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**Application of the United Nations Framework Classification for Resources (UNFC) in different geographical contexts.**

### **United Nations Framework Classification for Resources Case Studies from Finland/Estland, Sweden and Norway – Nordkalk limestone and Forsand sand and gravel mines**

**Prepared by the Geological Survey of Norway, the Geological Survey of Sweden, Nordkalk, Forsand Sandkompani and Petronavit a.s.**

#### *Summary*

This study demonstrates how the United Nations Framework Classification for Resources (UNFC) is being used to classify industrial mineral extraction projects for limestone in Estland and Sweden, and for a gravel and sand project in Norway. The report summarizes the main features of UNFC before describing the Nordkalk limestone projects. These projects demonstrate the usefulness of UNFC in categorizing environmental, social economic conditions and technical feasibility that may facilitate or hamper project development. The gravel and sand project demonstrates the use of UNFC in a case with few complications. This also shows an accounting method based on a standard that is common in national statistics as well as in project management. The gravel and sand case is also used to show how a UNFC inventory built with respect for the quality requirements embedded in the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) may be translated into a CRIRSCO inventory. This allows for new UNFC accounts to be compared with existing CRIRSCO accounts and thus prevents a break in the records when going from a CRIRSCO standard to the UNFC standard



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2. The report has been prepared as a result of cooperation between the Geological Survey of Norway (NGU), the Geological Survey of Sweden (SGU), Nordkalk, Forsand Sandkompani and Petronavit a.s..
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4. The contributions were as follows:
  - Nordkalk: The Karinu Case Study
  - SGU and Nordkalk: The Bunge Case Study
  - NGU, Forsand Sandkompani and Petronavit a.s.: The Forsand Case Study
  - Petronavit a.s.: Coordination of the case studies.

## II. Introduction

5. The United Nations Framework Classification for Resources (UNFC) (1)<sup>1</sup> has been developed for projects producing minerals, oil and gas, and renewable energy, as well as for underground storage, and anthropogenic resources. Groundwater is currently being added to the suite of resources to which UNFC applies. UNFC is a tool for policy formulation, government resource management, industry business process management and capital allocation.
6. In this report, the application of UNFC to the mining of industrial minerals demonstrates the simplicity and usefulness with which UNFC reflects the processes that form the mining projects. The report documents the principles at work in the cases presented. It does not necessarily reflect accurate estimates of the project quantities.
7. Mining on land often requires consideration of competing interests for land, water and other environmental resources handled through legal and regulatory framework conditions. Two limestone projects, the Karinu project in Estland and the Bunge project in Sweden, demonstrate how these environmental, social and economic conditions have been considered for reaching decisions to carry out mining or not and how UNFC reflects them.
8. The Forsand gravel and sand project documented here, shows how UNFC reflects an ongoing operation in a straightforward manner.
9. Many who wish to apply UNFC may be concerned that changing their reporting standard will create an undesirable break in the records. This can easily be avoided. The Forsand case demonstrates how the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) inventories may be generated more or less directly from UNFC inventories provided that both have been generated with the same professional diligence. In conclusion, the report highlights the advantages of UNFC.

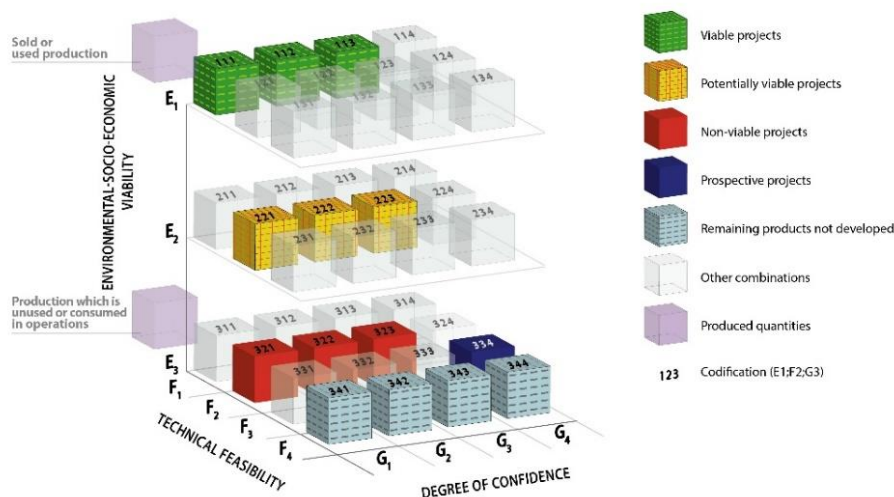
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<sup>1</sup> Numbers in parenthesis refer to references in the bibliography.

### III. Main features of UNFC

10. UNFC is a classification of projects and is based upon the three criteria of Environmental-Socio-Economic Viability (E), Technical Feasibility (F) and Degree of Confidence (G). Full details are given in (1) and the essential elements are depicted in Figure I.

Figure I  
UNFC Categories and Example Classes



11. In brief, UNFC works as follows for extractive activities:

(a) There is a source of material for future production. Before a project is conceived, the quantities that form the source are categorized as E3<sup>2</sup> and F4.<sup>3</sup> The confidence in the estimates is reflected in the range of quantities where G1<sup>4</sup> holds the low estimates, G1+G2<sup>5</sup> (in this report sometimes called 2G) the expected values or mean estimates and G1+G2+G3<sup>6</sup> (3G) the high estimates. This can also be communicated incrementally where G1 reflects estimates with a high level of confidence, G2 a moderate level of confidence and G3 a low level of confidence. G4<sup>7</sup> is used for prospects where there is a probability of less than 1 that a source exists at all.

(b) Once a project is conceived, it will be given an E Category reflecting its environmental and socio-economic maturity. It will also be given an F Category reflecting how far the project is matured technically, from early studies to production and abandonment. Two sets of produced quantities are reflected:

(i) Quantities delivered outside the project for sale or use. These quantities are produced from the class defined by Categories E1,<sup>8</sup> F1.<sup>9</sup>

<sup>2</sup> E3: Development and operation are not expected to become environmentally-socially-economically viable in the foreseeable future or evaluation is at too early a stage to determine environmental-socio-economic viability.

<sup>3</sup> F4: Technical feasibility of a development project cannot be evaluated due to limited data.

<sup>4</sup> G1: Product quantity associated with a project that can be estimated with a high level of confidence.

<sup>5</sup> G2: Product quantity associated with a project that can be estimated with a moderate level of confidence.

<sup>6</sup> G3: Product quantity associated with a project that can be estimated with a low level of confidence.

<sup>7</sup> G4: Product quantity associated with a Prospective Project, estimated primarily on indirect evidence.

<sup>8</sup> E1: Development and operation are confirmed to be environmentally-socially-economically viable.

<sup>9</sup> F1: Technical feasibility of a development project has been confirmed.

(ii) Quantities not delivered from the project and either not used, as is the case with mine tailings and flared gas or used in operations as is the case with quantities used for site remediation and fuel gas. These quantities are delivered from the class E3.1<sup>10</sup>F1.

(c) Material balance is preserved, so unless there is a re-evaluation of the initial product quantities not developed by identified projects (initial quantities in place) the sum of the quantities produced, remaining to be produced by projects and remaining products not developed from identified projects will be constant.

12. This brief summary is no substitute for the full description of UNFC where the granularity and definitions are precisely defined.

13. UNFC is a classification of projects, including their source material. When an inventory of the quantities associated with the projects is made, it is often convenient or necessary to also produce an inventory of the asset quantities for one or more stakeholders. An asset is the legal rights to the project that a stakeholder holds (2). When it comes to mineral quantities there may be only one stakeholder, or several in partnership or as royalty holders etc. The legal rights define the division of cash flows between stakeholders. In these analyses, the government will always be a holder of the asset through the legal rights it holds to the project or cash flows through the fiscal system and otherwise. This report is primarily concerned with projects. Assets will require a separate elaboration.

## IV. The Nordkalk limestone objects

### A. Nordkalk

14. Nordkalk Corp. is a North European limestone company and a fully owned subsidiary of the private family owned Rettig Group. Nordkalk is active in the Nordic countries, as well as in Turkey and Ukraine. The company is operating more than 20 limestone extraction sites. As the company is not listed, there is as such not a requirement to publish public records of the minerals assets. Due to the size of the company, it is still appropriate to keep asset records based on some recognized classification system. The widely used CRIRSCO standards are common within the metal ores resource reporting where there is a clear need to convince external financiers of the accurate assessment of the mineral asset and the true value of the ore deposit. In the operational environment in which Nordkalk is active, it has often turned out that the main challenges are related to access to land be it land purchasing issues or environmental permit related issues. This is described in general terms in a guidance document for Finland, Norway and Sweden (See<sup>11</sup> (3) (4)). In some countries the limestone mineral permits are regulated under the Environmental Act and not under the Minerals Act. Usually an industrial minerals mineralization may be verified more easily on a visual basis and with more limited geological investigations compared to a metal ore deposit where the content of the value minerals may be very low. An industrial minerals deposit usually includes a minor part of impurities. For the above reasons, the conclusion was made by Nordkalk that UNFC and its three-dimensional evaluation suits the company quite well and better than the CRIRSCO family of standards.

15. UNFC classification is now the basis for evaluation of the Nordkalk assets. The Environmental-Socio-Economic Viability Category E is mainly used to describe the permit issues and the status of the different required permits. Typically, this is about acquiring an environmental permit or a mining permit, depending on the local legislation, but it may also be about changing the land use status or a separate forest permit. This parameter is the most volatile and may change frequently over time. The Technical Feasibility and Maturity of the F Categories reflect the operational status; this is often associated with capex requirements

<sup>10</sup> E3.1: Estimate of product that is forecast to be developed, but which will be unused or consumed in operations.

<sup>11</sup> <http://resource.sgu.se/produkter/regeringsrapporter/2017/RR1713.pdf>

such as land purchasing<sup>12</sup>, big overburden removals or comparable infrastructure efforts. The land purchasing issues are quite common as the framework conditions for the permits, and usually cause a demand for buying the land prior to getting access to it. The third dimension (G axis), concerning the Degree of Confidence is, for the source of products the easiest to control. Nordkalk is for the most part operating in active quarry sites and even in the case of a new deposit or a new part of a known deposit the Degree of Confidence is controlled by the company internal decisions with respect to investing in information. This is done to the extent that the information holds value, i.e. provides a value to decisions exceeding the cost of the information. In some cases, new investigations will require an exploration permit and then the permit issuers may require investments in information. Barriers to progress in this regard will be reflected by the E-axis categorisation.

16. Industrial minerals deposits though having more or less economic value mineralization throughout the deposit, usually have spatial quality variations, due to the geological history of formation. It may be related to the stratigraphy and quality variations in different layers, it may be some kind of zoning phenomenon related to metamorphism or it may be about variations and disruptions related to tectonic causes. The quality variation is sometimes quite significant and must be considered in the resource evaluation. Parts of the deposit may yield products with a clear customer demand in the market whereas other parts may hold lower value minerals that lack a clear demand and customer base for the time being. These issues may change over time. New demand may occur in the market for qualities with different specifications. Sometimes the supplied quality doesn't meet the market demand anymore and the sales are fading away. When UNFC is applied in Nordkalk, this issue is solved by dividing the resource evaluation into different groups where there is a significant quality issue to be considered.

17. Another input to categorisation is obviously the permitting status. There are usually different generations of permits in the same deposit. Due to expansions or other reasons some parts may be fully permitted and some other parts may be under development and in a different phase of the permit process. Areas with such differences are also separated into different groups in the internal UNFC classification. A map is then very useful as a means of visualization of the separated subareas. The different aspects of subdivisions into separate quality volumes and different permit areas are demonstrated in the following case in one of the Nordkalk (Karinu) limestone deposits. This deposit is not one of the larger ones which the company is exploiting, but it is very suitable for demonstrating the application of the UNFC methodology due to the aspects mentioned above.

18. Based on earlier reporting of the geological deposits, the company has chosen to proceed with a two-fold reporting structure. For each deposit a basic template is used, with the static general and permit information on the deposit. Then a part is introduced which holds the product quantities, their UNFC coding and related information. This is accompanied by short explanatory texts.

19. The significance of the UNFC E Categories is well demonstrated in a separate case called Bunge which was quite extraordinary as a permit process. The permit application was launched in 2006 and the land was turned into a protected area in 2015 and made inaccessible. The permit process finally came to an end and a negative outcome in 2018-2019.

## **B. The Karinu Projects**

20. The commodity of the Karinu Projects is a very thin layer of useful mineral raw-material (limestone). The thickness is less than 10 metres across the open pit area. For this reason, all of the source material within the border of the permits can be extracted. In other cases, with thick deposits where surface mining requires the construction of multiple benches, an unused quantity in the benches would remain. These quantities are defined by the stepwise bench profile resulting in an overall slope angle required by local mining regulations and

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<sup>12</sup> It is debatable whether land purchasing should be reflected by the E or F Categories. Here it is judged that the land purchasing operation is an F Category issue, while financing it would be an E Category issue on par with the financing of other operations.

safety measures. Usually this unused mineral source is not calculated as it is not within the extractable part. UNFC allows remaining products from such an unused source to be reported with the code E3F4 and G1 to G3 depending on the investigations.

21. For each of the active deposits Nordkalk has chosen to report the general and permit related information which describes the main features of the cases as shown in Table 1. These descriptions are complemented by the actual UNFC report.

Table 1

**General and permit process information**

<b>Karinu Deposit</b>		<b>Photograph</b>
		
<b>Basic data</b>	<ul style="list-style-type: none"> <li>- Reported by</li> <li>- Location, parish</li> <li>- License</li> <li>- Personnel in charge</li> </ul>	
<b>Customer segment base. Quality.</b>	Who are the customers that are using this stone?	
<b>Secondary materials and commercialization aspects</b>	What secondary rocks are mined or is the overburden of useful quality?	
<b>Mining aspects</b>	Special mining features.	
<b>Challenges and focus areas</b>	What kind of developments actions are foreseen: (i) in the budget period; and (ii) in a strategic perspective.	
<b>Development comments</b>	Long term plans and prospecting plans, etc.	
<b>Geology, main features</b>	<p>Outlines and main features of the deposit geology:</p> <p>Silurian, almost horizontal beds with the Karinu layer on top and Tammiku layer beneath. The Kamariku layer is c. 0.5m thick with a violet-brownish colour. It commonly contains stromatoporoids and iron oxides. Some clay minerals and sulphides may occur and it is of lower quality than the Tammiku layer below. The Tammiku layer has a lighter brownish-greyish colour and consists of a large degree of pentameride shells with a binding material consisting of carbonate or clay. The amount of clay and MgO is increasing downwards. According to Kristina Ojamäe's MSc thesis, dolomitization commonly occurs in fractures and two N-S trending fractures.</p>	
<b>Historical aspects</b>	<p>The Rakke lime factory has been in use since 1910 (shaft kiln). In the beginning the kilns were supplied with limestone from the nearby quarry (Kamariku). In 1950's 4 new shaft kilns were erected (not in use anymore except for drying of filler raw material). In 1988 two new shaft kilns were built that were in use only a couple of years. Since 1913, raw material from the Karinu quarry has been transported to a kiln in Tamsalu. From 1984-1995, rocks were transported both from Kamariku and Karinu to Rakke. Today, Rakke raw material comes from Karinu some 25km distance away. In Rakke the shaft kilns were refurbished in 2010-2011 and put on stream. Now, however only one kiln is in use. The Kamariku quarry is being reclaimed.</p>	

## C. The projects

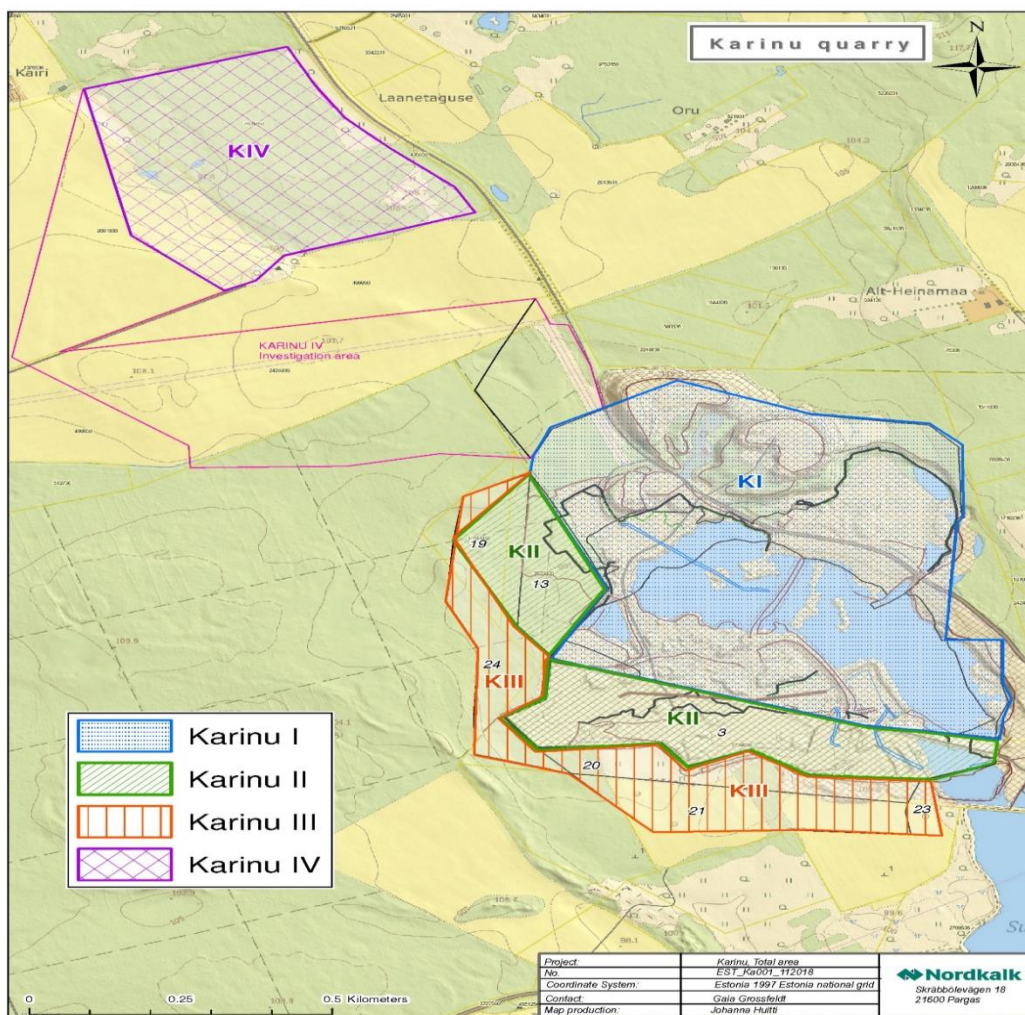
22. There are four Karinu domains or projects, called Karinu I, Karinu II, Karinu III and Karinu IV. They are shown on the map in Figure II. These separate domains reflect the development stages of the mineral resource and the permitting phases.

23. The projects produce two products based on the commercial demand for the limestone:

- (a) **Good** quality commercial limestone;
- (b) **High MgO** (magnesium oxide) limestone of partially non-commercial quality. This quality is coming to use but it must be blended and balanced with good quality stone or upgraded with an external resource.

Figure II

**Map showing the four different Karinu domains K I, K II, K III, K IV**



### 1. Karinu I (K I)

24. For assessment of quantities in the oldest Karinu I project this corresponds to 2G, i.e. (G1+G2).

25. There are no obstacles in the environmental and socio-economic domains as all permits are in place, the economics are satisfactory and the stakeholders are determined to proceed. The project is therefore categorized as E1. The geological investigation permit is valid and the prospecting works are done. The confidence level is considered 2G as noted above. The project is not yet prepared for production technically. Better understanding of the

MgO distribution is required. Also, further definition of the need to remove a surplus pile is required. The technical feasibility is therefore F2.<sup>13</sup>

26. From earlier operations, a pile of fine undersize material has been extracted and stored as it could not be used. In the UNFC inventory this would appear as production which is unused. If the initiative is taken to shape a project to use it, then this material would be a source for that project. At present it is therefore categorised as E3F4. If similar material is expected to be produced in future operations, this would be categorised as E3.1 and with the F Category of the project that is expected to produce it.

## **2. Karinu II**

27. The assessments of Karinu II provide quantities in Category 2G, i.e. G1+G2. The G1 (low estimate) is clearly not zero but investments in determining it have not been incurred as this information will not impact decisions and therefore is not of value.

28. Based on the local regulations, the drill holes are located at the outer borderlines and corners of each separate permit area. At each drilling point there is a G1 level of confidence.

29. The same two quality categories are present here as in the rest of the deposit. This domain is within existing permits and thus in the Category E1. The production is ongoing in this domain. The technical feasibility is therefore F1. Future production and use of the high MgO part of the resource which is accounted for separately is assigned the F2 Category as there are unresolved cost issues related to the externally-sourced blending material and upgrading of the quality that will need to be resolved before the layer containing this quality is mined. When resolved, this future production will be categorised E1F1 if it will be used and E3.1F1 if not. The confidence Category may be considered to be G1+G2, i.e. 2G.

## **3. Karinu III**

30. The Karinu III domain is the next expansion project and is now ready for exploitation to start. The quality categories are the same as above. The combined environmental and mining permit is granted and just recently the final formal change of land use purpose was approved. Thus, the E category has just progressed from E2 to E1. Technical feasibility comprises F1 for the good quality and F2 for the high MgO quality as for Karinu II. The level of confidence is 2G in this case as well.

## **4. Karinu IV**

31. This is the latest development project and is still partly in the prospecting phase or subject to ongoing evaluation and preparation for a coming permit application. As the Environmental Impact Assessment (EIA) and the permit application are still pending, the E Category is E2 in this case. The technical feasibility is considered to be conducted under the same premises as for the other Karinu projects. Due to some infrastructure issues to be taken care of, the technical feasibility is F2 at this point. A drilling programme is undertaken within the frame of the geological investigation phase. Part of the quantities is therefore estimated with a high degree of confidence meeting the criteria for categorising the quantities as G1. Due to further needs to specify the share of the good quality and the high MgO quality, the confidence is however considered to be 2G (G1+G2).

<sup>13</sup> F2: Technical feasibility of a development project is subject to further evaluation.

32. The aggregated Karinu Project is shown in Table 2.

Table 2

**The aggregated Karinu Project**

<i>Domain</i>	<i>Quality and volume (kT)</i>		<i>UNFC code</i>	<i>Coming actions</i>
Karinu I	Good	90	E1F2G1+G2	
	High MgO	420	E1F2G1+G2	
	Unsold not assessed		E3F4	Historical production of fine material.
Karinu II	Good	220	E1F1G1+G2	Extraction is in progress.
	High MgO	80	E1F2G1+G2	
Karinu III	Good	1400	E1F1G1+G2	Prepared for starting extraction.
	High MgO	350	E1F2G1+G2	
Karinu IV	Good	1900	E2F2G1+G2	Preparation of the EIA and a permit application.
	High MgO	310	E2F2G1+G2	Technical design plan. More investigation in order to add the confidence level.
Karinu	Good	3700		
<b>Total<sup>14</sup></b>	<b>High MgO</b>	<b>1200</b>		

#### D. Production which is unused or consumed in operations

33. Use of UNFC for classification may be helpful in management of all the natural resources in an extraction project over the whole life cycle. By classifying all the different resources with a UNFC code and by quantifying all the materials, useful input will be produced in line with circular economy ideas, natural resource management and in planning for the closure phase of the project.

34. The European Union (EU) Extractive Waste Directive requires Extractive Waste Management Plans to be drawn up. Overburden removal volumes and unsold volumes may be considered in the UNFC reporting as materials which will play a role in the closure of the site. The materials will be characterized mineralogically and the produced quantities will be reported. In this manner UNFC resource reporting may also be linked into the closure planning.

<sup>14</sup> In this case it is fair to assume that all projects will be progressed to production. In other cases, the aggregation may need to account for the risk that only some projects will succeed.

## E. The Bunge Case Study

35. One extraordinary and very prolonged permit process which is within the Nordkalk experience is the Bunge case study on the island of Gotland in Sweden. The Bunge limestone deposit has been designated a national interest by SGU, due to its high purity and the need for such quality of limestone for the Swedish steel industry.

36. In this case, it is clearly demonstrated how the E axis categorization in UNFC changes with time, depending on the evolving permit process. This is not a normal case but the environmental permit which is also the mining permit was processed in three different court instances. In Sweden, limestone is considered a land owner mineral which means that the permitting is not regulated within the Mining Act but through an environmental permit. It is given by the courts as regulated by the Environmental Act. Prospecting was carried out in the 1990s at the site and there was geological confidence at an early stage. In total, 238 drill holes were completed and logged, which formed the basis for the 3D model of the mineralization. The company also undertook technical planning, feasibility evaluation and concluded that it was viable to produce the limestone and therefore appropriate to apply for an environmental permit. The permit application was launched in 2006. The Bunge limestone deposit was at one stage granted a permit for 62 Mt limestone and an operating area of 170 hectares (ha). At the end of the prolonged permit process the area was finally made inaccessible by a largely new 6,540 ha nature protection area under the EU Species and Habitat Directive, a so-called Natura 2000 area in 2015. As a consequence of this development the national Supreme Court put a final end to the permit process in early 2019 and the E axis status according to UNFC dropped to the E3 Category. The journey is shown as follows:

Table 3  
Stages of the Bunge limestone deposit permit

Year	Court verdict	UNFC E Category
2008	1 <sup>st</sup> instance, application turned down.	E3
2009	2 <sup>nd</sup> instance, partial permit granted.	E2
2010	Supreme Court, sent back the case to the 1 <sup>st</sup> instance.	E2
2011	1 <sup>st</sup> instance, turned down the permit.	E3
2012	2 <sup>nd</sup> instance, permit granted.	E1
2013	Supreme Court, granted partial appeal, due to Natura 2000 evaluation. Case sent back to the 1 <sup>st</sup> instance.	E2
2014	1 <sup>st</sup> instance, permit granted. Case appealed.	E1
2015	2 <sup>nd</sup> instance trial put on hold due to new Natura 2000 proposal.	E2
2015	Swedish Government, Decision on a new Natura 2000 area.	E2
2018	2 <sup>nd</sup> instance, taking on the trial which was on hold since 2015. Permit not granted.	E3
2018	Supreme Court turned down an appeal. The 2018 verdict came into legal force.	E3
The UNFC F and G Categories were at an early stage concluded to be F2 and G1.		

37. Since this report addresses projects and not assets, the distribution of costs of this process between the public and private sector is not shown. It is clear that the costs to the private sector, in this case Nordkalk, have been significant. A part of the cost is normally transferred to the public sector, at least through reduced taxable income of the private party, in addition to the administrative costs falling to the public sector. This illustrates the economic importance of good resource management where decisions are taken at the right

time relative to investing in preparations for development. UNFC may expose how well this is done by tracking the movement of the projects through the E and F Categories.

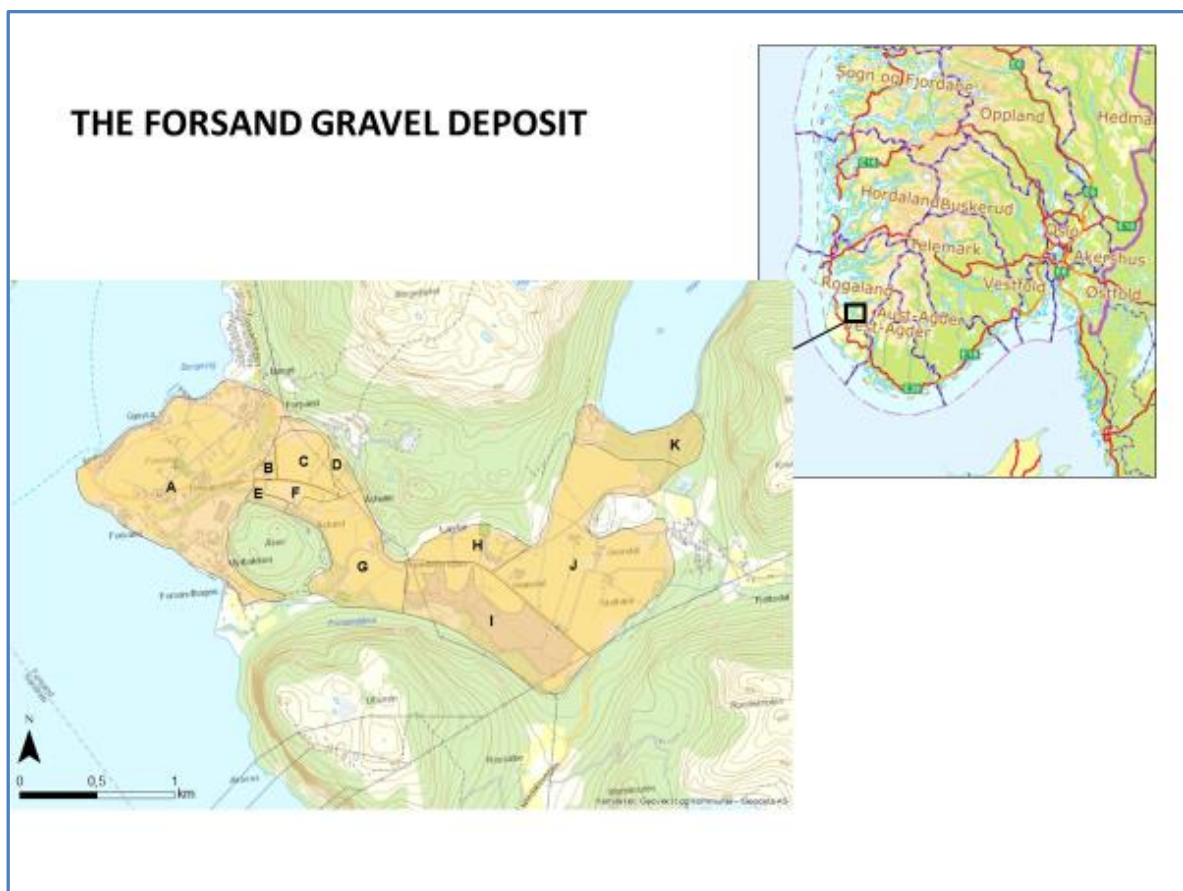
## V. The Forsand Gravel and Sand project

38. As part of the EU-funded Horizon 2000 ORAMA Project (Optimising quality of information in RAW Materials data collection across Europe), NGU carried out a pilot study on how to classify mineral resources using UNFC. One of the cases was the Forsand gravel and sand deposit at the Forsand municipality in Rogaland County in south-west Norway, where NGU has registered several large and minor gravel deposits. Information on these is kept in the NGU Gravel and Crushed Stone Resource Database. This information has been the basis for work to develop a resource management plan for construction raw material for the Ryfylke region, issued by the Rogaland County in 2013 (5). In the management plan, a regional impact assessment is included where different issues have been considered and prioritized, such as areas protected by natural diversity or cultural heritage, areas protected for agriculture or protected due to the presence of important resources. The largest deposit at Forsand, a glaciofluvial delta plain, is subdivided into zones (Figure III) where the level of conflict for future extraction of gravel and sand are identified.

39. NGU has rated the Forsand deposit of highest national interest due to the quality, (i.e. suitability for road construction and concrete production), size and marketing logistics (location).

Figure III

**Detailed map of the Forsand local community with the areas considered by NGU and classified using UNFC**



*Note: The Hestamoen area is marked 'C' on the map.*

40. NGU has used information including spatial information and metadata from various sources (data from NGU's resource database, applications to the Directorate of Mining Management (DMF) for mining concessions, local municipality area plans and the regional plan for construction raw materials resources management) in the UNFC classification to sand and gravel resource in the Forsand municipality. The areas are defined in the regional plan and are assessed one by one in the ORAMA Project.

## A. Case Study Hestamoen Locality

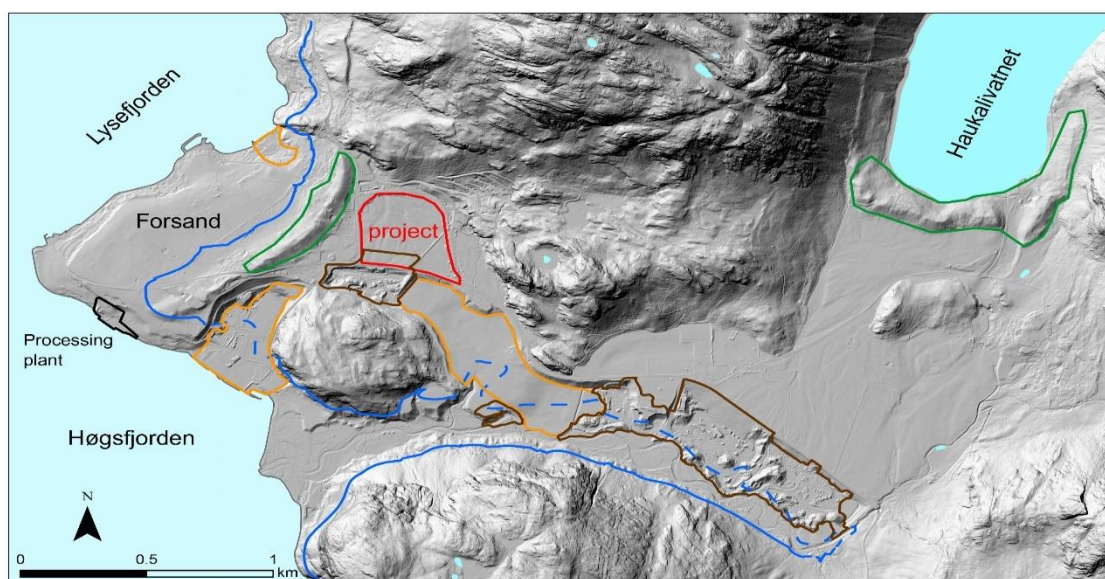
41. Hestamoen is one of the localities that NGU treated in the case study (Area C) presented in the ORAMA report (6). The mineral resource consists of glaciofluvial sediments deposited in front of terminal moraines during the deglaciation of the Fennoscandian Ice Sheet. The major part of these sediments was deposited during the so-called Younger Dryas period 12,000 years ago when the progressing sea level was approximately 33 metres above present mean sea level at the end of the period.

42. Forsand Sandkompani is a privately-owned local company founded in 1964 and operating in Forsand. The company is mining gravel and sand from several different sites at Forsand. It operates a processing plant at the seashore of Forsand. The company produces high quality concrete aggregates, special aggregates and mortar. Since it was founded, the company has produced more than 30 million tons with annual production of 0.42 million tons. The products are sold locally as well as on the national market. Some products are also exported. A large part of the production is transported in bulk by ships from the company's quay facility at the plant.

43. Forsand Sandkompani applied (April 2017) for mining concession for Hestamoen (Figure III) and has obtained the rights to mine gravel and sand from the plot. The company has entered into separate agreements with the landowners that give the company the right to mine the resource and the obligation to compensate the landowners for the amounts being mined. After the mining ends, the area must be re-established as farming land, all specified in the mining concession. The Hestamoen area is properly regulated in the municipal plans.

Figure IV

### Light Detection and Ranging (LiDAR) map of the Forsand gravel deposit



44. Figure IV shows the Light Detection and Ranging (LiDAR) map of the Forsand gravel deposit. LiDAR is a technology that is used to create high-resolution digital elevation models. The Forsand gravel deposit is bounded by two terminal moraine ridges (green lines): the Lysefjorden moraine to the west and the Vassryggen, also known as the famous Esmark

moraine, to the east. The estimated marine limit (approximately 33 m above mean sea level (amsl)) at the time of the formation of the gravel deposit (Younger Dryas) is marked with a blue line. The marine limit is reconstructed (dashed lines) from an old topographic map (M 711 Series, 1212 I Høle), published in 1967 based on air photos from 1955 before establishment of gravel pits which changed the topography significantly. Old, inactive gravel pits are indicated by the orange line and active gravel pits are depicted by the brown line. The Hestamoen project area is marked by the red line and the processing plant of the Forsand Sandkompani is indicated by black lines.

45. The Hestamoen area occupies 130,000 m<sup>2</sup> and the total volume<sup>15</sup> applied for in the mining concession is 1,300,000 m<sup>3</sup> with an annual production of 140,000 m<sup>3</sup>. The mining concession allows for out take down to 25 m amsl. The topsoil (approximately 0.5 m thick representing 66,000 m<sup>3</sup>) must be removed before the operation starts and will be reinstated when the mining operation is finished.

46. While the quantity of the gravel and sand in place is measured in m<sup>3</sup>, production is measured in tons. This is reflective of the estimation processes, where the volumes in place are easily estimated, while they change as production and sorting takes place. Extraction and production affect the degree of compaction and sorting and therefore also the volume, porosity and density. Produced quantities are measured in tons as the quantities are weighed at the reference point. The mass is unchanged. An estimate of the specific gravity of the deposit in situ allows the relation between mass and volume to be estimated. In this report we quote mass as the equivalent volumes in place using the estimated specific gravity in situ.

47. The mining operation at Hestamoen started in 2019 and about 290,000 tons have been mined. The site is close to the proximal part of the delta, which affects the properties of the sediments. The sediments from the proximal part are coarser and denser than sediments mined in distal parts of the delta. The specific gravity of the sediments in the gravel quarry is approximately 1.8 tons/m<sup>3</sup>, thus the production equals 160,000 m<sup>3</sup>.

48. To optimize the composition of the mined quantities before processing, sediments from different parts of the deposit are mixed at the sieve. The coarsest part of the sediment - boulders and stones - are crushed, treated in a drum and mixed with the rest of the sediments to reach the desired bulk composition for further processing. By sieving the sand and gravel is separated into different classes of aggregates based on the size distribution: 0 – 4 mm, 0 – 8 mm, 4 – 8 mm, 8 – 16 mm, 16 – 22 mm. In addition, sand products for special use are produced. Aggregates for mortar production is also part of the production. For simplicity, this study considers only the total production.

Figure V

#### The gravel pit at Hestamoen, Forsand



Photo: Courtesy of Per Blystad, 9 March 2020

<sup>15</sup> The volume estimate is based on more detailed studies and calculations than for the Regional resource management report as used in the NGU case study for the ORAMA project.

49. The gravel pit at Hestamoen, Forsand is shown in Figure V. Removed topsoil can be seen on the surface to the left. The sediments in the upper part (above the truck) consist of coarse sediments in parallel layers, deposited in a high energy environment.

50. The aggregates are stored in silos at the quay in the processing plant. The reference point is the conveyor belt outside the silos where the product is delivered in bulk either on trucks or on ships.

51. Classification is done by considering the Environmental-Socio-Economic Viability (E), the Technical Feasibility (F) and the Degree of Confidence (G).

52. The volumes considered are given as best estimates, hence G1+G2, here called 2G as in the Karinu case study. The bedrock topography (lower boundary of the occurrence) represents an uncertainty with respect to quantities in place where mining is not restricted by the mining permit or the ground water level. Prior mining and geophysical surveys have provided a good understanding of the distribution and quantities in place. They are considered to be recoverable. Investment in information to determine the quantities more accurately will not affect company decisions with respect to mining or commercial transactions and is therefore of no value at the moment.

53. To designate the maturity of the project and the different parts of the project, the E-F categorization is useful. The project status at different times is demonstrated by use of the matrix shown in Figures VI - IX. This accounting tool is not a part of the UNFC classification but is helpful.<sup>16</sup> It shows, in a precise manner, how new estimates relate to earlier ones. This is a common requirement in resource accounting.

54. The situation of the project at the time of application for mining concession is shown in Figure VI. The volume covered by the project, 1,300,000 m<sup>3</sup>, is the total in-place volume equivalent to 2.32 million tons. This is classified as E3.3F4, shown as the opening balance. As the area is properly regulated, all agreements with the landowners are in place, it is economic and the concession is granted, the project is classified E1.1F1.2<sup>17</sup> as shown in the NGU case study (Tom Bide, 2019). The topsoil will be removed and used for re-establishing the area for agricultural activity after the mining has ended. This part, approximately half a metre thick, estimated to be 66,000 m<sup>3</sup>, is equivalent to 0.12 million tons, is classified as E3.1F1.2.<sup>18</sup> The difference between the total resource and the part remaining in-place, is the volume assigned to the project E1.1F1.2. This is illustrated in Figure VI. Along the vertical axis are the different classes that the project will go through, as well as the sales and non-sales values. These classes are repeated on the top horizontal axis. The opening balance is the start of the project, shown at the bottom of the vertical axis to the left. The recoverable volume and the topsoil volume are entered into the input row box corresponding to the correct UNFC class shown in the top row. The closing balance of the first period is the sum of the items in each column (here there is only one item) and shown at the top row. This will then be the opening balance for the second period and entered on the vertical axis for this period.

<sup>16</sup> It builds on the Input-Output table standard from the System of National Accounts (8) and the Design Structure Matrix Methods (9) used in project management.

<sup>17</sup> F1.2: Capital funds have been committed and implementation of the development is underway

<sup>18</sup> Estimate of product that is forecast to be developed, but which will be unused or consumed in operations.

Figure VI  
The UNFC account for the first project period when the mining concession was granted

First period				Closing balance							Revisions
				Sales	Non-sales	E1.1F1.1	E1.1F1.2	E3.1F1.1	E3.1F1.2	E3.3F4	
						2G	2G	2G	2G	2G	
							2.20		0.12		
Opening balance	Sales										
	Non-sales										
	E1.1F1.1	2G									
	E1.1F1.2	2G									
	E3.1F1.1	2G									
	E3.1F1.2	2G									
	E3.3F4	2G	2.32	Input rows			2.20		0.12		

Note: Units in million tons.

55. The next step, preparing for production, starts after the mining concession is granted and is illustrated in Figure VII. The volume to be mined is moved from E1.1F1.2 to E1.1F1.1.<sup>19</sup> Hence, the non-sales production forecast attached to this project, will move from E3.1F1.2 to E3.1F1.1.

Figure VII  
The UNFC account for the second project period preparing for start of production

Second period				Closing balance							Revisions
				Sales	Non-sales	E1.1F1.1	E1.1F1.2	E3.1F1.1	E3.1F1.2	E3.3F4	
						2G	2G	2G	2G	2G	
							2.20		0.12		
Opening balance	Sales										
	Non-sales										
	E1.1F1.1	2G									
	E1.1F1.2	2G	2.20								
	E3.1F1.1	2G									
	E3.1F1.2	2G	0.12								
	E3.3F4	2G									

Note: Units in million tons.

56. The situation after one year of production is illustrated in Figure VIII. Before production starts, some of the topsoil adjacent to the production wall must be removed, approximately 16,000 m<sup>3</sup>, equals 0.03 million tons. This is recorded as non-sales and is moved from E3.1F1.1 to the non-sales box. Still there is topsoil left, 50,000 m<sup>3</sup>, equals 0.09 million tons which will be removed later when necessary. This part is carried forward in the E3.1F1.1 class.

<sup>19</sup> F1.1: Production is currently taking place.

Figure VIII

**The UNFC account for the third project period after the first year of production**

Third period 2019				Closing balance							Revisions
				Sales	Non-sales	E1.1F1.1	E1.1F1.2	E3.1F1.1	E3.1F1.2	E3.3F4	
						2G	2G	2G	2G	2G	
				0.29	0.03	1.92		0.09			
Opening balance	Sales										
	Non-sales										
	E1.1F1.1	2G	2.20	0.29		1.92					
	E1.1F1.2	2G									
	E3.1F1.1	2G	0.12		0.03			0.09			
	E3.1F1.2	2G									
	E3.3F4	2G									

Note: Units in million tons.

57. The opening balance for the next period (Year 2020) is shown in Figure IX.

Figure IX

**The opening balance for the second year of production**

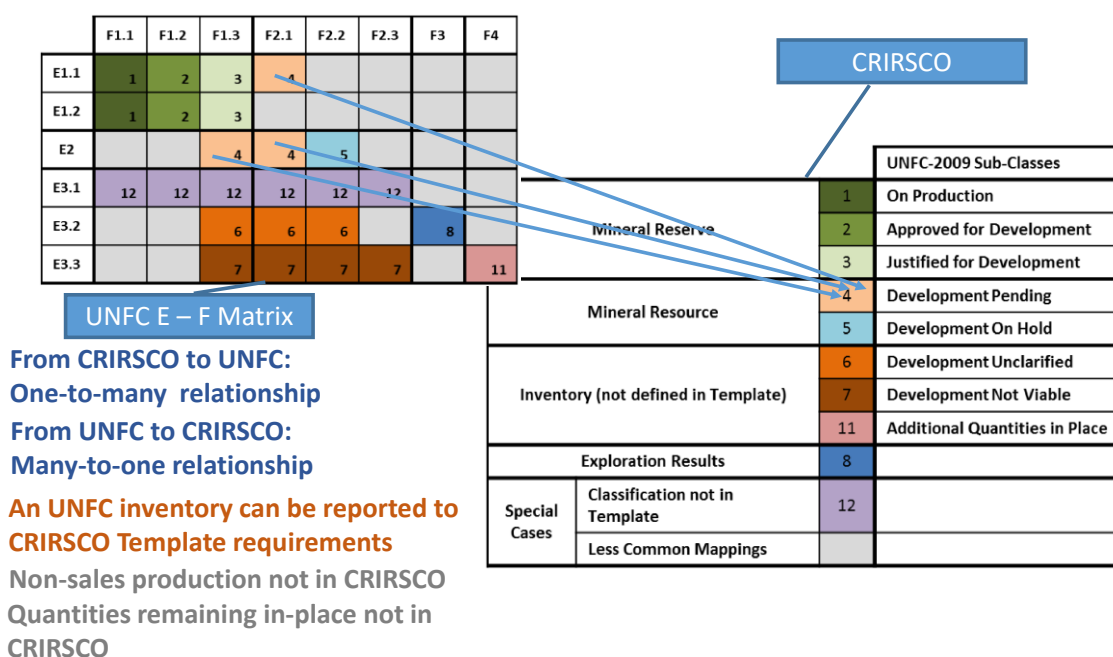
Fourth period 2020				Closing balance							Revisions
				Sales	Non-sales	E1.1F1.1	E1.1F1.2	E3.1F1.1	E3.1F1.2	E3.3F4	
						2G	2G	2G	2G	2G	
Opening balance	Sales		0.29								
	Non-sales		0.03								
	E1.1F1.1	2G	1.92								
	E1.1F1.2	2G									
	E3.1F1.1	2G	0.09								
	E3.1F1.2	2G									
	E3.3F4	2G									

Note: Units in million tons.

## VI. CRIRSCO compliance reports

58. A CRIRSCO account can be generated from the UNFC account. For CRIRSCO compliance, all the CRIRSCO requirements should be met. This document provides an overview only, demonstrating how a CRIRSCO account is easily generated. This is as shown in Figure X.

Figure X  
Detailed mapping between CRIRSCO and UNFC



59. In the case of Hestamoen projects categorised as E1F1, there is a one-to-one relationship between the accounts. All the quantities categorised as E1F1.1 will map to Mineral Reserves “On Production”. Those in E1F1.2 map to Mineral reserves approved for development. The quantities categorised as E3.1F1.1 (topsoil removed and saved for later rehabilitation) do not appear in the CRIRSCO account.

60. For proper transfer of quantities from the UNFC account to the CRIRSCO account, it is desirable to break out the 2G quantities in G1 and G2.

61. The uncertainties in quantifying the source of sand and gravel quantities are of two kinds:

- Uncertainty with respect to the topography of the underlying bedrock and thus the average thickness of the deposit;
- Uncertainty with respect to the average density of the sand and gravel in place. The poorly sorted material deposited in a high-energy sedimentation environment will have a lower porosity than the well-sorted material deposited in a low energy sedimentation environment and thus have a higher density.

62. Investing in information may reduce both uncertainties. In the Hestamoen operation, this added information will not affect any operational or commercial decisions. It will therefore not have economic value and is therefore not acquired. However, long operational experience in the area, together with some data obtained by geophysical research has allowed an estimate to be made that the G1 quantities will be roughly 80% of the 2G quantities. The uncertainty in the quantity of source material is considered to be the dominant uncertainty in this case. Uncertainties with respect to realising the production with respect to markets, cost, operational regularity, health, safety, environment etc. are estimated not to affect the aggregated uncertainty with respect to quantities eventually produced.

63. If this report had not been an illustration, but rather an operational study with access to field evidence, then the UNFC account would look as shown in Figure XI at the beginning of period 4.

Figure XI

**G1 and G2 quantities at the beginning of period 4 in million tons**

Fourth period 2020				G1	G2
Opening balance	Sales		0.29		
	Non-sales		0.03		
	E1.1F1.1	2G	1.92	1.54	0.38
	E1.1F1.2	2G			
	E3.1F1.1	2G	0.09		
	E3.1F1.2	2G			
	E3.3F4	2G			

64. Quantities are given with two significant figures as recommended by CRIRSCO and some rounding errors occur. The E1F1.1G1 quantity would translate to Proven Reserves in CRIRSCO, while the E1F1.1G2 quantity would translate to Probable Reserves. In the explanatory notes to section 30 of the CRIRSCO standards (7) the following is explained:

*“It should be noted that the Template does not imply that an economic operation should have Proved Mineral Reserves. Situations may arise where Probable Mineral Reserves alone may be sufficient to justify extraction, as for example with some alluvial tin, diamond or gold deposits.”*

65. With a basis in this statement, the 2G quantities (G1+G2) may for convenience and under the guidance to err on the conservative side, translate to Probable Reserves. This would apparently ignore the fact that proved reserves exist, as is apparent in the photograph in Figure III.

## VII. Conclusion

66. The UNFC classification is well suited to be used in assessment of industrial mineral resources. The Environmental-socio-economic axis (E) is in many cases the most important one with respect to development of the mineral source. It may concern the legal control of the land as well as the formal permit issues. This is very well reflected in the UNFC evaluation and demonstrated in the limestone mining cases.

67. In most cases it may be natural to divide the UNFC study of a mineral resource into different domains, or projects and they may be defined per permit stages and technical development depending on the local conditions. The quality aspect and the geological quality variations may dominate in the context of the commercial utilisation of the resource. The application of UNFC allows adjustments from case to case in order to cope with the quality parameter. The quality may be considered to be an additional domain which is superimposed on top of other domains.

68. It is not unusual that not all of the extracted resource can be sold and utilised. In this case the UNFC class E3.1 is useful. It is reported as a resource for potential future utilisation. The same can apply in the case of other rock types which must be removed in the mining operation but which are not the key resource in the project. Such other rock types may become a useful resource in the future.

69. Overburden removal is a routine in any surface mining operation. In most cases the overburden is not a commercial product but rather a volume of material which will be used in the restoration phase of the area. By keeping track of such volumes and giving them a UNFC code it is possible to connect the requirements of the EU Extractive Waste Directive<sup>20</sup> and the reporting of a waste handling plan. In fact, such overburden volumes may be assigned a future role in the restoration of the site.

<sup>20</sup> [https://ec.europa.eu/environment/waste/mining/call\\_for\\_input.htm](https://ec.europa.eu/environment/waste/mining/call_for_input.htm)

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