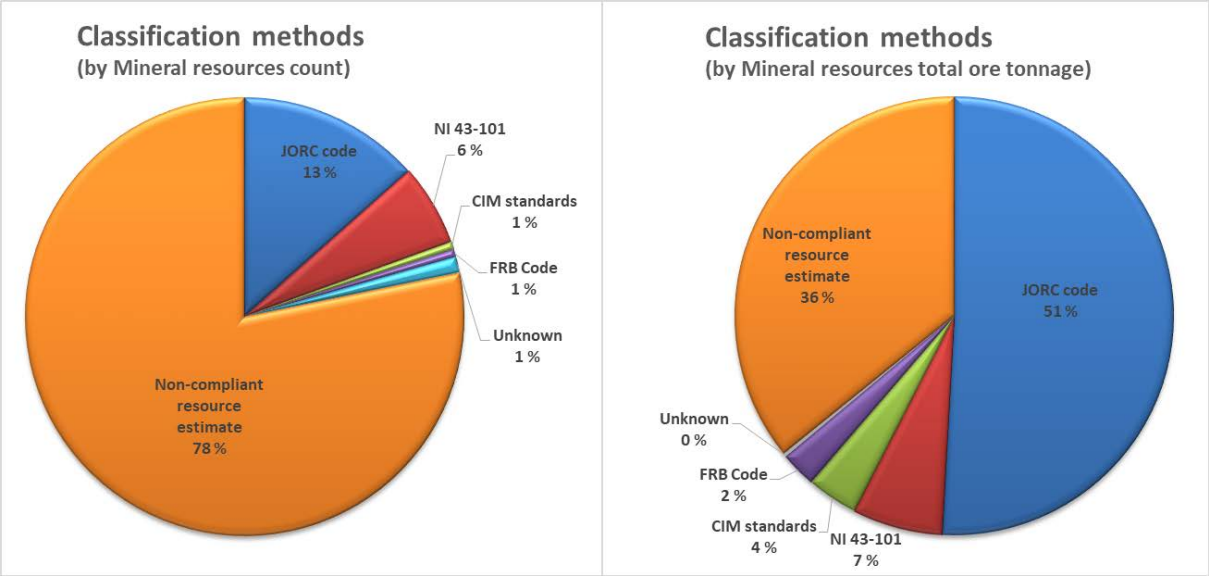


Figure 23: Mineral resources of Finland classified by the number of the resource estimates (349, on left) and by the total ore tonnage (7009 Mt, on right). Exploration and mining companies use mainly JORC and NI43-101 codes, but since there is no national code, all GTK and old mining company resource estimates are non-compliant.

Case studies from countries without a national reporting code

UK

As part of the ORAMA project, the British Geological Survey (BGS) has attempted to create an inventory of national resources for the UK using the UNFC. The UK has no centralised system of data collection for mineral resources, although data are collected for some aggregate minerals (see D1.5.10 for further details of resource data collection and reporting in the UK).

As a result, for many commodities, BGS was required to compile resource figures from a range of disparate sources such as company reports, historical estimates, regional assessments and data inferred from geological mapping. The initial work was undertaken in the Minerals4EU project and produced a resource inventory displaying data to whatever code, standard or confidence level the data was originally reported in or calculated to. This inventory was the first to have been developed for the UK but as data were presented in a wide variety of different formats it was difficult to compare with other national inventories, across commodities.

The ORAMA project has provided an opportunity to convert the Minerals4EU compiled data into the UNFC. This was a complex process due to the wide variety of data sources and commodities considered. This work is presented as a case study for the ORAMA project in D1.5.9 Technical guidance note: A minerals inventory for the UK using the United Nations Framework Classification system for 2018.

This work attempted to create a resource inventory that is as complete as possible using the full range of categories available in the UNFC. Consequently, efforts were made to collect data for the uneconomic proportion where geological and economic confidence was low as well as published industry and data published by national Government data. In some cases, figures were calculated via spatial analysis using GIS software to estimate the quantities of resources for certain minerals. This was done by applying assumptions, such as thickness of deposit, mineral to waste ratios and mineral quality, to surface mapping of mineral resources, which had been conducted previously by BGS. This method of spatial analysis using geological

information is the only way to estimate inferred resource quantities for many minerals in the UK due to a lack of any other data.

However, this spatial analysis approach estimates resource quantities on a regional or national level, and it was, therefore, difficult to integrate into the UNFC system, which is designed to examine resource quantities at a project level. There are some instances where existing projects have been incorporated into larger regional and national figures, calculated using GIS techniques or regional estimates that include resources over the entire geological outcrop or subcrop, because data may not be available on a project by project basis. In these cases, it is possible that a range of categories along the E and F axes of the UNFC system are included within a single number, which is never the case if resources are taken on a project by project basis. In these instances, footnotes have been applied. Similar issues would also arise if using probabilistic mapping or any kind of geostatistical analysis techniques.

Others issues arose with the use of historical estimates. For a country, like the UK, with a rich history of mineral exploration but no centralised system of reporting, information from past academic and industry studies formed the basis of many resource figures used in the inventory. However these historic studies were rarely reported according to any standards, codes or current definitions, although many undertook significant field campaigns involving drilling, laboratory analysis, detailed mapping, etc. As a result, a high degree of geological expertise was required in order to allocate some of these historical estimates to the UNFC categories. Knowledge of the deposit or deposit type was also required to assess how much geological information may be necessary for an accurate assessment of 'confidence', as well as knowledge of the economic situation for that particular commodity. This again highlights the importance of persons with appropriate levels of competence for compilation of this kind of resource inventory.

Fluorspar provides an example of the use of such historical estimates. Fluorspar has been historically worked in the UK since the Roman times and is still worked by one company. A previous study (2010) from when several sites were still operating estimated remaining resources as 25 million tonnes. Unfortunately, no methodology was recorded for how this estimate was calculated, although it is assumed to be robust due to a stringent quality assurance procedure on all published documents by the BGS. Ideally, this would be considered on a project by project basis, but no data are now available for many of the historic fluorspar deposits and past workings. If such data were available, it would be extremely time consuming to collect and analyse and a regional approach using the available published data is, therefore, preferred in the absence of the significant resources required to undertake such study. Due to the lack of metadata, regarding the levels of confidence associated with it, this estimate for fluorspar could go into UNFC category 334 (exploration results). However, it is known that fluorspar is likely to be present in certain locations due to the presence of past workings, and consequently it has been classified as G3 rather than G4 as a result of the large amount of geological information available.

Similar examples can be seen for metallic mineral deposits. For example, a nickel-copper deposit at Arthrath in north-east Scotland, was extensively explored in the 1970s with 6850 metres of core drilled and a considerable amount of chemical analysis and geophysical surveys also undertaken. The study resulted in a resource estimate but this was not in accordance with any reporting code and is not compliant with modern practices. After consideration, BGS classed the deposit as 333 in the UNFC system. G3 was given due to the amount of drilling and analysis undertaken, because the estimate was not based primarily on indirect evidence as for G4, which is normally used for exploration results. However, this might also be classified as G2 because the reported quantities could be estimated with a moderate level of confidence.

However, without detailed knowledge of the work actually undertaken and a reasonable understanding of the deposit geology, it would be difficult to confirm this. Similarly, nickel sulphide deposits of this type are reasonably well understood and, given the quantity of data available for this deposit, it could potentially be classed as F2. However, without the extra detail from the exploration campaign this cannot be verified.

Spain

IGME has conducted a study to illustrate mapping of national minerals data to the UNFC. Spain has a national dataset, the Spanish "National Inventories of Resources", a series of monographic studies conducted from 1978 to 2002 aimed at defining the resources and reserves of the main mineral substances and their distribution within the country. The National Inventories of Resources have been compiled using the standards set out in USGS Circular 831 (1980)[18]. This study is used as a worked example to demonstrate how this kind of data can be bridged across to the UNFC in D1.5.6, Technical Guidance Note: Worked example for conversion of Spanish copper resource data to UNFC.

This USGS classification is based on the system established by McKelvey in 1972[19], which allows extrapolation of the mineral resources to country level, as an alternative to resource definition from an operator perspective which can be focused on discovering sufficient ore as the exploitation progresses to guarantee the continuity of the mine for a certain number of years.

The system established by McKelvey in 1972, with the modifications made in 1980 by the USGS and that gave rise to the Circular 831, was considered the most suitable for the Spanish National Inventories of Resources based on two fundamental considerations:

1. Its ability to provide information on the most recommendable measures to be taken in the field of exploration of mineral resources.

2. Its flexibility to place the national resources and reserves into a potentially changeable economic environment in relation to geological and mining parameters.

The national inventories cover 21 metallic, non-metallic and industrial minerals as show in Table 4.

[18] US Bureau of Mines and US Geological Survey, 1980. Principles of a resource/reserve classification for minerals. *US Geological Survey Circular 831*, p.5.
[19] McKelvey, V.E., 1972. Mineral Resource Estimates and Public Policy: Better methods for estimating the magnitude of potential mineral resources are needed to provide the knowledge that should guide the design of many key public policies. *American Scientist, 60*(1), pp.32-40.

Date	Mineral
1979	Tin
1980	Iron
1980	Lead, zinc, silver
1981	Copper
1982	Fluorspar
1982	Manganese
1982	Titanium
1983	Barite
1983	Feldspar
1983	Pyrite
1984	Talc
1984	Kaolin
1985	Tungsten
1988	Titanium update
1989	Strontium
1991	*Sodium sulphate
1997	Sodium chloride & potash salts
2000	*Special clays
2000	Wollastonite
2002	*Special clays update

*glauberite, thenardite
**palygorskite-attapulgite, sepiolite,

Table 4: Date and mineral studied in each inventory for Spain.

Methodology

According to the USGS Circular 831 (1980) guidelines, known resources should be 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 analysis based on costs of extracting and marketing the material in a given economy at a given time (Figure 24 and Figure 25).

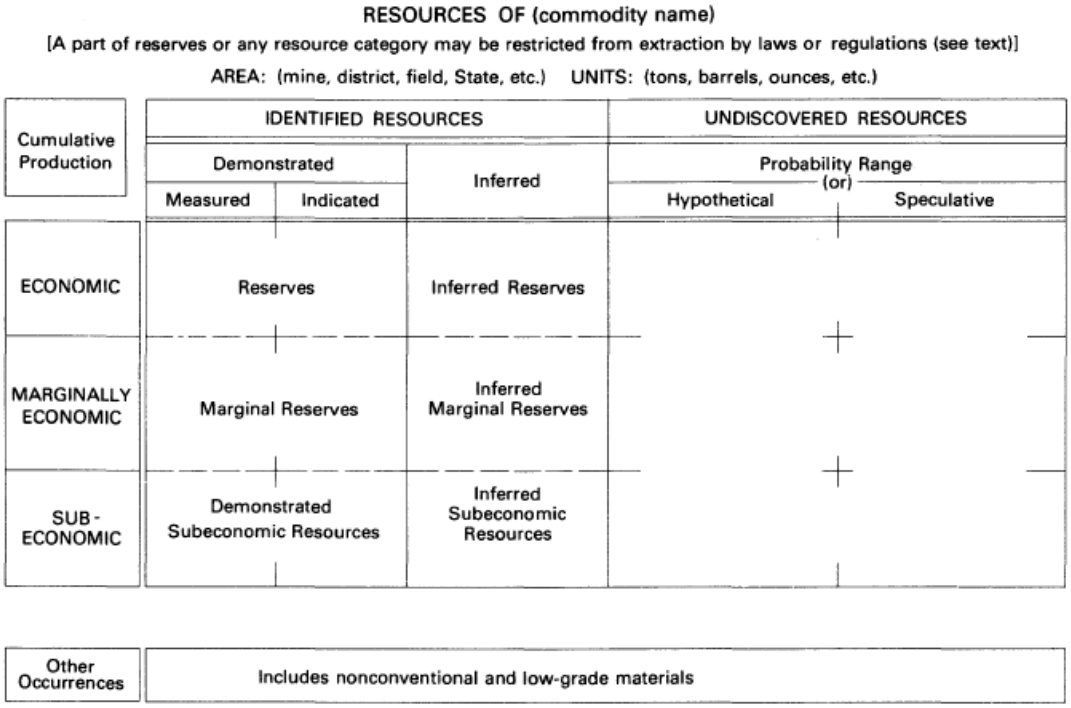


Figure 24: Major elements of mineral resource classification, excluding reserve base and inferred reserve base.

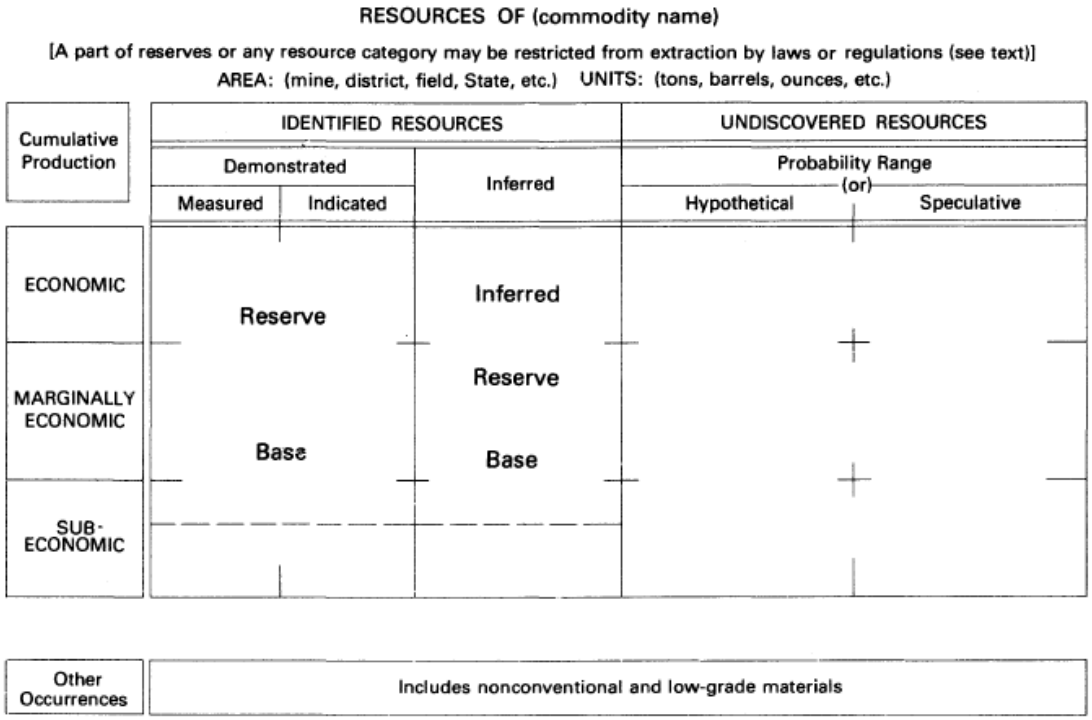


Figure 25: Establishment of the categories of reserve base and inferred reserve base, taking into account that the reserve base is a global resource category delineated by physical and chemical criteria and when those criteria are determined, the initial reserve-base estimate will be divided into three component parts: reserves, marginal reserves, and a remnant of subeconomic resources.

To determine those criteria of "geology and profitability" the information used at a national level is as follows:

- Types of deposits and methods of exploitation.
- Mineral and metallurgical processes.
- Volumes, specifications and market prices.
- Situation of the mining sector.
- Known resources of such mineral in the country (where the data came from: operating mining companies, operating mines, research projects, occurrences, provincial mining authority and the annual mining work plan of the mines).

These criteria results in a template where UNFC categories can be placed (Figure 26)

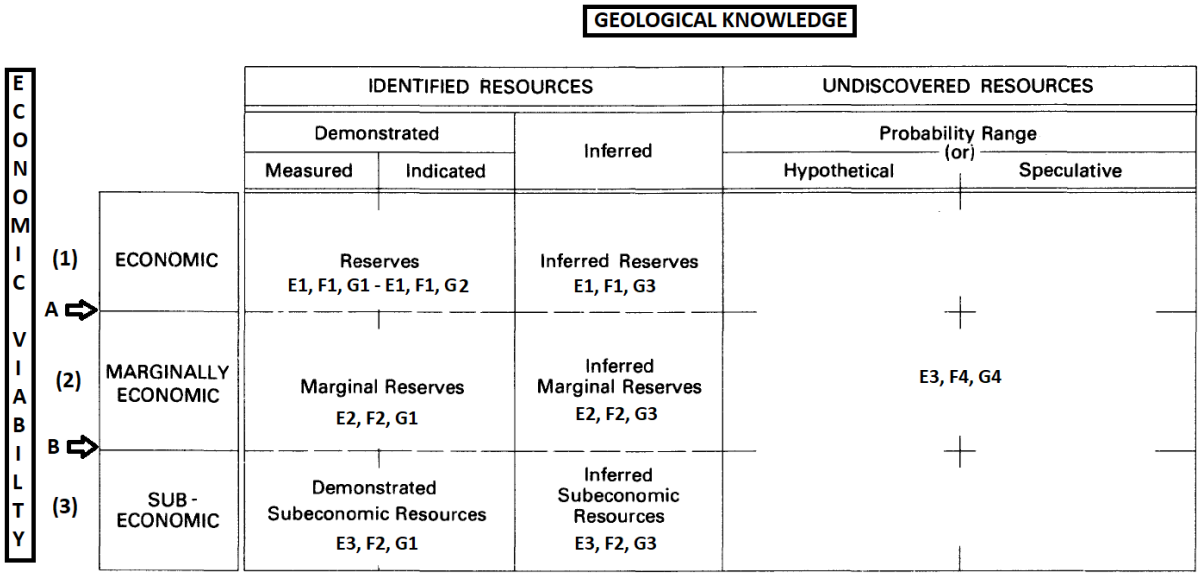


Figure 26: USGS categories with UNFC categories mapped on to them.

In the template (Figure 26), there are established two lines that inbound three economic zones.

- Line A: Establishment of the boundary between the part of the resources that it is possible to exploit profitably, and the category which the resource could become if there were changes in the current economic and technological factors.
- Line B: Indicates the minimum level, below which mining of a resource is not exploitable, in profitable terms, in the current situation of market and technology.

These delineate three economic zones:

(1) Economic: where the ore grade > cut-off grade resulting in reserves and inferred reserves.
(2) Marginally economic: where the ore grade is near the cut-off grade resulting in marginal reserves and inferred marginal reserves.
(3) Sub-economic: where the ore grade < cut-off grade resulting in demonstrated and inferred subeconomic resources.

This is based on the UNFC definitions as detailed in section 5 of this report and the following definitions from the USGS classification scheme:

Reserves: 'That part of the reserve base which could be economically extracted or produced at the time of determination'.

Inferred Reserves: 'Inferred reserves are postulated extensions of reserves. They are identified resources quantified with a relatively low degree of certainty'.

Marginal Reserves: 'That part of the reserve base which, at the time of determination, borders on being economically producible. Its essential characteristic is economic uncertainty. Included are resources that would be producible, given postulated changes in economic or technologic factors'.

Inferred Marginal Reserves: 'Inferred marginal reserves are postulated extensions of marginal reserves. They are identified resources quantified with a relatively low degree of certainty'.

Demonstrated Subeconomic Resources: 'The part of identified resources that does not meet the economic criteria of reserves and marginal reserves'.

Inferred Subeconomic Resources: 'Inferred subeconomic resources are postulated extensions of subeconomic resources. They are identified resources quantified with a relatively low degree of certainty'.

Hypothetical Resources: 'Undiscovered resources that are similar to known mineral bodies and that may be reasonably expected to exist in the same producing district or region under analogous geologic conditions. If exploration confirms their existence and reveals enough information about their quality, grade, and quantity, they will be reclassified as identified resources'.

Speculative Resources: 'Undiscovered resources that may occur either in known types of deposits in favourable geologic settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential. If exploration confirms their existence and reveals enough information about their quantity, grade, and quality, they will be reclassified as identified resources'.

This bridging exercise between the USGS Circular 831 and the UNFC revealed the following issues:

- Cumulative production: there is no distinction between "Sales Production" and "Non-sales Production". Whilst not an issue for resource and reserve data, this may have an impact on wider reporting of statistical minerals data.
- There is no place for "Exploration Projects (3, 3, 4)" neither for "Additional quantities in place associated with known deposits (3, 4, 1-2-3)".
- "Additional quantities in place associated with potential deposits (3, 4, 4)" are divided into "Hypothetical and Speculative Undiscovered resources".
- There is no mention of the need to have a competent or qualified person performing resource estimation and/or classification.

9 Commodity-specific issues

As well as considerations due to different national approaches when attempting to harmonise resource data, differences in commodities must also be considered. Different types of commodities will require different amounts of data to gain suitable levels of geological and economic confidence in a deposit. The UNFC recognises this and defers to the more detailed commodity-specific specifications that are contained within other internationally recognised standards and codes that have been aligned with the UNFC-2009. For example, the PERC code has separate guidelines for the reporting of data on construction, industrial and metallic minerals. Clearly, for example, a gold deposit will generally be more geologically complex and will require more capital investment than a sand and gravel quarry. Consequently, the latter may require less geological investigation and fewer economic studies before a project can begin production.

With regard to metallic mineral commodities, aggregation of data can be an issue. Many resource codes and standards, including the CRIRISCO template, include data on both the percentage of the metal within the ore (the grade) and the total tonnage of ore (or contained metal). This provides information on both how much metal there is within a deposit and the type of deposit, such as low grade–high tonnage or small but concentrated deposit. When aggregating resource data across multiple deposits using the UNFC, there is an issue of loss of resolution as there is no simple way using the UNFC to aggregate grades of multiple deposits (although advance methods such as weighed average grades do exist). The approach that majority of case studies used in converting national data to UNFC (including the Polish and UK examples discussed above) instead calculate metal content for each deposit and then aggregate this. This methodology does result in loss of resolution in the type of deposits that are involved, but this loss of resolution is inevitable when aggregating on national/regional scales from individual projects.

Another commodity-specific issue that may need to be considered is that different levels of information may be available for different commodities, which can become a challenge when building a comprehensive inventory of resources. When minerals data are collected on a national level, there is normally a practical reason for doing so; for example, data are often collected for minerals that the state owns or receives royalties for. However, in many cases this does not include all minerals, e.g. aggregates, industrial minerals or minerals currently uneconomic to extract may be excluded, and as such data gaps often exist. Data are also not collected in some national systems for smaller operations, e.g., those employing less than a certain number of people. These types of operations are more likely to be working construction and industrial minerals due to the lower amounts of infrastructure required for extraction. In countries where there is no centralised data collection, data for metals are often much more readily available as companies involved in metallic mineral extraction and development are likely to be publically listed and, therefore, required to publish results for investors. In contrast, construction and industrial mineral operations are more likely to be operated by private operations with no obligations for public reporting. This again can lead to data gaps for construction and industrial minerals.

10 Conclusions

In order to move forward with harmonisation of reserve and resource data for primary raw materials, to facilitate the creation of an adequate knowledge base for the formulation of policy decisions relating to raw materials, relevant EU public authorities need to come to an agreement about using a single system of reporting at European level.

Although there are several options for different systems of reporting, all with advantages and disadvantages regarding compilation of statistics at a European level, the ORAMA project recommends the use of the UNFC system. This classification system seems best suited for the task as it is designed for national scale resource management, has several guidance documents and case studies linked to it bridging other systems of reporting to the UNFC, and has the flexibility to include a variety of different resource types.

It is not being suggested that countries abandon their already well-established systems of reporting, which serve national needs and may have requirements in national law, only that the use of UNFC, or conversion to UNFC be considered for reporting at a European level to allow comparison and aggregation with other European data. Similarly, it is not suggested that UNFC can, or should, replace the CRIRSCO-compliant systems of reporting which serve a different purpose, principally aimed for protection of investors and the specific needs to the minerals industry.

11 Useful sources for further information

Table 5 outlines some of the main sources regarding harmonisation of mineral resource and reserve data from previous work that has been undertaken in this area, links to codes and classifications discussed in this document, links to the bridging documents discussed and some prominent national case studies attempting harmonisation of resource and reserve data.

Source	Description
Previous work	
https://ec.europa.eu/growth/content/final-report-minventory-eu-raw-materials-statistics-resources-and-reserves-0_en	Minventory final report. This report contains a great deal of background information on different resource definitions, codes, standards and classifications, as well as a proposed roadmap for resource data harmonisation.
http://www.minerals4eu.eu/images/images/minerals4eu_wp4_del4.3_20150730_bgs_v1.0.pdf	Minerals4EU report on minerals data. This report contains a discussion over some of the issues of resource data harmonisation and some recommendations for future harmonisation.
https://minatura2020.eu/wp-content/uploads/2018/01/MINATURA2020-D2.3_FINAL.pdf	Minatura Deliverable 1.2, a harmonised mapping framework. This contains a review of resource definitions, codes, standards and classifications and a brief discussion over some of the harmonisation issues.
https://minfuture.eu/sites/default/files/D5.3_Roadmap.pdf	MinFuture Roadmap – A roadmap towards monitoring the physical economy. This report outlines many of the problems in defining accurate representations of mineral resource stocks.
http://www.vmine.net/perc/documents/EGM-PAPER-PERC2013.pdf	An article explaining the differences, uses and purpose of both the UNFC and the CRIRISCO Template.
Resource codes a classifications	
https://www.unece.org/energy/se/unfc_2009.html	UNFC 2009
http://www.crirsco.com/template.asp	CRIRSCO template
Bridging documents	
https://www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/UNFC_specs/Revised_CRIRSCO_Template_UNFC_Bridging_Document.pdf	Revised annex iii bridging document between the CRIRSCO template and the UNFC-2009.
https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc5_apr2014/30Apr/10_Henley_UNFC_Minerals_CS.pdf	CRIRSCO-UNFC 2009 mapping Solid Minerals Case Studies. A presentation outlining detailed case studies converting figures from CRIRSCO-compliant data to the UNFC.
http://igi.ie/assets/files/courses/NRReporting%20Workshop/Alignment%20of%20CRIRSCO%20and%20RF%20systems-NYoung%20et%20al.pdf	Alignment of Resource and Reserve Classification Systems Russian Federation and the CRIRSCO Template.

http://www.vmine.net/PERC/russia/conversion_guidelines_2010_9.pdf	Guidelines on Alignment of Russian minerals reporting standards and the CRIRSCO Template.
National case studies	
https://static1.squarespace.com/static/592636dad482e9754a483451/t/5aefd42d88251b4d160dd0c2/1525666885536/Mineral_Resource_Estimate_Final_Ebeleben_Signed.pdf	This outlines a case study converting from German historic figures that have used the GKZ (Russian State System) of reporting to the JORC Code.
http://geoportal.pgi.gov.pl/css/surowce/images/2017/pdf/mineral_resources_of_poland_2017.pdf	A case study from Poland converting from the Polish national system to the UNFC.
https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc8_apr_2017/EGRC.8.2017.INF.8e.pdf	A guidance for the application of the UNFC-2009 for mineral resources in Finland, Norway and Sweden.
https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc9_apr2018/26.04/p.10_Horovath_Cases_HZ.pdf	Experience with mineral data harmonisation and UNFC application – case studies (Hungary / Central Europe).
https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc/IntWs_UNFC_Ankara_Sept2011/14_Rokavec.pdf	A case study on converting data from the Slovenian national system to the UNFC.

Table 5: useful sources for mineral resource and reserve data harmonisation.