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Development, maintenance and application of the United Nations Framework Classification for Resources: Anthropogenic resources

Draft Specifications for the application of the United Nations Framework Classification for Resources to Anthropogenic Resources

Prepared by the Working Group on Anthropogenic Resources of the Expert Group on Resource Classification

Summary

The United Nations Framework Classification for Resources (UNFC) is a system for classifying, managing and reporting resource quantities. This document increases the granularity of UNFC to enable its application to Anthropogenic Resources that arise from anthropogenic sources, such as mine tailings, buildings, infrastructure, consumer goods, and all sources from the material life cycle stages, including production, use and end-of-life.

This document provides guidance in classifying recoverable material quantities based on the maturity level of recovery projects, ranging from the stage of exploration studies to production of secondary raw materials. Three fundamental criteria influence the classification. First, the social, environmental and economic viability for retrieving the raw material quantities. Second, the project feasibility and status. Third, the confidence of knowledge of the raw materials at the source.

The classification framework is a principle-based system without prescribing specific factors of relevance for material sourcing projects, which may be context-dependent. The system principles need to be demonstrated in site-, commodity- or source-specific guidelines and case studies.

The target audience of this document is evaluators who estimate Anthropogenic Resource quantities, and government authorities, policymakers, investors and decision makers in the waste management sector, to help them make a reasoned and balanced judgment on the future potential of recycling and material sourcing projects.

This document is a Final Draft Version, which will be presented at the ninth session of the Expert Group on Resource Classification, 24-27 April 2018, in conjunction with a request for endorsement by the United Nations Economic Commission for Europe (ECE) Committee on Sustainable Energy.

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Preface

Securing the future supply of materials is fundamental for both regional and global economic development and prosperity. While the use of primary raw materials still dominates in terms of quantity, secondary raw materials play an increasingly important role in sustaining material supply, protecting primary deposits and reducing environmental impacts. In contrast to the traditional mining sector, the stakeholders in the urban mining, recycling and recovery sector lack reliable information on the material quantities which are expected to be available in the near future. This impedes the identification of recycling and recovery opportunities and creates risks for investment decisions concerning secondary raw material processing facilities. In addition, it hinders national resource planners from integrating primary and secondary sources into a comprehensive raw material system for use in accounting, scenario development, and policymaking.

To overcome the barriers, a team of experts started to develop case studies on estimating retrievable material quantities from landfills and wind turbines in 2012. It became clear that a principle-based system is needed for consistent estimation of retrievable material quantities from various sources. This was the starting point to review existing tools for resource classification. Among the strengths of sectoral and local standards, they witnessed progression towards a unifying global standard, the United Nations Framework Classification for Resources (UNFC). UNFC is a widely accepted and internationally applicable scheme for the classification, and management of all energy and mineral resources. Due to its flexibility and the willingness of the Expert Group on Resource Classification to incorporate secondary raw materials, this new standard on Anthropogenic Resources has been developed between 2016 and 2018. The full history of the development of the Specifications can be found in Annex 2.

The United Nations Economic Commission for Europe (ECE) and the Expert Group on Resource Classification encourage governments, regulators, industry and universities to apply and share this document, to promote the recoverability of secondary raw materials, and to support a secure, environmentally- and socially-friendly supply of materials in the context of a circular economy and the UN Sustainable Development Goals.

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This document is partly based upon work from COST Action Mining the European Anthroposphere, supported by COST (European Cooperation in Science and Technology). Details can be found in Annex 2.

Guidance for reading the document

The UNFC is a package of documents with the following hierarchical levels:

(a) Generic Specifications for its Application to all energy and mineral resources[1] [1].

(b) Specifications for its Application to specific resources, such as Anthropogenic Resources (this document), Renewable Energy Resources, Geothermal Resources, and Uranium and Thorium Resources [2-4].

(c) Guidance notes [e.g. 5]

[1] At the time of its publication in 2013, UNFC was designed for estimating geogenic material quantities. Currently a new version of the Generic Specifications is under way. It is expected that the new version will have a broader scope including Renewable Energies, Injection Projects and Anthropogenic Resources.

Contents

		Page
	Preface	2
	Acknowledgements	3
	Guidance for reading the document	3
I.	Introduction	5
II.	Terms and definitions	5
	A. Anthropogenic Resources and associated terms	5
	B. Criteria, Categories and supporting explanations	8
	1. E Axis	8
	2. F Axis	10
	3. G Axis	11
	C. Classes	14
	D. Sub-classes	15
	E. Definition of the Project	16
	F. Project lifetime	18
	G. Corporate versus National Reporting	18
	H. Entitlements	19
	I. Development plan	19
III.	Specifications for the Application of the UNFC in the context of Anthropogenic Resources	19
	A. Use of numerical codes	19
	B. Effective date	20
	C. Propect with multiple Anthropogenic Material Products	20
	D. Reference Point	20
	E.. Classification of Projects based on level of maturity	20
	F. Distiction between retrievable quantities and in situ (in-place) quantities	21
	G. Aggregation of quantities	21
	H. Optional labels for estimates	21
	I. Classification of quantities associated with Exploration Projects	21
	J. Classification of Additional Quantities in Place	21
	K. Retrieved quantities that may be saleable in the future	22
	L. Ebaloator qualifications	22
	M. Documentation	22
	N. Units and conversion factors	23
Bibliopraphy		23
Annex I:	Terms from UNFC and their interpretation in the context of Anthropogenic Resources	26
Annex II:	History of Development of these Specifications	30

I. Introduction

1. Resource classification systems are used to assess the availability of resource quantities under defined conditions. The quantities, identified as potentially extractable, change with progress in science, technology and shifts in political, societal, environmental and economic conditions. A number of resource classification systems have evolved over time in response to various sectoral needs and local requirements. These systems have witnessed progression towards a unifying global standard, the United Nations Framework Classification for Resources (UNFC).

2. UNFC is a principle-based system for classifying and managing resources from various sources. This document increases the granularity of UNFC to enable its application to Anthropogenic Resources. Anthropogenic Resources are material quantities from anthropogenic materials sources, such as mining tailings, buildings, infrastructure, consumer durable goods, and all material life cycle stages, including recovery, production, use and end-of-life.

3. This document provides guidance for communicating retrievable material quantities, which are *categorized* according to technical, socio-economic and confidence parameters, and are *classified* according to the maturity level of material sourcing projects. The *categorization* allows flexibility in defining factors that need to be satisfied before a material sourcing project is put forward. These factors depend on the circumstances of individual material sourcing projects and need to be considered by Evaluators (Section III.L), who estimate or supervise the assessment of material quantities. Applying these Specifications enables consistency and transparency in communicating retrievable material quantities. This allows government authorities, policymakers, investors and decision makers in the materials and waste management sectors to make a reasoned and balanced judgment on the future potential of a material sourcing project. From an operational point of view, it supports project portfolio management, national material management, policy setting and capital allocation.

4. The Specifications are a “living document”. They will evolve over time and be revised due to updates of UNFC, lessons learned from studies that estimate and classify anthropogenic resources, and results from expert discussions during workshops and conferences. Any proposals for revisions can be addressed to reserves.energy@unece.org.

II. Terms and definitions

A. Anthropogenic Resources and associated terms

5. It is recognized that across scientific disciplines and political-economic systems, the term “Anthroposphere” and "anthropogenic” are broad terms that lack a precise definition, particularly with respect to their implications regarding the degree of human influence and system boundaries. The terms are defined here for the purpose of this document, in a way that is consistent with practice in “material flow analysis” (MFA), which is used to analyse materials flows and stocks in defined systems.

6. The **Anthroposphere** denominates the part of the environment that is made or modified by humans. The Anthroposphere includes all domains of human activity. In the Anthroposphere, human beings have caused significant changes in earth systems through their transformation and use of materials and energy, and emissions of solid, liquid and gaseous wastes. The definition of the term “Anthroposphere” has been adapted from Wikipedia [6], Cambridge dictionary [7], Baccini and Brunner [8].

7. An **Anthropogenic Material** is physical matter without any attribution from an economic, legislative, social or environmental perspective, and without a specification of the aggregate state (solid, liquid, gaseous)[2]. Anthropogenic materials include, for instance, mineral materials, sewage sludge, biomass and off-gas.

8. An **Anthropogenic Resource** is a concentration or occurrence of Anthropogenic Material of intrinsic economic interest, in such form, quality and quantity that there are reasonable prospects for eventual economic exploitation. It is recognized that in traditional resource classification systems, the quantity is subdivided into resources and reserves with elaborated definitions of the two. UNFC does not use these terms but refers to "classes" (Section C) instead. The term "Anthropogenic Resource" has been adapted from the term „Mineral Resource" as defined in CRIRSCO [9].

9. An **Anthropogenic Material System** locates Anthropogenic Material quantities inside the Anthroposphere and its surrounding environment (Figure 1). "It comprises Anthropogenic Material Processes, linked by Anthropogenic Material Flows within defined system boundaries [Adapted from Brunner and Rechberger [10]]". Primary raw materials are the product of the primary production sectors, which encompass the extraction of materials from the earth's crust and their transformation through processing or refining. The obtained raw materials are primary commodities, the base materials for further manufacturing and consumption processes. Residues from primary production and primary commodities will finally end up in Anthropogenic Material Stocks, from which Anthropogenic Materials quantities can be sourced.

10. An anthropogenic material sourcing **Project** is a defined development or sourcing operation, which provides the basis for socio-economic and environmental evaluation and decision-making. Further details are given in section II.E. The UNFC is applied on the level of Projects, for which only relevant Anthropogenic Materials, Anthropogenic Material Processes, Anthropogenic Material Flows and system boundaries are considered.

11. "A process is defined as the transformation, transport or storage of materials" [10]. Depending on the location of the process, a process is further defined as "**Anthropogenic Material Process**" or "Environmental Material Process" (see Figure 1). In waste management, for instance, transformation and storage take place in terms of "recovery" and "disposal". These terms are used by the EU Waste Directive 2008/98/EC [11]. Guidance on the interpretation of terms is also given by the European Commission [12]. Each process is subject to the mass conservation principle, which means that the sum of inflows, stock changes and outflows is zero.

12. An **Anthropogenic Material Stock** results from the accumulation of an Anthropogenic Material quantity in an Anthropogenic Material Process. The definition of "Anthropogenic Material Stock" is adapted from ECE [3], Brunner and Rechberger [10], OECD [13].

13. An **Anthropogenic Material Flow** is the movement of Anthropogenic Material between two Anthropogenic Material Processes and is measured in mass per time. The definition of "Anthropogenic Material Flow" is adapted from Brunner and Rechberger [10].

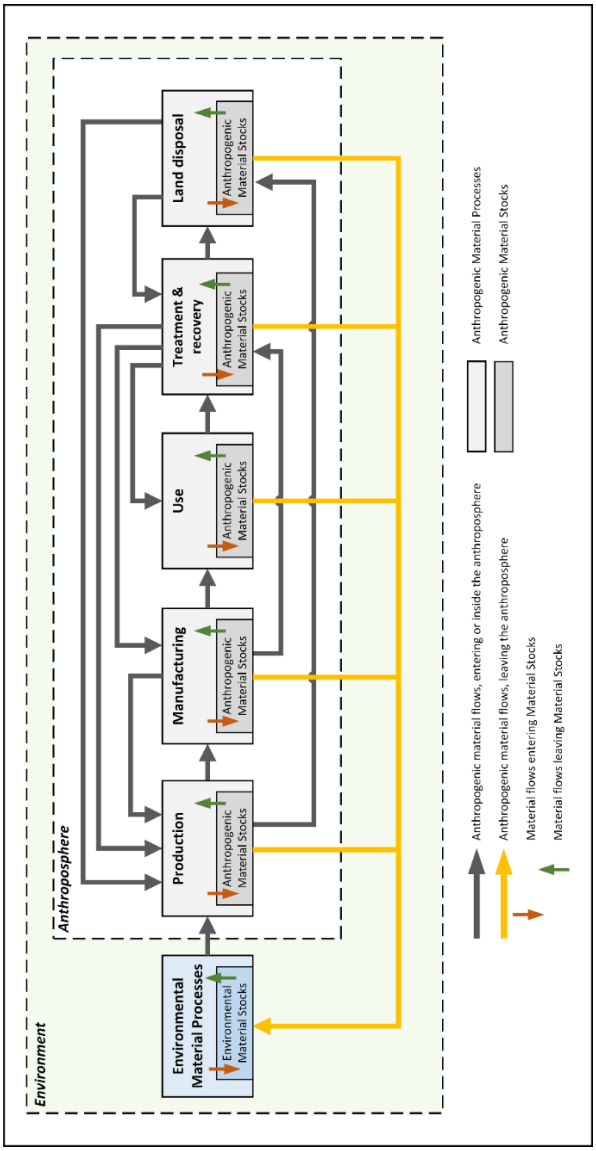
[2] An Anthropogenic Material can be labeled as Anthropogenic Resource and/or Waste, depending on the stage in the lifecycle and regulatory frameworks, but also on the specific evaluation criteria (economical vs legal). If an Anthropogenic Material is labeled as Waste, which is the case until it is properly reused, recycled or reaches a product status in line with end-of-waste ordinances, this Anthropogenic Material can simultaneously be an Anthropogenic Resource, if it is of commercial interest.

14. Any Anthropogenic Material Stock or any Anthropogenic Material Flow can be an **Anthropogenic Material Source**. An Anthropogenic Material Source contains material quantities that can be converted to Anthropogenic Material Products.

15. An **Anthropogenic Material Product** is a quantity that is saleable in markets. The cumulative quantities are equivalent to "Sales Production" according to the UNFC (see Table 4). It is noted that the term Anthropogenic Material Product does not necessarily correlate with legal product declarations. Guidance for Projects with multiple Anthropogenic Material Products and energy quantities is given in section III.C.

Figure 1

General Anthropogenic Material System[3], which encompasses Anthropogenic Material Processes (light grey boxes), Anthropogenic Material Stocks (dark grey boxes), Anthropogenic Material Flows (arrows) and system boundaries (dashed lines).

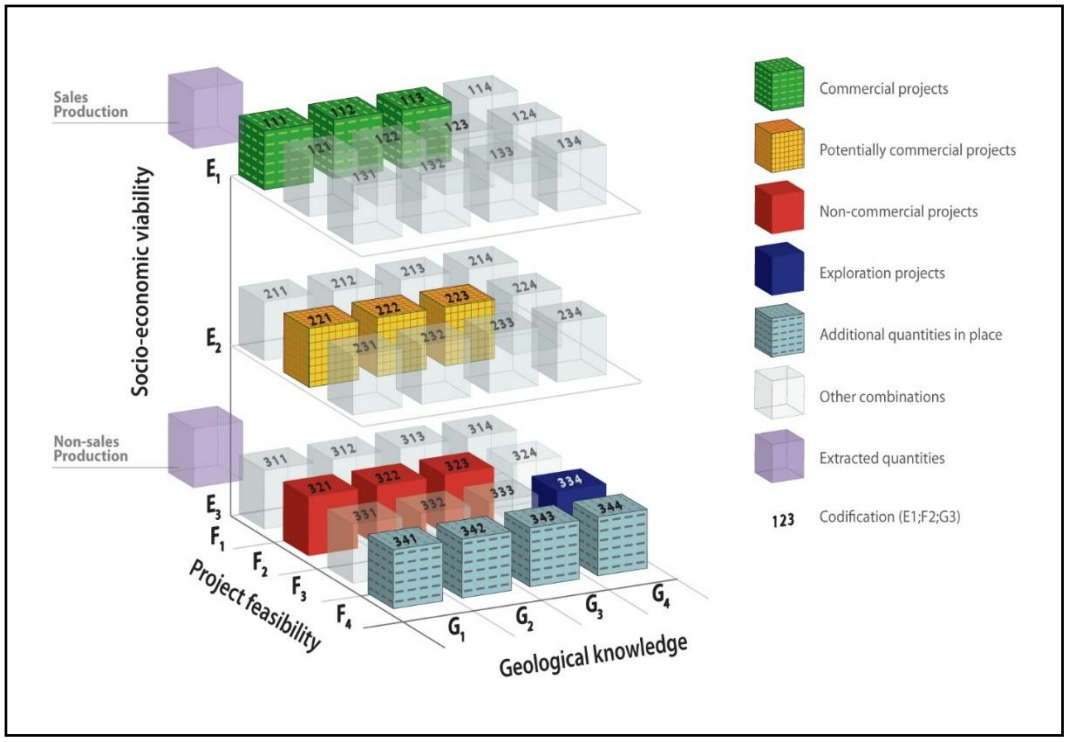


[3] The figure has been developed based on various diagrams about the life cycle of materials such as Graedel [14], Lederer, Laner and Fellner [15] and discussions among the authors of the Initial Draft Specifications (EGRC-8/2017/INF.7.).

B. Criteria, Categories and supporting explanations

16. UNFC is a generic principle-based system in which material quantities are categorized along three axes (Figure 2). First, the economic and social viability (E-axis), second, the project feasibility (F-axis), and third the geological knowledge (G-axis), which creates a three-dimensional system. Each axis is divided into categories (e.g. E1, E2, and E3) and subdivided into sub-categories (e.g. E1.1, E1.2). It is recognized that the term "geological knowledge" is not applicable to Anthropogenic Resources and needs further interpretation (see section II.B.c). At the eighth session, the Expert Group on Resource Classification agreed to find a broader definition of the G-Axis and to incorporate the recommendations from the G-Axis Working Group in the UNFC Principles and Generic Specifications [16, 17].

Figure 2
UNFC Categories and examples of Classes.



17. Guidance on the definition of *categories* and *sub-categories* is given in Generic Specifications [1]. In its current version, it is designed to classify traditional exploration and mining projects rather than anthropogenic material sourcing Projects. Guidance for the interpretation of terms is given in Annex 1: Terms from UNFC and their interpretation in the context of Anthropogenic Resources.

1. E Axis

18. The E-axis is labelled "socio-economic viability". It expresses the favourability of social and economic conditions for establishing the commercial viability of the Project (Section II.E), including consideration of market prices and relevant legal, regulatory, environmental and contractual conditions.

19. It is noted that an E-axis subgroup has been tasked to redefine the E-Axis label and to provide guidance on accommodating economic, environmental and social considerations in UNFC [18, 19]. It is expected that the final guidance document will receive Expert Group

approval within the next 12 months and the Specifications for Anthropogenic Resources will thereby have to be updated.

20. With respect to the current UNFC version, Table 1 defines the E-axis categories. Details on the distinction between the categories are described in paragraph 21 to 24 and on the economic assumption in paragraph 25 to 26.

Table 1
Definition of E-axis categories.

Category	*Definition [1, Part I, Annex I]*	*Supporting Explanation [1, Part I, Annex I]*
E1	Recovery and sale has been confirmed to be economically viable.	Recovery and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions. All necessary approvals/ contracts have been confirmed, or there are reasonable expectations that all such approvals/contracts will be obtained within a reasonable timeframe. Economic viability is not affected by short-term adverse market conditions provided that longer-term forecasts remain positive.
E2	Recovery and sale is expected to become economically viable in the foreseeable future.	Recovery and sale has not yet been confirmed to be economic but, on the basis of realistic assumptions of future market conditions, there are reasonable prospects for economic recovery and sale in the foreseeable future.
E3	Recovery and sale is not expected to become economically viable in the foreseeable future or evaluation is at too early a stage to determine economic viability.	On the basis of realistic assumptions of future market conditions, it is currently considered that there are not reasonable prospects for economic recovery and sale in the foreseeable future; or, economic viability of recovery cannot yet be determined due to insufficient information (e.g. during the assessment phase). Also included are quantities that are forecast to be converted, but which will not be available for sale.

The paragraphs 21 to 24 address the distinction between E1, E2 and E3.

21. To further elaborate the E-axis definitions, the E-axis subgroup prepared two draft guidance documents [18, 19] and in April 2018 will deliver detailed guidance on assessing the environmental and social considerations for the classification of resources according to the UNFC [20]. It is expected, that the detailed guidance will be combined with other elements reflected on the E-axis (economics in particular) and be of key relevance for classifying Anthropogenic Resource Projects.

22. "UNFC defines E1, E2 and E3 based on the economic viability of the Project. It may be noted that the phrase "economically viable" encompasses economic (in the narrow sense) plus other relevant "market conditions", and includes consideration of prices, costs, legal/fiscal framework, environmental, social and all other non-technical factors that could directly impact the viability of a development Project. In classifying estimated quantities that may be recovered in the future from a development project or mining operation, the E-axis Categories are explicitly defined to include both environmental and social issues that may be relevant to the commercial viability of such a venture, in addition to economic, legal and other non-technical factors." This paragraph has been adapted from the Guidelines for Application of the UNFC for Uranium and Thorium Resources [4].

23. "In particular, the identification and consideration at the time of the estimate of all known environmental or social impacts of the Project during its entire life cycle are recognized as an integral part of the project assessment. The presence of environmental or social impediments can prevent a Project from proceeding, or it can lead to the suspension or termination of activities in an existing operation." This paragraph has been adapted from the Guideline for Application of the UNFC for Uranium and Thorium Resources [4].

24. Non-technical and external factors are of key importance for classifying Anthropogenic Resources. For instance, the quantities of Anthropogenic Material Products are limited by social, legislative and environmental factors that go beyond economic (in the sense of financial) aspects in terms of costs and benefits. External factors, induced by the Project, or with direct impact on the viability of a Project in the economic and ecological dimension are relevant for the categorization of material quantities on the E-axis, such as:

(a) Impacts on the income or expenditures of a community, as well as on the government of the society that are induced by the Project. For instance, municipal solid waste dumpsites in urban areas are sometimes excavated due to environmental concerns and the need to extend the area of settlement. Removing and treating the waste in existing landfills eliminates the maintenance costs for emissions treatment and environmental damage associated with these landfills. The reclamation of the area for settlements allows recovery of the land value, with benefits for landowners and investors;

(b) The ecological impacts of secondary raw material production in contrast to primary raw material production;

(c) The presence and toxicity of toxic substances in the Anthropogenic Resource;

(d) All relevant environmental or social impacts and benefits of the project during its entire life cycle.

The paragraphs 25 to 26 address economic assumptions.

25. Details on economic assumptions are given in ECE [1, Part II, VI.L].

26. "Current market conditions and realistic assumptions regarding future market conditions should include favourable and adverse policy support mechanisms for anthropogenic material sourcing Projects, but shall not assume that such mechanisms will become more beneficial in the future unless already specified in the regulation. Adopted from ECE [3, IV., L.]".

2. F Axis

27. The F-axis is labelled "field project status and feasibility". It expresses the maturity of understanding of the Anthropogenic Resource and the multiple technical, society, and financial commitments necessary to implement the Project. These extend from early exploration efforts before an Anthropogenic Resource has been confirmed to exist, through to a project that is sourcing an Anthropogenic Resource and selling an Anthropogenic Material Product.

28. With respect to the current UNFC version, Table 2 defines the F-axis categories.

Table 2
Definition of F-axis categories and supporting explanations.

Category	*Definition [1, Part I, Annex I]*	*Supporting Explanation [1, Part I, Annex I]*
F1	Feasibility of recovery by a defined development project or mining operation has been confirmed.	Recovery is currently taking place; or, implementation of the development project is underway; or, sufficiently detailed studies have been completed to demonstrate the feasibility of recovery by implementing a development project or mining operation.
F2	Feasibility of recovery by a defined development project or mining operation is subject to further evaluation.	Preliminary studies demonstrate the existence of a project in such form, quality and quantity that the feasibility of recovery by a defined (at least in broad terms) development project or mining operation can be evaluated. Further data acquisition and/or studies may be required to confirm the feasibility of recovery.
F3	Feasibility of recovery by a defined development project or mining operation cannot be evaluated due to limited technical data.	Very preliminary studies (e.g. during the assessment phase), which may be based on a defined (at least in conceptual terms) development project or mining operation, indicate the need for further data acquisition in order to confirm the existence of a project in such form, quality and quantity that the feasibility of production can be evaluated.
F4	No development project or mining operation has been identified.	In situ (in-place) quantities that will not be produced by any current development project or mining operation.

29. Category F4 can be used to classify Anthropogenic Material quantities at the geographical location of the defined project that cannot be extracted due to multiple constraints, for example, ownership rights, site/area constraints, and technology limitations.

3. G Axis

30. The original G-axis label in the UNFC is “geological knowledge”. It expresses the level of confidence in the geological knowledge and potential recoverability of the quantities. This definition reflects the fact that, at the time of its publication, the UNFC was designed for estimating geogenic material quantities. In the case of Anthropogenic Resources, the label is “the level of confidence in the potential recoverability of the quantities”. It expresses the level of confidence in the understanding of the Anthropogenic Material characteristics and potential for exploitation of the quantities. Further guidance for the interpretation of the G-axis is given in Annex 1: Terms from UNFC and their interpretation in the context of Anthropogenic Resources.

31. The UNFC distinguishes between known and potential deposits (see Table 4), which is interpreted for Anthropogenic Resources as followed.

(a) Estimates on quantities from “Known Anthropogenic Material Sources” (also called “discovered”) are based on direct (e.g. sampling) and indirect evidence and are added to the categories G1 to G3. During the lifetime of the Project, the existing in-place quantities might change because Anthropogenic Material quantities are added to the Anthropogenic

Material Stock. The "future in-place quantities" are also added to the categories G1 to G3. Categorizing "future in-place quantities" as G1 to G3 for Anthropogenic Resources is in analogy to petroleum projects, which also have changing in-place volumes over time[4].

(b) Estimates on quantities from "Potential Anthropogenic Material Sources" (also called "undiscovered") are based primarily on indirect evidence and are added to the category G4. To qualify as a "Known Anthropogenic Material Source," there must be some direct evidence. This direct evidence shows that there is some Anthropogenic Material present, but indirect evidence (e.g. Anthropogenic Material composition data from comparable territories) is used to help quantify the amount of in-place quantities, and there can be significant uncertainties which would contribute to the range of recoverable quantities expressed by G1, G2 andG3.

32. There are three established approaches to determining appropriate estimates for G1, G2 and G3, two of which are based on the assessment of a range of uncertainty for quantities associated with a Project, with the other reflecting different levels of confidence. The terms and definitions used within these specifications originate from ECE [3]. They have been adapted and are as follows:

(a) The "incremental" approach, which is based on estimates for discrete portions of the Anthropogenic Material Source and/or the Project, where each estimate is assigned on the basis of its level of confidence (high, moderate and low)[5] reflecting available knowledge regarding potential retrievability;

(b) The "scenario" approach, which is based on three discrete scenarios that are designed to reflect the range of uncertainty in the possible outcomes (low, best and high estimates)[6] of the Project retrieving materials from the Anthropogenic Material Source as a whole;

(c) The "probabilistic" approach, where multiple possible scenarios are generated (e.g., by Monte Carlo analysis) from input distributions of parameter uncertainty associated with the Project retrieving material from the Anthropogenic Material Source as a whole. Three specific outcomes are then selected from the output cumulative probability density distribution as indicators of the range of uncertainty (P90, P50 and P10 values are equated to low, best and high estimates respectively, where P90 means there is 90% probability of equaling or exceeding that quantity).

33. Uncertainty assessment shall also apply to quantities in G4.1, G4.2 and G4.3 respectively [further explanations in 1, VI section P].

[4] The in-place volume may sometimes change over time. For example, an oil field may sometimes span 2 areas (cross a border between countries, or cross a border between blocks where producers only have interest in one or other of the blocks). A country or company estimating recoverable quantities will have to estimate the in-place volume in their country/block and estimate the flow across the boundary due to competing production/injection on each side. These flows typically change over time. If there is direct evidence (e.g. wells/samples) then the deposit is known, but indirect evidence (e.g. historical records of development activity, historical pressure data) can be necessary to estimate the flows/changes of in-place volumes.

[5] In the petroleum sector [21], for example, incremental reserves with high, moderate and low confidence would be documented as proved, probable and possible reserves respectively and would correspond to E1F1G1, E1F1G2 and E1F1G3 in the UNFC

[6] In the petroleum sector [21], for example, both the scenario and probabilistic approaches would equate low, best and high estimates for reserves with proved (1P), proved plus probable (2P) and proved plus probable plus possible (3P) reserves, which would correspond to E1F1G1, E1F1G1+E1F1G2 and E1F1G1+E1F1G2+E1F1G3 in the UNFC.

Table 3
Definition of G-axis categories and supporting explanations.

Category	*Definition [1, Part I, Annex I]*	*Supporting Explanation [1, Part I, Annex I]*	*Additional Anthropogenic Material Context*
G1	Quantities associated with a known deposit that can be estimated with a high level of confidence.	For in situ (in-place) quantities, and for recoverable estimates of Fossil Energy and Mineral Resources that are extracted as solids, quantities are typically categorized discretely, where each discrete estimate reflects the level of geological knowledge and confidence associated with a specific part of the deposit. The estimates are categorized as G1, G2 and/or G3 as appropriate. For recoverable estimates of Fossil Energy and Mineral Resources that are extracted as fluids, their mobile nature generally precludes assigning recoverable quantities to discrete parts of an accumulation. Recoverable quantities should be evaluated on the basis of the impact of the development scheme on the accumulation as a whole and are usually categorized on the basis of three scenarios or outcomes that are equivalent to G1, G1+G2 and G1+G2+G3.	The G axis reflects the level of confidence in the potential retrievability of the quantities. Thus, the G axis categories are intended to reflect all significant uncertainties impacting the estimated Anthropogenic Material quantities that are forecast to be recovered by the Project and typically would include (but not be limited to) areas such as characterization of Anthropogenic Materials and analysis of Anthropogenic Material Systems. Uncertainties include both variability in the Anthropogenic Material Source (e.g. composition, quantity) and the efficiency of the sourcing process (re-use, preparation for reuse, recycling and recovery). Typically, the various uncertainties will combine to provide a full range of possible outcomes. In such cases, categorization should reflect three scenarios or outcomes that are equivalent to G1, G1+G2 and G1+G2+G3.
G2	Quantities associated with a known deposit that can be estimated with a moderate level of confidence.		
G3	Quantities associated with a known deposit that can be estimated with a low level of confidence.		
G4	Estimated quantities associated with a potential deposit, based primarily on indirect evidence.	Quantities that are estimated during the exploration phase are subject to a substantial range of uncertainty as well as a major risk that no development project or mining operation may subsequently be implemented to extract the estimated quantities. Where a single estimate is provided, it should be the expected outcome but, where possible, a full range of uncertainty in the size of the potential deposit should be documented (e.g. in the form of a probability distribution). In addition, it is recommended that the chance (probability) that the potential deposit will become a deposit of any commercial significance is also documented.	Category G4 is equally applicable to Anthropogenic Material quantities and defined with “Estimated quantities associated with a potential Anthropogenic Material Source, based primarily on indirect evidence” (e.g. exploration studies on the quantities in a territory). It might be helpful to introduce sub-categories (G4.1, G4.2, and G4.3).

C. Classes

34. A class is defined by selecting a particular category or sub-category from each of the three criteria (E-axis, F-axis, G-axis). A class is uniquely defined by its codification (e.g. E1 F1 G1). Any combination of categories is possible, to form classes and sub-classes. Typically, Projects involve quantities in several classes or sub-classes. The total commodity initially in place is classified at a given date. Table 4 shows an abbreviated version of the UNFC and selected classes for Projects.

35. A Project is considered to be *economic* when it indicates a positive return on investment, measured by a monetary criterion, such as having a positive net present value (NPV) at a particular discount factor [19].

36. A Project is considered to be *commercial* when it is not only *economic* but also satisfies all the other factors of the E, F, and G axes that are required for the Project to proceed. These requirements are described as contingencies until they are satisfied [19].

37. Contingency factors are factors or conditions that must be satisfied before a Project can proceed [adopted from 19] and may include market prices and relevant legal, regulatory, environmental, social and contractual conditions [1].

Table 4
An abbreviated version of UNFC, showing selected classes for Anthropogenic Resource Projects.

Total material quantity initially in place	**Past sourcing**		**Sales Production** [a)]			
			Non-sales Production [b)]			
	Future sourcing		**Class**	**Categories**		
				E	F	G
	Known Anthropogenic Material source	Future sourcing by commercial development projects or ongoing sourcing operations. [c)]	Commercial Projects [e)]			, 2, 3
		Potential future sourcing by contingent development projects or ongoing sourcing operations. [c)]	Potentially Commercial Projects [f)]			, 2, 3
			Non-Commercial Projects [g)]			, 2, 3
		Additional quantities in place associated with known Anthropogenic Material Sources. [d)]				, 2, 3
	Potential Anthropogenic Material Source	Potential future sourcing by successful exploration activities from potential Anthropogenic Material Sources.	Exploration Projects			
		Additional quantities in place associated with potential Anthropogenic Material Sources. [d)]				

38. As shown in Table 4, the total material quantity initially in place is categorized into classes at a given date (see III.B) in terms of the following:

(a) Sales Production: Anthropogenic Material Product quantities that have been sold. In contrast to geogenic deposits, Anthropogenic Material Stocks might receive material

quantities during the Project lifetime. Consequently, the reporting of "Sales Production" for two different years might include one and the same type and quantity of physical matter.

(b) Non-sales Production: Anthropogenic Material Product quantities that have not been sold.

(c) Quantities associated that may be sourced in the future. Technical and commercial evaluation studies based on defined development projects or preparation for reuse, recovery and recycling operations constitute the basis for the classification.

(d) A portion of these quantities may become recoverable in the future as technological developments occur or legal, social and environmental factors change. Some or all of these quantities may never be recovered due to technological, legal, social and environmental constraints.

(e) Commercial Projects have been confirmed to be technically, economically and socially feasible. Retrievable quantities associated with Commercial Projects are defined in many classification systems as Reserves, but there are some essential differences between the specific definitions that are applied within the extractive industries, and hence the term is not used here. It is noted that G3 quantities might be only commercial because of the existence of G1 and G2, but G3 quantities are not commercial on their own.

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

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

D. Sub-classes

39. For the clarity of global communication, Table 5 defines examples of possible sub-classes based on the full granularity provided by the sub-categories included in ECE [1, Annex II].

Table 5
UNFC Classes and Sub-classes with selected categories for Anthropogenic Resource Projects.

Total material quantity initially in place	**Past sourcing**		**Sales Production**			
			Non-Sales Production			
	Future sourcing					
		Class	**Sub-class**	**Categories**		
				E[7]	F	G
	Known Anthropogenic Material source	Commercial 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 Commercial Projects	Development Pending	2	2.1	1, 2, 3
			Development On Hold	2	2.2	1, 2, 3
		Non-Commercial Projects	Development Unclarified	3.2	2.2	1, 2, 3
			Development Not Viable	3.3	2.3	1, 2, 3
		Additional quantities in place		3.3	4	1, 2, 3
	Potential Anthropogenic Material source	Exploration Projects	[No sub-classes defined]	3.2	3	4
		Additional quantities in place		3.3	4	4

E. Defining the Project

40. A guidance note reproduces the UNFC definition of a Project, highlights the differences between this definition, documents some of the underlying principles of project based resource classification, and finally provides a set of guidelines that should enhance the consistency of application of the UNFC by its users [5].

41. An anthropogenic material sourcing Project is a defined development or sourcing operation, which provides the basis for socio-economic and environmental evaluation and decision-making. In the early stages of evaluation, including exploration, the Project might be defined only in conceptual terms, whereas more mature Projects will be defined in significant detail.

42. Where no development or sourcing operation can currently be defined for quantities, based on existing technology or technology currently under development, all quantities associated with that Project (or part thereof) are classified in Category F4 (see section III.J).

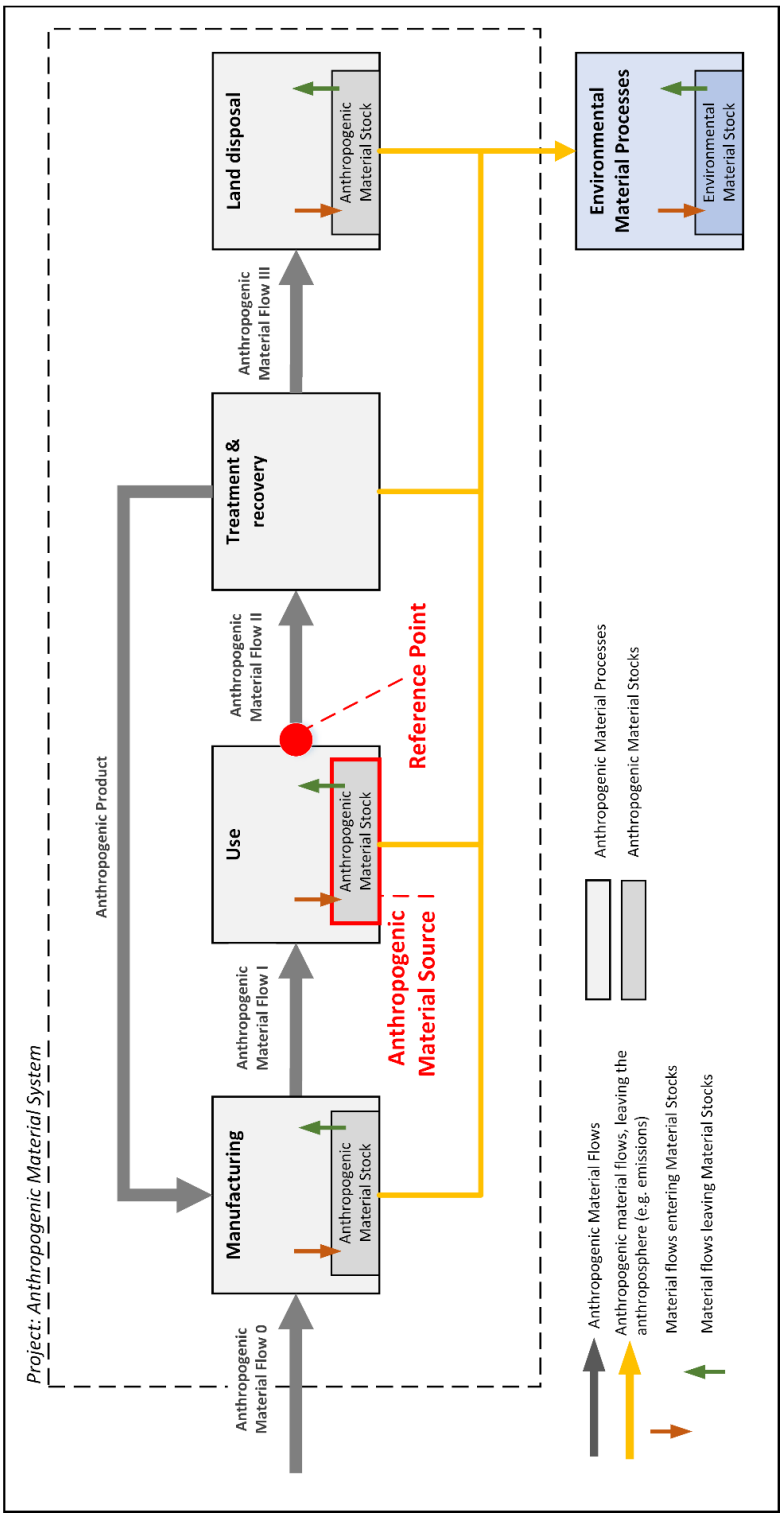
43. The classification procedure consists of identifying a Project, or Projects, estimating the existing and future quantities in place, with an associated level of confidence, and classifying the Project(s) based on Project status (or maturity) and commercial viability.

44. Figure 3 is a generic example for defining an Anthropogenic Material System at Project level. More details including the definition of terms can be found in section II.A.

[7] These are minimum categories. Classes using higher categories such as E1 F2 G1, 2, 3 are valid.

Figure 3

Example for a specific Anthropogenic Material System at project level including the location of the Reference Point. The default for the Reference Point shall be the location in the sourcing process at which the reported quantities of Anthropogenic Material Products are measured or estimated (see section III.D).



45. The "treatment and sourcing" process is the link between the quantities in the Anthropogenic Material Source and the Anthropogenic Material Products. There is a clear recognition of risk versus reward for the investors and key stakeholders such as governments and industry associations, linked to uncertainties and/or variability in the material quantity and quality, the efficiency of the sourcing process (e.g. reuse, preparation for reuse, recycling, recovery), the Anthropogenic Material Product prices and market conditions (including policy support mechanisms), social acceptance and the environmental benefits compared to primary material sourcing. In the early stages of evaluation, the Project might be defined only in conceptual terms, whereas more mature Projects will be defined in significant detail.

46. Anthropogenic Material Stocks cover Anthropogenic Material quantities and qualities, which change over time. So, estimates on future quantities are based primarily on indirect evidence. Under the UNFC, a deposit with quantities based on indirect evidence is defined as a "Potential deposit", which is a "Potential Anthropogenic Material Source" in this document. These quantities must be added to category G4. It might be helpful to introduce sub-categories (G4.1, G4.2, and G4.3), based on the level of confidence, as it is defined for G1, G2 and G3 (see section II.B.c).

F. Project lifetime

The following text originates from the Specifications for the application of the UNFC to Geothermal Energy Resources [2] and with an adaptation of the terminology for Anthropogenic Resources.

47. The estimated quantities for a Project shall be limited to quantities that will be produced during the Project Lifetime, which is defined as the economic limit, design life, or contract period for the Project, as defined below. The Project lifetime can sometimes be limited by the availability of the source material or by the extent of entitlement or social licenses. Because of its importance in estimating material quantities, the Project Lifetime and its basis shall be disclosed in association with any reported quantities.

(a) The 'economic limit' is defined as the time at which the Project reaches a point beyond which the subsequent cumulative discounted net operating cash flows from the Project would be negative. For a Project, the economic limit may be the time when the expected recovery rate declines to a level that makes the Project uneconomic, or when it is uneconomic to invest in the further infrastructure required to retrieve remaining quantities from the Anthropogenic Material Source;

(b) The 'design life' of a Project is the expected operating life of major physical infrastructure as defined during the technical and economic assessment of the Project. The replacement of significant project components will constitute a new Project, and a new evaluation and estimation of Anthropogenic Resources shall be performed;

(c) The 'contract period' for an Anthropogenic Material sourcing Project is the term of all existing, or reasonably expected, sales contracts for the Anthropogenic Material Products. The contract period should not include contract extensions unless there is a reasonable expectation of such extensions, based upon the historical treatment of similar contracts.

G. Corporate versus National Reporting

The following text originates from the Specifications for the application of the UNFC to Geothermal Energy Resources [2], with an adaptation of the terminology for Anthropogenic Resources.

48. The UNFC is geared toward classifying material quantities associated with single Projects. For reporting of corporate or national quantities, the estimated quantities of the 'single' Projects may need to be aggregated.

49. The UNFC, Part II, section IV and section VI.K provide guidance on the issues of national reporting and aggregation of estimated quantities.

50. For national reporting, the aggregation of known Projects from commercial, non-commercial and/or governmental organizations may not cover the total amount of quantities in the territory. The creation of a Project at a territorial level may allow an estimate and classification of all the territories quantities based on a system approach, including quantities not yet linked to Projects as defined under the UNFC. These territorial quantities could be adequately classified as, e.g. E3, F3.3, and G1 to G3 or G4 (depending on the data availability with direct and indirect evidence).

H. Entitlement

The following text originates from the Specifications for the application of the UNFC to Geothermal Energy Resources [2] and with an adaptation of the terminology for Anthropogenic Resources.

51. Entitlement refers to the rights to access Anthropogenic Material quantities that accrue to Project participants.

52. The 'entitlement period' is the term of all licenses and permits which provide rights to access the Anthropogenic Material Source, respectively, retrieve the material quantities and deliver the Anthropogenic Material Product into the market.

53. The Anthropogenic Material Source may be expected to last much longer than the Project Lifetime (see section II.F), but any future recovered quantities beyond those estimated for the Project would be assessed and classified as subsequent or additional Projects.

I. Development plan

The following text originates from the Specifications for the application of the UNFC to Renewable Energy Resources [3], with an adaptation of the terminology for Anthropogenic Resources.

54. In order to assign Anthropogenic Resources to any class, except for category F4 (No development project or sourcing operation has been identified), a development plan consisting of one or more Projects needs to be defined. The level of detail appropriate for such a plan may vary according to the maturity of the Projects and may also be specified by regulation.

III. Specifications for the Application of the UNFC in the context of Anthropogenic Resources

This section presents the generic Specifications for the application of the UNFC to Anthropogenic Resources through the provision of additional guidance and clarification, where required.

A. Use of numerical codes

55. Guidance on the use of numerical codes is given in ECE [1, p. 20].

B. Effective date

56. The effective date is defined in ECE [1, p. 20].

C. Projects with multiple Anthropogenic Material Products

57. Guidance on Anthropogenic Material Products is given in section "commodity or product type" in ECE [1, Part II, VI.D.]

58. Where a Project produces more than one Anthropogenic Material Product (e.g. copper and zinc), the quantities for each shall be estimated and included in a single report for the Project. For each Reference Point (The definition of "reference point" is given in section III.D) the same information shall be declared for each reported quantity, including the type of Anthropogenic Material Product.

59. It is noted that the Specifications focus primarily on Anthropogenic Material Products from Anthropogenic Material Sources. In some cases, it might be that the Project produces multiple Anthropogenic Material Products (material quantities) and energy quantities. In such a cases, each single quantity should be reported and considered for the evaluation of the Project. For example, a landfill mining project recovers metals (material quantity) and produces refuse-derived fuel (energy quantity). Further reading in section III.C.

60. A Project might also produce material quantities that are disposed on land (e.g. landfills, underground storage facilities and tailings). These quantities should be included in the reporting (see also guidance relating to the use of sub-category E3, in section II.B.a).

D. Reference Point

61. Guidance on the definition of the "Reference Point" is given in ECE [1, Part II, VI.F.].

62. Additional guidance for the application of the UNFC to Anthropogenic Resources has been adapted from ECE [3] as followed. The default for the Reference Point shall be the location in the sourcing process at which the reported quantities of Anthropogenic Material Products are measured or estimated. Any deviation from this location shall be clearly justified. In all cases, the additional obligations for disclosure contained in the Specifications for the Application of the UNFC as in ECE [1, Part II] shall still apply.

63. The material quantities through the Reference Point should be coherent (e.g. identical in time, quantity, quality and price) with the common definitions in general statistics, accounting and reporting schemes, as for instance, the System of Environmental-Economic Accounting [22] and European Waste Statistics [23].

64. No matter where the reference point is located, the categorization and classification of material quantities have to consider all relevant factors on the E-axis and F-Axis from all relevant Anthropogenic Material Processes, Stocks and Flows in the Project.

65. Where a Project produces multiple Anthropogenic Material Products, there might be different Reference Points for each Anthropogenic Resource (see section III.C).

E. Classification of Projects based on the level of maturity

66. Guidance on the classification of Projects on the level of maturity is given in ECE [1, Part II, VI.G.].

F. Distinction between retrievable quantities and in situ (in-place) quantities

67. Guidelines on Classification of quantities associated with Exploration Projects are given in ECE [1, Part II, VI.J.].

G. Aggregation of quantities

68. Guidance on commodity or product type is given in ECE [1, Part II, VI.K.].

H. Optional labels for estimates

69. Guidance on optional labels for estimates is given in ECE [1, Part II, VI.Q.]

I. Classification of quantities associated with Exploration Projects

70. Details on the classification of quantities associated with "Exploration Projects" are given in ECE [1, Part II, VI.R.]. Instead of terms such as "site-specific geological studies", "exploration activities", "drilling" and "testing", use "site-specific studies" or "data acquisition activities" that are relevant to corresponding Anthropogenic Resource Projects. The term "geological province" can be replaced by "territory" or "Project area".

71. In Exploration Projects, quantities might be estimated based on indirect evidence. These quantities add to G4 (see section II.B.c).

J. Classification of Additional Quantities in Place

72. In some situations, it may be helpful to add categories to the class "Additional Quantities in Place" on the basis of the current state of technological developments. Guidance is given in ECE [1, Part II, VI.S.]

73. Additional quantities in place might be restricted by unavailable technologies, but there are also factors beyond technological aspects that may prevent the sourcing. For instance, ownership of the materials, temporal availability, unacceptable impacts on human and environment health during recovery or a potential transfer of hazardous substances into the Anthropogenic Material Product.

The following paragraphs originate from ECE and IGA [2] and have been adapted for Anthropogenic Resources.

74. In the context of finite resources, 'additional quantities in place' make up the material balance between recovered quantities and total initial quantities in-place. Although a portion of these quantities may become retrievable in the future, as technological development occurs, some or all of these quantities may never be retrieved.

75. In the context of Anthropogenic Materials, the total initial quantity in place might be poorly defined, as a consequence of methodological constraints in characterizing quantities and variations over time.

76. There may be situations where it is desirable to report additional quantities in place for a Project. At such times, by definition, the Reference Point for additional quantities in place is in situ.

K. Retrieved quantities that may be saleable in the future

77. Details on recovered quantities that may be saleable in the future are given in ECE [1, Part II, VI.T.].

I. Evaluator qualifications

78. Guidance on evaluator qualifications are given in the two documents, ECE [1, Part II, VI.M.] and ECE [24].

The following paragraphs originate from ECE and IGA [2], with the alignment of Anthropogenic Resource terminology.

79. Evaluators shall possess an appropriate level of expertise and relevant experience in the estimation of Anthropogenic Resources associated with the type of Anthropogenic Materials under evaluation.

80. Relevant national, industry or financial reporting regulations may require an Evaluator to have specific qualifications and/or experience. In addition, regulatory bodies or certifying associations may explicitly mandate the use of a "competent person", as defined by regulation, with respect to corporate reporting.

81. Unless such relevant national, industry or financial reporting regulations prevail, the following shall apply when reporting Anthropogenic Resources according to the UNFC.

82. Where a report detailing Anthropogenic Resources is prepared for public reporting or submission to government authorities, the Anthropogenic Resources shall be estimated by, or under the direction of, an Evaluator.

83. Any public report detailing Anthropogenic Resources shall disclose the name of the Evaluator, including qualifications and experience, state whether the Evaluator is an employee of the entity preparing the report, and, if not, name the Evaluator's employer.

84. Estimation of Anthropogenic Resources is very commonly a team effort, involving several technical disciplines. It is, however, recommended that only one Evaluator sign the Anthropogenic Resource report and that this person be responsible and accountable for the whole of the documentation. It is important in this situation that the Evaluator accepts overall responsibility for an Anthropogenic Resource estimate and supporting documentation prepared in whole or in part by others, and is satisfied that the work of the other contributors is acceptable.

85. Notwithstanding the above, the reporter remains responsible for the report being correct. This will normally be the board of directors of the Company issuing the report or the equivalent if a public body is issuing it.

M. Documentation

86. Guidance on the documentation is given in ECE [1, Part II, VI.O.]

87. The documentation shall respect the code of good scientific practice. This includes, for instance, the documentation in sufficient detail to allow an independent external reviewer the reproduction of estimates of material quantities, the application of sound citation rules, the common responsibility of the authors, the declaration of conflict of interest of each author and the financial transparency of Project development – especially naming the Evaluators that received financial support or that have personal financial interest in the Project development.

N. Units and conversion factors

88. Guidance on units and conversation factors is given in ECE [1, Part II, VI.N.]

Bibliography:

1. ECE (2013). United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 incorporating Specifications for its Application. ECE Energy Series No. 42. United Nations Economic Commission for Europe (ECE). Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/pub/UNFC2009_Spec_ES42.pdf.

2. ECE and IGA (2016). Specifications for the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) to Geothermal Energy Resources. United Nations Economic Commission for Europe (ECE) and International Geothermal Association (IGA). Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/UNFC_GEOTH/UNFC.Geothermal.Specs.pdf.

3. ECE (2016). Specifications for the application of the United Nations Framework Classification of Fossil Energy and Mineral Reserves and Resources 2009 to Renewable Energy Resources. United Nations Economic Commission for Europe (ECE). Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/UNFC_specs/UNFC.RE_e.pdf.

4. ECE (2017). Guidelines for Application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 for Uranium and Thorium Resources. Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/images/pub/1734723E_WEB.pdf.

5. ECE (2016). Guidance Note to support the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009. Definition of a Project. Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/UNFC-Guidance-Notes/UNFC.Project.Guidance.Note_15.07.2016.pdf.

6. Wikipedia (2017). *Anthroposphere*. Retrieved on: 8. March 2017; Retrieved from: https://en.wikipedia.org/wiki/Anthroposphere.

7. Cambridge dictionary (2017). *Anthropogenic*. Retrieved on: 28. February 2017; Retrieved from: dictionary.cambridge.org.

8. Baccini, P. and Brunner, P.H. (1991). *Metabolism of the Anthroposphere*. Springer.

9. CRIRSCO (2013). International Reporting Template for the public reporting of exploration results, mineral resources and mineral reserves. Committee for mineral reserves international reporting standards (CRIRSCO). Retrieved from: www.crirsco.com/crirsco_template_v2.pdf.

10. Brunner, P.H. and Rechberger, H. (2004). *Practical Handbook of Material Flow Analysis*. CRC Press.

11. European Union (2008). *Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives*. Retrieved from: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN.

12. European Commission (2012). Guidance on the interpretation of key provisions of Directive 2008/98/EC on waste. Retrieved from: http://ec.europa.eu/environment/waste/framework/pdf/guidance_doc.pdf.

13. OECD (2015). Material Resources, Productivity and the Environment. Organisation for Economic Co-operation and Development (OECD). Retrieved from: http://dx.doi.org/10.1787/9789264190504-en.

14. Graedel, T. (2010). Metal Stocks in Society - Scientific Synthesis. United Nations Environment Programme (UNEP) and International Panel for Sustainable Resource Management. Paris. Retrieved from: www.resourcepanel.org/file/387/download?token=XhxT85ju.

15. Lederer, J., Laner, D. and Fellner, J. (2014). *A framework for the evaluation of anthropogenic resources: the case study of phosphorus stocks in Austria.* Journal of Cleaner Production. **84**(0): p. 368-381.

16. ECE (2017). Report of Expert Group on Resource Classification (ECE/ENERGY/GE.3/2017/2). Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc8_apr_2017/ece.energy.ge.3.2017.2_e.pdf.

17. Primrose, J. (2017). *G Axis Review Working Group: Progress Report*. Eighth session of the Expert Group on Resource Classification, 25.-28. April 2017, Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc8_apr_2017/26_April/8-James-Primrose-G-Axis-Review.pdf.

18. ECE (2017). Draft guidance on accommodating environmental and social considerations in the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (ECE/Energy/GE.3/2017/6). United Nations Economic Commission for Europe (ECE). Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc8_apr_2017/ECE.ENEGRY.GE.3.2017.6_EN.pdf.

19. ECE (2017). Draft guidance on accommodating environmental and social considerations in the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009: Concepts and Terminology (ECE/Energy/GE.3/2017/7). United Nations Economic Commission for Europe (ECE). Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc8_apr_2017/ECE.ENERGY.GE.3.2017-7_e.pdf.

20. ECE (2017). Work Plan for the Expert Group on Resource Classification for 2018-2019 (ECE/ENERGY/GE.3/2017/2/Add.1). United Nations Economic Commission for Europe (ECE). Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc8_apr_2017/ece.energy.ge.3.2017.2.Add1_e.pdf.

21. SPE, AAPG, WPC and SPEE (2007). Petroleum Resources Management System (PRMS). Society of Petroleum Engineers (SPE) - American Association of Petroleum Geologists (AAPG) - World Petroleum Council (WPC) - Society of Petroleum Evaluation Engineers (SPEE).

22. United Nations, European Commission, Food and Agriculture Organization of the United Nations, International Monetary Fund, Organisation for Economic Co-operation and Development (OECD) and The World Bank (2014). System of Environmental-Economic Accounting 2012: Central Framework. United Nations. New York. Retrieved from: https://unstats.un.org/unsd/envaccounting/seearev/seea_cf_final_en.pdf.

23. Eurostat (2013). *Manual on waste statistics: A handbook for data collection on waste generation and treatment* Publications Office of the European Union. Luxembourg. Retrieved from: http://ec.europa.eu/eurostat/documents/3859598/5926045/KS-RA-13-015-EN.PDF/055ad62c-347b-4315-9faa-0a1ebcb1313e.

24. ECE (2017). Guidance Note to support the United Nations Framework Classification for Resources Specification for Evaluator Qualifications. Geneva. Retrieved from:

https://www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/UNFC-Guidance-Notes/Revised_UNFC_Guidance_Note_to_support_UNFC_Specification_for_Evaluator_Qualifications.pdf.

25. Winterstetter, A. (2016). *Mines of Tomorrow. Evaluating and Classifying Anthropogenic Resources: A New Methodology*, PhD Thesis. Technische Universität Wien. Retrieved from: http://repositum.tuwien.ac.at/obvutwhs/download/pdf/1484101?originalFilename=true.

26. Winterstetter, A., Laner, D., Rechberger, H., Fellner, J., Stiftner, R. and Weber, L. (2015). *United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources - How do anthropogenic resources fit in?* in *6th Expert Group Meeting on Resource Classification*. 28 April - 1 May 2015. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pdfs/egrc/egrc6_apr2015/UNFC_Anthropogenic.Resources.pdf.

27. Winterstetter, A. and Fellner, J. (2015). *Classification of Anthropogenic Resources*. Expert Group on Resource Classification, 6th Session, 28. April - 1. May 2015, Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc6_apr2015/30_April/11_Wiintersletter.Fellner.AnthropRes.pdf.

28. ECE (2015). Report of the Expert Group on Resource Classification (ECE/ENERGY/GE.3/2015/2). Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pdfs/egrc/egrc6_apr2015/ECE.ENERGY.GE.3.2015.2_e.pdf.

29. Winterstetter, A., Laner, D., Rechberger, H. and Fellner, J. (2016). *Integrating Anthropogenic Resources into UNFC-2009: Update on Case studies*. Expert Group on Resource Classification, 7th Session, 26.-29. April 2016, Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc7_apr2016/28_April/11_Winterstetter.pdf.

30. Kral, U., Heuss-Aßbichler, S. and Simoni, M. (2016). *Towards a Classification System for Anthropogenic Raw Materials*. Expert Group on Resource Classification, 7th Session, 26.-29. April 2016, Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc7_apr2016/28_April/11_Ulrich.pdf.

31. ECE (2016). Report of the Expert Group on Resource Classification [ECE/ENERGY/GE.3/2016/2]. Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pdfs/egrc/egrc7_apr2016/ECE.ENERGY.GE.3.2016.2_e.pdf.

32. Simoni, M., Heuss-Aßbichler, S. and Kral, U. (2016). *Workshop on "Opportunities and Challenges for the Classification & Reporting of Anthropogenic Resources" (Book of Abstracts)*. COST Action Mining the European Anthroposphere. Retrieved from: http://www.minea-network.eu/upload/1_BookofAbstracts.pdf.

33. Heuss-Aßbichler, S. (2017). *Update on the application of UNFC-2009 to Anthropogenic resources (EGRC-8/2017/INF.7)*. Expert Group on Resource Classification, 8th Session, 25. - 28. April 2017, Geneva. Retrieved from: https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc8_apr_2017/27_April/07-Soraya-Heuss-Assbichler.pdf.

Annex I

Terms from UNFC and their interpretation in the context of Anthropogenic Resources

ECE (2013). United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 incorporating Specifications for its Application. ECE Energy Series No. 42.	*Interpretation in context of Anthropogenic Resources*
Geological knowledge	Level of confidence in the potential recoverability of the quantities When applied to Anthropogenic Materials, the G axis should be understood to reflect the "level of confidence in the potential recoverability of the quantities", which might require a multi-disciplinary approach. Thus, the G axis categories are intended to reflect all significant uncertainties impacting the estimated Anthropogenic Material quantities that are forecasted to be sourced or not sourced by the Project. Uncertainties refer to all parameters that influence both variability in the Anthropogenic Material Source and the efficiency of the recovery and conversion methodology (where relevant).
Mining (the geosphere) Not defined explicitly.	**Mining** (the anthroposphere) Sourcing quantities of Anthropogenic Material from Anthropogenic Material Sources. The term "sourcing" is equivalent to "production" or "recovery", commonly used for petroleum projects. It includes diverse activities for waste "re-use", "preparing for re-use", "recycling", "recovery" and "disposal". The latter terms are used by the EU Waste Directive 2008/98/EC [11], and guidance on their interpretation is given in [12]. "Sourcing" implies the overall process of converting quantities from an Anthropogenic Material Source into Anthropogenic Material Products.
Exploration Project A Project that is associated with one or more Potential Deposits (as defined below).	**Exploration Project** A Project that is associated with one or more Potential Anthropogenic Material Sources (as defined below).
Known deposit A deposit that has been demonstrated to exist by direct evidence. More detailed specifications can be found in relevant commodity- specific Aligned Systems.	**Known Anthropogenic Material Source** An Anthropogenic Material Source that has been demonstrated to exist by direct evidence. More detailed specifications can be found in relevant commodity- specific Aligned Systems.

ECE (2013). United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 incorporating Specifications for its Application. ECE Energy Series No. 42.	*Interpretation in context of Anthropogenic Resources*
Potential deposit	**Potential Anthropogenic Material Source**
A deposit that has not yet been demonstrated to exist by direct evidence (e.g. drilling and/or sampling), but is assessed as potentially existing based primarily on indirect evidence (e.g. surface or airborne geophysical measurements). More detailed specifications can be found in relevant commodity-specific Aligned Systems.	An Anthropogenic Material Source that has not yet been demonstrated to exist by direct evidence (e.g. sampling), but is assessed as potentially existing based primarily on indirect evidence (e.g. aerial and satellite photograph, indirect estimations based on statistics and proxy indicators, dynamic material flow analysis). It also includes material quantities that are assumed to become available in the project lifetime, but that are not yet observable in the Anthropogenic Material Stock.
Category	No interpretation needed.
Primary basis for classification using each of the three fundamental Criteria of economic and social viability (related Categories being E1, E2, and E3), field Project status and feasibility (related Categories being F1, F2, F3 and F4), and geological knowledge (related Categories being G1, G2, G3 and G4). Definitions of Categories are provided in Annex I to UNFC.	
Class(es)	No interpretation needed.
Primary level of resource classification resulting from the combination of a Category from each of the three Criteria (axes)	
Complementary texts	No interpretation needed.
Additional texts to provide mandatory requirements (i.e. Specifications) and further guidance regarding the application of UNFC. (This Specifications Document is an example of a complementary text.)	
Criteria	No interpretation needed.
UNFC utilizes three fundamental Criteria for reserve and resource classification: economic and social viability; field Project status and feasibility; and, geological knowledge. These Criteria are each subdivided into Categories and Sub-categories, which are then combined in the form of Classes or Sub-classes.	

ECE (2013). United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 incorporating Specifications for its Application. ECE Energy Series No. 42.	*Interpretation in context of Anthropogenic Resources*
Evaluator Person or persons, performing resource estimation and/or Classification	No interpretation needed.
Extraction	**Sourcing** Sourcing stands for obtaining material and energy quantities from Anthropogenic Material Sources under consideration of technical, legal, environmental, social and economic considerations. A sourcing operation can include re-use, preparation for re-use, recycling and recovery.
Generic Specifications Specifications (as documented in this Specifications Document) that apply to the classification of quantities of any commodity using UNFC.	No interpretation needed.
Numerical Code Numerical designation of each Class or Sub-class of resource quantity as defined by UNFC. Numerical Codes are always quoted in the same sequence (i.e. E; F; G).	No interpretation needed.
Specifications Additional details (mandatory rules) as to how a resource classification system is to be applied, supplementing the framework definitions of that system. Generic Specifications provided for the UNFC in this Specifications Document ensure clarity and comparability and are complementary to the commodity-specific requirements included in Aligned Systems, as set out in the relevant Bridging Document.	No interpretation needed.
Sub-categories Optional subdivision of Categories for each of the fundamental Criteria of economic and social viability, field Project status and feasibility, and geological knowledge. Definitions of Subcategories are provided in Annex II to UNFC.	No interpretation needed.

ECE (2013). United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 incorporating Specifications for its Application. ECE Energy Series No. 42.	*Interpretation in context of Anthropogenic Resources*
Sub-classes Optional subdivision of resource classification based on Project maturity principles resulting from the combination of Subcategories. Project maturity sub-classes are discussed further in Annex V of the Specifications Document.	No interpretation needed.
Système International d'Unités Internationally recognized system of measurement and the modern form of the metric system. Prefixes and units are created, and unit definitions are modified through international agreement as the technology of measurement progresses, and as the precision of measurements improves. Abbreviated to SI.	No interpretation needed.
UNFC United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (ECE Energy series No. 42).	No interpretation needed.

Note: Underlined text refers to Anthropogenic Resource definitions from section II.A.

Annex II

History of Development of these Specifications

1. In October 2012, the research project "Anthropogenic Resources" (funded by the Christian Doppler Association) started functioning at the Technische Universität Wien with a lifetime of six years, aiming to develop methodological fundamentals for characterizing, evaluating and classifying anthropogenic resources. The basic idea was to assess retrievable quantities from secondary sources and to contrast them to retrievable quantities from primary sources. A review of existing classification systems and discussions among the project leader Johann Fellner, PhD Candidate Andrea Winterstetter and the advisory panelist Leopold Weber [Federal Ministry of Economy, Family and Youth, Austria] resulted in the selection of the United Nations Framework Classification (UNFC) as the most appropriate tool to incorporate anthropogenic resources into an existing classification standard. From this time on, Andrea Winterstetter started to test the application of UNFC to landfill mining projects and published her thesis on the evaluation and classification of anthropogenic resources [25] as well case studies in cooperation with the Flemish Public Waste Agency of Flanders.

2. In April 2015, Johann Fellner and Andrea Winterstetter joined the 6th Session of the Expert Group on Resources Classification of the United Nations Economic Commission for Europe (ECE) and presented case studies for classifying anthropogenic materials [26, 27]. The Expert Group recommended that "the applicability of UNFC-2009 to landfill mining not be pursued at this time nor included as part of its 2016–2017 Work Plan, noting that further research is needed to define specific, quantifiable criteria for categorizing various kinds of anthropogenic resources under UNFC-2009 that would allow for fair comparisons between naturally occurring and anthropogenic resource deposits" [28]. In April 2015, Johann Fellner and Andrea Winterstetter joined the 6th Session of the Expert Group on Resources Classification of the United Nations Economic Commission for Europe (ECE) and presented case studies for classifying anthropogenic materials.

3. Based on the Expert Group recommendations and discussions on potential next steps, Helmut Rechberger [Technische Universität Wien, Austria] suggested to form a pan-European Network on urban mining and to broaden the discussion on the classification of anthropogenic resources. His team member Ulrich Kral [Technische Universität Wien, Austria] developed the proposal with the support of Jakob Lederer and Johann Fellner [Technische Universität Wien, Austria],, based on their previous research findings and experts across Europe. The submission of the proposal was supported by a network of 80 experts from 29 countries. On 30th October 2015, the proposal "Mining the European Anthroposphere" (MINEA) received a grant from COST (Cooperation in Science and Technology), which is funded under the European Research Programme Horizon 2020. According to the Memorandum of Understanding, the main aim is "to actuate the reporting of material resources/reserves in the anthroposphere". The network is tasked to coordinate ongoing research activities across Europe and to build capacities for fostering knowledge exchange and for involving relevant stakeholders.

4. On 4th March 2016, the first Management Committee (MC) Meeting of COST Action MINEA was held in Brussels. The MC appointed Ulrich Kral as Scientific Chair, Dagmar Juchelkova (Technical University of Ostrava, Czech Republic) as Vice-Chair, Mohamed Osmani (Loughborough University, United Kingdom), Teresa Carvalho (Centro de Recursos Naturais e Ambiente, Portugal) and Jakob Lederer as Leaders of the Working Groups on construction and demolition waste (WG1), landfills (WG2) and waste incineration residues (WG3). The MC appointed Soraya Heuss-Aßbichler (Ludwig-Maximilians-Universität München, Germany) as Working Group 4 (WG4) Leader on the assessment of anthropogenic resources and reserves. Mr. Mark Simoni (Norwegian Geological Survey, Norway) committed

to volunteer for strategic development and finding of experts for the WG4. The MC appointed Nemanja Stanisavljevic (University of Novi Sad, Serbia) as WG5 Leader on knowledge management and dissemination and Pedro Haro (Universidad de Sevilla, Spain) as Coordinator for Short-Term-Scientific Mission Grants.

5. In April 2016, at the 7th Session of Expert Group, Andrea Winterstetter presented challenges and potentials for integrating anthropogenic materials into UNFC [29], and Ulrich Kral introduced the pan-European expert network MINEA [30]. They invited Expert Group Members to join the network and proposed to establish a new Expert Group Working Group on Anthropogenic Resources. Among other recommendations, the Expert Group proposed to "establish a sub-group on Anthropogenic Resources with the goal to develop Specifications or Guidelines for the application of UNFC-2009 to anthropogenic resources" and that "the Bureau monitor the COST Action 'Mining the European Anthroposphere (MINEA)' Project and any implications for UNFC-2009, in particular in relation to mine tailings and provide an update to the 8th Session" [31].

6. On 6/7. October 2016, Soraya Heuss-Aßbichler, Mark Simoni, Ulrich Kral and Zoltan Horvath [Geological and Geophysical Institute of Hungary (MFGI), Hungary] organized a public Workshop on "Opportunities and Challenges of Anthropogenic Resources Classification" at the Geological and Geophysical Institute in Budapest and invited potential WG4 Members to reflect on resource assessment [32]. After two days of mutual exchange on the topic, Sigurd Heiberg (Petronavit a.s., Norway), Julian Hilton (Aleff Group, United Kingdom], Andrea Winterstetter (Flemish Institute for Technological Research (VITO), Belgium), Daniel Müller (Norwegian University of Science and Technology, Norway), Mark Howson (Pan European Mineral Reserves and Resource Reporting (PERC)), Katalin Sari (MFGI, Hungary), Julia Stegemann (University College London (UCL), United Kingdom) and Dominic Wittmer (EC Joint Research Center Ispra, Italy) volunteered to become WG4 Members. The WG4 followed a proposal from Sigurd Heiberg according to which the start for the development of Draft Specifications in alignment with UNFC and Pan European Resource Classification (PERC) should be done as soon as possible and to provide it for discussion among ECE and non-ECE member States. The intention was to establish the Specifications with terms, definitions and rules for application in a first step, to develop case studies in a second step and to revise the Specifications, based on case study findings, over time.

7. From October 2016 to February 2017, Ulrich Kral, Soraya Heuss-Aßbichler and Mark Simoni developed the *Initial Draft Specifications* to apply UNFC to Anthropogenic Resources. In a first step, the Specifications built on prior Renewable Energy Specifications and aligned terms and definitions with common terminology in the waste and resource sector.

8. On 23 February 2017, the 2nd MINEA MC Meeting and WG1-5 Meetings took place at the Slovenian Geological Survey in Ljubljana. During a plenary Workshop, the *Initial Draft Specifications* were presented and the framework, terms and definitions were discussed among all WG1-5 Members. Comments from each WG were incorporated into the *Initial Draft Specifications*. In addition, a breakout session was dedicated to mapping the benefits and barriers of anthropogenic resource classification. At the same time, MINEA WG2 was divided into two subgroups. Joakim Krook [Linköping University, Sweden] took the lead on the resource potential of waste in landfills and Teresa Carvalho on residues from extractive industries and mine tailings. The WG4 elected new Members, namely Felix Müller [Environmental Federal Agency, Germany], Sandra Müller and Patrick Wäger [Swiss Federal Laboratories for Materials Science and Technology (EMPA), Switzerland].

9. In March 2017, the *Initial Draft Specifications* were submitted to the Technical Advisory Group for review and presented as unofficial room document (EGRC-8/2017/INF.7) at the 8th Expert Group on Resource Classification Session in April 2017 [16]. Soraya Heuss-Aßbichler provided an update on the development of the *Initial Draft Specifications* [33]. The Expert Group Bureau elected Ulrich Kral to represent the anthropogenic resource sector in his

role as Expert Group Bureau Vice-Chair and as Leader of the Expert Group Working Group on Anthropogenic Resources , which was founded with the following Members: Soraya Heuss-Aßbichler, Sigurd Heiberg, Julian Hilton, Mark Howson, Zoltan Horvath, Ulrich Kral, Daniel Müller, Felix Müller, Sandra Müller, Mark Simoni, Julia Stegemann, Katalin Szabo, Patrick Wäger, Andrea Winterstetter and Dominic Wittmer. Finally, the Expert Group requested the Working Group on Anthropogenic Resources to "prepare draft specifications for the application of UNFC to anthropogenic resources for review at the 9th Session".

10. In March 2017, the *Initial Draft Specifications* were submitted to the Technical Advisory Group for review, and the Expert Group was updated with ongoing work at the 8th Session in April 2017.

11. On 20 July 2017, the Working Group on Anthropogenic Resources submitted a revised version of the *Initial Draft Specifications* to the Technical Advisory Group, which approved the document for public review. The public review was organized by ECE and lasted from 14 August 2017 to 12 October 2017. During this period, 20 commentators provided 245 comments in total. Sandra Müller and Ulrich Kral compiled all comments and produced a "Reviewer comment table".

12. On 16/17 November 2017, a resolution meeting for incorporating the comments was held at Evangelische Akademie Tutzing, Germany. The Working Group on Anthropogenic Resources appointed Ulrich Kral, Soraya Heuss-Aßbichler, Mohamed Osmani and Andrea Winterstetter to consolidate all comments (with and without resolutions) and to develop *Final Draft Specifications*, which will be available for final review by the Working Group on Anthropogenic Resources Members prior to its submission to the Technical Advisory Group in mid-February 2018. Technical Advisory Group comments were addressed in the *Final Draft Specifications* which were submitted to the Expert Group Bureau together with the *Respond to public comments of Draft Specifications for the application of the United Nations Framework Classification for Resources (UNFC) to Anthropogenic Resource*s in mid-March 2018.

13. The *Final Draft Specifications* will be presented at the Expert Group on Resource Classification 9th Session on 25-27. April 2018 in conjunction with a request for endorsement by the ECE Committee on Sustainable Energy.