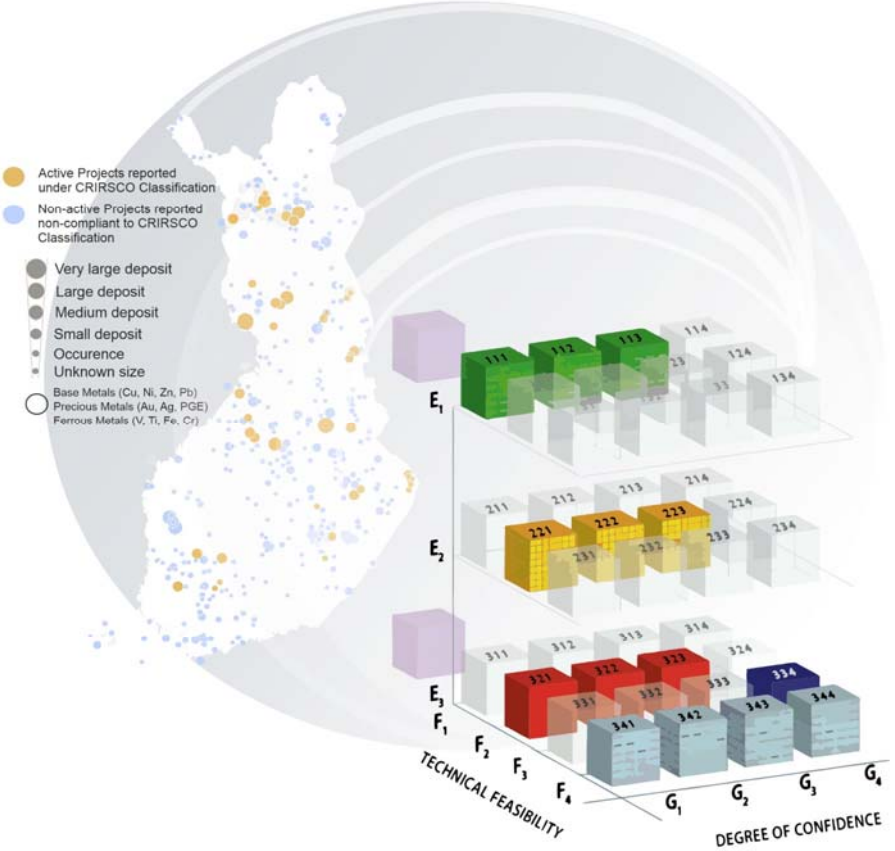
Geological Survey of Finland
MTR
Espoo, Kuopio, Rovaniemi

5.10.2020

Open File Work Report
46/2020



Application of the UNFC resource code in Finland
Practical guidelines

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

GEOLOGICAL SURVEY OF FINLAND **DOCUMENTATION PAGE**

Date / DnroAuthors Hokka, J., Eilu, P., Ahtola, T., Kivinen, M., Konnunaho, J., Kuusela, J., Lintinen, P., Törmänen, T.	Type of report GTK Open File Work Report Commission by Mintell4EU, GTK
Title of report Application of the UNFC resource code in Finland – Practical guidelines	

Abstract

These practical guidelines are intended to aid in mapping public mineral resource and reserve data into the UNFC code in Finland. This report provides specific Finnish case examples of active and non-active projects that have been reported either under CRIRSCO classification or are without any classification framework. The aim of this mapping is not to re-assess or re-evaluate existing resources. We do not aim to forecast changes in exploration and mining permitting, but only to harmonize the existing information under the UNFC framework and to give resource coding also to cases where the current industrial standards cannot be applied for.

UNFC-2019 provides a global communications tool that transcends language, commodity type and extraction methodology. This harmonised classification provides an effective management tool for national resource endowment and accounting. It also gives a coherent mineral resource and reserve terminology that aids in transparency and improved comparability of assessments of mineral resource assets which further provide more informed and efficient invest decisions.

Keywords

Mineral resources, ore reserves, classification systems, mineral economics, databases, Finland

Geographical area

Finland

Map sheet

-

Other information

Report serial GTK Open File Work report		Archive code 46/2020	
Total pages 31 p., 4 App.	Language English	Price 0	Confidentiality public
Unit and section Mineral Economy Solutions		Project code 50403-30115	
Signature/name Irmeli Huovinen		Signature/name Janne Hokka	

Tekijät Hokka, J., Eilu, P., Ahtola, T., Kivinen, M., Konnunaho, J., Kuusela, J., Lintinen, P., Törmänen, T.	Raportin laji GTK:n työraportti Toimeksiantaja Mintell4EU, GTK
Raportin nimi UNFC luokittelukoodin käyttöönotto Suomessa – Käytännön ohjeistus	

Tiivistelmä

Raportissa esitetään käytännön ohjeistus mineraalivarantojen ja -varojen luokittelemiseksi UNFC-koodin mukaisiksi Suomessa. Raportissa on suomalaisia esiintymäesimerkkejä, joilla on jo olemassa CRIRSCO:n mukainen resurssiluokitus ja esiintymiä joille ei ole tällaista luokittelua. Luokittelun CRIRSCO:sta UNFC:hen tarkoitus ei ole arvioida tai tulkita uudelleen olemassa olevia mineraaliesiintymiä tai esimerkiksi arvioida mahdollisia muutoksia malminetsintä- ja kaivosluvituksessa, vaan ennen kaikkea yhdenmukaistaa resurssiluokittelu UNFC:n mukaiseksi. Tämä mahdollistaa yhdenmukaisen, harmonisoidun luokittelun myös esiintymille, joista saatavilla oleva tieto ei täytä kansainvälisten arvopaperipörssien hyväksymien raportointistandardien vaatimuksia.

UNFC-2019 –luokittelukoodi on kielestä, esiintymätyypistä ja hyödyntämismenetelmästä riippumaton globaali viestintäväline i. Yhdenmukainen luokittelu mahdollistaa myös aiempaa selkeämmän kansallisten mineraalivarantojen hallinnoinnin, ja yhtenäinen terminologia helpottaa läpinäkyvyyttä ja vertailua mineraaliesiintymien välillä. Tämä taas mahdollistaa paremman esiintymien arvottamisen ja edesauttaa investointipäätöksissä.

Avainsanat
Mineraalivarat, malmivarat, luokitusjärjestelmät, mineraalitalous, tietokannat, Suomi

Maantieteellinen alue (maa, lääni, kunta, kylä, esiintymä)
Suomi

Karttalehdet
-

Muut tiedot

Arkistosarjan nimi GTK:n työraportti		Arkistotunnus 46/2020	
Kokonaissivumäärä 31 sivua, 4 liitettä	Kieli Englanti	Hinta 0	Julkisuus julkinen
Yksikkö ja vastuualue Mineraalitalouden ratkaisut		Hanketunnus 50403-30115	
Allekirjoitus/nimen selvennys Irmeli Huovinen		Allekirjoitus/nimen selvennys Janne Hokka	

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1 INTRODUCTION

The United Nations Framework Classification for Resources (UNFC) is a universally acceptable and internationally applicable scheme (i.e., a code) for the sustainable management of all energy and mineral resources. It has been designed to meet the needs of applications relating to: 1) policy formulation based on resource studies; resources management functions; corporate business processes, and 2) financial capital allocation (UNECE 2009, 2015, 2019; Lax et al 2017). The UNFC code is used in many countries for effective management of national resource endowments and socio-economically efficient development of the energy resources contributing to sustainable development. It also allows a direct comparison of projects that extract primary energy fuels, such as oil, gas, coal and uranium, with renewable energy projects.

The UNFC code can be applied in various ways from classifying to harmonising and mapping between various resource classification systems, such as the CRIRSCO template (Committee for Mineral Reserves International Reporting Standards 2013, 2019), to directly applying the UNFC as a reporting standard. A UNFC category can be given to any deposit, prospect or occurrence (or any part of it) for which there is a mineral resource estimated by somebody, be that resource a CRIRSCO-compliant or non-compliant.

This document provides practical guidelines on how to use the UNFC code as a classifying tool to active and non-active (historical) exploration and mining projects in Finland which are managed through the Mineral Deposit Database of Finland (https://gtkdata.gtk.fi/mdae/index.html). Our aim is to provide a harmonised classification of quantities to critical raw materials (solid minerals) as part of effective management of national resource endowment (mineral resources accounting) and facilitate mineral resources-related communication at local, regional, country- and EU-wide to global scales.

This report is created to help in mapping public mineral resource and reserve data into the UNFC code. The aim of this mapping is not to re-assess, re-evaluate existing resources, not, for example, to forecast changes in exploration and mining permitting or in demand of mineral resources, but only to harmonise the existing information and to give resource coding also to cases where the current industrial standards cannot be applied for.

The focus of this report is in the Finnish mineral resources. Hence, also all examples we give are from Finland. The focus is on non-CRIRSCO compliant resources which represent the majority of mineral deposits in the national mineral deposit database and also which have been commonly mapped without any systematic approach. Everything described and discussed hereby can be applied in the same way in any jurisdiction, as the UNFC reporting code and their application are created to be globally used.

Most of the resource inventories in Finland are non-compliant or historical estimates that have not been prepared in accordance with CRIRSCO Template. These estimates were

predominantly prepared before international reporting standards and reported by Finnish state-owned companies and Geological Survey of Finland (GTK). The industrial mineral and industrial rock deposits and mines are exception where the operating companies in most cases do not use the CRIRSCO Template reporting code. All these non-compliant resources are currently categorised as 'non-compliant' resources, but reflect the confidence of historical classification from mineral resource to mineral reserves. Thus, they misrepresent the national-scale resource management. The UNFC-2019 code provides a standardised reporting for different source types and reporting formats, including uneconomic and undiscovered resources. It hence provides a neutral framework for reporting national-level resources which serve longer-term minerals development and industrial strategy planning on a national and supra-national scale.

This report is a product of the Horizon 2020 funded three year project Mintell4EU. In this project, GTK is one of the nine partners currently investigating how the UNFC code can be used as a tool to obtain more accurate Pan-European mineral inventories providing better harmonisation of minerals resource data in Europe. An eventual implementation of the UNFC as a standard tool will thus provide better insights into the European stocks "in the ground" and potential for, e.g., critical raw materials, and their possibilities for future supply from European sources to European industries.

Terminology used in this report is summarised in Appendix 1.

2 BASICS OF THE UNFC CODE

This section is essentially based on the UNFC guidelines by UNECE (2009, 2019). Any part below fully or partially relating to other sources of information is indicated by respective relevant reference(s).

The UNFC classification code is principles-based system and based on three-dimensional presentation where category definitions are the building blocks of the system (Fig. 1). The categories are defined as three fundamental Criteria of environmental-socio-economic viability (E-axis), technical feasibility (F-axis), and degree of confidence (G-axis). Primary level of resource classification results from the combination of a Category from each of the three Criteria. Table 1 is an abbreviated, 2D, version the full (3D) Criteria image and shows the most commonly usable UNFC Category Classes.

There are no constraints on combinations of Categories, but not all be meaningful in context of solid mineral projects, as also becomes evident from the case descriptions and discussion through this document.

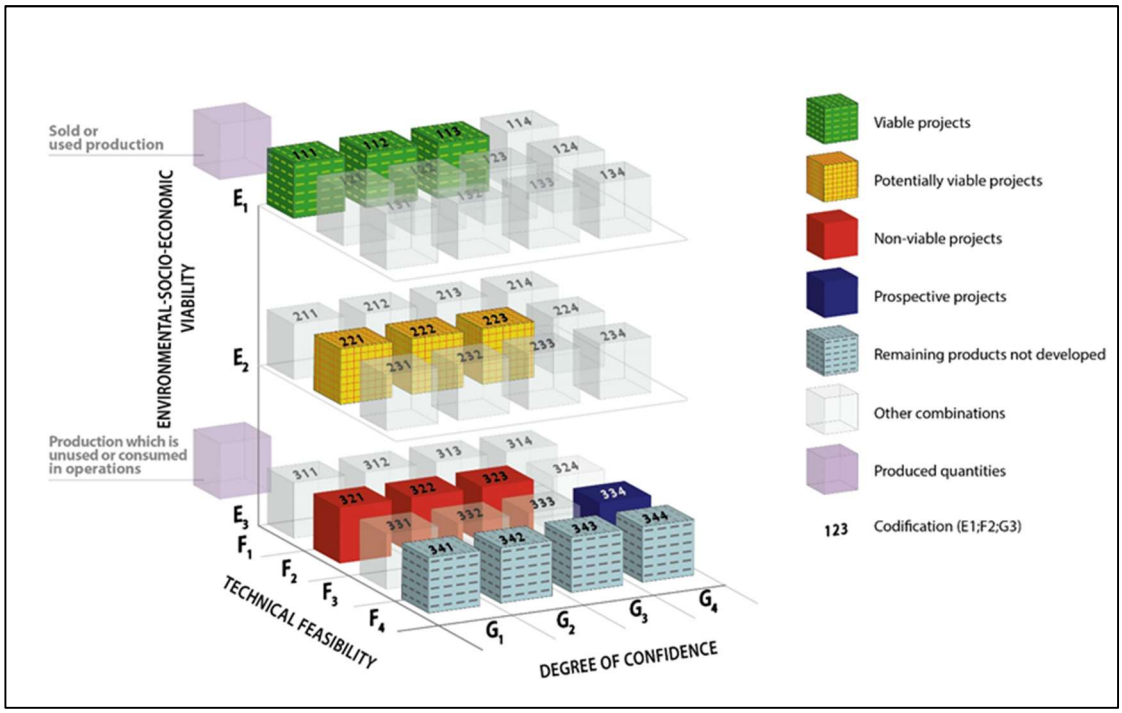

Figure 1 UNFC-2019 Classification.
Kuva 1 *UNFC-2019 -luokittelu. Kuvan suomenkielinen versio on liitteessä 3, kuva 1.*

Table 1 Abbreviated Version of the UNFC, showing the most commonly used Categories ('Primary Classes').
Taulukko 1 *UNFC-koodituksen tiivistetty versio; yleisimmin käytetyt luokat ja niitä vastaavat kategoriat. Suomenkielinen versio on liitteessä 3, Taulukko 1.*

	Produced	Sold or used production			
		Production which is unused or consumed in operations[a]			
		Class	Minimum Categories		
			E	F	G[b]
Total Products	The project's environmental-socio-economic viability and technical feasibility has been confirmed	Viable Projects[c]	1	1	1, 2, 3
	The project's environmental-socio-economic viability and/or technical feasibility has yet to be confirmed	Potentially Viable Projects[d]	2[e]	2	1, 2, 3
		Non-Viable Projects[f]	3	2	1, 2, 3
	Remaining products not developed from identified projects[g]		3	4	1, 2, 3
	There is insufficient information on the source to assess the project's environmental-socio-economic viability and technical feasibility	Prospective Projects	3	3	4
	Remaining products not developed from prospective projects[g]		3	4	4

a Future production that is either unused or consumed in the project operations is categorized as E3.1. These can exist for all classes of recoverable quantities.
b G categories may be used discretely, or in cumulative scenario form (e.g., G1+G2).
c Estimates associated with Viable Projects are defined in many classification systems as Reserves, but there are some material differences between the specific definitions that are applied within different industries and hence the term is not used here.
d Not all Potentially Viable Projects will be developed.
e Potentially Viable Projects may satisfy the requirements for E1.
f Non-Viable Projects include those that are at an early stage of evaluation, in addition to those that are considered unlikely to become viable developments within the foreseeable future.
g Remaining products not developed from identified projects or prospective projects may become developable in the future as technological or environmental-socio-economic conditions change. Some or all of these estimates may never be developed due to physical and/or environmental-socio-economic constraints. It is emphasized that the remaining products are quantities which, if produced, could be bought, sold or used.

Application of the G-axis

G-axis refers to degree of confidence which (note: in UNFC-2009 it is 'Geological confidence'*)* designates the degree of confidence in the estimate of the quantities of products from the project. The G-axis categories are intended to reflect all significant uncertainties (e.g. source uncertainty, geologic uncertainty, facility efficiency uncertainty, etc.) impacting the estimate forecast for the project. Mainly, the G-axis reflects the confidence through geological studies which have been carried out. It also refers to an estimate of the quantity of mineralization that is possible to be estimated

(volume, tonnes, grade/quality, etc.). Then, the classification takes place on the degree of confidence category axis and can be subdivided into four numerical codes on the basis of the level of detail of the studies and the degree of confidence in the geological model. Uncertainties related to the G-axis values are described in Appendix 2.

Application of the E-axis

E-axis refers to Environmental-Socio-Economic Viability which designates the degree of favourability of environmental-socio-economic conditions in establishing the viability of the project, including consideration of market prices and relevant legal, regulatory, social, environmental and contractual conditions.

Application of the F-axis

F-axis refers to technical feasibility which designates the maturity of technology, studies and commitments necessary to implement the project. These projects range from early conceptual studies through to a fully developed project that is producing, and reflect standard value chain management principles.

Sub-categories

UNFC provides scope to classify projects in more detail by applying the full range of *Sub-category* definitions (Table 2). The sub-categories reflect the concept of classification on the basis of project maturity, which broadly corresponds to the probability that the project will eventually achieve viable operation and product sales or use. The projects are divided into four main maturity types: 1) Viable Projects, 2) Potentially Viable Projects, 3) Non-Viable Projects, and 4) Prospective Projects. In addition, the remaining products not developed from identified projects or prospective projects are classified separately; such cases are presented below, in Section 4.2.

Table 2 Two-dimensional presentation of UNFC Classes defined by Categories and Sub-categories.
Taulukko 2 *Pää- ja alaluokat ja niitä vastaavat alakategoriat UNFC:n kaksiulotteisessa kentässä. Suomenkielinen versio on liitteessä 3, Taulukko 2.*

UNFC Classes Defined by Categories and Sub-categories						
Total Products	Produced	Sold or used production				
		Production which is unused or consumed in operations				
	Class		Sub-class	Categories		
				E	F	G
	Known Sources	Viable Projects	On Production	1	1.1	1, 2, 3
			Approved for Development	1	1.2	1, 2, 3
			Justified for Development	1	1.3	1, 2, 3
		Potentially Viable Projects	Development Pending	2[b]	2.1	1, 2, 3
			Development On Hold	2	2.2	1, 2, 3
		Non-Viable Projects	Development Unclarified	3.2	2.2	1, 2, 3
			Development Not Viable	3.3	2.3	1, 2, 3
		Remaining products not developed from identified projects		3.3	4	1, 2, 3
	Potential Sources	Prospective Projects	[No sub-classes defined]	3.2	3	4
		Remaining products not developed from prospective projects		3.3	4	4

b Development Pending Projects may satisfy the requirements for E1.

The most commonly used UNFC Categories (UNECE 2019)

Viable Projects (UNFC classes 111,112)

Material from a project which is actually producing and selling or using one or more product (ore) as at the Effective Date of the evaluation.

Necessary requirements for this Category are:

1. Development and operation are confirmed to be environmentally, socially, and economically viable (UNFC Sub-classes E1.1; F1.1)
2. Technical feasibility of a development project has been confirmed
3. Product quantity associated with a project that can be estimated with high level of confidence

Viable Project Sub-classes:

- **Not environmentally-socially-economically viable (Sub-class E1.2):** Development is not environmentally-socially-economically viable on the basis of current

conditions and on realistic assumptions of future conditions, but is made viable through government subsidies and/or other considerations.

If a part of the project development plan is still subject to separate approval and/or commitment of capital funds such that it is not currently certain to proceed, that part should be classified as a separate project in the appropriate Sub-class as follows:

- **Approved for Development (Sub-class F1.2):** Requires that all approvals and contracts are in place, and capital funds have been committed. Construction and installation of project facilities should be underway or due to start imminently. Only a completely unforeseeable change in circumstances that is beyond the control of the developers would be an acceptable reason for failure of the project to be developed within a reasonable time frame.

- **Justified for Development (Sub-class F1.3):** Requires that the project has been demonstrated to be technically feasible and environmental-socio-economic viable, and there shall be a reasonable expectation that all necessary approvals and contracts for the project to proceed to development and operation will be forthcoming.

Potentially Viable Projects (UNFC classes 221,222, 223)

A Potentially Viable Project is a case where the project's environmental-socio-economic viability and/or technical feasibility has yet to be confirmed, and development and operation are expected to become environmentally-socially and economically viable in the foreseeable future.

Necessary requirements for this Category are:

1. Development and operation are not yet confirmed to be environmentally-socially-economically viable but, on the basis of realistic assumptions of future conditions, there are reasonable prospects for environmental-socio-economic viability in the foreseeable future.

2. Preliminary studies of a defined project provide sufficient evidence of the potential for development and that a further study is warranted. Further data acquisition and/or studies may be required to confirm the feasibility of development.

Potentially Viable Project Sub-classes:

- **Development Pending (Sub-class F2.1)** is limited to those projects that are actively subject to project-specific technical activities, such as acquisition of additional data (e.g. appraisal drilling) or the completion of project feasibility studies and associated socio, environmental and economic analyses designed to

confirm project viability and/or to determine the optimum development scenario. Also, this sub-category may include projects that have nontechnical contingencies, provided these contingencies are currently being actively pursued by the developers, and are expected to be resolved positively within a reasonable time frame. Such projects would be expected to have a high probability of achieving viability.

- **Development On Hold (Sub-class F2.2)** is used where a project is considered to have, at least, a reasonable chance of achieving viability (i.e., there are reasonable prospects for eventual economic production), but where there are currently major non-technical contingencies (e.g., environmental or social issues) that need to be resolved before the project can move towards development.

  The primary difference between 'Development Pending' and 'Development On Hold' is that in the former case the only significant contingencies are ones that can be, and are being, directly influenced by the developers (e.g., through negotiations), whereas in the latter case the primary contingencies are subject to the decisions of others over which the developers have little or no direct influence and both the outcome and the timing of those decisions is subject to significant uncertainty.

Prospective Projects (UNFC class 334)

Technical feasibility of a development project cannot be evaluated due to limited data. Development and operation are not expected to become environmentally-socially-economically viable in the foreseeable future <u>or</u> evaluation is at too early a stage to determine environmental-socioeconomic viability.

1. Very preliminary studies of a project indicate the need for further data acquisition, study, or both, in order to evaluate the potential feasibility of development.

2. On the basis of realistic assumptions of future conditions, it is currently considered that there are no reasonable prospects for environmental-socio-economic viability in the foreseeable future; or, environmental-socio-economic viability cannot yet be determined due to insufficient information.

   Also included are estimates associated with projects or resources that are forecast to be developed, but which will be unused or consumed in operations.

3. Product quantity associated with a Prospective Project, estimated primarily on indirect evidence. Where a single estimate is provided, it should be the expected outcome but, where possible, a full range of uncertainty should be calculated and reported for the prospective project. In addition, it is recommended that the

chance of success (probability) that the prospective project will progress to a Viable Project is assessed and documented.

Prospective Project Sub-classes:

- **Sub-class F3.1:** Site-specific studies have identified a potential development with sufficient confidence to warrant further testing.
- **Sub-class F3.2:** Local studies indicate the potential for development in a specific area but requires more data acquisition and/or evaluation in order to have sufficient confidence to warrant further testing.
- **Sub-class F3.3:** At the earliest stage of studies, where favorable conditions for the potential development in an area may be inferred from regional studies.
- **Sub-class G4.1:** Low estimate quantities.
- **Sub-class G4.2:** Incremental amount to G4.1 such that G4.1+G4.2 equates to a best estimate of the quantities.
- **Sub-class G4.3:** Incremental amount to G4.1+G4.2 such that G4.1+G4.2+G4.3 equates to a high estimate of the quantities.

Remaining products not developed from projects (UNFC class 343)

1. Quantities should only be classified as 'Remaining products not developed from projects' where no technically feasible projects have been identified that could lead to the production of any of these quantities. Some of these quantities may subsequently be produced in the future due to the development of new technology.
2. No development project has been identified.
3. Product quantity associated with a Prospective Project, estimated primarily on indirect evidence.

3 CRIRSCO TEMPLATE

The Committee for Mineral Reserves International Reporting Standards (CRIRSCO) Template is the most recently developed international standard for the reporting of Exploration results, Mineral Resources and Mineral or Ore Reserves (Committee for Mineral Reserves International Reporting Standards 2013). It is in turn based on a number of national or regional reporting standards (such as JORC, PERC, NI43-101, SAMREC) which are accepted and in many cases required to be followed, by stock exchanges, when

listed mining and exploration companies report their mineral resources and reserves (e.g., National Instrument 43-101 2011, CIM 2019, JORC 2012, Pan-European Reserves and Resources Reporting Committee 2013). These reporting standards are compatible and consistent with each other and the Template, and whose authors contributed to the development of the Template that represents current international best practice for Public Reports by companies.

Public Reports prepared in accordance with the CRIRSCO Template are reports prepared for the purpose of informing investors or potential investors and their advisors. Classification is accomplished by professionals with demonstrable experience in estimation projects of the type being reported. These professionals are referred to a Competent Person (Australia) or a Qualified Person (Canada). The standards do not regulate the procedures used by the Competent or Qualified Person to estimate and classify Mineral Resources or Mineral Reserves. The Template is focused on establishing and maintaining consistent and appropriate standards for Public Reports (as defined by CRIRSCO) and, thus, sets the minimum standards for public reporting.

Canadian Securities Administrators published a notice presenting the results of 58 resource estimates disclosed in mining issuers' technical reports in British Columbia, Ontario, Quebec and Alberta (CSA 2020). The document outlines how regulators assess mineral resource estimates and provides guidance on addressing common deficiencies. The results identified inadequate disclosure in the following areas: 1) reasonable prospects for eventual economic extraction (RPEEE), 2) data verification, 3) risk factors, and 4) sensitivity to cut-off grade.

Within the CRIRSCO, '*Mineral Resource*' is a concentration or occurrence of solid material of economic interest in or on the Earth's crust in such form, grade (or quality), and quantity that there are reasonable prospects for eventual economic extraction. Therefore, the portions of a mineral deposit that do not have Reasonable Prospects for Eventual Economic Extraction (RPEEE) must not be included in a Mineral Resource.

A *Mineral Reserve* is the economically mineable part of a Measured and/or Indicated Mineral Resource. In other words, "*Mineral Reserves are those portions of Mineral Resources which, after the application of all mining factors, result in an estimated tonnage and grade which, in the opinion of the Competent Person making the estimates, can be the basis of a viable project, after taking account of all relevant Modifying Factors*". The latter "*are considerations used to convert Mineral Resources to Mineral Reserves. These include, but are not restricted to, mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social and governmental factors*". (Committee for Mineral Reserves International Reporting Standards 2013)

The CRIRSCO codes allow reporting into exploration results, mineral resources and reserves as described in Figure 2. On the other hand, anything that is regarded, for

example, 'possible', 'assumed', 'hypothetical', 'speculative', or 'undiscovered', cannot be reported. In addition, resources and reserves not reported according to the CRIRSCO template may be mentioned in public reporting, but must be regarded with low confidence, are typically called 'historic' and 'non-compliant', and must not to be included into any of the resource or reserve categories shown in Figure 2.

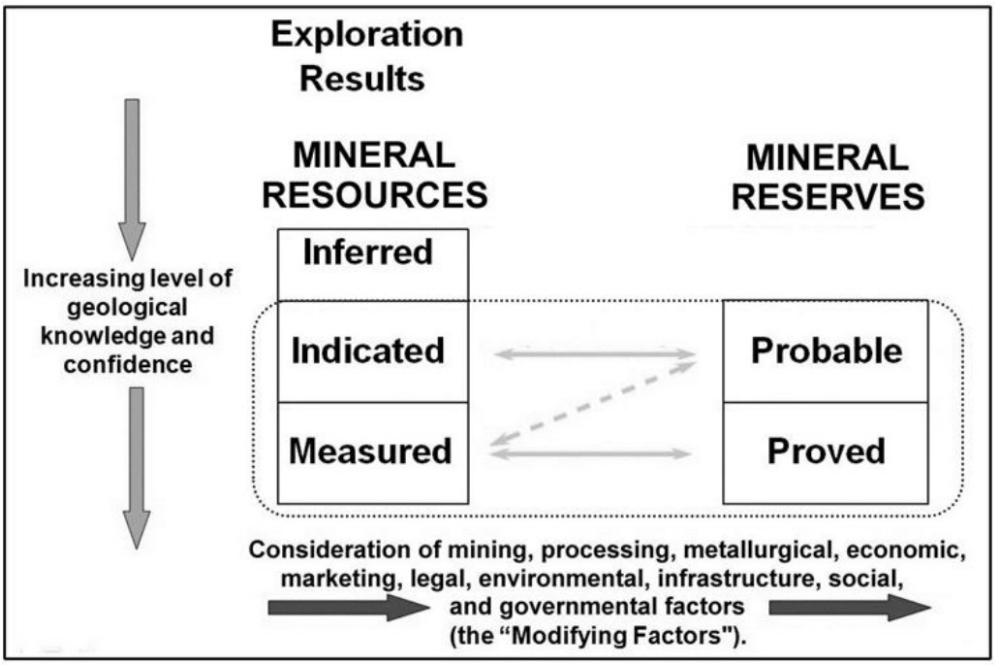

Figure 2 Classification of Exploration Results, Mineral Resource and Mineral Reserves according to CRIRSCO Template.
Kuva 2 *Mineraalivarojen ja -varantojen sekä 'malminetsinnän tulosten' luokittelu CRIRSCO:n sääntöjen mukaan. Suomenkielinen versio on liitteessä 3, Taulukko 3.*

3.1 Bridging Document between the CRIRSCO Template and the UNFC

The UNFC is aligned with other classification systems via bridging documents. A Bridging Document explains the relationship between UNFC and another classification system, including instructions on how to classify estimates generated by application of that system using the UNFC Numerical Codes (UNECE 2015, 2019).

CRIRSCO-compliant resources and reserves can be directly coded into UNFC categories following the mapping presented in Table 3.

Table 3 Mapping of CRIRSCO Template to UNFC-2019 Classes and Categories.
Taulukko 3 *CRIRSCO:n luokittelun mukaisten mineraalivarojen ja -varantojen sekä 'malminetsinnän tulosten' luokittelu UNFC-koodiin. Suomenkielinen versio on liitteessä 3.*

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

Mapping into UNFC categories is based on the following reasoning, as described by, e.g., Kresse (2019):

- In the G-axis, Mineral Reserves are classified as G2 (probable) or G1 (proven)
- Mineral Resources are classified as G3 (inferred), G2 (indicated) or G1 (measured) reflecting an increasing level of geological knowledge and confidence
- Mineral reserves are the economically minable quantities and always correspond to categories E1, F1 (G1 or G2)
  - Proved mineral reserves are classified as 111
  - Probable mineral reserves are classified as 112
- Mineral resources are generally classified as E2, F2 (G1, G2 or G3)
  - Measured resources are classified as 221
  - Indicated resources are classified as 222
  - Inferred resources are classified as 223
- E and F categories set minimum standards for UNFC classes which means mineral resource estimates can also be classified as E1 F2 (in case there is no doubt of economic viability) or E2 F1 (in case there is no doubt in technical viability). These combinations can still be described as Potentially Commercial Projects.
- An Exploration Target is located in a defined geological setting, with a statement or estimate (range of tonnes and a range of grade or quality) of its exploration potential,

and where exploration is insufficient to estimate mineral resources according to CRIRSCO Template. It is classified into E3 F3 G4.

4 VARIOUS CODING CASES IN FINLAND AND RESULTING SPECIFIC GUIDELINES

The GTK mineral deposit database (https://gtkdata.gtk.fi/mdae/index.html) contains information on current and historical exploration and mining projects that have been classified in according to CRIRSCO Template (e.g., JORC, NI43-101 or PERC), historical estimates that have been reported prior to international standards, other international best practice guidelines (pre-2000), and cases with recent exploration but with no CRIRSCO-compliant resource. These resource and reserve estimates include a wide range of deposit types and styles of mineralisation at different project maturity levels (Appendix 4).

The non-CRIRSCO estimates were typically carried out by domestic mining and exploration companies and the GTK before 1995 and by domestic and foreign companies and GTK until about 2000. GTK has released non-compliant mineral resource estimates also since the year 2000. This GTK policy derives from the role of the GTK as an organisation to provide as extensive as possible early-stage mineral potential information for the industry. In addition to these, there are other specific cases where the CRIRSCO–UNFC bridging cannot be used. All these are discussed, with case examples, in this main section.

4.1 Mapping of CRIRSCO-compliant Active Projects to UNFC-2019

Active Projects (Fig. 3; both exploration and mining projects) with viable or potentially viable know sources that have been classified in accordance with the CRIRSCO Template and, therefore, having assumed or demonstrated "*reasonable prospects for eventual economic extraction*" should be classified following the CRIRSCO–UNFC Bridging Document (UNECE 2015). This is described in Section 3.1 of this report.

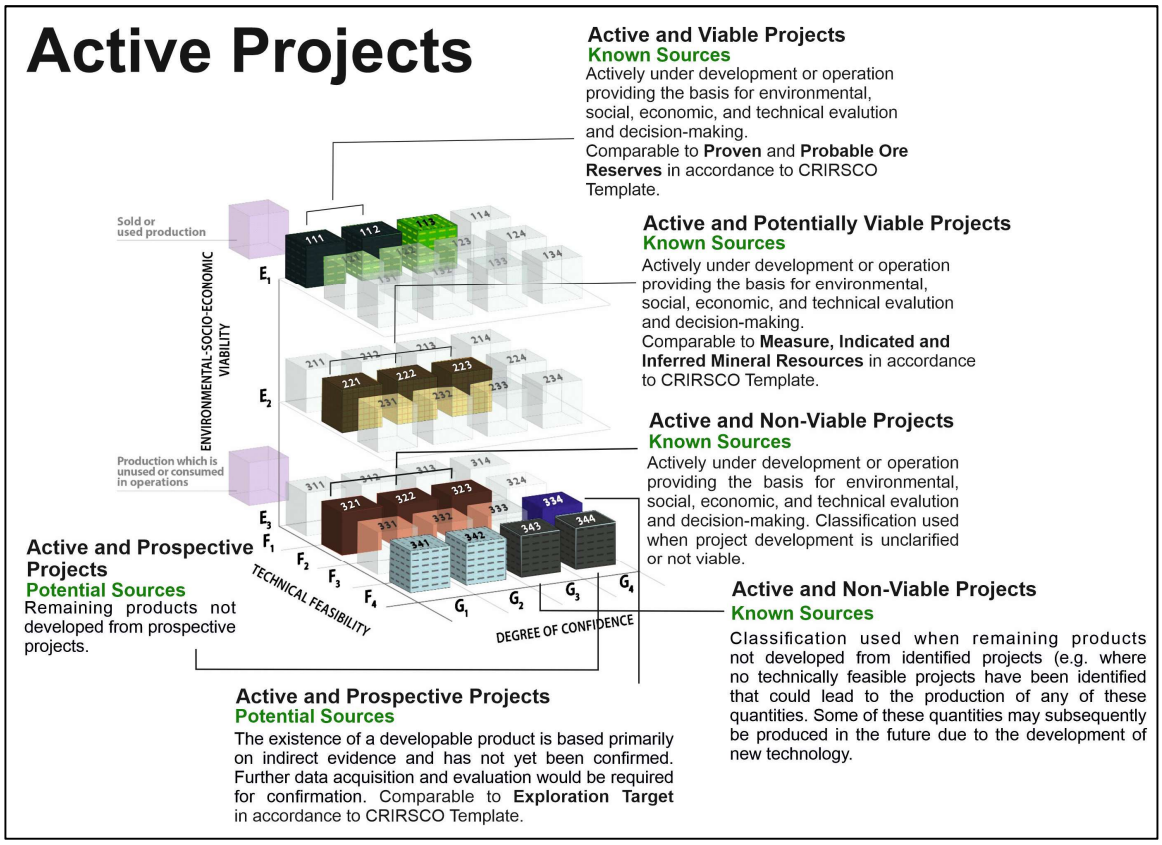

Figure 3. Active projects.
Kuva 3. *Aktiiviset projektit.*

4.2 Mapping of non-compliant Active Projects to UNFC-2019

These are essentially industrial mineral and industrial rock deposits and mines where the operating company does not use the CRIRSCO Template reporting code. There currently are several active projects under development or operation in Finland which have not been reported in accordance with CRIRSCO-family codes (Appendix 4). Commonly, the industrial mineral and industrial rock deposits have much higher recovery ratio which means that these deposits possess a higher portion of valuable mined material and further converted to final marketable products. In addition to grade values, the quality criteria (e.g. colour, impurities, yellowness, grain size or shape, fibre length, etc.) are important for commercial industrial mineral production.

Currently, Yara International (ASA) is the only company which is reporting its phosphate exploration results, mineral resources and ore reserves under CRIRSCO-family code (The JORC Code). On the other hand, Nordkalk has adopted the UNFC-2019 and is currently working on different case studies (UNFC 2020).

Other companies are only reporting the annual quantities of mined ore and waste rock to the Mining Authority. For an industrial mineral deposit, mineral resource data may occur in environmental permit applications, but there typically is no indication of which CRIRSCO template category such resources might go into. If there is a decision to build a mine or it is an active mine, some of the material most probably is in reserve categories, but an environmental permit typically does not tell how much.

An example of the latter is the Jänissuo talc deposit where the decision of the environmental permit application only states that "the total amount of ore is 800,000 t" (Aluehallintovirasto Pohjois-Suomi 2019). In such cases, if the permitting was granted, the entire resource could go into the UNFC category ***1,2,2***: 1) Granted permit puts the resource in E1; 2) Mining permit is applied for so we can assume technical feasibility is extensively investigated but we do not know how much of the resource is technically feasible to exploit so the F-axis value is 2 (some probably would go into F1 and perhaps some into F3); 3) Just as for F-axis, the same assumptions can be given for the G-axis, hence G2. Alternatively, if we follow the strict lowest-confidence rule, we should classify the resource into ***1,3,3***. In any case, in all cases of the UNFC category reported, one must give a detailed basis how such category was decided to apply for that resource.

4.3 Non-Viable quantities in CRIRSCO-compliant Active Projects to UNFC-2019

In case of Non-Viable quantities, the Bridging Document (UNECE 2015) should also be followed:

"Where adequate geological studies have been carried out but preliminary assessment of the Modifying Factors indicates that the project is not viable in the foreseeable future (i.e., it does not have "reasonable prospects for eventual economic extraction"), the mineralization is classified as "inventory" and is not converted to a Mineral Resource. "Inventory" is not a defined term in the Template, and such quantities may not be disclosed in a Public Report (as defined above), but for other purposes would generally be classified in UNFC-2009 as either E3F2 where the quantities are technically recoverable but are not expected to become economically viable in the foreseeable future (Sub-categories E3.3, F2.3) or where the economic viability cannot yet be determined due to insufficient information (Sub-categories E3.2, F2.2), or E3F4 where no technically viable development project or mining operation can be identified (Sub-category E3.3). The inventory will be reviewed in future should conditions change."

In accordance with the CRIRSCO Template, publicly listed companies normally cannot report non-viable quantities, unlike a geological survey. Non-viable quantities are, hence, during the past two decades less commonly reported; such cases do exist, however, as exemplified immediately below.

Case examples

Companies provide quantities of stockpiled material which have been processed but not sold. 'Stockpiling' may in this context mean storing processed material separated from: 1) primary ore, 2) material in the tailings at mine or at processing or refinery plant. If in tailings, it is assumed that the commodity or commodities in question could be recovered by existing technologies or by technologies under development and clearly coming into use in near future.

The focus of this report is in exploration and mining; therefore, we do not cover any further possible or known resources at processing, refinery, and smelting plant sites. However, we remind the reader to keep in mind of these potentially additional resources. This is because such materials may in the future become viable due to, e.g., disruptions in supply of virgin raw materials, change in commodity prices, development of new processing technologies, and/or increasing political pressure to use as much as possible materials that have been mined or processed but not used.

Companies' estimates include elements that have been preliminarily assumed as having by-product potential but discarded in a later study stage due to not having reasonable prospect for economic extraction. For example, Ramboll Finland (2013) reported U, Th and TREO in the environmental assessment report on the Kuusamo Project held by Dragon Mining. The commodity concentration data was provided by Dragon Mining. However, Dragon Mining did not report these metals in their public, JORC-compliant reports. Also, the trade for thorium is very minor and price low (has been so for at least two decades), so it is nowhere a main commodity in a viable mine (e.g., USGS 2019). Consequently, these U, Th and TREO resources should be classified into UNFC Category ***3,4,3***, as they are within the definition: *"Remaining products not developed from identified projects or prospective projects may become developable in the future as technological or environmental-socio-economic conditions change. Some or all of these estimates may never be developed due to physical and/or environmental-socio-economic constraints"* (UNECE 2019).

In the UNFC categorising sense, a similar case is the commodity concentration data on a set of spodumene-rich LCT pegmatites in Western Finland. Many of these are currently held by Keliber Oy which is developing the deposits into a mine, and only reporting the lithium content in JORC-compliant resource and reserve (www.keliber.fi/en/geology/mineral-resources-and-ore-reserves/). However, there are older reports, in this case not by the current holder of the deposits, giving also Be, Nb, and Ta grades in the resource of some of these pegmatites (Koistinen et al. 2010, 2011). These metal grades are given to different, typically smaller, tonnages than what is most recently reported by Keliber Oy. These data should go into the UNFC Category ***3,4,3***, because they are not by the current project owner, not reported in accordance to the

recent JORC code (i.e., are old), and there are no indications in any reporting that the metals would be recovered with the planned or even speculated extraction.

4.4 Mapping of CRIRSCO-compliant Potentially Viable Projects to UNFC-2019

A Potentially Viable Project (Table 2) is a case where the "*project's environmental-socio-economic viability and/or technical feasibility has yet to be confirmed*", and which either are in situation of *Development Pending* or *Development On Hold*. The two alternatives are described in detail in Appendix 1. Essentially these are cases where the project is active, there is a CRIRSCO-compliant resource by the current operator, but the decision to build or re-start a mine has not been done.

"*The primary difference between Development Pending and Development On Hold is that in the former case the only significant contingencies are ones that can be, and are being, directly influenced by the developers (e.g., through negotiations), whereas in the latter case the primary contingencies are subject to the decisions of others over which the developers have little or no direct influence*" (UNECE 2019).

Depending on degree of confidence of data, the UNFC Category values a Potentially Viable Project may get are 2,2.1,1–3 and 2,2.2,1–3 for Development Pending and Development On Hold, respectively. In some cases or parts of a deposit, a Potentially Viable Project may satisfy the requirements for E1 (Table 2; UNECE 2019).

Development Pending case examples

The Pahtavaara gold mine, in Central Finnish Lapland, has been in care and maintenance since 2013 when the operator and owner went bankrupt apparently due to dealings elsewhere (Lappland Goldminers 2014). Since 2016, Pahtavaara has been owned by Rupert Resources which has released a new mineral resource (NI43-101 compliant) and is exploring for more gold at and near the mine site (Wolfe 2018, Rupert Resources 2020). The mine also has all the permits needed to re-start operation and all infrastructure in place, so the deposit can be classified into Development Pending category. As the current mineral resource only includes the inferred category, following the guidelines of Table 2, all the currently known resources have the UNFC Category ***E2,F2.1,G3***.

Similar to Pahtavaara, also the Laivakangas gold mine, in western Finland, went into care and maintenance, in 2014, due to the financial problems of the then owner and operator (Bektas et al. 2019). Since 2018, Laivakangas (also called 'Laiva Mine' and 'Otso Mine') has been held by Otso Gold (previously known with the name 'Nordic Gold'). Otso mined the deposit briefly in 2018–2019, but then put it in care and maintenance and started to re-evaluate the deposit. All the necessary permitting and infra to re-start mining are in place, and the company is working towards re-opening the mine. In 2019, Otso Gold released a new NI43-101 compliant mineral resource containing material in Measured,

Indicated and Inferred categories (Bektas et al. 2019); in UNFC Category classes, following the guidelines of Table 2, these are ***E2,F2.1,G1*** (Measured), ***E2,F2.1,G2*** (Indicated), and ***E2,F2.1,G3*** (Inferred).

Development On Hold case examples

We do not have a clear case in Finland to fulfil the definition of this category. A case going into this category would be one where the technical and economic feasibility are positive but one of more of the essential permitting is not in place.

4.5 Mapping of CRIRSCO-compliant Non-active Projects to UNFC-2019

In the CRIRSCO Template (2019, Clause 8.20) it is stated as follows: "*If re-evaluation indicates that any part of the Mineral Reserves is no longer viable, such Mineral Reserves must be re-classified as Mineral Resources and be removed from the Mineral Reserve statements".* In addition, the UNFC Categories (221, 222 and 223) would be only used for Active Projects (Fig. 3) that fulfil the "*reasonable prospects for environmental-socio-economic viable development in the foreseeable future*" criteria.

These restrictions result in a re-classification of reserves and resources in Non-Active Projects (Fig. 4), even when the resources and reserves were originally estimated according to the CRIRSCO Template. We interpret the resulting changes in the UNFC category classes as follows:

- Original 111 → Now 331
- Original 112 → Now 332
- Original 221 → Now 331
- Original 222 → Now 332
- Original 223 → Now 333

The changes in the E and F Categories, from 1 and 2 to 3, are due to the fact that, as the project is no more active, the environmental-socio-economic viability (E-axis) and technical feasibility (F-axis) assessments done previously can no more be regarded valid. This means that if another company takes control over the deposit, it must make full re-assessments of the factors relating the E and F axes, not just geology. This is not only because another company may have other interests and targets, but also because new technologies come available, and metal prices, environmental regulations, and the values

of the society change with time (e.g., Angerer et al. 2009, Wellmer & Dalheimer 2012, Arndt et al. 2017, Tolvanen et al. 2019).

Contrary to the E and F axes, the degree of confidence (G-axis), that is, the degree of uncertainty related to geology, is not essentially changed.

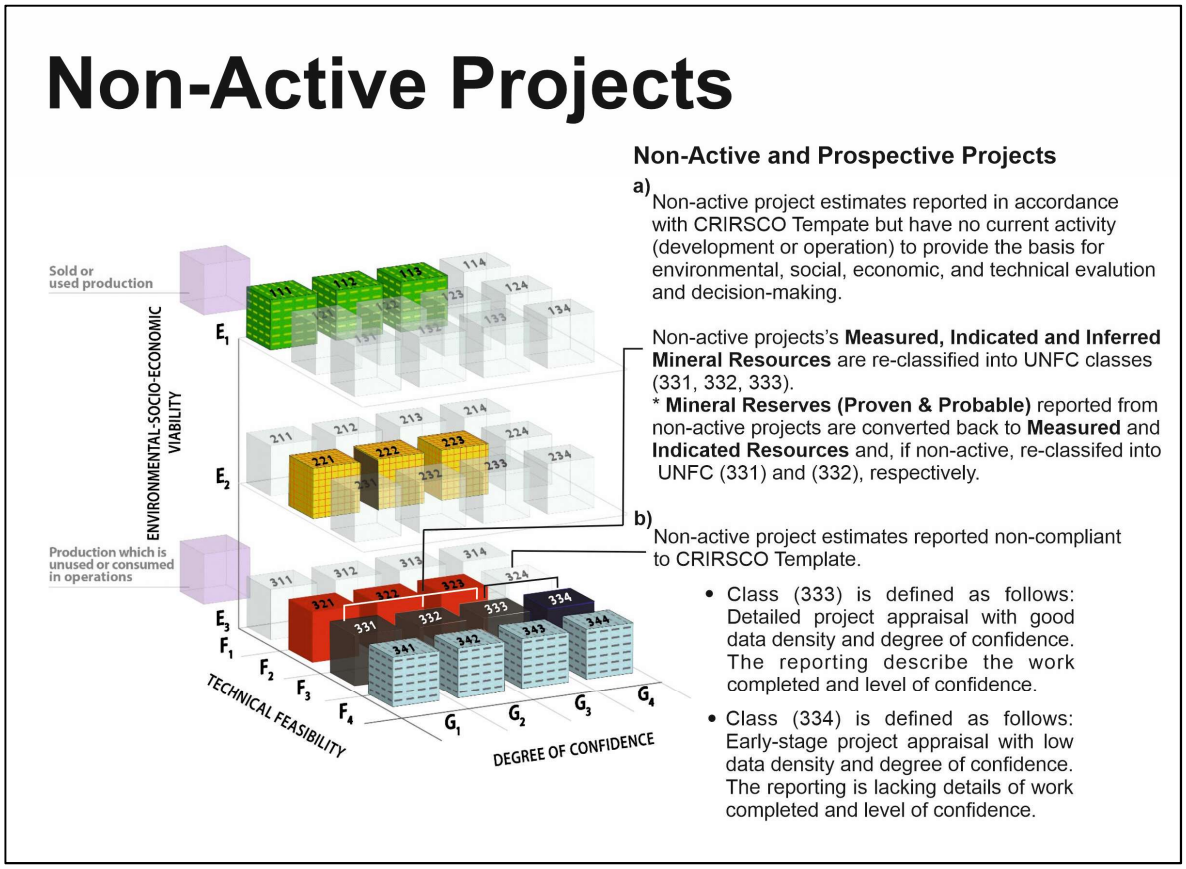

Figure 4 Non-active projects.
Kuva 4 *Projektit, jotka eivät ole aktiivisessa vaiheessa.*

Case examples

Vulcan Resources reported in 2009 mineral resources for three komatiite-hosted Ni-Cu-Co-PGE deposits in the Kuhmo-Suomussalmi greenstone belt, Finland: Hietaharju, Peura-Aho, and Vaara (Vulcan Resources 2009). The reporting was done according to the 2004 version of the Australian JORC code (JORC 2004). All three deposits were reported to have both indicated and inferred mineral resources. Since that, the company has abandoned the project, and the deposits have been held and explored by other companies. This

means that the 2009 resource must now be regarded as parts of a Non-Active Project, and the reported indicated and inferred resources have UNFC Categories ***3,3,2 and 3,3,3***, respectively.

Northland Resources reported in 2010 mineral resources for the Hannukainen mine project (Risto et al. 2010). The reporting was done according to the Canadian NI43-101 code, probably according to its 2006 version. Since the 2010 reporting, the company went bankrupt, albeit not due to problems with the Hannukainen project, and the deposits are now held and developed by another company (Northland Resources 2014, Hannukainen Mining 2019). Although this is an advanced mine project, the situation related to E and F axes of the UNFC code have been changed since the 2010 reserve and resource estimate: metal prices, the social license to operate (SLO), i.e. acceptance of the project by local community and environmental permit issues have been changed, and there is another company with a somewhat different focus and culture. Consequently, all of the 2010 measured resources must be re-coded into ***3,3,1***, indicated into ***3,3,2***, and inferred into ***3,3,3*** categories. In 2010, these resources would have been coded into 2,2,1, 2,2,2, and 2,2,3, respectively.

4.6 Mapping of resources that are non-compliant to CRIRSCO into UNFC-2019

These types of resources are typically from the pre-CRIRSCO time. They are not CRIRSCO-compliant, even when extensive work was done and the work reported in detail. For example, there is no QP (as defined by the CRIRSCO-family codes) that has signed off the report. Often, what is entirely missing is description of QA/QC information. Also, chemical analyses, feasibility and beneficiation studies (if any at all), permitting, and references to commodity prices are outdated fully or for most parts. Practically always, also the holder of the deposit has been changed since, often more than once. This means that for E-axis, the value is 3, and for F and G axes 3 or 4. These non-compliant resources are also referred as historical estimates in this report.

For F-axis, value 3 can be used in a number of cases, as that value is defined "*Very preliminary studies of a project, indicate the need for further data acquisition or study in order to evaluate the potential feasibility of development*" (UNECE 2019). Preliminary studies may include mineralogical research and primary metallurgical test work (e.g. small-scale testing for beneficiation). Also a pit optimization may be included. Such preliminary studies can be found in even quite old reporting. If sub-categories are used, perhaps F3.2 or F3.3 are possible. In some cases, even F3.1 might come into question, as suggested for the Jouhineva deposit, below. However, the historical data should always be treated with a high level of uncertainty and, therefore, the mapping should not exceed F3 regardless of the technical development of certain historical projects.

For the G-axis, the UNFC coding depends on data density and quality, and follows this general rule (UNECE 2019):

- good data density + high geological confidence => **G3** (*Product quantity associated with a project that can be estimated with a high level of confidence*)
- poor data density + low geological confidence => **G4** (*Product quantity associated with a Prospective Project, estimated primarily on indirect evidence*)

Below, we present examples of non-CRIRSCO-compliant resource reporting with varying degree of work being done in both before after the CRIRSCO-compliant coding started.

Case examples

Indicated and inferred mineral resources were reported for the Jouhineva Co-Au-Cu deposit by Isohanni (1984). This report is among the best documented and the best data density cases of the old reporting we have so far seen for a prospect not been mined in full scale. It includes block modelling, assessment of data density as what to include into a resource and what not, beneficiation test, and economic and technical feasibility evaluation. Based on the UNFC rules (UNECE 2019) and the discussion above, we regard the Jouhineva resource, both indicated and inferred, into the UNFC Category ***3,3,3***. The F-axis may, in this specific case, even get the value of 3.1: "*Site-specific studies have identified a potential development with sufficient confidence to warrant further testing*" – this is supported by the fact that the current holder of the deposit is actively exploring it (www.europeancobalt.com/jouhineva-co-cu-au).

Quite a different level of reporting, compared to Jouhineva, has been done for the resource at the Hotinvaara Ni occurrence in Central Finnish Lapland. Inkinen et al. (1984) reported resource for two ore bodies at Hotinvaara, one hosted by komatiites and another in metasedimentary rocks next to komatiites. Both resource estimates are 'geologic' in-situ estimates. Resource in the komatiite-hosted ore body is based on 9 drill holes with one or two drill holes per profile in profiles 50 m apart. Resource in the metasediment-hosted ore body is estimated at similar data density (six holes). At Hotinvaara, technical feasibility is not assessed, beneficiation is not tested, nor is there any environmental permitting or social acceptance tested. This deposit could get the UNFC Category of E3,F3.2,G3, or E3,F3.3,G3.

The category F3.2 is based on the definition in the UNECE (2019) guidelines: "*Local studies indicate the potential for development in a specific area but requires more data acquisition and/or evaluation in order to have sufficient confidence to warrant further testing*", which we see as potentially valid for Hotinvaara. Alternatively, if the drilling is seen too sparse for F3.2, the code F3.3 should be applied: "*At the earliest stage of studies, where favourable conditions for the potential development in an area may be inferred from regional studies*" (UNECE 2019). Selecting between F3.2 and F3.3, when the drilling density is rather low, depends on the interpreted or assumed complexity of an ore body.

If we have a complex case at Hotinvaara, then certainly the value 3.3 should be given for the F-axis. The same holds for selecting between values 3 and 4 for the G-axis. The deposit is open along strike and depth, and there is a number of additional possible ore bodies in the vicinity (Inkinen et al. 1984) suggesting a *Prospective Project* (UNFC 3,3,4). As we regard komatiite-related nickel sulphide deposit within a multiply deformed belt potentially quite complex in shape and commodity concentration variable at significant degree, the resulting UNFC Category for Hotinvaara is ***E3,F3.3,G4***.

Today, unlisted companies and other entities, such as geological surveys, may also report mineral resources not in accordance with the CRIRSCO Template. A recent example of such reporting is the 2016 resource for the polymetallic Loukinen occurrence in Central Finnish Lapland, as reported by Lepistö & Lahti (2016). The description following is based on that report. The 3D modelling of the ore body was based on drilling in 11 profiles (27 holes) and on indirect indications of geophysical surveys in a model extent of 410 x 250 x 220 m. The deposit is open along strike and down depth. The database included a total of 847 chemical assay samples which were composited to 1 m lengths. The estimation included estimation domains (wireframes) and a 3D sub-cell block model using a 5 m x 2 m x 5 m block size. The grade interpolation was done using Inverse Distance Weighting (IDW2) method. Geophysical data used in modelling comprises ground magnetic and 3D inversion model of ground magnetic data, VLF-R, self-potential and IP surveys. Sparse outcrop and trenching observations including structural measurements were used, where available, in modelling. Sampling and assaying is briefly described, but there is no information on what kind of QA/QC procedures were used. Drilling took place in several stages during 1994–2001, core was not oriented and structural measurements, except of rare alpha angles, are not available. No beneficiation tests have been reported. The report has not been signed by a Competent Person/Qualified Person. The deposit was outlined using a 0.2 % Cu cut-off grade. However, the report has no mention on Reasonable Prospects for Eventual Economic Extraction (RPEEE) and, therefore, no resource classification have been used. Reported tonnage is smallish and commodity grades low (2.57 Mt @ 0.41 % Cu, 0.18 ppm Au, 0.13 % Ni), but as the Loukinen ore body is open at three directions and there are in total seven similar, possible, sub-cropping, ore bodies within a 5 km long, 120 m wide 'structural corridor', all open at 100–150 m depth, there is potential for a major open-pittable deposit.

All information we have from Loukinen suggests it is a *Prospective Project*, meaning UNFC Category of ***3,3,4*** (Table 1). The fact that the deposit is just a few kilometres from a major winter sports resort, may put the value of E-axis to ***3.3*** "*On the basis of realistic assumptions of future conditions, it is currently considered that there are not reasonable prospects for environmental-socio-economic viability in the foreseeable future*" (UNECE 2019).

Also the white dolomite deposit at Reutuaapa is reported and a non-CRIRSCO resource estimated by the GTK (Lintinen et al. 2007): geological mapping, a geophysical ground

survey on a 2.4 km^2 systematic grid, diamond drilling of 1790 meters (24 holes of which 15 intercepting the white dolomite), and chemical and XRD analysis of 550 dolomite samples were performed. In addition, flotation tests were made for 5 representative samples. The work indicates that the dolomite is exceptionally white and iron-poor, and that all the silica can be removed by flotation. The deposit was intersected with four drilling profiles, each including a continuous 150-200 m wide section of white dolomite marble. These investigations indicate that the deposit is exceptionally homogeneous both along and across strike. The outcropping, subvertical ore body has a size of, at least, 50 Mt at 88 % of white carbonates and 10 % quartz. Of the carbonates, 90 % is dolomite and 10 % calcite. Drilling and surface geology indicates that the deposit is open at depth and along strike at both ends. With this information (Lintinen et al. 2007), we may classify the Reutuaapa dolomite deposit into the UNFC Category ***3,3,3***. For F-axis, we may apply the sub-category F3.2, as some beneficiation tests have been done and these "*indicate the potential for development in a specific area*" (UNECE 2019), but clearly more testing would be needed before development decision can be done. Value for G-axis is 3, as the work done indicates that there are no major complexities in the local geology.

Also flake graphite deposit at Käpysuo is currently under reporting at GTK. Work at Käpysuo includes geological mapping, a geophysical ground survey on a 7.3 km^2 systematic grid, diamond drilling of 5900 meters (31 holes of which 26 intercepting flake graphite bearing rock). Also, chemical analysis of 555 graphite-bearing drill core samples were performed. The deposit was intersected with 16 drilling profiles, each including graphite-bearing rock of varying thickness and Cg content. In addition, flotation tests were made for 9 representative samples with carbon content of 5 to 25 %. The best grade of final concentrate contains 85 % carbon with a recovery of 88 %. With additional purification techniques, the graphite content of Käpysuo ore can be increased into ultra-high-purity (>99.95 % C). Ground geophysical survey and drilling indicate that the graphite-bearing rock forms an about 3 km long, W-trending deposit which is open at depth and along strike at both ends.

With this information, we may classify the Käpysuo graphite deposit into the UNFC Category ***3,3,3***. For F-axis, we may apply the sub-category F3.2, as some beneficiation tests have been done and these "*indicate the potential for development in a specific area*" (UNECE 2019), but clearly more testing would be needed before development decision can be done. Value for G-axis is 3, as the work done indicates that there are no major complexities in the local geology. Naturally, all this categorising requires the reporting of a mineral resource, and this has not yet taken place.

4.7 Where do we use the UNFC code 344

The UNFC Category 344 represents undiscovered, hypothetic, and speculative estimates which amount and quality are too uncertain to justify quantification. The quantity is

estimated essentially on *indirect evidence*. Indirect evidence, in other words soft data, is imprecise or indirect measurements of the variables of interest. These estimates can be either regional-scale assessments of particular mineral endowment with different probability scenarios or target-scale estimates based on soft data.

Some specific examples of target-scale indirect estimates include geophysical data such as just magnetic survey data used in estimating the volume of the iron (magnetite) deposit. Another example is the use of radiometric readings (a gamma probe) to obtain the ratio of parent-to daughter products of uranium isotope 238 (^{238}U) decay chain, from which, and after proper calibration, the ^{238}U grade of an occurrence may be estimated.

Another type for UNFC 344 is a case where the grade of a commodity is estimated from a small number of samples analysed, or the commodity grade is based on uncertain sources, and these values are assumed for the entire tonnage of the resource in question. Typically, these data are for the potential byproduct commodities not consistently analysed when the resource estimate was done. Examples of this are the Co grade in resource for the Sirkka gold and Loukinen Cu-Ni-Au deposits, and the Ag and PGE grades in the Talvivaara Ni-Zn-Cu-Co deposit. In such cases, explanatory notes shall be included to explain that the grade information is predominantly based on local indirect evidence rather than regional data.

A prime example of resources estimated based only, or just partially, on indirect *regional evidence*, and the resource not given for any distinct location but for a region, are the statistical probability estimates produced by assessments of undiscovered mineral resources. By definition, ‘undiscovered resources’ are resources in undiscovered mineral deposits whose existence is postulated based on indirect geological evidence (U.S. Geological Survey National Mineral Resource Assessment Team 2000). Such resources can be estimated by various methods; perhaps most commonly is the USGS 3-part method used (Singer 1993, Singer & Menzie 2010). The USGS method is also used in Finland, since 2008, with the latest report being by Rasilainen et al. (2020). Essential here is that each genetic type of mineral deposit is assessed separately, all existing direct and indirect mineralization and mineral resource indications are used, and the results are presented by a probability range. This means that a range of ore and commodity tonnages are given for each terrain where geology allows to such deposits to occur. Also important to note is that the results of the assessment do not take into account the economic, technical, social or environmental factors that might in the future affect the potential for economic utilisation of a resource. Hence, part of the estimated undiscovered resources may be located in non-economic occurrences or may not even be found. Consequently in the UNFC template, all such resource must go into the class ***3,4,4***. Regarding sub-categories, both 3.2 and 3.3 for the E-axis, and 4.1, 4.2, and 4.3 for the F-axis may be included into an undiscovered resource. However, as the evidence is indirect and an extensive range of uncertainties is included, we do not see a reason to use the sub-

categories for undiscovered resources. The same holds for speculative and hypothetic resources, too.

5 CONCLUSIONS

This report attempts to give a practical guidance through various case examples on how to apply UNFC-2019 for active and non-active exploration and mining projects in Finland. Classification has been focused on non-compliant resources which represent the majority of mineral deposits in the Finnish national mineral deposit database and also which are commonly mapped without any systematic approach.

Most of the resource inventories in Finland are non-compliant or historical estimates that have not been prepared in accordance with CRIRSCO Template. These estimates are predominantly prepared before international reporting standards and reported by Finnish state-owned companies and GTK. The same also holds for the industrial mineral and industrial rock deposits where the operating companies in most cases still do not use and CRIRSCO reporting template. All such resources are currently categorised as 'non-compliant' resources, even where a resource is known at a high confidence. By applying the UNFC-2019 code, we can solve these data harmonisation problems as the code provides a standardised reporting for different source types and reporting formats, including uneconomic and undiscovered resources. The UNFC code hence also provides a neutral framework for reporting aggregated national-level resources which serve longer-term minerals development and industrial strategy planning on a national and supra-national scale.

Classifying or mapping reported mineral resources and reserves into the UNFC categories can be summarised as follows (note that this is not an exhaustive list, but aims to cover the most common cases):

- For active projects which have been reported in accordance with CRIRSCO Template, the Bridging Document between UNFC and CRIRSCO codes is used.
- Non-compliant Active Projects to UNFC-2019: Depending on quality, extent, and age of the data, and on the stage of the project, almost any UNCF category may come into question.
- For non-viable quantities in CRIRSCO-compliant active projects, the typical UNFC categories are within E3, F3–4, G2–4. Again, defining the right category depends on the quality, extent, and age of the data.
- For non-active projects or historical projects, the disclosed information are no longer valid for the CRIRSCO Template due to several reasons and must be re-classified into

the UNFC categories according to the current project maturity and using all available data and information.

- If there is a resource (± reserve) that was reported according to CRIRSCO, but the project is no more owned by the company which reported that quantity of ore, and the current owner has not confirmed the old reporting by a recent investigation (proper due diligence), the current UNFC categories, based on that old reporting, must have both the E- and F-axis values re-assessed into class 3. The G axis value does not change, however.

- UNFC-categories for resources that are non-compliant to CRIRSCO: these depend on 1) what information there is on socio-environmental issues, 2) technical feasibility, and 3) quality of geological data. Typically, the resulting UNFC category is E3, F3-4, G3-4. These include, e.g., all the resources called 'non-compliant, historic' in today's company reporting.

- The UNFC Category 344 is used when the resource quantity is based mainly or completely on indirect evidence. Such coding can also be used for regional-scale assessments.

- The originally reported quantities and grades should always be the same before and after classification. The systematic approach to classify mineral quantities into the UNFC categories provides a coherent mineral resource database that enables to communicate project maturity, uncertainties and risk factors inherent in mining and exploration projects.

- Where relevant detailed information of a project is available, sub-categories can be used to define the UNFC class for a resource or reserve.

- UNFC categories can also be given for past situations, but then one must clearly state that the given resource classes reflect the situation of that given year, and that the UNFC categories defined do not necessarily reflect the present situation, the present known resource (and reserve) for that certain deposit.

Anthropogenic resources are not covered by this report. Such resources commonly exist at, for example, mine, refinery and smelter sites. They may, in the future, become viable resources due to, e.g., disruptions in supply of virgin raw materials, change in commodity prices, development of new processing technologies, and/or increasing political pressure to focus in green and circular economies. Classification of anthropogenic resources according to the UNFC would is a topic that needs to be covered by another report.

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Appendix 1. Terminology

Active Project [Aktiivinen projekti] *is an exploration project or a mine where work is currently ongoing or only temporarily pending or on hold by a company. Only an active project may include Mineral Reserves.*

Bridging Document [Siltadokumentti] *explains the relationship between UNFC and another classification system, including instructions on how to classify estimates generated by application of that system using the UNFC Numerical Codes.*

Category [Kategoria] (UNFC) *is the primary basis for classification using each of the three fundamental Criteria of environmental-socio-economic viability, technical feasibility, and degree of confidence.*

Class(es) [Luokka] (UNFC) *is the primary level of resource classification resulting from the combination of a Category from each of the three Criteria (axes).*

Development Pending [Projektin kehittäminen vireillä] (UNFC) *is limited to those projects that are actively subject to project-specific technical activities, such as acquisition of additional data (e.g., appraisal drilling) or the completion of project feasibility studies and associated socio, environmental and economic analyses designed to confirm project viability and/or to determine the optimum development scenario. In addition, it may include projects that have nontechnical contingencies, provided these contingencies are currently being actively pursued by the developers and are expected to be resolved positively within a reasonable time frame. Such projects would be expected to have a high probability of achieving viability.*

Development On Hold [Projektin kehittäminen pysäytetty] (UNFC) *is used where a project is considered to have at least a reasonable chance of achieving viability (i.e., there are reasonable prospects for eventual economic production), but where there are currently major non-technical contingencies (e.g., environmental or social issues) that need to be resolved before the project can move towards development. The primary difference between Development Pending and Development On Hold is that in the former case the only significant contingencies are ones that can be, and are being, directly influenced by the developers (e.g., through negotiations), whereas in the latter case the primary contingencies are subject to the decisions of others over which the developers have little or no direct influence and both the outcome and the timing of those decisions is subject to significant uncertainty.*

Evaluator [Arvioitsija] *is a person, or persons, performing estimation and/or classification.*

Exploration Target [Malminetsintäkohde] (CRIRSCO) *is a statement or estimate of the exploration potential of a mineral deposit in a defined geological setting where the statement or estimate, quoted as a range of tonnes and a range of grade or quality, relates to an occurrence for which there has been insufficient exploration to estimate Mineral Resources.*

Hypothetical resources [Hypoteettiset varannot] *are undiscovered resources in known types of mineral deposits postulated to exist in favourable geological settings where other well-explored deposits of the same types are known to occur.*

Identified Project [Tunnistettu projekti] *is a project associated with a known source.*

Inferred mineral resource [Mahdolliset mineraalivarannot] *is that part of a mineral resource for which tonnage, grade and mineral content can be estimated with low level of confidence. It is inferred from geologic evidence and assumed but not verified geologic or grade continuity.*

Indicated mineral resource [Osoitetut mineraalivarannot] *is that part of a mineral resource for which tonnage, densities, shape, physical, characteristics, grade, and mineral content can be estimated with a reasonable level of confidence. The locations are too wide or inappropriately spaced for confirm geologic and/or grade continuity but are spaced close enough for continuity to be assumed.*

Measured mineral resource [Mitattu mineraalivaranto] *is that part of a mineral resource for which tonnage, densities, shape, physical, characteristics, grade, and mineral content can be estimated with a high level of confidence. The locations are spaced closely enough to confirm geologic/or grade continuity.*

Known Source [Tunnistettu arvoaines] *is a source that has been demonstrated to exist by direct evidence.*

Mineral resources[*Mineraalivarannot*] *is a concentration or occurrence of solid material of economic interest in or on the Earth's crust in such form, grade (or quality), and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, continuity and other geological characteristics of a mineral resource are known, estimated or interpreted from specific geological evidence, sampling and knowledge. Mineral resources are subdivided in order of increasing geologic confidence into inferred, indicated, and measured categories.*

Mineral reserves/Ore reserves [Mineraalivarat/Malmivarat] *is the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses that may occur when material is mined. Appropriate assessments, which may include feasibility studies, have been carried out, and include consideration of and modification by realistically assumed mining, metallurgic, economic, marketing, legal, environmental, social, and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified.*

Non-Viable Project [Kannattamaton projekti] *is at an early stage of evaluation in addition to those that are considered unlikely to become viable developments within the foreseeable future.*

Potential Source [Mahdollinen arvoaines] *is a source that has not yet been demonstrated to exist by direct evidence, but is assessed as potentially existing based primarily on indirect evidence.*

Potentially Viable Project [Mahdollisesti kannattava projekti] *is a project where environmental-socio-economic viability and technical feasibility has yet to be confirmed. For example, in case with either Development Pending or Development On Hold.*

Probable mineral reserves [Todennäköiset mineraalivarat] *is the economically mineable part of an indicated and some circumstances measured mineral resource.*

Product [Tuote] *is the primary outcome of economically extractable part of mineral deposit that is mined, processed and sold. Material from a project which is actually producing and selling or using one or more products (ore concentrate) as at the Effective Date of the evaluation is typically classified as (111). The product does not include refinery production or other type of material in the material chain.*

Project [Projekti] *is a defined in UNFC-2019 as development or operation which provides the basis for environmental, social, economic and technical evaluation and decision-making. In the early stages of evaluation, including verification, the Project might be defined only in conceptual terms, whereas more mature Projects will be defined in significant detail. Where no development or operation can currently be defined for all or part of a source, based on existing technology or technology currently under development, all quantities associated with that source (or part thereof) are classified in Category F4. These are quantities which, if produced, could be bought, sold or used.*

Prospective Project [Malmipotentiaalinen projekti] is one where the existence of a developable product is based primarily on indirect evidence and has not yet been confirmed. Further data acquisition and evaluation would be required for confirmation. Where a single estimate is provided, it should be the expected outcome but, where possible, a full range of uncertainty should be calculated for the prospective project.

Proven mineral reserves [Toteennäytetyt mineraalivarat] *is the economically mineable part of a measured mineral resource.*

Public report [Julkinen raportti] *Any form of public disclosure (e.g. company annual reports, purpose of making of a reasoned and balanced judgment regarding the Exploration Targets, Exploration Results, Mineral Resources or Mineral Reserves being reported. Public Reports include but are not limited to company annual reports, quarterly reports and other reports to regulatory authorities, or as required by law.*

Sources [Arvoaines] *such as bioenergy, geothermal, hydro-marine, solar, wind, injection for storage, hydrocarbons, minerals, nuclear fuels and water, are the feedstock for resource projects from which products can be developed. The sources may be in their natural or secondary (anthropogenic sources, tailings, etc.) state.*

Sub-class(es) [Alaluokka] *Optional subdivision of resource classification based on project maturity principles resulting from the combination of Sub-categories.*

Speculative resources [Spekulatiivinen mineraalivaranto] *are undiscovered resources that may occur either in known types of deposits in favourable geological settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential.*

Undiscovered mineral deposit [Löytämätön mineraaliesiintymä] *is a mineral deposit believed to exist less than a certain depth below the surface of the ground, or an incompletely explored mineral occurrence within that depth range that could have sufficient size and grade to be classified as a deposit.*

Undiscovered resources [Löytämättömät mineraalivarannot] *are resources in undiscovered mineral deposits whose existence is postulated based on indirect geological evidence.*

Viable Project [Kannattava projekti] *is a project where environmental-socio-economic viability and technical feasibility has been confirmed.*

Appendix 2

Sources of risk and uncertainty in the G-axis (Degree of confidence)

In the UNFC-2019, it is stated that *"The G axis Categories are intended to reflect all significant uncertainties (e.g. source uncertainty, geologic uncertainty, facility efficiency uncertainty, etc.) impacting the estimate forecast for the project."(UNECE 2019, 7)*. This appendix in the UNECE report is to provide background information to the main uncertainties related to designating the degree of confidence in the estimate of the quantities of mineral products form the project.

The confidence category selection should consider uncertainty and risk existing in the estimates. The UNFC-2019 guidelines provide two approaches to categorize the degree of confidence: 1) Product quantities categorized as G1, G2, and/or G3 based on the degree of confidence in the estimate based on direct evidence. 2) Range of uncertainty as reflected by either three specific deterministic scenarios (low, best, and high cases) or probabilistic analysis (P90, P50 and P10).

The reliability of mineral inventory estimates does not imply a 100 % knowledge or a 100 % confidence in the estimate. Mineral inventory estimation is a complex process with many inherent uncertainties and subjective decisions from many different fields of technical professionals. It is an outcome of a multi-disciplinary approach. It requires a diligent and well-structured approach that forces the estimator(s) to pass several critical decision points. Therefore, effective assurance process for the governance of mineral resource and ore reserve estimation process should be implemented (Noppe 2018).

There are several factors that contribute to the overall uncertainty. The following uncertainties and factors are typically assessed and reported in the evaluation process regardless of the scope of the estimate (global or local estimate). These uncertainties are related to the degree of confidence used as criteria for application of the UNFC resource code in the GTK mineral deposit database, essentially when the CRIRSCO–UNFC bridging document cannot be used.

Geological error

This results from assumptions of mineralization continuity (both geological and grade) and interpretation of the geometry in the mineral deposit. Geological interpretation and modelling requires that site-specific geological concepts and models are integrated with numeric data to construct a 3D model of geological domains (Rossi & Deutsch 2014). Understanding of geological character of the mineral deposit is often the most important factor or base on which to build an estimate of mineralized tonnage. In general, geological interpretations are continually evolving components of inventory studies as new information is gained and therefore should geological concepts be systematically upgraded and reviewed.

Data Integrity

Data quality and adequacy are the fundamental base of mining and project decisions. The resource model should be a fair and accurate representation of the available data. To ensure this, checks must be completed at every step of the modeling process to ensure that predicted outcomes can be reproduced consistently without errors or omissions. The overall process of Quality Assurance and Quality Control (QA/QC) should encompass field practices, sampling, assaying, and data management. This is necessary to ensure confidence in the mineral resource and mineral reserve estimation. For example in CIM Guidelines (CIM 2019), it is stated that the QA/QC information must be considered and evaluated for all data used for mineral resource and reserve estimation. All historical data (data acquired by previous operators of the mineral property) require validation including re-locating the historical data in the field, resampling and re-assaying of historical drill core or other drilling samples and submission, with external quality control samples, to an analytical laboratory.

The data adequacy and representativeness of the mineralization under consideration include an assessment of sample population size, quality, and spatial distribution of the data so that it is adequate to determine the variability and distribution of the economically significant minerals.

Spatial variability

Analysis of spatial continuity is about comparing samples according to the distance and orientation between samples using variography (Coombes 2008). The spatial variability is modelled using the variogram and related measures of spatial correlation. Understanding of spatial variability aspects of the data collection and quality, geological context, and statistical properties of the domain should be carefully assessed (Coombes 2008). For example, careful consideration should be taken when quantifying the spatial correlation beyond the adequacy of the data being used, inadequate definition of estimation domains, or use of estimators less robust with respect to skewed data (Ross & Deutsch 2014).

Estimation methodology

The estimation confidence is dependent on uncertainty related to the process of grade interpolation including data spacing, estimation method chosen, and estimation parameters (Rossi & Deutsch 2014). Selection of the estimation parameters used, as part of grade interpolation, should be carefully optimized (e.g., block size, search parameters, maximum and minimum number of samples, discretization). Model validation is the process of confirming that the particular model is an accurate reflection of the data used. Detailed description on validation techniques are given in, e.g., Sinclair and Blackwell (2002), Coombes (2008), Rossi and Deutsch (2014). Several validation techniques should be used to assess the estimation confidence. A Viable or a Potentially Viable Project that has passed through production or is currently being mined, should include reconciliation of production against the estimation model to allow evaluation on long-term and

short-term accuracy of the data (e.g., data collection, preparation and analytical procedures, and modelling procedures and parameters used in resources block model) (CIM Guidelines 2019, Parker 2014).

Bulk density

It is important to obtain representative estimates of bulk density so that appropriate values can be used for purposes of global and local estimation of tonnage. Insufficient density data can produce significant errors in tonnage estimates for both mineralized volumes and for adjoining non-mineralized or weakly mineralized material. The choice of density methods for a deposit or project will depend on the physical characteristics of the ore and waste material (Lipton & Horton 2014). Several factors, such as lithologies, weathering characteristics, alteration types and character, variations in ore mineral assemblage, and porosity contribute to spatial variations in bulk density.

Other relevant factors

Many other relevant aspects may also contribute at different levels of uncertainties such as mineralogical, mineral process recoveries, penalty elements and geometallurgical factors. In addition, uncertainties and sensitivities which the developer has little or no direct influence (e.g., commodity prices, exchange rates, operating costs, waste disposal costs, and environmental and social considerations) affect the selection of the cut-off grades and value estimate (CIM Guidelines 2019, AusIMM 2014).

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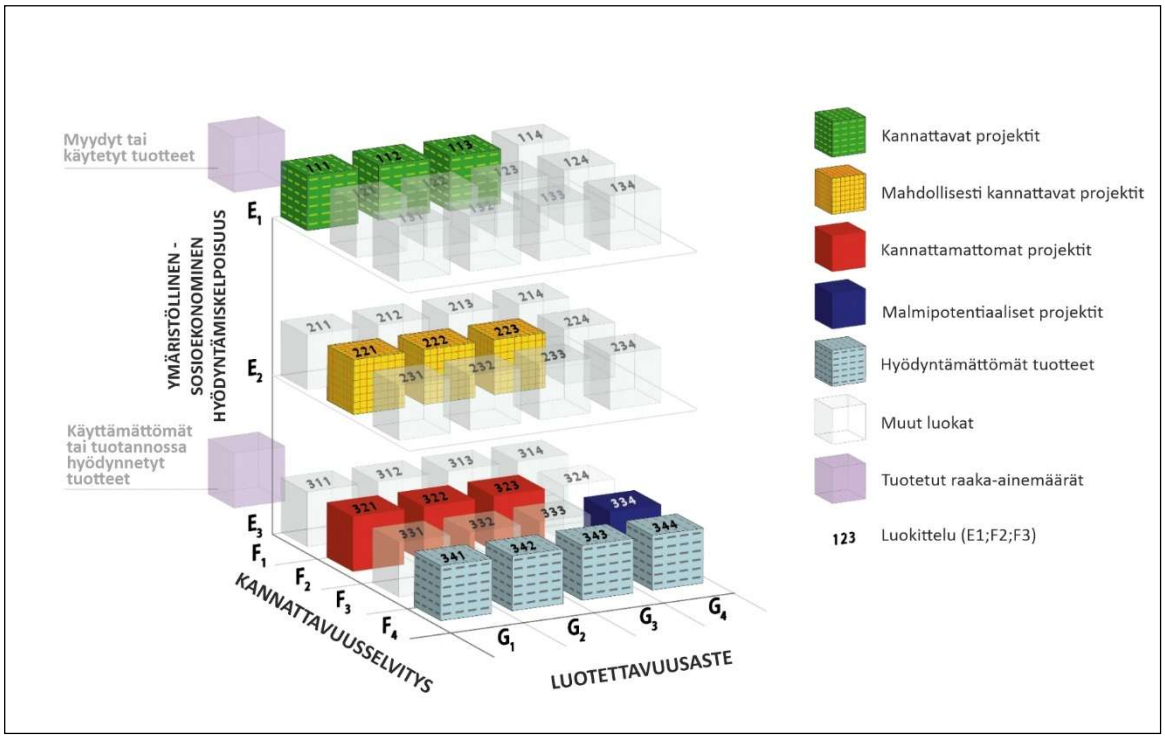
www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/publ/UNFC_ES61_Update_2019.pdf

Appendix 3 Images and tables in Finnish



Kuva 1. UNFC-2019 kolmivaiheinen luokittelu.

Taulukko 1. UNFC-koodituksen tiivistetty versio; yleisimmin käytetyt luokat ja niitä vastaavat kategoriat.

	Tuotetut	Myydyt tai käytetyt tuotteet			
		Käyttämättömät tai tuotannossa hyödynnetyt tuotteet			
		Luokka	Minimikategoriat		
			E	F	G[b]
Tuotteet	Projekti on ympäristöllisesti ja sosioekonomisesti hyödyntämiskelpoinen sekä projektin kannattavuus on todennettu	Kannattavat projektit[c]	1	1	1, 2, 3
	Projektin ympäristöllinen ja sosioekonominen hyödyntämiskelpoisuus sekä projektin kannattavuus ei ole todettu	Mahdollisesti kannattavat projektit[d]	2[e]	2	1, 2, 3
		Kannattamattomat projektit[f]	3	2	1, 2, 3
	Hyödyntämättömät tuotteet osana tunnistettuja projekteja[g]		3	4	1, 2, 3
	Informaation riittämättömyys ympäristöllisen ja sosioekonomisen hyödyntämiskelpoisuuden sekä projektin kannattavuus todentamiseen	Malmipotentiaaliset projektit	3	3	4
	Hyödyntämättömät tuotteet osana malmipotentiaalisia projekteja[g]		3	4	4

a Tulevaisuuden tuotantoyksiköt, jotka ovat joko hyödyntämättömiä tai tuotannossa hyödynnettyjä tuotteita (E3.1). Nämä voivat esiintyä kaikissa luokissa, jossa hyödyntämiskelpoista materiaalia.

b G kategoria, jota voidaan käyttää suoraan tai kumulatiivisena ennustuksena (esim. G1+G2)

c Taloudellisesti kannattavien projektien arvioinnit on eri luokittelukoodeissa yleisesti määritetty varoiksi (reserveiksi). Materiaalierot ja eri teollisuuden aloilla käytössä olevien käsitteiden takia tätä termiä ei käytetä.

d Kaikkia mahdollisesti kannattavia projekteja ei tulla kehittämään.

e Mahdollisesti kannattavat projektit voivat täyttää määritelmän E1.

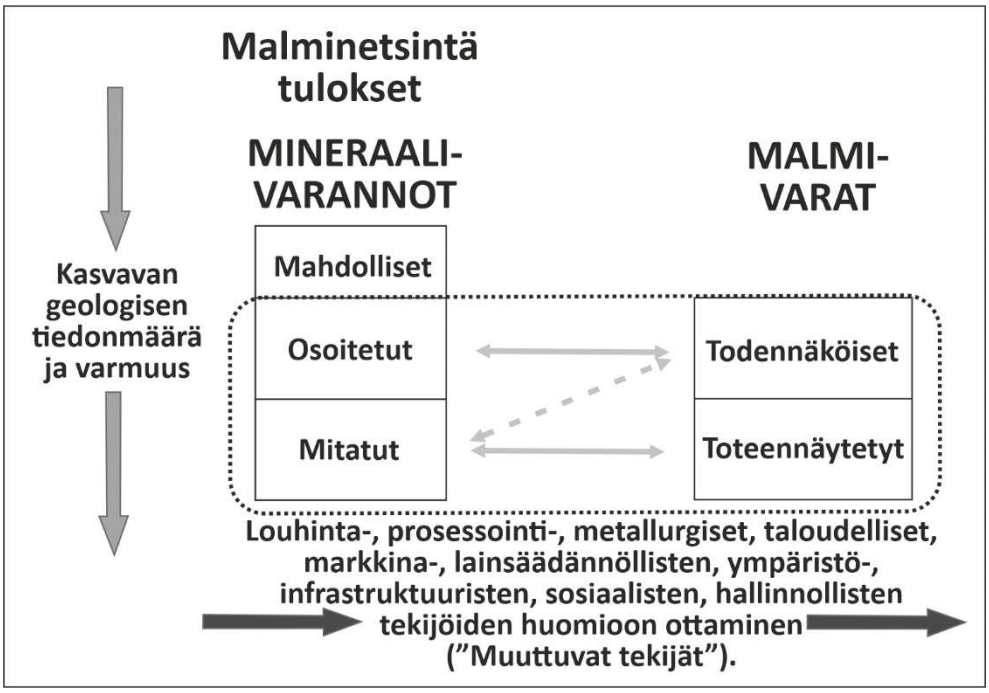
f Kannattamattomat projektit sisältävät alkuvaiheen projektit sekä projektit, jotka eivät tule olemaan taloudellisesti kannattavia tulevaisuudessa.

g Hyödyntämättömät tuotteet osana tunnistettuja ja malmipotentiaalisia projekteja voivat olla tulevaisuudessa hyödyntämiskelpoisia teknologian tai ympäristöllisen ja sosioekonomisen tekijöiden muuttumisen johdosta. Hyödyntämättömillä tuotteilla tarkoitetaan tässä yhteydessä raaka-ainemääriä, jotka tuottaessa olisi mahdollista ostaa, myydä tai hyödyntää.

Taulukko 2. Pää- ja alaluokat ja niitä vastaavat alakategoriat UNFC:n kaksiulotteisessa kentässä.

UNFC luokittelu pääluokkien ja alaluokkien mukaan						
Tuotteet	Tuotetut	Myydyt tai käytetyt tuotteet				
		Käyttämättömät tai tuotannossa hyödynnetyt tuotteet				
		Luokka	Alaluokka	Kategoriat		
				E	F	G
	Tiedossa oleva arvoaines	Kannattavat projektit	Tuotannossa	1	1.1	1, 2, 3
			Projektin kehittäminen osoitettu kannattavaksi	2	1.2	1, 2, 3
			Projektin kehittäminen perusteltua	2	1.3	1, 2, 3
		Mahdollisesti kannattavat projektit	Projektin kehittäminen vireillä	2[b]	2.1	1, 2, 3
			Projektin kehittäminen pysäytetty	2	2.2	1, 2, 3
		Kannattamattomat projektit	Projektin kehittäminen epäselvä	3.2	2.2	1, 2, 3
			Projektin kehittäminen ei kannattava	3.3	2.3	1, 2, 3
		Hyödyntämättömät tuotteet osana tunnistettuja projekteja		3.3	4	1, 2, 3
	Mahdollinen arvoaines	Malmipotentiaaliset projektit	[Ei määriteltyjä alaluokkia]	3.2	3	4
		Hyödyntämättömät tuotteet osana malmipotentiaalisia projekteja		3.3	4	4

Taulukko 3. Mineraalivarojen ja -varantojen sekä 'malminetsinnän tulosten' luokittelu CRIRSCO:n sääntöjen mukaan.



Taulukko 4. CRIRSCO:n luokittelun mukaisten mineraalivarojen ja -varantojen sekä 'malminetsinnän tulosten' luokittelu UNFC-koodiin.

CRIRSCO Template		UNFC-2019 "Minimiluokitus"			UNFC-2019 Luokat
Mineraalivarat	Toteennäytetyt	E1	F1	G1	Kannattavat projektit
	Todennäköiset			G2	
Mineraalivarannot	Mitatut	E2	F2	G1	Mahdollisesti kannattavat projektit
	Osoitetut			G2	
	Mahdolliset			G3	
Malminetsintätulokset		E3	F3	G4	Malmipotentiaaliset projektit

Appendix 4. Selected maps showing distribution of mineral resource reporting types in Finland.

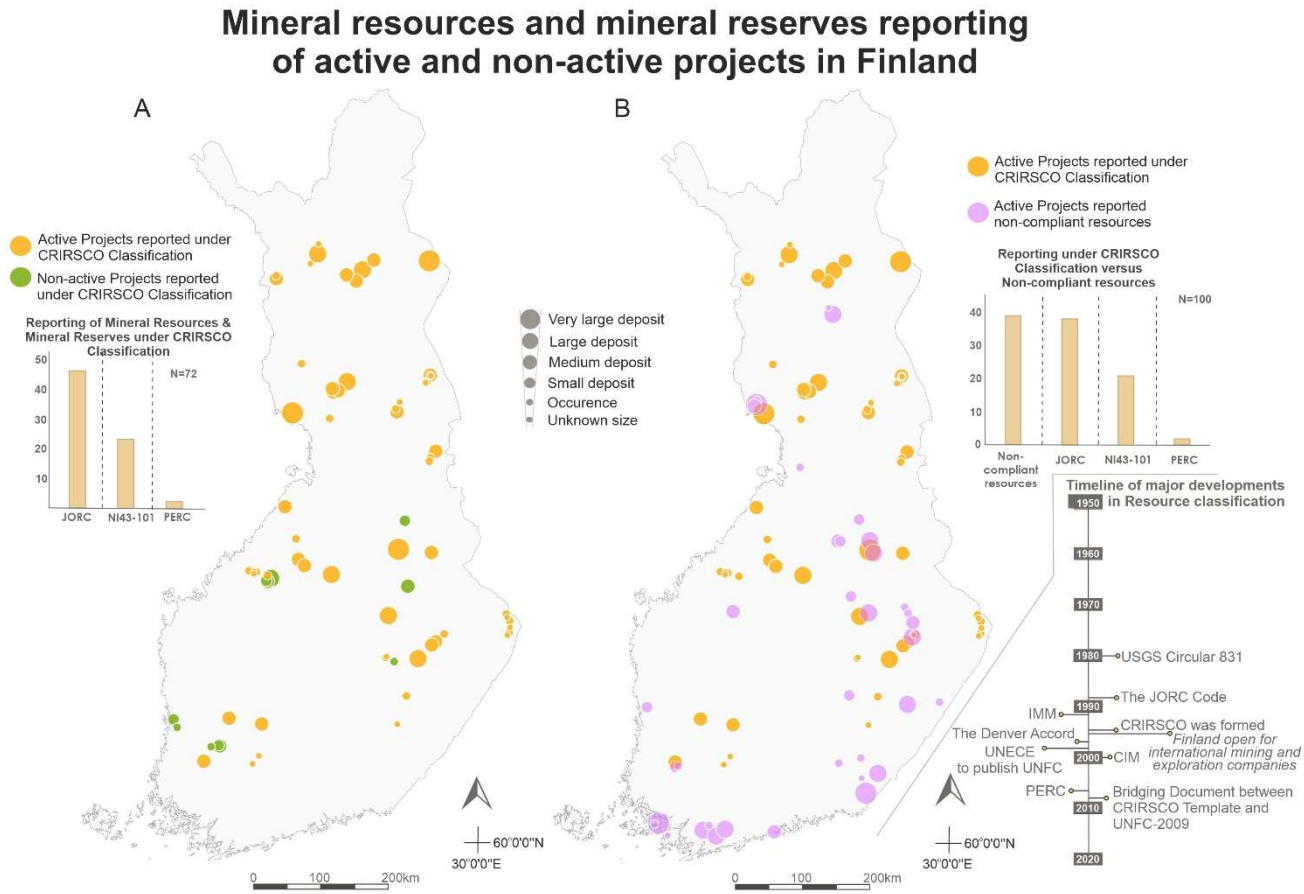


Figure 1. These two maps present active and non-active projects which have been reported in accordance with the CRIRSCO Template and as non-compliant resource estimates. (A) Active and non-active projects reported in accordance with CRIRSCO-family codes. The JORC Code is currently the most commonly used reporting code for public reporting in Finland. (B) Active projects that have disclosed non-compliant resources, or only annual production quantities, are presented by pink dots. These are mostly represented by industrial mineral and industrial rock deposits where entities are not using CRIRSCO-family codes as reporting standard.

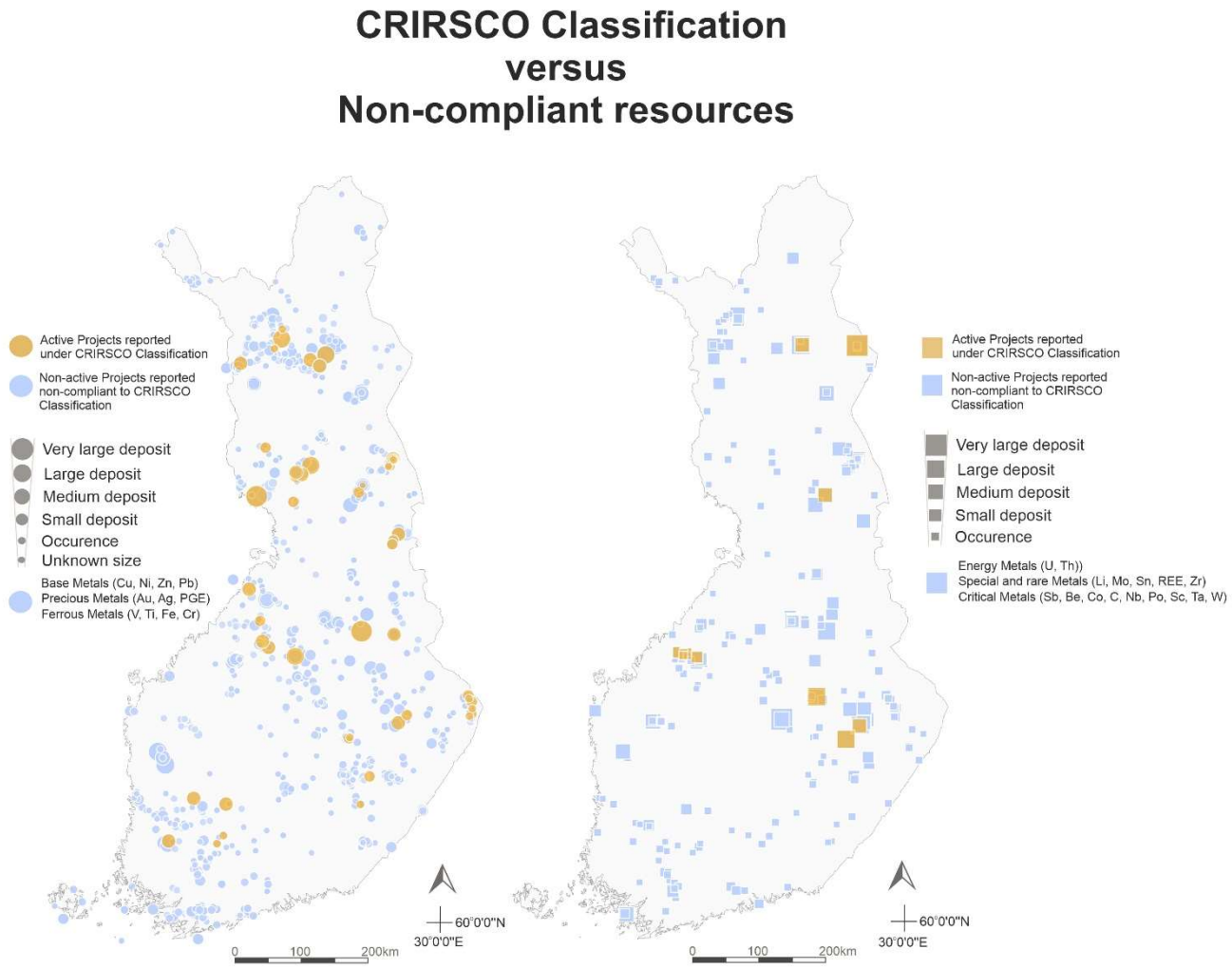


Figure 2. These maps present active projects which have been reported in accordance with the CRIRSCO Template compared to all non-compliant resources in Finland. The non-compliant resources include both historical estimates and active projects not reported in accordance with CRIRSCO-family codes. (A) All base, ferrous and precious metal deposits are presented for both cases. (B) All critical, special and energy metal deposits for both cases.