MODIFIED INDIAN STANDARD PROCEDURE FOR COAL RESOURCE ESTIMATION: 2017

1.0 Introduction:

1.1 Coal is the most abundant fossil fuel in the India. Its spatial distribution and estimation of quantity and quality is important for planning and development to meet the rapid growth of energy and other industrial requirements of the country. In 1956, the erstwhile Ministry of Production set up "Coal Council of India" (CCI) to supervise and guide the development of the coal resources of the country. CCI set up a Committee on Assessment of Resources (CAR) in 1956 and the committee drew up the "Indian Standard Procedure for Coal Reserve Estimation" (ISP) in 1957 and defined the classes of coal in India. The ISP, however, with changing and developing industrial economy, had been reviewed and modified from time to time and the last such modification attended during 2007. In 2012, Ministry of Coal decided to switch over from existing UHV based classification to the Gross Calorific Value (GCV) based classification system for grading of non-coking Indian coals. A Task Force was constituted in the 7th Meeting of CGPB Committee V during 2011 to formulate action plan for this switch over which had recommended to have a relook on the provisions of ISP to incorporate 17-fold GCV-based classification system (G1 to G17) in place of the existing 7-fold UHV-based classification system and emphasized on the need of conversion of National Inventory for coal from a UHV-based one to a GCV-based one. The issue of adopting UNFC by all exploration agencies for classifying and reporting reserve/ resource data of fossil fuels also came up for discussion in the 9th Meeting of CGPB Committee V during October 2013. Thus, there had been a long-standing need for reviewing the ISP for Coal Resource Estimation to draw criteria, definitions and guidelines required for uniform application by all. Another Task Force was constituted in the 10th Meeting of CGPB Committee V in September 2014 to revise the ISP norms in terms of newly introduced GCV based coal classification system, in tune with Geological axis of UNFC system and to finalize modus operandi for preparation of National Inventory of Coal and Lignite and to get the revised ISP norm certified from BIS.

1.2 The following modified standard procedure for coal resource estimation is intended to provide uniform criteria, terms and modalities for Geologists and Mining Engineers so that the geological and grade continuity estimate prepared in different areas of insufficient exploration and by different persons can be suitably correlated and combined. These framework guidelines are broad in nature to accommodate the wide variation of Indian coal deposits, in terms of rank, quality and geological environment and cannot be applied rigidly to all coal bearing areas and modifications within its broad framework to suit the geological features in particular areas are permissible. Wherever such modifications are made, however, proper explanation should be recorded with justification. The framework guidelines are intended for periodic review and refinement to reflect prevailing technology and economic conditions.

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1.3 The basis of estimation of all coal resources is the **Observation data** collected from outcrops, trenches, pits, workings and drill holes through geological mapping, exploratory drilling, sampling and chemical analysis carried out through appropriate techniques under regional or detailed exploration and documented in a Geological Report (GR) on Exploration. The **Interpretive Data** are observations supporting the geological continuity of coal beds, gathered by interpretive or indirect methods like downhole geophysical logs, seismic, magnetic, gravity and other geophysical and geological surveys, for increasing the confidence level. The Geological Reports must include all relevant information such as exploration context, type and method of sampling, relevant sample intervals and locations, distribution, dimensions and relative location of all relevant laboratory data, methods of analysis, data aggregation methods, land status etc that are required for an assessment.

1.4 All the latest available geological maps and data should, therefore, be used in every case without omission of relevant geological information that is known to the authors of report, for the reasonable and balanced judgement of exploration results and coal resources. If some data/information is not provided in the report, an explanation must be provided to justify its exclusion. Sufficient data should be provided in the report and the presentation should be clear to understand the report without ambiguity that is reasonably expected to be available in the report.

1.5 The Geological Report for coal blocks must be prepared/approved by suitably qualified and experienced persons or Organization recognized by a 5-member Committee of Central Geological Programming Board of GSI (having members from GSI, CMPDI, MECL, SCCL and CIMFR). The authors must provide assumptions, deviation or omission of data used in preparation of Geological Report and estimation of Coal Resources. It must clearly spell out any relevant aspect which could greatly affect the perception or value of the coal occurrence reported in GR. The report by an organization is the responsibility of the company's Board of Directors or Head of Government Organization and must reflect the information and supporting documentation prepared/approved by a Recognized Person who is a full-time employee of the company or organization. If more than one person acts as a team, clear division of responsibility within a team should be indicated.

2.0 Coal Resource Categorization:

2.1 The Working Group on Energy Policy constituted by the Planning Commission set up a Task Force on Coal in 1972 to estimate coal resource of the country following the ISP. In 1972, all these assessment were compiled by GSI and an estimate of total resources of the country was made. The estimate was incorporated in the Report of the Fuel Policy Committee (1974). The working Group also felt that the information should be updated. Accordingly, Geological Survey of India (GSI), entrusted with the responsibility of updating the National inventory for coal, brought out the coal resource inventory of the country in 1976, 1978, 1984, 1986 and annually from 1988 onwards. In recent past it was felt that for proper understanding and harmonization of Indian coal resources with International bodies, the compatibility with United Nations Framework Classification (UNFC) for Fossil Energy Mineral Reserve and Resources may be made. The adoption of modern techniques in exploration also requires modification of existing system.

2.2 In UNFC, the coal resource quantities are classified on the basis of the three fundamental criteria of - economic and social viability (E), field project status and feasibility (F), and geological knowledge (G), using a numerical coding system. Combinations of these criteria create a three-dimensional class system in order EFG e.g. 331, 332, 333, etc.. The quantities are always estimated figures associated with uncertainty in level of geological knowledge and confidence associated with any part of the deposit. This has been expressed in decreasing levels of confidence (high, moderate, low). i.e. high confidence (G1 for G axis), moderate confidence (G2 for G axis) and low confidence (G3 for G axis) and estimates based on indirect evidence (G4 for G axis).

2.3 To correlate geological knowledge of resources estimated in Geological Reports prepared according to ISP with the UNFC guidelines for fossil energy and mineral reserves and resources, following categorization of coal resources is introduced:

Existing Nomenclature	**Revised Nomenclature**	
Category	**Category**	**UNFC Class Code for GR Resource**
Proved Resource	Measured Resource	331
Indicated Resource	Indicated Resource	332
Inferred Resource	Inferred Resource	333
Prognosticated Resource*	Reconnaissance Resource*	334
** Not to be included in National Coal Resource Inventory*		

2.4 The UNFC codes adopted in above table refers to compatibility of geological knowledge of coal resources estimated in an ISP compliant Geological Report, with UNFC. The first two digits of 331 code represents E and F axis of UNFC Class code. The categorization is aimed to quantify the total amounts of coal in the ground (in-situ) at different confidence level. Normally, the persons preparing geological reports and estimating resources are not expert in the economics of mining, transportation, processing, marketing and changing economic conditions, so the quantities in E and F axis of UNFC system will not be estimated in present system and lowest confidence level of UNFC code will be assigned for E and F axis. These axes can be classified to higher level whenever such studies are carried out.

3.0 Important Terms: Different terms, used in this document, are defined below for clarity:

3.1 UNFC (United Nations Framework Classification) for Fossil Energy and Mineral Reserves and Resources: It defines that G axis designates the level of confidence in the geological knowledge and potential recoverability of the quantities. It also indicates that it is for in situ (in-place) quantities that are typically categorised discretely, where each discrete estimate reflects the level of geological knowledge and confidence associated with a specific part of the deposit. The exploration stages are categorized as G1, G2, G3 and/or G4 as appropriate.

3.2 Reconnaissance Study (G4 stage)**:** Geological knowledge-base of a coal basin is a desirable prerequisite for taking up exploration over a particular area. To begin with, preliminary studies in large and fairly-demarcated area involving methods like aerial-photographs/remote sensing, Geological mapping on about 1:25,000 scale, aerial/surface geophysical survey, etc are taken up to carve out area for prospecting/regional exploration. Any estimation of resources, if attempted, would be placed under Reconnaissance Resources category (334) through G4 stage of exploration.

3.3 Prospecting (G3 stage)**:** Large demarcated area is taken up for surface and sub-surface exploration to know the possible occurrence of feasible resources. This involves methods like Geological mapping on 1:10,000 scale, preliminary geophysical survey, drilling of boreholes at 1000m to 2000m intervals, etc to form base for regional exploration. The coal resources estimation would be categorized as Inferred Resources (333), for which the degree of confidence is considered to be less than 50%, an average value of 40% being suggested as optimum.

3.4 Regional (or Promotional Regional or General) Exploration (G2 stage)**:** Regional exploration for coal involves work components, such as, establishing disposition and structural layout of different geological formations and the stratigraphic sequence, depth of occurrence, thickness and continuity of different coal seams, determination of quality (indicated category) and assessment of coal resources on regional scale. The resources of regionally explored area will be categorized mainly (majority) as Indicated Resources (332), for which the degree of confidence is considered to be 50-80%, with an average value of 65%. Large scale geological mapping on a scale of 1:10,000 is carried out, immediately preceding and/or simultaneous with drilling where boreholes are generally placed upto 1000m apart. To understand the stratigraphic set-up of the block, at least one borehole is needed to be drilled up to the base of the coal bearing formation to the extent feasible (e.g. Talchir Formation/ Metamorphics).

3.5 Detailed Exploration (supplemented with Developmental Exploration or Production Support Drilling) (G1 stage)**:** The 'Measured' Resources (331) will be estimated only on the basis of Detailed Exploration to establish occurrence of coal with highest level of confidence, to be considered as more than 80%, with an average value of 90%. Close spaced drilling, geological mapping and geophysical survey are taken up to prepare survey and interpretive maps on 1:4000 to 1:5000 scales.

As per existing practice, during Detailed Exploration (G1 Stage) an average of 10 to 15 boreholes per sq km are being drilled for estimating proved / measured resources, for ascertaining structural complexity and incrop proving and onward mine planning. However, it is recommended to prepare an Integrated Geological Report based on drilled borehole data undertaken during Regional Exploration and interpreted 2D Seismic data before planning for detailed exploration which may reduce the borehole density (6 to 7 boreholes per sq km) for estimating proved / measured resources. This would save time and cost provided the outcome gives appropriate degree of confidence.

It has been observed that the seismic survey can be incorporated as a partial replacement of drilling only after its veracity is proved through some pilot exploration programme in different

coalfields. Difficulty of identifying thin seams and quality of coal seams is the main hindrance in adopting 2D seismic survey as a replacement for drilling. However, in such cases the thickness and quality parameters may be extrapolated from the remaining boreholes drilled within the block. Considering the cost and requirement of infrastructural facilities, deployment of 2D seismic survey may be kept optional for promising blocks during regional exploration.

3.6 In situ Coal Resource: Refers to coal found in original position in the ground.

3.7 Potential Deposit: 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 surveys).

3.8 Known Deposit: A deposit that has been demonstrated to exist by direct evidence.

3.9 Category: UNFC's 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 and F3 and geological knowledge (related Categories being G1, G2, G3 and G4). The 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.

3.10 G1 Category: UNFC indicates knowledge base of Detailed Exploration label with three dimensional delineation where quantities associated with a known deposit can be estimated with a high level of confidence.

3.11 G2 Category: UNFC indicates knowledge base of General/Regional Exploration label with initial delineation where quantities associated with a known deposit can be estimated with a moderate level of confidence.

3.12 G3 Category: UNFC indicates knowledge base of Prospecting label with systemic process of searching by narrowing down areas of promising enhanced potential where quantities associated with a known deposit can be estimated with a low level of confidence.

3.13 G4 Category: UNFC indicates knowledge base of Reconnaissance Study label where areas of enhanced mineral potential are identified on regional scale, based primarily on indirect evidence like preliminary field inspection, airborne surveys, mapping to draw geological inference and extrapolation.

3.14 Exploration results: UNFC defines that where exploration activities have taken place but are insufficiently advanced to estimate resource quantity, the generic term Exploration Results is applied. Exploration Results are insufficient to determine the volume, tonnage, grade or quality and should not be stated as Coal Resources (G4 stage of exploration).

3.15 Documentation: The exploration data, analytical tests, results and resource quantities shall be documented in sufficient detail. This will be in the form of a Geological Report.

3.16 Geological Report and Geological Note/Interim Report/Investigation Report: In a Geological Report on Exploration, the estimates of resource quantities shall be documented in sufficient detail that would allow an independent evaluator or auditor to clearly understand the basis for estimation of the reported quantities and their classification. This is an obligation for ensuring that appropriate internal documentation is generated and kept, and is not an obligation for external disclosure of such information. A document without this specification but giving other geological information about the area shall be placed as Geological Note or Investigation Report or Seasonal Interim Report.

3.17 Observation Data/Points of Observation are intersections of coal bearing strata recorded at marked locations to obtain data by observation, measurement and/or sample collection. This could be at outcrop, surface or underground working or borehole cores. All Points of Observation for coal quantity estimation may not necessarily be used for coal quality evaluation which may be carried out by testing samples obtained from surface or underground exposures, from borehole core samples having an acceptable level of recovery (normally >90 per cent). The downhole geophysical logs may be used for seam delineation in case of lower recovery. Sonic and Neutron log is supportive logs along with deviation logging in boreholes of >500m depth.

3.18 Interpretive Data are not **Points of Observation** and may increase confidence in the continuity of seams between **Points of Observation.** Geophysical methods like calibrated downhole geophysical logs (minimum suit of–Density/Gamma-Gamma, Caliper, Resistivity & Natural Gamma), seismic, resistivity profiling/sounding/imaging and magnetic, to demarcate the continuity of coal seams, fault planes and intrusive, increase the confidence level of resource assessment, indirectly through interpretation. Gravity survey will help in predicting basement of basin.

3.19 Spatial Distribution: The area of exploration (block boundary) for resource estimation should be superimposed directly on latest Survey of India Toposheet (at present WGS-84 datum plane with UTM projection system) for Geo referencing. For areal coverage in detailed exploration, coal grid (datum line modified Everest India 1956 and Lambert Conic Conformal (LCC) projection system) will be applied. Wherever coal grid is not available, the survey will be carried out in National grid or by using UTM projection system till common coal grid is developed in all areas of coal. Cardinal points of block boundary, important land marks and boreholes drilled in the block need to be surveyed and few pillars of survey stations fixed on the ground for verification of Coal Grid & WGS-84/UTM values.

3.20 Density of coal: Represent mass of coal per unit volume. The conversion of coal volume to tonnage requires knowledge of density of coal. As the data on density is sparsely available, a constant value is being adopted for different grades of Indian coal. This has been approved by Core-group of CGPB Committee-V in its meeting held on 28.02.2014.

3.21 Quality: The term indicates rank, type and grade of coal according to its properties suitable for commercial utilization.

3.22 Rank of Coal: The rank indicates classification of coals according to their degree of metamorphism and degree of coalification of plant material in coal formation. This is defined mainly by moisture and calorific value in low rank coals and mean maximum reflectance of vitrinite in higher rank coals.

3.23 Grade: Refers to commercial classification according to ash content in coking coals and GCV range in non-coking coals.

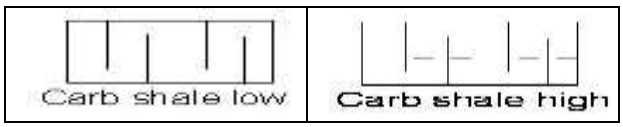
3.24 Band-by-band Analysis for Seam Delineation: Sample of solid fuel layers corresponding to lithology 'Coal', 'Shaly Coal', 'Carb Shale Low' and 'Carb Shale High' along with 'Non-combustible Band (ash+Moisture>75%) of >0.05m within seam/zone' may be separated through detailed visual logging (to the extent possible) for determination of ash & moisture by Lab (band-by-band analysis) for proximate analysis on air dried basis or as received basis. In coking coal blocks, Volatile Matter determination may also be taken up in case of de-volatized coal. The samples of litho units 'Coal', 'Shaly Coal', and 'Carb Shale Low' will be numbered as C1, C2, C3 etc. from top seam of borehole to bottom of lowermost seam whereas samples of 'Carb Shale High' and other bands (analysis of sandwiched shale band is required) will be numbered as D1, D2 etc. in similar manner, for band by band analysis by Lab.

3.25 Non-Combustible Band: The shale/sandstone etc with ash+moisture >75% of >0.05m thickness will be excluded from the seam.

3.26 Carbonaceous Shale- Low and High: The 'carbonaceous shale' as defined under old 'UHV' System of classification with 55% to 75% Ash+Moisture content will be sub-divided into:

i) Carb Shale with Ash+Moisture from of 55.1% to 65.0% will be named "Carb Shale Low"

ii) Carb Shale with 65.1% to 75.0% Ash+Moisture will be named "Carb Shale High" (Dirt Band).



3.27 Important Litho units: Coal is defined as combustible sedimentary rock formed from altered plant material in coalification process in which organic matter including residual moisture is more than 65%/60% by weight. Accordingly, the important lithounits coal, shaly coal etc. will be defined as:

Item	Name of Litho-unit	For High Moisture Coal (M%>2)	For Low Moisture Coal (M%<2)
Coaly Matter	Coal	Ash + Moisture upto 40%	Ash upto 35%
	Shaly Coal	Ash + Moisture 40.1-55.0%	Ash 35.1-50.0%
	Carbonaceous Shale Low	Ash + Moisture 55.1-65.0%	Ash 50.1-60.0%
Combustible Dirt Band	Carbonaceous Shale High	Ash + Moisture 65.1-75.0%	Ash 60.1-75.0%

Non-Combustible Dirt Band	Sand Stone, Shale, Intercalations, etc.	Ash + Moisture above 75.0% (assumed value, if analysis not available, may be taken)	Ash above 75.0% (assumed value, if analysis not available, may be taken)

3.28 Coking Coal Grades (Air dried moisture upto 2% and volatile matters usually not more than 35% on unit coal basis):

Grade	Ash %		Sp. Gravity/ Density(g/cc)
	Lower	Higher	
Steel Grade-I		Upto 15.0%	1.42
Steel Grade-II	15.1%	18.0%	1.44
Washery Grade-I	18.1%	21.0%	1.46
Washery Grade-II	21.1%	24.0%	1.50
Washery Grade-III	24.1%	28.0%	1.53
Washery Grade-IV	28.1%	35.0%	1.58
Washery Grade-V	35.1%	42.0%	Yet to be determined
Washery Grade-VI	42.1%	49.0%	Yet to be determined
Non-coking Coal	49.1%	65.0%	As applicable

Note: (1) Two new grades in the range of >35% to 42% and >42% to 49% ash are included in low moisture coking coal category as Washery Grade-V and Washery Grade-VI respectively, subject to showing coking propensity on Carbonization alone or in blends. Otherwise it is non-coking coal.

(2) Balance low moisture coal beyond 49.1% ash is non-coking coal and is to be classified according to GCV.

3.29 Semi-Caking to Weakly Caking Coal:

Grade	Ash + Moisture%		Sp. Gravity/ Density(g/cc)
	Lower	Higher	
Semi-caking-I		Upto 19%	1.44
Semi-caking-II	19.1%	24%	1.46

3.30 Non-coking Coal Grades and average density for resource estimation (air dried moisture more than 2% or volatile matters usually more than 35% on unit coal basis. Sulphur less than 1% in either case): The Ministry of Coal, GOI vide notification No.S.O.2020 (E) dated 30.12.2011 has prescribed for switching over from useful Heat value (UHV) based System of grading and pricing of non-coking coals to Gross Calorific Value (GCV) based system with effect from 01.01.2012. The Core-group of CGPB Committee-V, in its meeting held on 28.02.2014, has adopted following average density for G1-G17 grades of non-coking coal for resource estimation:

Grade	GCV (kcal/kg)	Density(gm/cc)
G1	> 7000	1.36
G2	6701 – 7000	1.40
G3	6401 – 6700	1.43
G4	6101 – 6400	1.44

G5	5801 – 6100	1.47
G6	5501 – 5800	1.50
G7	5201 – 5500	1.53
G8	4901 – 5200	1.56
G9	4601 – 4900	1.58
G10	4301 – 4600	1.61
G11	4001 – 4300	1.65
G12	3701 – 4000	1.69
G13	3401 – 3700	1.73
G14	3101 – 3400	1.78
G15	2801 – 3100	1.81
G16	2501 – 2800	1.84
G17	2201 – 2500	1.87

During detailed exploration, a minimum of 7-8 boreholes/sq.km and in regional exploration, all boreholes to be analyzed for GCV. For resource estimation, the GCV shall be determined 'in-band'.

3.32 In the absence of data on Gross Calorific Value for a particular seam and subject to availability of Moisture and Ash values of coal seams, the B.K.Mazumdar's formula can be used to arrive at the Gross Calorific Value of coal seam.

i) for high moisture (>2%) coal

Gross CV = 85.6[100-(1.1A+M)]-60M Kcal/Kg

(Note: The validity of this formula for certain data at CIMFR not found suitable)

ii) for low moisture (<2%) coal

$$\text{Gross CV} = \frac{165 \times F + 136 \times (V-0.1A) - 108 \times M}{1.8} \text{ Kcal/Kg}$$

where A = Ash%, V = Volatile Matter%, F = Fixed Carbon% .

M = Moisture% on equilibrated basis determined/calculated as per IS 1350, Part I, 1984. (Note: This formula for certain data at CIMFR found suitable)

3.33 **Moisture Content:** Content of moisture in coal expressed in percentage. Two types of moisture are found in coal, namely, free or surface moisture removed by exposure to air, and inherent moisture entrapped in the coal and removed by heating to 105^0C.

3.34 **Bed moisture/In-situ Moisture:** The percentage of moisture or water in a bed or sample of coal before mining.

3.35 **As-received basis:** Represents basis of analysis of a sample as received at a laboratory.

3.36 **60% RH & 40^0C basis:** Represents basis of analysis of a sample at 60% Relative Humidity and 40^0 C temperature.

3.37 Dry, mineral-free basis: A basis of calculated analytical value of a coal sample expressed as if the moisture and mineral matter had been removed (dmf).

3.38 Proximate analysis: A type of analysis for determination of moisture, ash, volatile matter, fixed carbon (by difference) by prescribed methods. Proximate analysis is reported by percent and on Air dried or 'Dry' or 60% RH & 40^0C basis, as per IS.

3.39 Ultimate analysis: A type of analysis for determination of carbon, hydrogen, nitrogen, oxygen(by difference) and sulfur contents by prescribed methods to report results, as per IS.

3.40 Special Tests: Tests for non-coking involves determination of Phosphorous, Ash Fusion Temperature Range, Ash Analysis, HGI, Crossing point & Ignition point temperatures, etc and for coking coal additional tests are involved like Coke Type, CSN, Fluidity, Dilation, Ro, maceral analysis, Carbonization etc. Washability Tests/Float-sink are desirable at exploration stage, to assess desired characteristics. The geological report on detailed exploration should also include sufficient geo-technical data of the overlying sub-surface strata/inter-seam partings (based on study of appropriate no. of boreholes) to enable the planners to design pit slope for OC and support design for UG mines.

3.41 Feasibility: This defines detailed study of possibility of extracting coal.

3.42 Seam: A persistent bed of coal lying between dominantly non-coaly roof and floor and occupying majority of the investigation area. (para 4.10, 4.11, 4.12)

3.43 Overburden: Rocks including insignificant coal and unconsolidated material that overlies a coal bed.

3.44 Parting: A layer of predominantly non-coal bed which may include insignificant coal if any between two seams

3.45 Metric tonne: A metric unit of weight equal to 1,000 kilograms.

3.46 Drilling: Samples of N/NQ (or B/BQ) series size to be generated through coring drilling to study the sub-surface rock types (for Physical, Mechanical & Chemical characteristics). In upper horizons, it may be of H/HQ series or P/PQ series size, whereas in deeper horizons it may be reduced to B series size, exceptionally.

3.47 Chemical/Coal Analysis: The coal beds of the block need to be analyzed in standard chemical labs for determination of moisture, ash, volatile matter, elemental composition, sulphur, phosphorous contents and coking properties tests. During detailed exploration, ash fusion temperature & composition and grindability tests are also required. All boreholes of Regional Exploration and 400m grid boreholes of Detailed Exploration need to be analyzed for Seam Overall with GCV determination. Upto 10% of such boreholes may be taken up for Ultimate Analysis, HGI, AFT & coking propensities and

2-3 boreholes per block for Ash Composition analysis in detailed exploration. For standard chemical analysis, coal sample with >90% recovery is preferred.

3.48 **Coal Zone:** A series of laterally extensive and (or) lenticular coal beds and associated strata that arbitrarily can be viewed as a unit. Generally, the coal beds in a *coal zone* are assigned to the same geologic member or formation.

3.49 **Correlation:** Demonstration of the apparent continuity of a coal bed between control, measurement, or sampling points by showing correspondence in character and stratigraphic position. Where a coal bed is continuously exposed along an outcrop or stripmine face, continuity of the coal bed becomes an established fact and not a correlation.

3.50 **Competent Person:** It is necessary that qualified, experienced and healthy geoscientists are duly tested and certified to discharge the functions of Competent Person (Geologist/Mining Geologist) for Geological Assessment of coal prospects and mines. They must possess an appropriate level of expertise and relevant experience in the estimation of quantities associated with the type of deposit under evaluation.

4.0 Data Acquisition and Criteria of Resource Categorization:

4.1 The tonnage of coal present in an area can be determined by estimating the areal extent, thickness and density of coal seams from various points of observations. For this, understanding of coal seam thickness, points of observations and density parameters of coverage area is important. The category of coal resources, thus estimated, is defined on the basis of geologic assurance associated with these categories. The geologic assurance depends on distance from the points of observation where thickness of coal & other lithologies have been measured, samples taken for laboratory tests to determine rank, thickness of seam, quality, depositional pattern and correlations of coal seams to prepare structural layout of the deposit. The areal extent, geological continuity, grade, quantity and other characteristics of a coal occurrence are studied and estimated/ interpreted from geological observations at selected points and knowledge of associated structural features. The understanding of these elements is necessary to provide the highest degree of geologic assurance. The seam thickness and location must be unambiguous. Seams covered by downhole geophysical logs in non-cored boreholes can be used for quantity estimation only. The term ‘estimated' should always be used instead of ‘calculated’ for coal resource reporting. The Coal Resources are sub-divided into Reconnaissance (334), Inferred (333), Indicated (332) and Measured (331) categories on the basis of increasing geological assurance. After deducting 10% from Gross resources, to rule out any geological surprises, Net resources would be reported. However, surprises to be recorded during actual mining to justify/rule out 10% or part of resources so deducted.

It is recommended to report net resources as 95% of gross resources, where resource estimation is assessed based on Integrated Geological Report prepared by assimilating 2D Seismic data and borehole data in Detailed Exploration (G1 Stage).

4.2 The Committee discussed the provisions regarding borehole/sample point spacing for different stages of exploration in detail and concluded that existing provisions will continue. The existing Indian practice for coal exploration, when compared with categories of UNFC system, had shown that the "Systematic Mapping" stage along with associated activities undertaken by GSI appeared to be akin to the "Reconnaissance" Stage of UNFC. The "Prospecting" and "General Exploration" stage of UNFC were not being essentially followed sequentially in India, rather they were being employed complementarily, both being covered under "Regional" exploration. "Detailed Exploration" stage of both the systems was practically identical. Thus, there are only marginal differences between the stages of exploration identified in the UNFC system and the practice in India.

4.3 **Measured Resource (331):** This has the highest degree of confidence among the geological resources, which is to be estimated over an influence area of upto 200m from the point of observation. The boreholes are to be drilled in grid pattern. Measured Resource (331) is to be estimated in G1 (Detailed) category of exploration only. In areas where seams are faulted, intruded, split, lenticular, or subject to significant variations in thickness or quality, closely spaced observation points, supported by Interpretive data like in-between non-coring/coring boreholes, down hole geophysical logging, seismic/ resistivity/ and/or magnetic survey, will be required. Geological mapping is to be carried out on 1:5000 or larger scale. This category of resources is good enough to draw a Mine Plan and Project Report on Mining and Washing plant. Minor amount of resources not fulfilling above criteria in G1 (Detailed) category of exploration, due to some constraints, to be placed in Indicated/Inferred category.

4.4 **Indicated Resource (332):** This has to be estimated over an influence area of upto 1000m from the point of observation, subject to geological evidence of continuity. While estimating such resources, care should be taken that the boreholes are usually 1 Km apart during G2 stage of exploration. Indicated Resource (332) is to be estimated, normally, in G2 (General) category of exploration and G1 category also, if required. The scale of geological mapping being 1:10000. Quality assessment is to be carried out while estimating resources from individual boreholes, supported by interpretive data, wherever required. The level of confidence for G2 (General) category of exploration should be sufficient for deciding whether a prefeasibility study and G1 (Detailed) exploration are warranted. Minor amount of resources not fulfilling above criteria in G2 (General) category of exploration, due to some constraints, to be placed in Inferred category.

4.5 **Inferred Resource (333):** Inferred Resource (333) is to be estimated in G3 (Prospecting) category of exploration, where the scale of geological mapping being 1:10,000/25,000 and while estimating such resources, care should be taken that the boreholes are usually 2 Km. The area of influence is to be considered upto 2000m from the point of observation, subject to geological evidence of continuity. However, during G2 (General) stage also, Inferred Resource (333) may be estimated, over an influence area beyond 1000m and upto 2000m from the point of observation, if some area is available beyond the indicated area within the block. In such cases, thickness

consideration may be the same as that of the indicated resource beyond which it is estimated. Inferred Resource (333) may be assessed as unclassified coal with an average density of 1.6 for non-coking coal & coking coal. The Inferred (333) resources may be continued to be classified as "Explored Inferred" resources and "Unexplored Inferred" resources based on the status of geological information. The resources estimated as 'Inferred' based on the geological mapping only are to be separately categorized as "Unexplored Inferred" resources. The level of confidence for G3 (Prospecting) category of exploration is not sufficient to allow a prefeasibility study to be carried out. Estimates for this confidence category should not forecast quality continuity as quantity and quality is likely to change significantly with further exploration.

4.6 **Reconnaissance Resource (334):** Reconnaissance Resource (334) is that part of coal resource for which the lay, disposition and continuity of coal seams can only be conjectured based on geological inference and extrapolation. The level of confidence with respect to their shape and tonnage estimates is quite low, usually not sufficient to quote tonnage and grade figures. They were earlier identified as 'Prognosticated' coal resource and assessed in extension areas adjoining Inferred coal resources. Such estimates of resources were informal and previously not provided in the ISP.

Reconnaissance Resource (334) is to be estimated borehole-wise in G4 (Reconnaissance) category of exploration, which stipulates geological mapping on a scale of 1:25,000 or smaller with a few scout boreholes, if required, to know the existence of coal, with an aim to identify areas of enhanced potential worthy of further investigation. For assessment of such Unclassified coal resource, the coal seams of >0.90m thickness upto an area of 2 Km from point of observation will be demarcated on geological considerations taking an average density of 1.6. This may be recorded separately and not to be included in the National Inventory. However, coal resource classification system should also include them to bring out the full resource potential of the country.

4.7 **Unclassified Resources:** In Inferred and Reconnaissance resource, where no data are available or where reliable data are lacking, the resources to be placed under a category of 'unclassified resource' and for the calculation of the quantity, an average density of 1.6 may be used. These will be redefined as and when reliable data become available.

4.8 **High Sulphur Coal:** These occur in North eastern states with Sulphur content of more than 1%. Although some of them are semi-caking, they are not suitable for metallurgical purposes.

4.9 **Abnormal Coal/Coal with Special characteristics:** Some coals may exhibit abnormal properties because of their unusual petrographic composition. These should preferably be reported separately.

The categories of Indian coal resource and the corresponding categories of exploration are proposed in following table:

Resource Category	Category of Exploration/Knowledge Base
Measured Resource (331)	G1 (Detailed)
Indicated Resource (332)	G2 (General) G1 [under special circumstances]
Inferred Resource (333)	G3 (Prospecting) G2 [under special circumstances]
Reconnaissance Resource (334)	G4 (Reconnaissance)

4.10 **Thickness of coal for resource estimation:** The thickness of coal used for resource estimation is the net thickness of coal bed, excluding all partings, referred as Seam or Seam Zone with specific name. The minimum thickness for each seam need to be ≥0.90 metre for resources suitable for underground mining methods and ≥1.00 m for opencast mining methods. Consistent seams of ≥0.50m thickness need to be targeted during exploration for demarcation of such thicknesses. Coal beds should occupy majority of the explored block area in continuity to be called Seam.

4.11 A 'Seam' includes 1.00m & below combustible dirt band (Ash+ Moisture 65.1-75.0% or Ash 60.1-75% for high & low moisture coal) for opencast resources and 0.30m & below combustible dirt bands for resources amicable for Underground mining. All 'Noncombustible Band' (Ash+ Moisture >75% or Ash> 75% in high & low moisture coal) of >0.05m thickness will be excluded from seam/zone. Beds and parts of beds made up of alternating layers of thin coal and partings will be excluded from estimation if the partings comprise more than one-half of the total thickness. The burnt out portions of coal and *jhama* shall be excluded while taking thickness of the seams for the purpose of coal resource estimation. Any dilution of ISP in estimation of resources, not following these criteria, should be reported at all relevant places justifying the inclusion of waste.

4.12 During detailed exploration, a minimum of 7-8 boreholes/sq.km and in regional exploration, all boreholes shall be chemically analyzed for GCV determination of Seam. Chemical analysis of a seam without inclusion of combustible-dirt & non-combustible dirt bands will be called as 'BCSH'. However, the GCV of seams shall be determined 'inband' for resource estimation and resources including combustible dirt bands of below 1.00m will be known as 'I_{100}' and below 0.30m of combustible dirt bands as 'I_{30}'. Resources including all combustible dirt bands will be defined as 'I_P'. The moisture basis of the estimate(s) and the moisture adjustment factor (if applied) should be clearly mentioned.

Seam Thickness Criteria	Opencast (in metre)	Underground (In metre)
Minimum Seam Thickness for resource estimation	1.00	0.90
Thickness of combustible dirt bands to be included in Seam	below 1.00	below 0.30
Maximum thickness of non-combustible band included in resource estimation	0.05	0.05
Coal : rock thickness for inclusion in seam	>1:1	>1:1

Coal:Overburden ratio (in General otherwise clearly mentioned)	<1:10	>1:10

Measured (331) resources may be estimated seam-wise and thickness-wise i.e. 0.9/1.0m-1.2m, 1.2m -3.0m, 3m-6m, 6m-9m, 9m and above. However, assessment of resource for coal seams with thickness 0.50m to <0.90m/1.00m may be carried out separately as thin seam resources in geological reports but are not to be considered in National Inventory. A Similar practice is being followed for Indicated (332) and Inferred (333) Resources as well.

During the G2/G3/G4 stages of exploration if OC/UG criteria could not be ascertained, any of the above criteria may be adopted by considering minimum seam thickness of 0.90m clearly mentioning at all the relevant places to undertake appropriate measures during up-gradation in G1 stage of exploration.

As per the Concordance Table depicting broad correlation between old UHV-based 7-fold non-coking coal classification system and new GCV-based 17-fold non-coking coal classification system, as published in Coal Directory of India 2012-13 by Coal Controller's Organisation, MoC, earlier superior non-coking coal grades, viz. A, B & C, correspond to G1 to G6 grade coal of the new system, while inferior non-coking coal grades, viz. D, E, F & G, correspond to new G7 to G14 grades. G15 to G17 are additional grades, corresponding to earlier carbonaceous shale with >55-65% ash + moisture.

4.13 <u>Thickness Range for Thin Seam Resource Estimation:</u> Assessment of resource for coal seams with thickness 0.50m to <0.90m/1.00m may be carried out separately during all G1, G2 and G3 categories of exploration. These thin seam resources may be recorded for all Measured (331), Indicated (332) and Inferred (333) categories. However, these resources will not be included in block resources/ National Inventory. Details of these resources will be made available to GSI by the concerned exploration agencies for keeping record.

4.14 <u>Depth Range of Resource Estimation:</u> The resources of the block would be classified in the depth range of 0-300m, 300-600m, 600-1200m and 1200-1800m depth level.

4.15 <u>Calculation of Area:</u> The method of determining the areal extent of coal seam, utilizing the data from point of observations, depends on local geology. In low dip areas, the contour maps can be prepared to measure the areal extent. The areal extent can also be assessed by methods like polygonal, triangulation, isochore etc. after drawing thickness and GCV-band maps for each seam. As the areas are measured, mean results ascertained by averaging the planimeter or graph paper readings are recorded. Coal seam correlations and geological structure should be confirmed using down-dip and along-strike sections.

4.16 <u>Density/Weight of Coal:</u> The estimation of coal resource depends on thickness of seam, areal extent and weight of coal per unit volume. The weight of coal per unit volume (density or specific gravity) varies with rank, ash content and amount of each macerals group in the coal.

4.17 In absence of data of numerous specific gravity determinations on unbroken coal of different grades, the average density of all grades have been worked out by a task force constituted for the purpose. These average density data should be used for estimation of coal resources on uniform basis.

4.18 **Estimation of Coal Resources:** After estimation of area occupied by average thickness of coal seams, the in-band thickness is considered and multiplied by prescribed average density for each grade of coal. The tonnage is estimated by the following formula:

***Th x area x density* = tonnage of coal**

Where,

Th = Thickness of coal in metre,
Area = Area underlain by coal in metre^2/square km,
Density = Prescribed average density for each grade band.

Annexure-I:

Following are relevant standards of BIS for Chemical Tests:

Analysis Type	BIS	Preferable Samples
Sub-sampling of borehole Coal cores	IS:436 Part-1/1976, Reaffirmed – 2001	
Field sample (ROM, Channel) collection	IS:436 Part-1 Reaffirmed – 2001	
Proximate analysis	IS:1350 Part-1/1984, Reaffirmed – 2002	Band by Band/Seam Overall, BCS, 'I_{30}' or 'I_{100}'
Moisture at 60% RH & 40^0 C	IS:1350 Part-1/1984, Reaffirmed – 2001	BCS, 'I_{30}' or 'I_{100}'
Gross Calorific Value	IS:1350 Part-2/1970, Reaffirmed – 2000	BCS, 'I_{30}' or 'I_{100}'
Carbon and Hydrogen	IS:1350 Part-4/1974, Reaffirmed – 2000	BCS
Carbonate Carbon Dioxide	IS:1350 Part-5/1979, Reaffirmed – 2000	BCS
Sulphur	IS:1351 /1969, Reaffirmed – 2000	BCS
Form of Sulphur	IS:15438	BCS, 'I_{30}' or 'I_{100}'
Total Sulphur and Form of Sulphur	IS:1350 (Part III)-1969	BCS, 'I_{30}' or 'I_{100}'
Nitrogen	IS:1350 Part-4/1974, Reaffirmed – 2000	BCS
Phosphorous	IS:1355 - 1984, Reaffirmed – 2000	BCS
Ash composition	IS:1355 - 1984,	'I_{100}'
Ash Fusion Temperature Range	IS:12891: 1990 (or IS:1355 - 1984)	'I_{100}'
Hard Grove Grindability Index	IS:4433 -1979, Reaffirmed – 2000	'I_{100}'
Giesler Plastometric Test	ASTM-D -1990	BCS, 'I_{30}' or 'I_{100}'
Coal Carbonization	IS:1353 - 1993, Reaffirmed – 2013	BCS, 'I_{30}' or 'I_{100}'
Coke Tests	IS:1354, Reaffirmed – 1992	BCS, 'I_{30}' or 'I_{100}'
Petrographic Analysis	IS:9127, Reaffirmed – 2004	BCS
Brown Coal & Lignite tests	IS:5062 - 1989, Reaffirmed – 2004	
Trace Elements		BCS, 'I_{30}' or 'I_{100}'

Note: In present context, BCS may be read as BCSH.

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