MINERAL INTELLIGENCE FOR EUROPE

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Case study review with guidance and examples for applying the UNFC to European mineral resources

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GENERAL INTRODUCTION

The extraction of primary mineral resources underpins industrial value chains and provides a continuous flow of construction materials, metals, and industrial and energy minerals to society. These materials are essential for sustaining a modern standard of living, and are needed to repair and replace existing infrastructures, secure economic development, enable the global energy transition, and build the cities of the future to house the growing global population. As the global annual primary material use is expected to almost double from 89 billion tons (Gt) in 2017 to 167 Gt in 2060 (OECD 2019), it becomes ever more important to develop new geological sources for mining.

Insufficient access to resources threatens raw material supply chains and economic development, making it imperative that potentially suitable geological prospects are identified, assessed, protected from competing land-use claims, and developed for future production. Reliable information is an integral part of mineral development and sustainable resource management, both on a per-site project and on a national policy-making scale. However, there is no EU-framework and funding mechanism for collecting, maintaining, updating and aggregating Pan-European UNFC data on mineral resources. The extractive industries, particularly larger stock-market listed companies, use national and international classification codes and standards to quantify and classify their mineral projects at a local, i.e., site-scale, to support operations planning and facilitate public disclosure and stock market reporting. For many mineral deposits, however, relevant data on in-ground material quantities remain undisclosed and inaccessible. National regulatory frameworks, institutional mandates, and reporting obligations and procedures differ significantly across countries, making it difficult to find, access, compare, and aggregate relevant site-scale mineral project information. Government organisations such as mining authorities may collect some site-scale industry information including often confidential commercial production data through mandatory industry reporting for permitting, taxation, and oversight purposes, but such data are not necessarily accessible for UNFC classification. Geological Survey Organisations (GSOs), on the other hand, typically collect pre-commercial data on mineral resources alongside a wide range of other information relating to the subsurface, including geological, geophysical and geochemical data, but they may lack the national mandate to access and integrate commercial mineral project information held by other agencies.

Quantitative national-scale aggregated estimates on the amounts of mineable in-ground mineral resources are thus typically compiled based on fragmented information of variable quality obtained from multiple different sources, including mandatory industry reporting, data in the public domain, and legacy information in government inventories. Comparing and aggregating such data is inherently time-consuming and error prone.

The United Nations Framework Classification for Resources UNFC (UNECE 2020c) aims to improve regional and national data harmonisation and aggregation. It provides a generic unified and principles-based framework plus additional ‘Specifications’ for defining the environmental-socio-economic viability and technical feasibility of resource projects for different resource types including fossil fuels, geothermal energy, minerals, anthropogenic resources, and injection projects.

The scope of the GeoERA Mineral Intelligence for Europe (MINTELL4EU) Work Package 4 (WP4) described in this report was to conduct a Pan-European UNFC Pilot Study comprised of UNFC case studies for a selection of commodities in different countries, to assess the current status and key challenges concerning the application of UNFC across Europe, and to make recommendations for optimizing resource classification and aggregation procedures using UNFC.

EXECUTIVE REPORT SUMMARY

Mineral resources are essential for achieving global sustainable development goals and for fulfilling the European Green Deal and digital transformation ambitions. Despite having significant potentials for domestic production, the EU does not have sufficient mining to meet demand and is highly dependent on imports, particularly for a number of 'critical' raw materials for key enabling technologies and strategic industry sectors. Reliable and transparent national-scale and Pan-European mineral resource data are needed to improve the access to domestic resources in the EU and to diversify sustainable raw material supply from primary and secondary sources.

The United Nations Framework Classification for Resources (UNFC) can support this by facilitating the harmonisation of mineral resource data. The MINTELL4EU Work Package 4 UNFC Pilot described herein provides an overview of 19 case studies from nine countries compiled to test and assess how the UNFC can be used to harmonise and aggregate information on in-ground geological resources across Europe. The UNFC case studies prepared for this reflect the current status of UNFC implementation across Europe and should not be understood as international best practice concerning UNFC application. Their main purpose was to map different approaches for applying UNFC based on existing national data and inventories, to identify and analyse key challenges relating to the technical UNFC classification workflow, and to build a common understanding of how to address UNFC classification across Europe. To this effect, this report serves mainly as an introduction to the case studies, makes some general observations concerning their scope and data coverage, and highlights key issues that need to be resolved to facilitate Pan-European UNFC application and data aggregation.

The results of the Pilot demonstrate that it is indeed feasible and meaningful to use the UNFC classification to categorise different types of mineral occurrences in different countries according to their environmental-socio-economic viability (E), technical feasibility (F), and degree of confidence in the estimate (G). The case study preparation was very time consuming and involved significant case-by-case manual data compilation, expertise, and familiarity with the UNFC system. In many cases relevant information was known to exist but inaccessible to the Geological Survey Organisations issuing the case studies, making it challenging to apply the UNFC. The case studies show a large variance in how evaluators quantified resources, interpreted the EFG criteria, and presented their results. Moreover, data confidentiality issues also affected the case study work and results, and some case studies had to be generalised because granular (i.e., per-site level) information could not be published.

Using the UNFC for classification across different types of resources and countries is both feasible and meaningful and can make a significant contribution to achieving global sustainable development and EU raw material policy objectives. However, (1) national and international policy frameworks are needed to overcome poor data availability and sharing; (2) data compilation and classification procedures and UNFC reporting templates must be developed to improve quality and facilitate automation; (3) extensive training is required to overcome the lack of a common understanding of the UNFC system and make the results more transparent, comparable and reliable; and (4) relevant EFG data needs to be collected and made available in suitable interoperable format.

TABLE OF CONTENTS

1 STRATEGIC FOCUS

The overall aim of the GeoERA[1] Mineral Intelligence for Europe (MINTELL4EU)[2] project is to improve the quality and availability of European information on the location and spatial distribution of primary and secondary materials to better support decision making and sustainable resource governance across project, country and international levels. The MINTELL4EU WP4 – UNFC Pilot[3] focuses on how the UNFC can facilitate harmonization of mineral resource data across Europe and aims to demonstrate its strength as a tool for establishing more accurate Pan-European mineral inventories.

The objective of WP4 Task 4.1 was to test the feasibility of applying the UNFC to national mineral information held by Geological Survey Organisations (GSOs), by compiling a collection of case studies from across Europe covering a range of solid mineral resource types including critical raw materials (CRM). The work with UNFC is a continuation of previous projects dealing with Pan-European mineral information in general, and specifically relates to the results of the EU-funded H2020 ORAMA project[4]. ORAMA highlighted the need for better data collection and harmonisation procedures for information on primary mineral raw materials, and introduced UNFC in its deliverables D1.5.1 to D.1.5.10 (Bide *et al.* 2020).

Several developments at the international and EU policy level are considered to be particularly relevant for evaluating the MINTELL4EU UNFC case studies. Recent policy documents concerning geospatial information such as the United Nations Integrated Geospatial Information Framework (UN-GGIM 2018), the European strategy for data (European Commission 2020), and the raw-material related sections concerning data and skills in the 'Strategic dependencies and capacities' (European Commission 2021) are important both for assessing the accessibility of the data needed for the case studies, and for evaluating the usefulness of the case studies themselves. The high-level documents also provide directions for future development priorities in the European digital sphere.

The UNFC is undergoing continuous development, and the United Nations Economic Commission for Europe has published various documents that have been consulted for assessing the compliance of UNFC case studies with the UNFC System, and for drawing conclusions that ensure that future GSO work related to UNFC and the complementary United Nations Resource Management System (UNRMS). They include the most recent version of the 'United Nations Framework Classification for Resources UNFC' (UNECE 2020c), the 'Draft UNFC Supplemental Specifications for Minerals Projects' prepared by the Minerals Working Group (UNECE 2021a), the concepts note concerning the 'United Nations Resource Management System' (UNECE 2021c), the 'Guidance for Social and Environmental Considerations for the UNFC' (UNECE 2021b), and the notes on 'Principles of Resource Classification' (UNECE 2020b).

[1] https://geoera.eu/
[2] https://geoera.eu/projects/mintell4eu7/
[3] https://geoera.eu/projects/mintell4eu7/mintell4eu-wp4-unfc-pilot/
[4] https://orama-h2020.eu/

2 OVERVIEW OF CASE STUDIES

The selection of case studies for the MINTELL4EU UNFC Pilot represents a cross-section of different mineral resource types including industrial minerals, construction aggregates, base and precious metals, dimension stone, rare earth elements (REE) and peat as an organic energy material.

The case study compilation was supported by a workshop with 41 participants from project partners conducted on 29th of October 2020 to present and discuss first preliminary case study results and exchange ideas on how to address key challenges regarding data gaps and harmonisation issues. The structure and output format for the case studies to be conducted was not defined in detail, aside from providing the template shown in Figure 1, in order to get an overview over the different approaches towards UNFC classification, and to map the national practices and current status across the different countries. Up to 30 case studies were planned in the project, for various reasons this ended up in a total of 19 case studies compiled by the GSOs of Austria (GBA), Belgium (RBINS-GSB), Croatia (HGI-CGS), Denmark (GEUS), Finland (GTK), Hungary (MFBZS), Norway (NGU), Slovenia (GeoZS) and Sweden (SGU), as shown in Table 1,Table 2 & Figure 2.

2.1 Spatial and temporal data coverage of case study reporting

To aggregate mineral resource information, it is important to understand the spatial and temporal scope and granularity of the case study information *as reported/published* by the issuing organisation. The UNFC is a 'resource project-based and principles-based classification system' and the 'Project', a 'defined development or operation' (UNECE 2020c) can be understood as the most detailed (most granular) unit of consideration within the framework (i.e. per-project reporting of quantities classified into different categories). Notably, the very existence of a UNFC Project in a specific area may change over time, and historical, current and future Projects may overlap spatially. In contrast, GSOs typically collect and manage information on mineral occurrences that is to some degree independent of whether there are defined industry projects with development or operation. Indeed, the EarthResourceML (ERML) and EU-INSPIRE data model for mineral resources explicitly distinguish between 'Earth Resources' and 'Mining Features' (Vuollo *et al.* 2018).

To assess the spatial and temporal coverage of the reported UNFC data in a purely geographical context, the case studies were categorised according to their ***scope* and *granularity*** using following definitions: The *scope* of a case study describes the spatial extent of interest in three classes, *national, regional* and *site*. It refers to the georeferenced outer boundary of the area of investigation and can be shown as a polygon in a Geographical Information System (GIS). The *granularity* as used in this document refers to the *level of detail* of the UNFC case study documentation including any accompanying spatial dataset in two classes, *aggregated* and *site*. *Aggregated* indicates that the case study report, associated documentation, or accompanying GIS dataset discloses the UNFC quantities only in aggregated form (totals across several projects) without explicitly disclosing the individual data records and georeferencing of the source data that were used to compile the totals. *Site* explicitly provides detailed low-level georeferencing and UNFC quantities for all the individual lowest-level data records within the scope of the dataset (site/deposit/project resolution).

This results in five different combinations of case study scope and granularity*: National,aggregated; National,site; Regional,aggregated; Regional,site; and Site,site*, as shown by the colour coding in Table 1 and the symbols used for the map on Figure 2.

A second consideration is whether the data are ***collectively exhaustive*** and ***mutually exclusive***. For instance, a *national and aggregated* dataset, will not be *collectively exhaustive* if it reports only the total quantities for some but not all of the operating mines for a specific resource type in the country, e.g., because required data for UNFC classification of some of the mines may not be available. Under these circumstances, the reported 'total' national resource quantities underestimate de-facto quantities that could be mined. *Mutually exclusive*, implies that there is no double-counting within the area of investigation. A 'regional' GIS study may for instance quantify the total sand and gravel volume assumed to be exploitable, but there may be industry projects in the same area that report UNFC quantities in higher detail. This spatial overlap (data not mutually exclusive) creates a challenge for aggregation, as simply adding the regional GIS-based estimates and the industry project quantities would overestimate the de-facto resource potential.

The third consideration relates to the **temporal validity**. Mining continuously removes material from the ground and the physical in-ground resources change over time. It is important to explicitly state at what point in time resources were evaluated and classified (cf. also 'Reference Point' (UNECE 2020c)), and to provide additional information on the timestamps/timeliness of the input datasets as well as the used calculation method to support this declaration, in order to ensure that the reported quantities are, in fact, representative of the de-facto potential at that point in time.

UNFC Case study – xxx

Introduction/Background

Define the resource

What is your case study about , what kind of resource, location, situation, scale (project, local, regional or National) etc,

Methodology

Did you use *bridging from CRIRCSO-compliant data?*

How have data been gathered?

What kind of data have been used?

Availability of data sources

UNFC

Evaluation of data and areas, calculation of volumes.

Defining the E, F and G-axis

Challenges

Describe the challenges, harmonization issues and uncertainties one may encounter in this kind of work. What is the quality of the data? What are the issues concerning availability of data?

Additional Questions:

What have you learned from this work?

What kind of challenges have you experienced during this work?

How can your work and experience be used into a UNFC guideline?

How can this case and your experience be used into the next deliverables and Milestones in Mintell4EU WP4:

D4.1 Case study review with practical guidelines/work flows and examples for applying UNFC to European mineral resources

D4.2 Report on harmonization issues, data gaps and challenges, reviewing also the quality of Pan-European aggregated inventories for selected commodities

References

List all the data sources and other relevant reports you used

Table 1: Overview over UNFC pilot case studies with *classification scope* (national/regional/site) and *granularity* (aggregated/site) at which the case study data is reported. Case studies marked with square brackets [] have been prepared at site-level granularity but were made available by the issuing organisation only in a generalized form due to confidentiality constraints.

N: National,aggregated (7) | n: National,site (2) | R: Regional,aggregated (3) | r: Regional,site (6) | S: Site,site (1)

Country	Gold	Copper	Cobalt	Manganese	REE	Phosphate	Carbonates	Graphite	Aggregates	Natural stone	Peat	Gypsum	Perlite	#
Austria									R					**1**
Belgium						**n**								**1**
Croatia									R					**1**
Denmark							N		N					**2**
Finland	N	N	N					N			R			**5**
Hungary				[S]								r	[r]	**3**
Norway						**n**		**r**	**r**	**r**				**4**
Slovenia									N					**1**
Sweden					r									**1**
#	**1**	**1**	**1**	**1**	**1**	**2**	**1**	**2**	**5**	**1**	**1**	**1**	**1**	**19**

Table 2: Issuing organisations involved in the compilation of UNFC case studies.

Country	Issuing Organisation	Org	Address	URL Organisation Website
Austria	Geological Survey of Austria	GBA	Neulinggasse 38, 1030 Vienna, Austria	https://www.geologie.ac.at/
Belgium	Geological Survey of Belgium	RBINS-GSB	Jennerstreet 13, 1000 Brussels, Belgium	https://www.naturalsciences.be/
Croatia	Croatian Geological Survey	HGI-CGS	Sachsova 2, 10000 Zagreb, Croatia	http://www.hgi-cgs.hr/
Denmark	Geological Survey of Denmark and Greenland	GEUS	Øster Voldgade 10, 1350 Copenhagen K, Denmark	https://www.geus.dk/
Finland	Geological Survey of Finland	GTK	Vuorimiehentie 5, 02151 Espoo, Finland	https://www.gtk.fi/
Hungary	Mining and Geological Survey of Hungary	MFBZS	Columbus street 17-23, 1145 Budapest, Hungary	https://mbfsz.gov.hu/en
Norway	The Geological Survey of Norway	NGU	Leiv Eirikssons vei 39, 7040 Trondheim, Norway	https://www.ngu.no/
Slovenia	Geological Suvrey of Slovenia	GeoZS	Dimičeva 14, 1000 Ljubljana, Slovenia	https://www.geo-zs.si/
Sweden	Geological Survey of Sweden	SGU	Villavaegen 18, S-75128 Uppsala, Sweden	http://www.sgu.se/

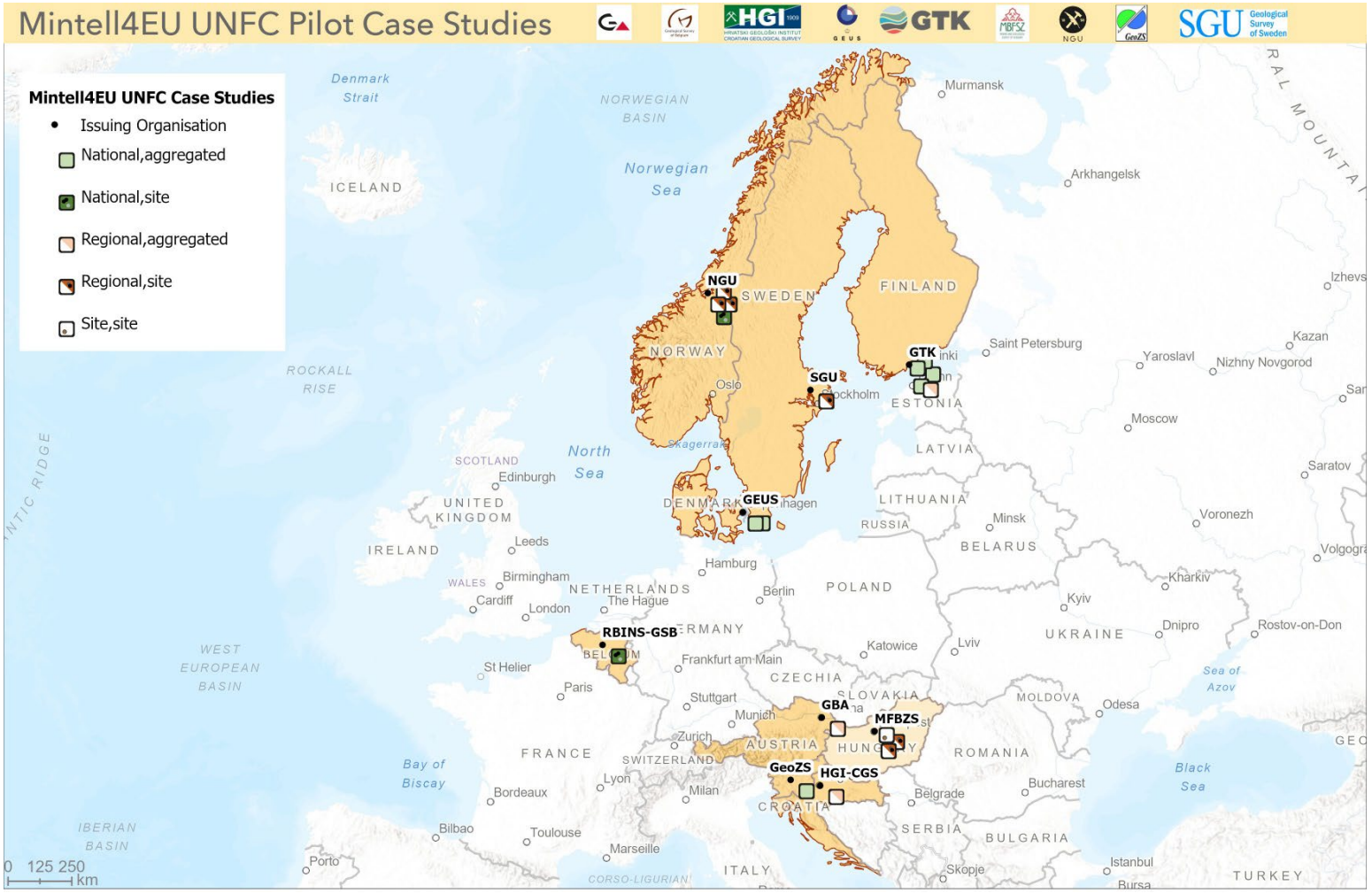

Figure 2: Overview map of project partner countries with UNFC pilot case studies grouped to issuing the organisations. Aggregated UNFC totals can only be shown on maps by generic locations, unless granular site-scale data are made available as well.

Table 3: Case study details including authors, commodity, scope, granularity and reporting date.

Country	Case Study Authors	Commodity	Spatial Scope	Granularity	Date
Austria	Sebastian Pfleiderer	Aggregates (sand & gravel)	Regional	aggregated	06/12/2020
Belgium	Christian Burlet	Phosphates	National	site	11/06/2021
Croatia	Željko Dedić, Nikolina Ilijanić, Nikola Gizdavec	Aggregates (crushed stone, sand & gravel)	Regional	aggregated	04/02/2021
Denmark	Niels Nørgaard-Pedersen	Aggregates (marine)	National	aggregated	18/02/2021
Denmark	Lisbeth Flindt Jørgensen, Peter Roll Jakobsen	Carbonates	National	aggregated	20/04/2021
Finland	Pasi Eilu, Janne Hokka, Taina Eloranta	Cobalt	National	aggregated	21/02/2021
Finland	Pasi Eilu, Janne Hokka, Taina Eloranta	Copper	National	aggregated	12/03/2021
Finland	Pasi Eilu, Janne Hokka, Taina Eloranta	Gold	National	aggregated	12/03/2021
Finland	Pasi Eilu, Janne Hokka, Taina Eloranta	Graphite	National	aggregated	12/03/2021
Finland	Teuvo Herranen	Peat	Regional	aggregated	31/03/2021
Hungary	Zoltán Horváth, Árpád Máthé	Gypsum and anhydrite	Regional	site	21/06/2021
Hungary	Zoltán Horváth, Árpád Máthé, Bálint Polonkai	Manganese	Site	site	24/08/2021
Hungary	Zoltán Horváth, Árpád Máthé, Bálint Polonkai	Perlite	Regional	site	24/08/2021
Norway	Mark Simoni, Thomas Hibelot	Aggregates (crushed stone)	Regional	site	18/03/2021
Norway	Janja Knežević Solberg, Håvard Gautneb	Graphite	Regional	site	16/02/2021
Norway	Tom Heldal, Helene Fromreide Nesheim	Natural stone	Regional	site	25/01/2021
Norway	Agnes Raaness, Nolwenn Coint	Phosphate	National	site	15/02/2021
Slovenia	Duška Rokavec	Aggregates (crushed stone)	National	aggregated	01/03/2021
Sweden	Lena Lundqvist, Erika Ingvald	Rare Earth Elements	Regional	site	10/08/2021

3 CURRENT STATUS AND ISSUES

The 19 UNFC case studies show that the scope and granularity of reporting varies considerably across countries and evaluators (Table 1, Figure 2, Table 3 & Figure 2). This reflects the differences in data availability (e.g., government mandate, existence of national classification standards, availability of EFG input datasets) and the choice of UNFC classification approach (e.g., bridging from other classifications, GIS analysis of spatial data, semi-automated workflow for database extraction, or manual compilation based on literature and legacy datasets). Specific challenges and technical issues regarding UNFC classification are evaluated in D4.2 (Hokka *et al.* 2021), while this report discusses only the general approaches and their implications for comparing and aggregating data across projects and administrative boundaries.

3.1 Data gaps, quality and transparency

It is important to note that, by design, the provided case study template (Figure 1) did not explicitly ask for what specific documentation and information are to be included. The UNFC is rapidly changing and UNFC Specifications for minerals, and standardised templates for documenting UNFC case studies are still under review (UNECE 2021a) or have yet to be defined. It was thus a deliberate choice to not be prescriptive, but rather to solicit, test and evaluate current national approaches, and to develop a consensual understanding of how GSOs can use the UNFC. More specifically, the purpose was to (1) obtain a representative overview over the status of UNFC application across Europe as understood by the GSOs in EU project partner countries, (2) collect as many different approaches as possible, (3) identify key challenges related to data and knowledge gaps, and (4) to inform recommendations for resolving these challenges though future work, international standards, guidance, and training. In practice, the issuing organisations have expansive expertise and extensive geological data inventories that can be used for UNFC analyses, but Pan-European UNFC-specific data structures, templates, workflows and training are needed to make the UNFC operable, as well as to address the common information gaps and the at times very specific technical challenges (Hokka *et al.* 2021) across the UNFC pilot case studies.

When analysed according to the criteria outlined above, many of the case studies did not explicitly specify details such as the scope (national, regional, site); the nature, source and quality of input data (e.g., date and resolution for GIS datasets), the assumptions, workflows and Reference Points for classification; the ‘Effective Date’ of evaluation (UNECE 2020c), classification and publication details on the authors, the main responsible evaluator (i.e. the Competent Person responsible for signing off on the estimates), and the legal issuing organisation with address. Moreover, the level of detail provided for the case studies varied significantly. While some are only one page long and do not provide any UNFC quantities, others exceed 20 pages and contain in-depth reasoning for using specific UNFC categories.

It is, in consequence, difficult to deduce whether case studies have a national or regional scope, whether data are mutually exclusive and collectively exhaustive with respect to the inventory of known deposits within the case study perimeter, and whether the reported quantities can be considered as ‘up-to date’ at the time of publishing, or whether UNFC quantities were calculated based on outdated estimates.

3.2 Aggregation of UNFC case study results

The lack of transparency and information has direct effects on the results and on whether it is methodically correct, technically feasible, and informative to aggregate them across case studies and countries.

Table 1, for instance, shows five UNFC case studies from different countries for construction aggregates: Would it make sense to aggregate their UNFC quantities for similar EFG categories into 'aggregated UNFC totals for construction aggregates' across all these countries? Indeed, it can be done by adding the numbers, yes, but the result needs several disclaimers: (1) The quantities in the case studies reported by Austria, Croatia, Denmark, Norway and Sweden, and sometimes even within individual case studies, refer to different types of resources (marine, land-based, sand and gravel, and crushed stone) that all fall under the same umbrella term 'construction aggregates' but typically have very different physical properties, operating conditions, and applications; (2) some countries did not report quantities, i.e. no UNFC quantities to add; (3) the data have different spatial scopes (national and regional); and (4) the Effective Date of reporting (Reference Points) are distributed across two years (2020 and 2021). The data are thus not consistent for individual commodities/resource types, are not collectively exhaustive and possibly not mutually exclusive, are reported for different accounting periods, and lack information on the temporal validity of the estimates. An important distinction is also to be made between the roles of independent evaluators, commercial operators/project owners, and government organisations tasked with resource mapping and management functions. Competent persons or independent evaluators performing estimation and/or classification need to consider 'current conditions and realistic assumptions of future conditions', and they are obliged to disclose and explained the basis for any such assumptions (UNECE 2020c). 'Resource classification is carried out for a specific purpose and for different users who have different purposes and often a need for different information' (UNECE 2020b). Operators may want to consider both the current, and the future (forward-looking perspective) technical feasibility and economic viability of operations. For operators to have external evaluators perform estimation on the behalf, they need to make all relevant assumptions and information available to the evaluator. The purpose of government-commissioned regional-scale predictive models and assessment typically differs from that of industry-commissioned classification of commercial operation. Government resource managers are generally not in the position to prepare UNFC estimates on behalf of operators, as they often lack both the mandate and access to relevant EFG input data needed for assessing the economic and technical feasibility. They, however, often have national and regional-scale pre-competitive/pre-commercial datasets that they can use to prepare coarse, early-stage assessments of a region's general resource endowment. Integrating, comparing and aggregating UNFC datasets that have been preprepared for different purposes is a major unresolved challenge. Better documentation and granular disclosure are likely essential for making UNFC results more useful, and to facilitate comparisons and aggregation at national and international levels.

3.3 *Data availability, harmonisation, and interoperability*

Data needs to be FAIR, findable, accessible, interoperable and reusable (Wilkinson *et al.* 2016; European Commission Expert Group on FAIR Data 2018) to facilitate analysis and integration. For assessing the interoperability of datasets many different indicators and ranking metrics exist (Peng *et al.* 2021), among them the simplified Interoperability Readiness Level (IRL) scale shown in Figure 3 that we qualitatively applied to evaluate the current level of utility of both the input data, and of the UNFC case study results.

NASA Interoperability Readiness Levels (IRLs)

High IRLs
Extensive interoperability. Little human interpretation and intervention required. Simple configuration rather than custom coding.

Low IRLs
Little interoperability. Significant human interpretation and intervention required. Extensive custom coding.

No interoperability

	Capability Enablement
Level 9	Automatic discovery and incorporation of novel data and services into applications with no human intervention
Level 8	Human-triggered incorporation of novel data and services into applications
Level 7	Incorporation of novel data and services into applications with minimal configuration
Level 6	Incorporation of novel data and services into applications with substantial configuration
Level 5	Incorporation of novel data and services into applications with minimal custom code
Level 4	Programmatic access to data services from different sources via extensive custom code
Level 3	Programmatic use of data from different sources via extensive custom code
Level 2	Human use of data from different sources using different code for each
Level 1	Data from different sources cannot be used together

Figure 3: Interoperability Readiness Level (IRL), modified from NASA Technology Infusion Working Group (2012).

3.4 Challenges with accessibility and interoperability of EFG input data

Input data for UNFC classification needs to provide information on the environmental-socio-economic viability (E), technical feasibility (F), and degree of confidence in the estimate (G), of projects. Such data is typically obtained from different national data sources of variable quality and accessibility, which poses various challenges for the compilation of the UNFC case studies.

The general level of interoperability of input data across the case studies in this pilot can roughly be estimated to be in the range of IRL 1 to IRL 4. The required EFG-related input data for certain aspects concerning for instance the environmental-socio-economic viability (e.g., datasets on endangered species, social license to operate, and regional government subsidies) may not yet exist all together, may need to be solicited from different organisations, or may need to be compiled from literature or other data formats that are unsuitable for integration (paper maps, remote physical document archives and libraries). This makes the UNFC classification both time consuming and expensive, if not impossible. For example, the Norwegian hard rock aggregates UNFC case study compiled by the Geological Survey of Norway (NGU) tested an automatic GIS workflow for resource evaluation and UNFC classification but did not have access to interoperable GIS datasets for permitted mining areas. NGU does not have the institutional mandate to access the original GIS datasets managed by the Directorate of Mining, and the publicly accessible web data service for permitted areas does not allow for data extraction and is thus non-reusable (IRL1). Across case studies and countries, there are similar challenges with obtaining EFG-related input data.

3.5 *Interoperability and UNFC data for Pan-European integration*

The 19 case studies evaluated for this report were all in PDF or Microsoft Office format, compiled manually form different data sources. Both the input data required to compile the individual case studies, and the information contained in the respective case studies is poorly accessible, as it can only be extracted manually (IRL 1 or 2) and needs a significant amount of expertise to understand, compare, and aggregate quantities across case studies, as discussed in sections 3.1 and 3.2. Ensuing the EU-funded Minerals4EU[5] project, which also published a Minerals Yearbook[6], UNFC was adopted as an option for classification or resources, and several GSOs have since extended their database structures to allow for registration of UNFC attributes, and others have established workflows to map/bridge the existing data in their national resource inventories to UNFC. However, none of the case studies were accompanied by original full-granularity (site-scale) GIS datasets with all the UNFC categories and full metadata. In general, data confidentiality is a major issue concerning granular data disclosure. The European strategy for data observes that 'data is the lifeblood of economic development' and that 'the value of data lies in its use and re-use' (European Commission 2019, 2020). The value of mineral data increases with its granularity (NRGI 2017), but there are significant and often national legal barriers to making such data available on a granular, per-site or project scale. The European Open Data Directive (European Commission 2019) defines that 'to facilitate re-use, public sector bodies should, where possible and appropriate, make documents, including those published on websites, available through an open and machine-readable format and together with their metadata, at the best level of precision and granularity, in a format that ensures interoperability, for example by processing them in a way consistent with the principles governing the compatibility and usability requirements for spatial information under Directive 2007/2/EC. Data ownership and disclosure is a common challenge for most, if not all, countries and case studies presented here. In effect, many case studies only provided aggregated numbers, others omitted resources that could not be assessed due to confidentiality issues, and Hungary, for instance, compiled three case studies with site-resolution (Gypsum: *Regional,site*; Manganese: *Site,site*; and Perlite: *Regional,site*), two of which had to be generalised to make them publicly available, see also MINTELL4EU D4.2 (Hokka *et al.* 2021).
Generally, data disclosure and interoperability of UNFC resource estimates are prerequisites for international aggregation. While the next sections provide some guidelines and workflows as first steps to support this, substantial future development efforts will be needed to improve data availability and interoperability across Europe.

4 CASE STUDY DESIGN WORKFLOW AND GUIDELINES

'Geospatial information is a critical component of the national infrastructure and knowledge economy; a blueprint of what happens where, and the means to integrate a wide variety of government services' (UN-GGIM 2018). The UNFC case studies have demonstrated the need to consider spatio-temporal data coverage (cf. section 2.1: *scope and granularity; collectively exhaustive and mutually exclusive; temporal validity*) of datasets, and that availability and interoperability of data are key requirements, both for successful compilation of UNFC case studies, and for re-use and aggregation. Understanding the broader institutional context of case studies and the technical aspects of UNFC classification is important for case study design. While D4.2 (Hokka *et al.* 2021) addresses the latter, the following sections discuss more general aspects.

[5] http://www.minerals4eu.eu/
[6] http://minerals4eu.brgm-rec.fr/m4eu-yearbook/

4.1 Workflow for UNFC case study design

To support UNFC case study design and planning, the decision flow diagram shown in Figure 4 was developed. A key question is how to integrate UNFC case studies that are government commissioned with those that are industry led, as they have different purposes and vary in terms of data availability, confidentiality, and requirements for accountability. The workflow can be used both to decide what needs to be considered for compiling UNFC case studies, and for communicating challenges with integrating data into national UNFC inventories and with international aggregation: Resource data that is privately held without mandatory reporting can be understood as 'siloed' as it is not systematically made available for re-use (Figure 4 D);, the classification according to UNFC becomes impossible where relevant EFG input data are lacking or inaccessible (C); if there is no government mandate to collect, compile and store UNFC-related input data and/or classification results these data likely won't be systematically inventoried and available for further aggregation (B); regional UNFC GIS datasets may be incompatible with site-resolution data (not mutually exclusive, A3) and even if they can be integrated they may not be useful for continuous accounting if inconsistencies are unclear or cannot be resolved (A2); ultimately, consistent, granular, and well-documented data are needed for national and EU-level UNFC accounting and aggregation (A1).

One key aspect is that the roles and responsibilities of different UNFC stakeholders and users need to be clarified both on a national and EU level, particularly with regard to data management and disclosure. This primarily concerns data providers, commercial operators, and government organisations directly involved in collection, evaluation and management of mineral resource information, but also associated professional and industry umbrella associations such as the European Federation of Geologists, Euromines, and the European Aggregates Association, as well as Pan-European data providers such as EuroGeoSurveys (EGS) with its European Geological Data Infrastructure (EGDI), and various European Union bodies and affiliated information gateways for Pan-European data, including the European Commission's Raw Materials Information System (RMIS) as documented in various EU commissioned reports (Manfredi *et al.* 2017; Manfredi *et al.* 2019; Bide *et al.* 2020; Cassard and Tertre 2021).

Building the necessary national and EU competences, workflows and data structures to develop, populate and maintain consistent national and international UNFC inventories requires significant capacity development and investments, as well as in-kind commitments. The process may benefit from the establishing International Centres of Excellence on Sustainable Resource Management (ICE-SRM) (UNECE 2020a), and may need further clarifications and refinement of the UNFC and the associated Specifications by the UNECE Expert Group on Resource Classification (EGRC), particularly with respect to the classification, accounting and aggregation of quantities associated to regional studies, and the reporting of pre-commercial resource quantities for the lower levels of maturity. Common internationally standardized data models and reporting templates with examples on how to use these are yet to be developed following the clarifications described above. As Figure 4 illustrates, consistent and collectively exhaustive national UNFC inventories and Pan-European resource estimates and accounting cannot be achieved unless legislative frameworks and national jurisdictions mandate the use of UNFC and enforce appropriate public disclosure and reporting to GSOs and other relevant public authorities.

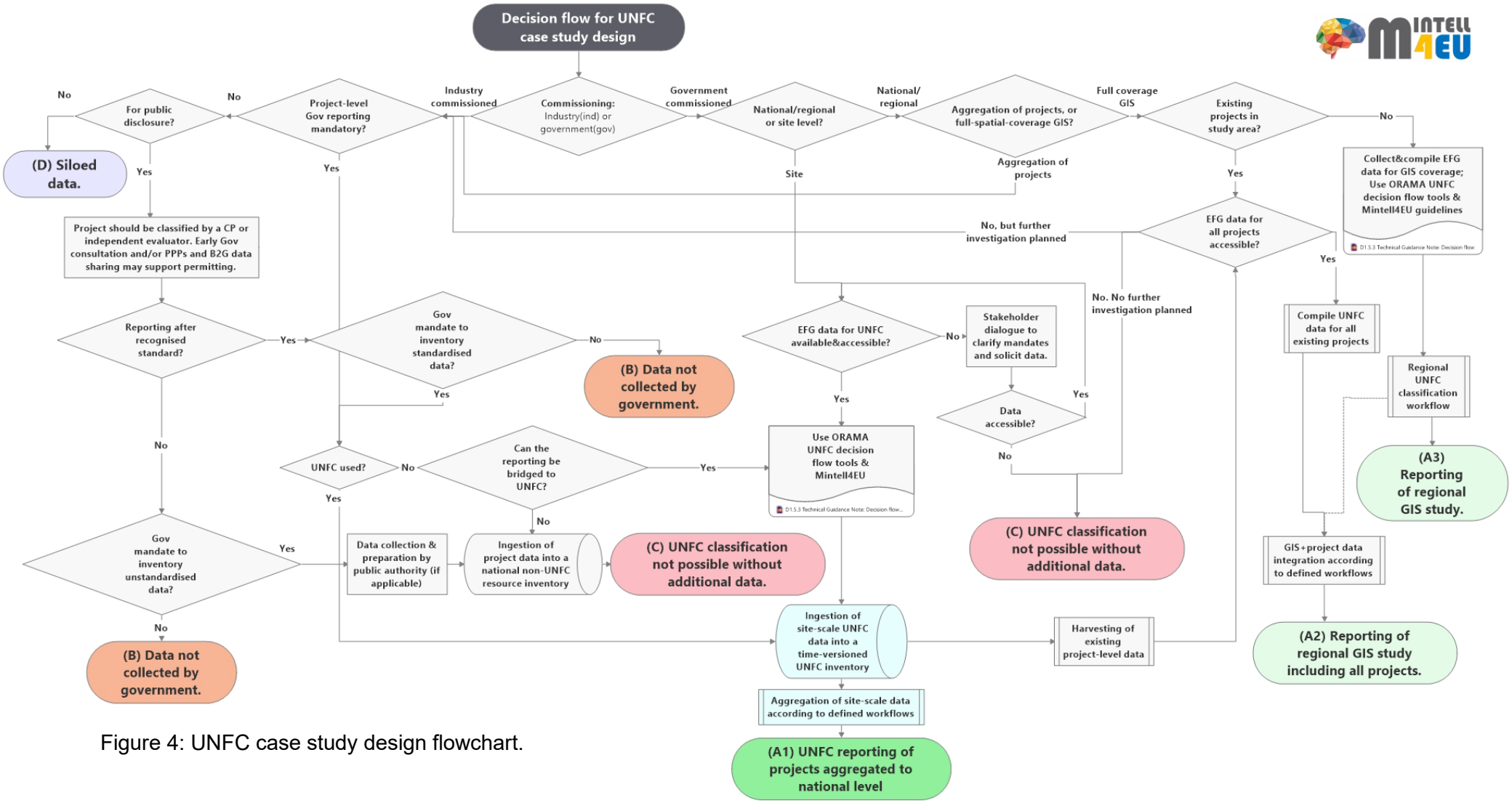

Figure 4: UNFC case study design flowchart.

4.2 Guidelines for UNFC data quality and interoperability

Data templates and associated guidelines are particularly important for facilitating UNFC estimates and associated metadata content that are complete and conform with the UNFC system; and second, that spatial data infrastructures and automatic data harvesting and aggregation workflows can be established across national agencies and EU countries.

Some of the UNFC-classification related issues and data gaps can be resolved through detailed UNFC reporting templates and transparent data compilation workflows that define relevant mandatory (i.e. must-have) data attributes and illustrate possible step for input data compilation, resource evaluation, and UNFC classification. As a guideline such templates and workflows should consider the scope, granularity, temporality, and whether the reporting is collectively exhaustive and mutually exclusive, as discussed in section 2.1. The details of what information should be included and what needs to mandatory or voluntary still needs to be defined and can be informed by, among others, the Principles of Resource Classification (UNECE 2020b) and the Draft UNFC Supplemental Specifications for Minerals that are currently under development by the UNECE ERGM (UNECE 2021a), and the ICE-SRM. Once overarching generic templates are defined, these will have to complemented by 'country specific' UNFC templates and/or guidelines that take the national data sources, mandates, and regulations into account. It can be anticipated that this will significantly improve the quality of UNFC estimates.

Resource data are intrinsically geospatial; using harmonised and consistent geospatial datasets with predefined attributes and mandatory metadata for case study compilation is a necessity for interoperability. The INSPIRE Directive (European Commission 2007) is an important step towards harmonisation of geospatial information, but further development efforts are needed to extend it such that UNFC data can be fully integrated and aggregated. The FAIR Digital Objects data model (European Commission Expert Group on FAIR Data 2018) as shown in Figure 5 illustrates which dimensions of essential data are needed: Digital object (data content, e.g. INSPIRE coverages for UNFC areas); Identifiers (to facilitate connectivity of the mineral inventories); Standards and codes (e.g., INSPIRE Data Specification for Mineral Resources to structure and contextualise data); and Metadata (e.g., author, UNFC-related information on model and scenario assumptions).

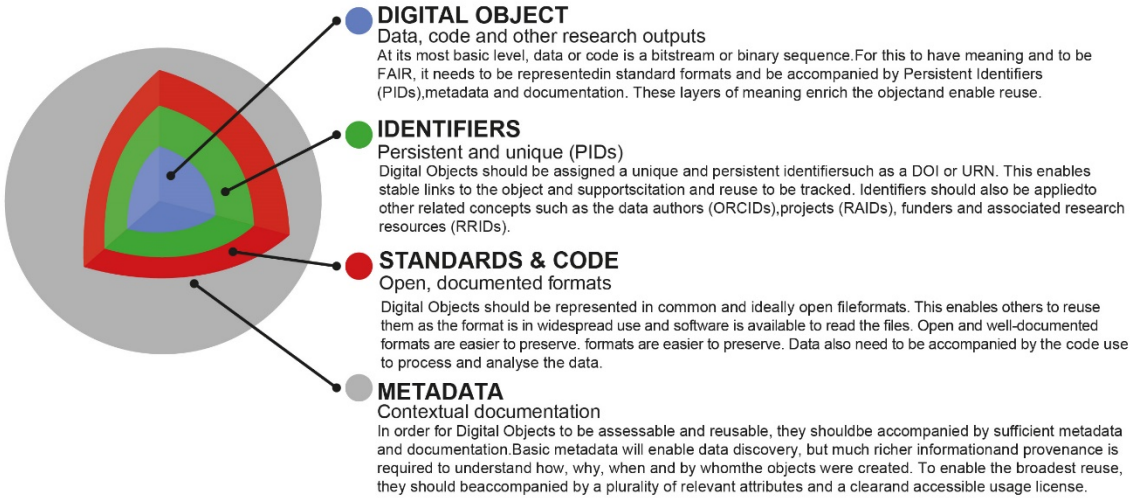

Figure 5: Data model for FAIR Digital Objects, modified from European Commission Expert Group on FAIR Data (2018).

Significant UNFC-related additional development efforts are required to fulfil the aims of the United Nations Resource Management System (UNECE 2021c) and the vision outlined by the United Nations Integrated Geospatial Information Framework (IGIF) as shown in Figure 6. Developing and implementing the UNFC across Europe can be guided by such frameworks. Based on the observations of the MINTELL4EU UNFC Pilot, several key aspects are highlighted in red in Figure 6 to emphasize what needs to be part of future UNFC work, including governance and legislation, data, standards, and capacity building.

Figure 6: Integrated Geospatial Information Framework (UN-GGIM 2018). Key aspects to emphasize what needs to be part of future UNFC work is highlighted in red.

5 SUMMARY

Data harmonisation and standardisation using the UNFC can help make project data in national mineral inventories more accessible and re-usable. Reliable data on the environmental-socio-economic viability (E), technical feasibility (F), and degree of confidence in the estimate (G), of projects are key to creating favourable operating conditions for the mining and processing industry. Moreover, they provide a basis for developing effective policies to remove contingencies that impede project development, simplify and accelerate lengthy planning and permitting procedures, and help to secure investments that unlock domestic raw materials supply.

The case studies produced by the UNFC Pilot and analysed in this report demonstrate that it is possible and meaningful to use the UNFC as a harmonisation tool to classify projects for different types of solid mineral resources, and that it is feasible to aggregate the results across countries if the identified key challenges are addressed.

Significant work remains to be done to make the UNFC operational across EU countries, and to produce meaningful Pan-European level aggregated totals:

1. A clarification of roles including those of Competent Persons and institutions, and international and national legal and policy frameworks are needed to overcome poor data availability and interoperability, and to establish legal, institutional and technical infrastructures for data sharing and aggregation.
2. Data value chains, workflows, and reporting templates must be developed to facilitate automation, improve consistency, and reduce costs and expedite data compilation, UNFC classification, and aggregation across projects and countries.
3. Further UNFC method development and extensive capacity building and training are required to overcome the lack of a common understanding of the UNFC system, and to make the results more transparent, comparable and reliable.
4. Geological and other geospatial EFG ‘input data’ need to be collected and made available as interoperable datasets to support industry operators, evaluators, and government organisations in their efforts to assess, classify and report UNFC resource estimates.

It can be anticipated that the use of the UNFC as an international standard for resource classification will make it possible to compare and aggregate resource project data across countries on a Pan-European level. It has the potential to provide essential information for decision making and policy development, to the benefit of the European Industrial Strategy (European Commission 2021), and in fulfilment of the United Nations Treaty on Mineral Resource Governance (United Nations Environment Assembly 2019).

6 ABBREVIATIONS

CRIRSCO	Committee for Mineral Reserves International Reporting Standards
EFG	UNFC Criteria (axes) for Environmental-socio-economic viability (E), technical feasibility (F), and degree of confidence in the estimate (G)
EGDI	European Geological Data Infrastructure
EGS	EuroGeoSurveys
EU	European Union
EURMKB	European Union Raw Materials Knowledge Base
GeoERA	European Geological Surveys Research Area
GIS	Geographical Information System
INSPIRE	Infrastructure for Spatial Information in the European Community
ICE-SRM	International Centres of Excellence on Sustainable Resource Management
MINTELL4EU	Mineral Intelligence for Europe
QAQC	Quality Assurance and Quality Control
RMIS	Raw Materials Information System (from EC DG JRC)
UNECE	United Nations Economic Commission for Europe
EGRC	Expert Group on Resource Classification of the United Nations Economic Commission for Europe
UNFC	United Nations Framework Classification for Resources
UNRMS	United Nations Resource Management System
WP	Work Package

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