Overview of the Practical and Theoretical Approaches to the Estimation of Mineral Resources. A Financial Perspective

Leontina Păvăloaia[1]

Abstract: Mineral resources represent an important natural resource whose exploitation, unless it is rational, can lead to their exhaustion and the collapse of sustainable development. Given the importance of mineral resources and the uncertainty concerning the estimation of extant reserves, they have been analyzed by several national and international institutions. In this article we shall present a few aspects concerning the ways to approach the reserves of mineral resources at national and international level, by considering both economic aspects and those aspects concerned with the definition, classification and aggregation of the reserves of mineral resources by various specialized institutions. At present there are attempts to homogenize practices concerning these aspects for the purpose of presenting correct and comparable information.

Keywords: mineral resources; proven reserves; probable reserves; possible reserves

JEL Classification: Q32; O13

1. Introduction

In certain states, in the absence of specific norms, the reporting of reserves and resources is done in compliance with the practice of the mining industry in that area. Because estimated reserves have a special importance for the entities in the mining industry there have been numerous preoccupations to define and classify reserves. The Association of Petroleum Engineers has drawn a guide to estimate Petroleum reserves, and it has recommended taking into account the following information in the estimation of reserves (Mitchell, 2004, p. 4):

- *economic* (information on current costs, prices and taxes for the proven reserves, the prevision of costs, prices and future charges for the other categories of resources);
- *feasibility* (feasible development schemes, depending on the available technologies and the restrictions on environmental protection);
- *geological* (initial evaluation of crude oil reserves and the establishment of the characteristic features of reserves).

[1] Senior Lecturer, PhD, Faculty of Economics and Business Administration, "Alexandru Ioan Cuza" University of Iasi, Romania, Address: 11 Carol I Blvd, 700506, Iasi, Romania, Tel.: +40232201388, Corresponding author: betianu@uaic.ro.

Proven identified reserves could not be mined due to technical difficulties or very high costs. But, an oil field which is declared non-mineable for the moment could be mined in the future due to technological progress.

In establishing reserves, one must consider that:

- reserves cannot be measured directly;
- they are estimated on the basis of available data (geological, technical, economic), and they are analyzed depending on the extant methods and professional reasoning;
- the precision of estimations depends on the quantity and quality of available data and the evaluators' experience.

In order to better understand these aspects, we shall first present a few aspects concerning the definition and classification of mineral reserves drawn by various national and international bodies.

2. Points of View in Defining and Classifying Mineral Resource Reserves

In order to define and determine reserves and resources, various institutions have adopted different practices, such as (Frost, 2005, p. 26):

- ***security norms***:
  - USA SEC guide 7 - *Industries Description of property by issuers engaged or to be engaged in significant mining operations*, (Securities and Exchange Commission – SEC 1978);
  - Canada *National Instrument 43-101 Standards of Disclosure for Mineral Projects* and *National Instrument 51-101 Standards of Disclosure for Oil and Gas Activities*;
  - United Kingdom *Statements of Recommended Practices* (SORP 2001) etc.
- ***stock exchanges***:
  - Australia - *Australian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves – JORC Code*;
  - Johannesburg bourse from South Africa - *South African Code for Reporting of Mineral Resources and Mineral Reserves - SAMREC Code* etc.
- ***national norms***:
  - Russia – Ministry of Natural Resources (RF- 2005);
  - China - Department of Petroleum Reserves (PRO- 2005);

- Norway – Petroleum Department (NPD -2001);
- USA - Geological Department (USGS - 1980) etc.

- ***technical standards***:
  - SPE/WPC/AAPG - Oil and Gas Reserves Committee of the Society of Petroleum Engineers - SPE; World Petroleum Council - WPC, American Association of Petroleum Geologists - AAPG;
  - United Nations Framework Classification - UNFC - 2004;
  - Committee for Mineral Reserves International Reporting Standards - CRIRSCO;
  - Organization of the Petroleum Exporting Countries - OPEC.

The efforts towards standardization were initiated by the Society of Petroleum Engineers (SPE) during the World Petroleum Congress (WPC) where around 50 states participated. In the **WPC-SPE** documents, reserves are divided into two large groups depending on the probability of estimating the quantity and the possibility of commercial mining (IASC, 2001, p. 45): *proven reserves* (developed and little developed) and *little known reserves* (probable and potential). The estimation of reserves is permanently re-evaluated depending on the new discoveries and the improvement of extractions.

Proven reserves represent that quantity of petroleum that, in the case of known reserves and on the basis of geological and technical analyses, of current data and extant *economic conditions, operating methods and government rules,* can be estimated at *a reasonable certainty level* to be mineable commercially.

Probable reserves represent the minable economic part of indicated mineral resources and, in certain cases, of measured mineral resources, demonstrated via a preliminary feasibility study. This study can comprise appropriate information concerning the mining method, the adopted treatment, and other economic aspects can be proved when drawing the report to justify economic extraction.

Possible reserves are represented by those reserves that at present are not exploitable economically. The evaluation of economic viability of potential reserves includes the economic evaluation of the long-term production plan for each area or project. The production period is established depending on the variable limits of the model used during the evaluation before optimizing the profitableness of resources, the mine's capacity and the profit generated by the inflow of capital. This viability is grounded on preliminary feasibility studies.

According to the **4-10** norm **in the SEC's S-X regulation, *proven reserves*** are estimated on the basis of geological and technical data that make it possible to determine at a reasonable certainty level the quantity of petroleum or natural gas

extant in reserves known to be exploited under extant economic and operational conditions. This process implies subjective judgments that make the evaluation of an exercise's reserves to be revised. The estimation of proven reserves is done every year by experimented engineers and geologists, and it is subject to an expertise before being validated by the management (Frost, 2005, p. 24).

The **SORP** British norm (paragraph 12) classifies reserves as:

- ***proven and probable reserves*** of petroleum and gas, which include the estimated quantity of crude oil, natural gas or natural liquid gas based on geological, geophysical and technical data demonstrated at a certainty degree that can be exploited in the following years based on known reserves and which are considered mineable commercially;
- ***developed and little developed reserves*** represent the estimated quantity of crude oil, natural gas or natural liquid gas based on geological and technical data demonstrated with a reasonable certainty, that can be mined over the following years based on reserves that are known from an economic point of view and from the point of view of operating conditions, i.e. prices and costs at the data when the estimation is done.

The norm stipulates that reserves can be considered minable commercially if there is the intention to extract hydrocarbons, and this intention is based on:

- the reasonable evaluation of future economic knowledge for this activity;
- the reasonable estimation of the existence of a distribution market for all or almost all foreseen hydrocarbon production;
- proof of ownership or of the possibility to own the equipment necessary for production, transportation etc.

Eurostat acknowledges the following three categories of reserves for the petroleum and gas sector (Eurostat, 2005):

- ***proven reserves*** - those reserves of a high degree of certainty (90% or more) that can be technically and economically mined depending on current technologies and prices;
- ***probable reserves*** - those reserves that are not yet proven, but in whose estimation there are more than 50 % chances that they can be mined technically and economically;
- ***possible reserves*** - those reserves which at present cannot be seen as probable, but which have a significant chance, yet lower than 50%, that they will be mined.

OPEC carries out a classification similar to Eurostat, by dividing resources into:

- ***proven reserves*** – the estimation of the total quantity of hydrocarbons on the basis of geological and technical data demonstrated at a reasonable

certainty level to be minable in the following years and under certain economic conditions and operating methods;

- ***probable reserves*** are those reserves which, following the analysis of geological and technical data, are suggested to be probable to be recovered. In this context, when probabilistic methods of determination are used, there is a probability higher than 50% to be recovered;
- ***possible reserves*** are those reserves that, following the analysis of geological and technical data, suggest that it is more likely that they will not be recovered. In this context, when probabilistic methods are used, there is a probability higher than 10% for that resource to be mined.

In order to ensure the convergence of the definitions used, Eurostat and the London Group have inventoried national practices concerning mineral resources accounts, and in 2002, Eurostat published information on practices in certain states from Europe (Eurostat, 2002, p. 15) that are presented in Table no. 1.

Table 1. The way to define reserves and the source of data

Country	Source of data to estimate reserves	Definition of reserves		The stock in physical units that will be evaluated	Applies SEEA or SCN
		Known reserves	Little known reserves		
Denmark	The Danish Agency for Energy	The evaluated sum of proven, probable and possible reserves	No available data	Discovered reserves	SEEA
Germany	Niedersächsisches Landesamt für Bodenforschung	The sum of proven and probable reserves	No available data	No available information	No information
France	Secretariat for the Conservation of Hydrocarbons Deposits in the Ministry of Industry	Include only certain reserves	No available data	Certain reserves	SCN
The Netherlands	Ministry of Economy and Business	Probable estimated reserves	Future adding of reserves determined following exploitation	Basis of estimation is established by the government and is close to the rent of rent	Not clear
Austria	Austrian Organization of Geology and	Sum of proven reserves developed (1),	No available data	Discovered reserves	More SEEA

Country	Source of data to estimate reserves	Definition of reserves		The stock in physical units that will be evaluated	Applies SEEA or SCN
		Known reserves	Little known reserves		
	extraction companies	proven non-developed (0,9), probable (0,5) and possible (0, 1)			
Great Britain	The Ministry of Trade and Industry	The sum of certain and probable reserves	The higher and lower limit of estimated non-discovered reserves	Discovered reserves and the lower limit of non-discovered resources	More SCN than SEEA
Norway	Norwegian Petroleum Direction (NPD)	Foreseen level of discovered reserves estimated by NPD	Foreseen level of non-discovered reserves estimated by NPD	Discovered reserves and the foreseen level of non-discovered ones	SEEA

Source: (Eurostat, 2002, p. 15)

Given the multitude of definitions and classifications, attempts have been made to uniformize them, with a view to carrying out comparable reports.

3. Tendencies towards Uniformization

The SEEA 2003 model does not define clearly the terms "resources" and "reserves" used in classifying assets:

- *reserves* refer to a subset of *resources* on the basis of certain criteria (for instance, the economic recovery of resources given by the current conditions);
- *resources* include discovered *reserves* (according to UNFC) or anything that lies under ground (SPE/AAPG/WPC) based on geological data.

SCN 93 considers only the assets of monetary values and only certain reserves, which include *estimated quantities based on specific, geological and technical data which allow one to determine at a reasonable certainty level if the quantity of petroleum or natural gas in the known reserves can be mined under the current economic and operating circumstances* (Commission of the European Communities, International Monetary Fund, Organization for Economic Co-operation and Development, United Nations, World Bank, 1993, par. 21. 152). SEEA 2003 considers reserves to be proven, probable and possible in physical accounts (certain states also include hypothetical estimated reserves), while monetary accounts include proven and probable reserves.

In the SEEA 2003 manual, chapters 7 and 8 present general principles concerning mineral resource accounts in physical and monetary units, and the foreseen treatment for the classification of mineral resources in physical units is not harmonized with various classifications adopted by each state. However, it comprises, in fact, a framework for the interpretation of the way of classifying reserves, which applies to problems connected to the type of reserves that will be included or excluded from the monetary accounts of mineral assets. The SEEA 2003 Manual refers mainly to the McKelvey diagramme, which classifies reserves according to economic feasibility and the degree of uncertainty (Figure no. 1) (United Nations, et al., 2003, pp. 324-340).

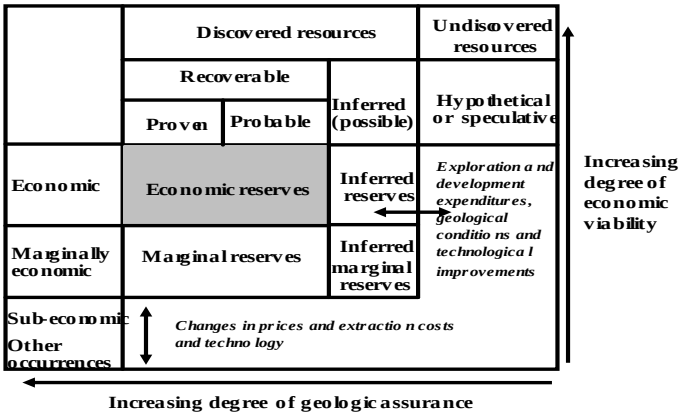

Figure 1. McKelvey Scheme

(Edens & DiMatteo, 2007, p. 10)

Certainly, this system of classification is not used in all countries. In order to converge national systems with McKelvey's system, certain retreatment are made, but they are not always carried out coherently, in order to obtain comparable results.

After the publication of SEEA 2003, the London Group has continued to analyze these aspects and it has been trying to harmonize the extant practices by collaborating in this sense with specialized institutions, such as the group of UNECE experts for the harmonisation of the definition of non-renewable energy and of mineral resources (Group of Experts the Harmonization of Fossil Energy and Mineral Resources United Nations Economic Commission for Europe).

UNFC (United Nations Framework Classification) (Hass & Kolshus, 2006) elaborated a new framework for the classification of resources, for convergence in defining and classifying reserves. This classification (Figure no. 2) considers three criteria: *economic and commercial viability* (E), *feasibility* (F) and *characteristic geological features* (G).

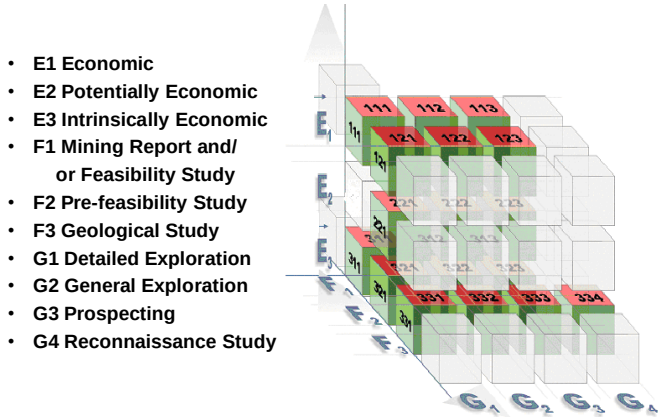

Figure 2. Classification of resources according to UNFC

(McDonald, 2007, p. 18)

The classification done by UNFC uses the numeric codification, made of 3 figures, depending on the three criteria of classification. For instance, box 111 shows that those quantities are recoverable from an economic and commercial point of view (first figure), are justified via feasibility studies which show that they can be exploited with current technologies (the second figure) and the estimations were done on the basis of reasonable geological data (the third figure). UNFC recommends the use of the terms "low"/"the best"/"the highest" to express estimation and not of the terms "proven"/"probable"/"possible". In the UNFC classification the G1 category corresponds to proven reserves, G2 to probable reserves and G3 to possible reserves.

UNFC has been trying to harmonize various classifications concerning mineral resources by establishing correspondences with the other classifications. In 2006, Blystad and his collaborators carried out a study which established the correspondence between several national and international classifications, by comparing the UNFC system with the Norwegian one, with the SPE/WPC/AAPG system and the Russian one (Blystad, Griffiths & Heiberg, 2006).

The classification system in **Norway** comprises 3 categories, *prospective resources* (in yellow), *contingent resources* (in green, 4A-7F) and *reserves* (in red, 1-3F). In the **UNFC** system potential reserves correspond to boxes 111 and 112 (red), contingent resources in green and potential ones in box 334 (yellow). Figure no. 3 features this conversion for accounts from 31.12.2003.

		NPD		UNFC
Class	Type	Category	Mill Sm³ o.e.	
	Fields	0	3779	
Reserves	Fields	1	2837	
Reserves	Fields	2A	36	
Reserves	Fields	2F	387	
Reserves	Fields	3A	412	
Reserves	Fields	3F	402	
Reserves	Fields	Sum	**4074**	111-2
Contingent resources	Fields	4A	274	121
Contingent resources	Fields	4F	49	122
Contingent resources	Fields	5A	120	221
Contingent resources	Fields	5F	55	222
Contingent resources	Fields	7F	3	332
Contingent resources	Fields	7A	400	331
Contingent resources	Discoveries	4F	297	122
Contingent resources	Discoveries	5F	401	223
Contingent resources	Discoveries	7F	66	333
Contingent resources	Discoveries	Sum	1665	
Prospective resources		8 & 9	**3400**	334

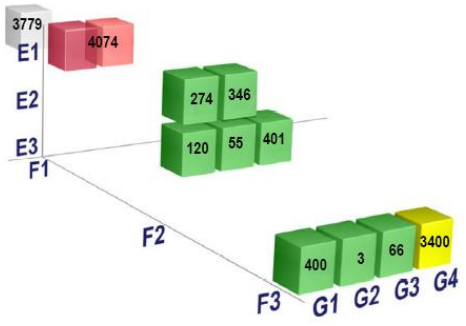

Figure 3. Correspondence between the classification of resources in Norway and UNFC classification

where:

0 –petroleum deliveries
1 – reserves in production
2 F/A – reserves for which the operational plan and development plan have been approved
3 F/A - reserves for which the extension of the license has been approved
4 F/A – resources in the planning phase
5 F/A – resources for which recovery is possible but not clear
6 – resources for which exploitation is not profitable
7 F/A – resources which are not yet well evaluated
8 – resources during the prospecting stage
9 –non-localized resources

Source: (Blystad; Griffiths & Heiberg, 2006, p. 15)

The **SPE/WPC/AAPG** classification is similar to the one in **UNFC** (Frost, 2005, p. 26), and the correspondence between the two classifications is presented in Figure no. 4. In general, several expressions are used to estimate reserves. For potential resources the terms used are "low"/ "the highest"/ "high" estimation, noted with 1C/2C/3C, and for *proven/probable /possible* reserves, the notations used are 1P/2P/3P. In fact, 1P means proven reserves, 2P proven and probable reserves, and 3P proven, probable and possible reserves.

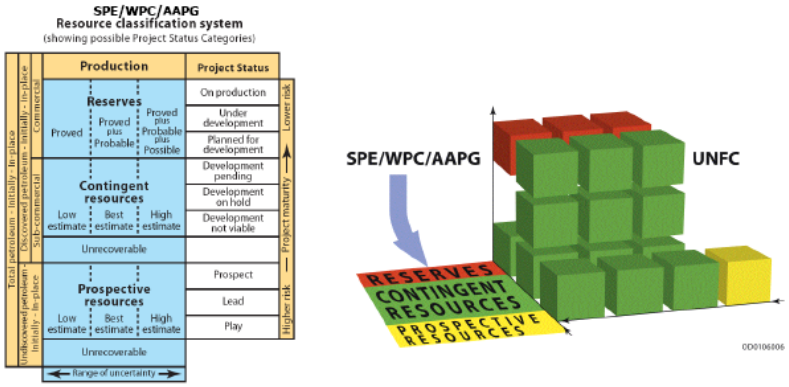

Figure 4. Correspondence between the SPE/WPC/AAPG classification and the UNFC classification

(Frost, 2005, p. 26)

In establishing the correspondence between the classifications carried out by **Russia and UNFC,** the authors considered only geological reserves. This correspondence is presented in Figure no. 5.

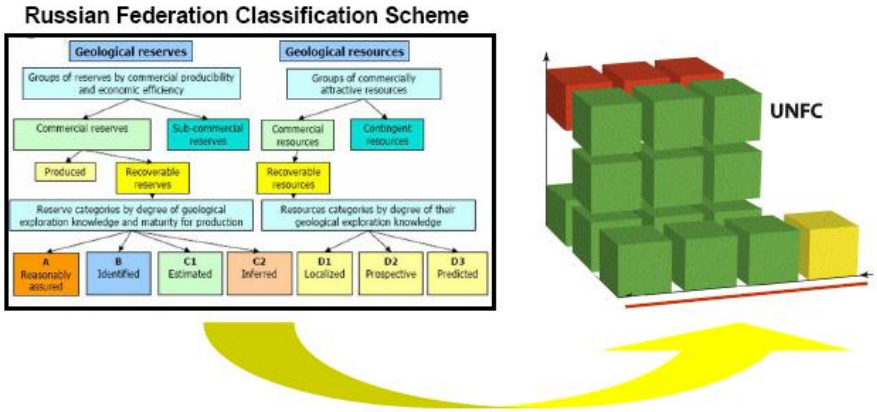

Figure 5. Correspondence between the classification carried out by Russia and the UNFC classification

(Blystad, Griffiths & Heiberg, 2006, p. 16)

In order to ensure the unitary treatment of mineral resources we must also consider the methods to approach them: deterministic or probabilistic.

4. The probabilistic and deterministic approach in the evaluation of mineral resources

In defining reserves, two approaches are adopted:

- ***the deterministic approach*** which defines categories of reserves in qualitative terms "with a reasonable certainty";
- ***the probabilistic approach*** which defines categories of reserves by quantifying probable evaluations.

If *deterministic methods* are used, then the term "reasonable certainty" is the expression of a high degree of conviction that those quantities can be exploited. In the case of *probabilistic methods* there is a higher than 90% probability that the estimated quantity would be exploited (Figure no. 6). JORC adopts the deterministic approach for ore, while in the field of petroleum, the probabilistic method: 90% for proven reserves, 50%-90% probable reserves, 10%-50% possible reserves.

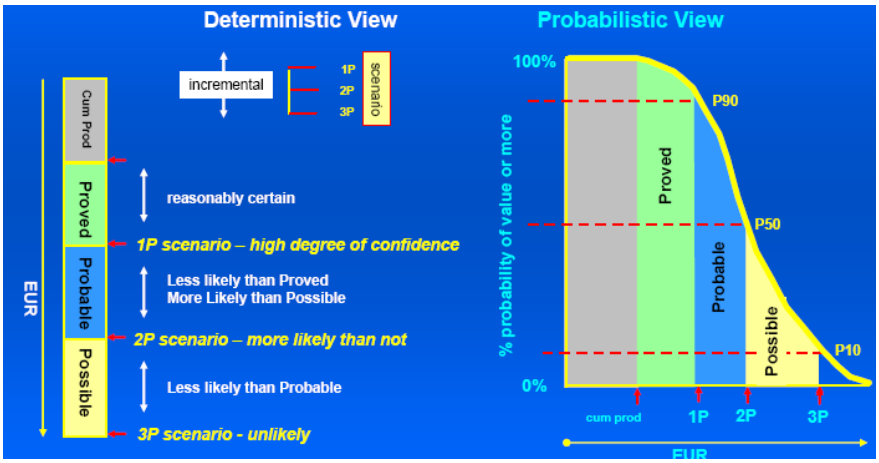

Figure 6. Deterministic vs probabilistic approach

(Ritter & Etherington 2007, p. 18)

Apart from the way to approach reserves, there also arises the issue of summing up the various categories of reserves: which of them are *considered* and how they are *aggregated*. SEEA 2003 recommends to consider the monetary accounts of proven and probable reserves, while Eurostat recommends all three categories: proven, probable and possible (Figure no. 7).

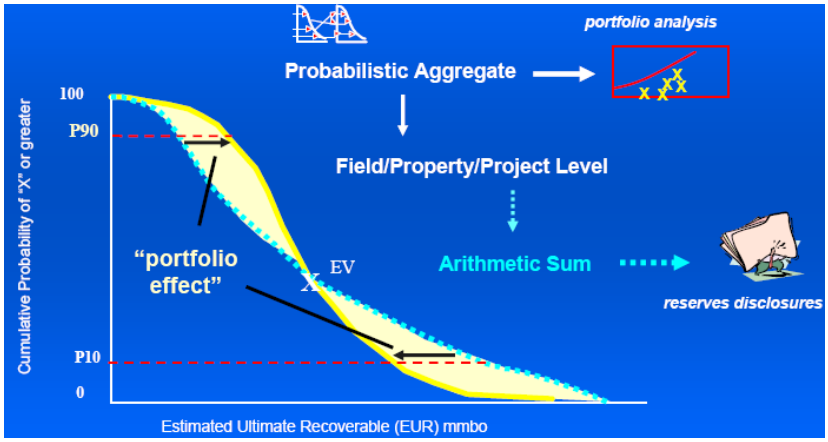

Figure 7. Aggregation of reserves

(Hass & Kolshus, 2006)

In yearly reports most companies that exploit mineral resources present information concerning methods to estimate reserves and what types of reserves were considered (proven, probable, possible...). For instance, the Russian company Lukoil (www.lukoil.com) stipulates that in 2006, proven reserves increased by 4, 1%. Thus, over the last seven years, the company has managed to compensate completely the production of hydrocarbons by discovering new reserves. The evaluation of reserves was carried out in compliance with the SPE/WPC requirements, while the situation of petroleum and gas reserves for the period 2008-2010 is presented in Table 2.

Table 2. Lukoil petroleum and gas reserves in 2008-2009

	2010			2009			2008		
	Oil, million barrels	Gas, billion cubic feet	Oil+gas*, million boe	Oil, million barrels	Gas, billion cubic feet	Oil+gas*, million boe	Oil, million barrels	Gas, billion cubic feet	Oil+gas*, million boe
Proved	13319	23615	17255	13696	22850	17504	14458	29253	19334
Probable	6474	11888	8455	7293	15163	9820	8083	22103	11767
Possible	2780	2318	3167	3683	8226	5054	3333	11694	5282

** The ratio used for recalculation of cubic feet as barrels of oil equivalent (boe) is: 1 boe = 6, 000 cubic feet.*

With a view to harmonizing the reflection of reserves of mineral resources in yearly reports, numberless studies and projects were carried out, at both international and national level, but so far, as we have shown above, no common

viewpoint has been reached, which leads to the provision of various information, and most often comparisons are difficult to make.

5. Conclusion

The different definitions of resources show that there is no common point of view for the estimation of reserves. This is why, in the presentation of information connected to these reserves, entities must apply the regulations of the state on the territory whose exploitation is made, and groups transacted on the stock exchange use this information depending on the regulations of the respective stock exchange.

Changes in the classification of reserves can have a significant impact on the value of resources. For instance, Shell, at the moment when it was admitted to be transacted on the New York stock exchange, had to apply the SEC stipulations, and following the application of these norms, 4,47 billion barrels of equivalent petroleum had to be reclassified, which determined the diminishing by approximately 23%, of proven reserves that had been previously reported (www.shell.com).

Also, certain companies publish information on resources in yearly reports. This information differs depending on the stock exchange where the company is quoted or on the adopted norms reporting. Thus, SEC stipulates that only *proven reserves* be published, in Canada *proven and probable reserves*, while in Great Britain entities can choose to present *proven reserves* or *proven and probable reserves*. Other companies also present in yearly reports, so as to offer users a comprehensive image, a situation of all estimated reserves, but which are not audited (for instance, Total, Shell, BP etc.). Due to this fact, it becomes imperative to have a unitary approach, because only information thus presented can be comparable, and users could be correctly informed.

6. Acknowledgement

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