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OECD Task Force on the implementation of the SEEA Central Framework
Background note on the volume measurement of stocks of natural resources[1]

PRELIMINARY DRAFT – PLEASE DO NOT QUOTE – COMMENTS WELCOME

Remaining stocks of natural resources expressed in physical units are probably the first statistics coming to the mind of those caring about the depletion of natural assets. Estimates of remaining stocks also usefully complement the already available statistics on material flows and resource productivity[2]. Lastly, the measurement of physical stocks is a necessary intermediary step before valuing these stocks. Valuation then allows to aggregate different stocks and to assess the evolution of the aggregate natural asset base. Making data on physical stocks of natural resources available should therefore receive a high priority in the implementation phase of the SEEA Central Framework (SEEA-CF).

Even if the statistical reporting of stocks of natural resources in physical units may seem more straightforward than their valuation, practical difficulties should not be understated. The main issue is the coexistence of different classifications to measure remaining stocks. This note explains how the main classifications (CRIRSCO, SPE-PRMS, UNFC-2009 and SEEA-2012) work. It also shows that two main difficulties can be encountered in practice when trying to move to the SEEA-2012 classification. First, data need to be available with a sufficient level of disaggregation in the original classification system. This is not always the case. Second, countries need to consider a wide range of resource types in order to fill the (quite large) resource classes advocated by the SEEA-CF. Some countries currently prefer to focus on the most economically viable deposits and those estimated with the highest geological confidence in their statistical reporting, whereas the SEEA-CF may consider broader definitions. Our advice is therefore that countries engaged or interested in the statistical reporting of physical stocks of natural resources should keep the SEEA-2012 classification in mind.

This note also compares national estimates of remaining stocks of selected resources in four countries (Australia, Canada, the Netherlands and the United Kingdom) with those that can be found in international databases (BP, EIA and USGS). Even when definitions are aligned, reported estimates may be extremely different. Based on available estimates for these four countries, our conclusion is

[1] This note benefited from explanations and/or comments from Maryse Fesseau (ABS), Bram Edens (CBS), Patrick Adams (Statistics Canada), Andrew Carr (DECC), Peter Greene and Jawed Khan (ONS). We would like to thank them.

[2] The OECD already provides guidelines for the measurement of material flows and resource productivity and suggests ways to improve resource productivity, see: http://www.oecd.org/env/indicators-modelling-outlooks/resourceefficiency.htm.

therefore that national data sources should be preferred, even if this implies to focus on some resources and the main producing countries in a first stage.

All member countries of the Task Force are kindly invited to share their experience and the difficulties they encounter for the volume measurement of stocks of natural resources.

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I. Existing classifications for the volume measurement of stocks of natural resources

1. Overview of existing classifications

Four main classifications are currently available to report stock volumes of natural resources. They result from a convergence process in reporting standards that started at the beginning of the 1990s. While CRIRSCO and SPE-PRMS focus on different types of resources, the UNFC-2009 and SEEA-2012 classifications apply to all types of resources. None of these classifications only takes geological criteria into account. Economic and technical criteria are also considered. This implies that resource stocks have to be regularly reassessed in the light of new geological knowledge, progress in extraction technology and shifts in economic and political conditions.

Table 1: Overview of existing classifications

Abbreviation	Full Name	Subject Resource	Latest edition (first edition)
CRIRSCO[3,]	Committee For Mineral Reserves International Reporting Standards	Minerals	2013 (2006)
SPE-PRMS[4]	Society of Petroleum Engineers – Petroleum Resources Management System	Fossil Energy (crude oil and natural gas)	2007
UNFC-2009[5,]	United Nations Framework Classification for Fossil Energy and Mineral Resources	Minerals and Fossil Energy	2009 (1997)
SEEA-2012[6]	System of Environmental-Economic Accounting – Central Framework	Renewable and non-renewable natural resources and land	2012 (2003)

a. CRIRSCO classification system for minerals

Only a few countries (Australia, Canada, South Africa, the United Kingdom and the United States) initially participated in the negotiations that established the CRIRSCO classification. In 1997, the five initial participants reached an agreement, also called Denver Accord, for the definition of two major categories of minerals, mineral resources and mineral reserves, and their respective sub-categories, measured, indicated and inferred mineral resources on the one hand, proved and probable mineral reserves on the other hand.

The CRIRSCO classification system is two-dimensional: the vertical axis is for "geological confidence" while the horizontal axis is for "modifying factors", corresponding to several socio-economic factors

[3] See CRIRSCO (2013). CRIRSCO's scope includes all solid minerals (metals, gemstones, bulk commodities, aggregates, industrial minerals, energy minerals such as coal and uranium).

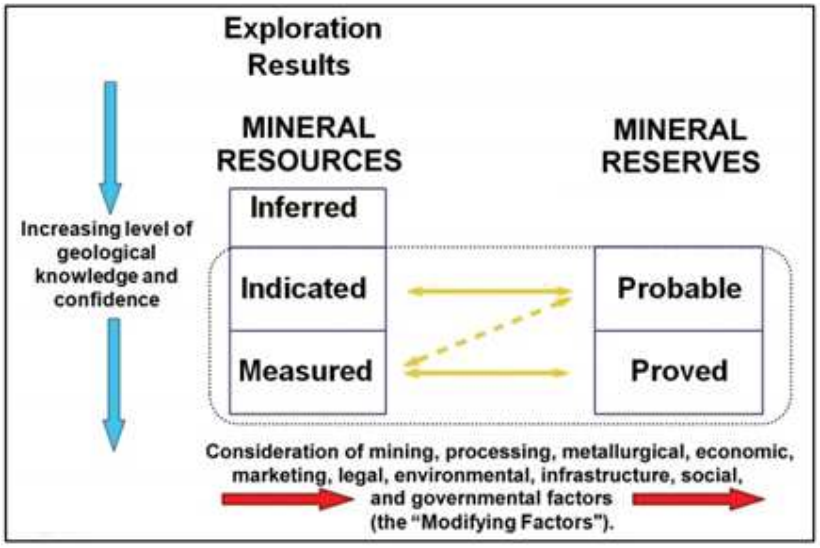
[4] See SPE *et al.* (2007).

[5] See http://www.unece.org/energy/se/unfc_2009.html. The 1997 UNFC classification was only dedicated to solid fuels and minerals. It was later extended to crude oil and natural gas.

[6] See SEEA (2012).

such as resource prices or legal constraints. Sub-categories are precisely defined in an appendix. Figure 2 summarises the main principles of the CRIRSCO classification system.

Figure 2: CRIRSCO classification system



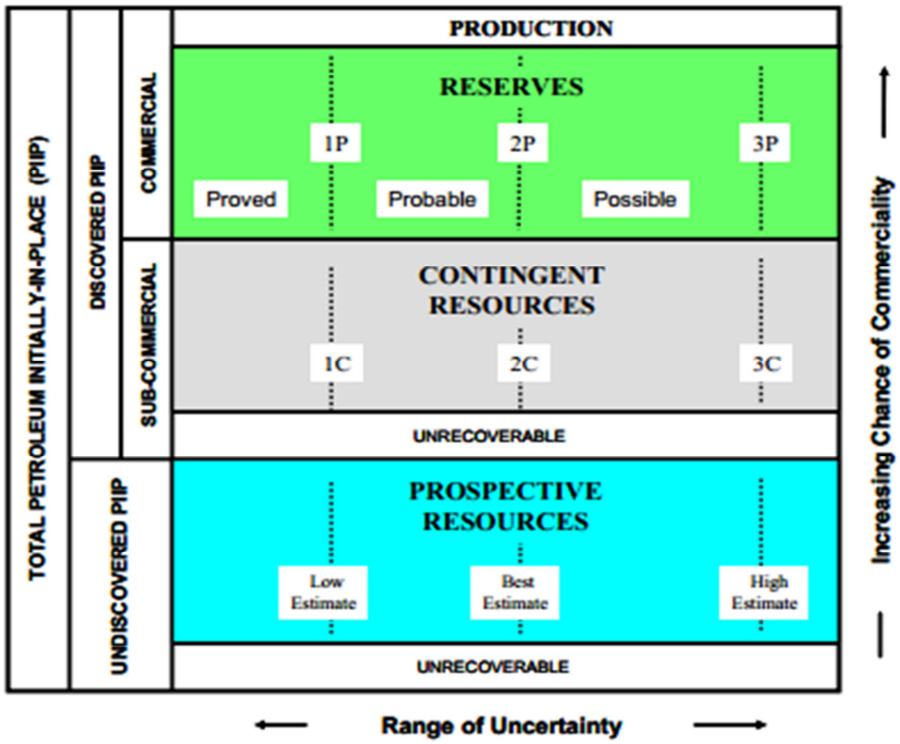
b. SPE-PRMS classification system for fossil energy

SPE-PRMS is the main classification for the reporting of crude oil and natural gas. "Because no petroleum quantities can be recovered and sold without the installation of (or access to) the appropriate production, processing, and transportation facilities, SPE-PRMS is based on an explicit distinction between (1) the development project that has been (or will be) implemented to recover petroleum from one or more accumulations and, in particular, the chance of commerciality of that project; and (2) the range of uncertainty in the petroleum quantities that are forecast to be produced and sold in the future from that development project"[7].

Similarly to CRIRSCO, SPE-PRMS is a two dimensional classification system where the vertical axis corresponds to the degree of commerciality of the resource, while the horizontal axis corresponds to its range of geological uncertainty. Three main categories are distinguished on the vertical axis: reserves, contingent resources and prospective resources. Projects classified in the reserves category should be understood as satisfying all commerciality requirements. On the horizontal axis, at least three estimates of the potential quantity to be extracted are captured. Depending on the degree of commerciality of the reserve/resource, these estimates are called proved, probable and possible quantities or low, best, and high estimates. Sub-categories are precisely defined in an appendix. Figure 3 summarises the main principles of the SPE-PRMS classification system.

[7] See http://www.spe.org/industry/docs/PRMS_Guidelines_Nov2011.pdf, p.7.

Figure 3: SPE-PRMS classification system



c. UNFC-2009 classification system

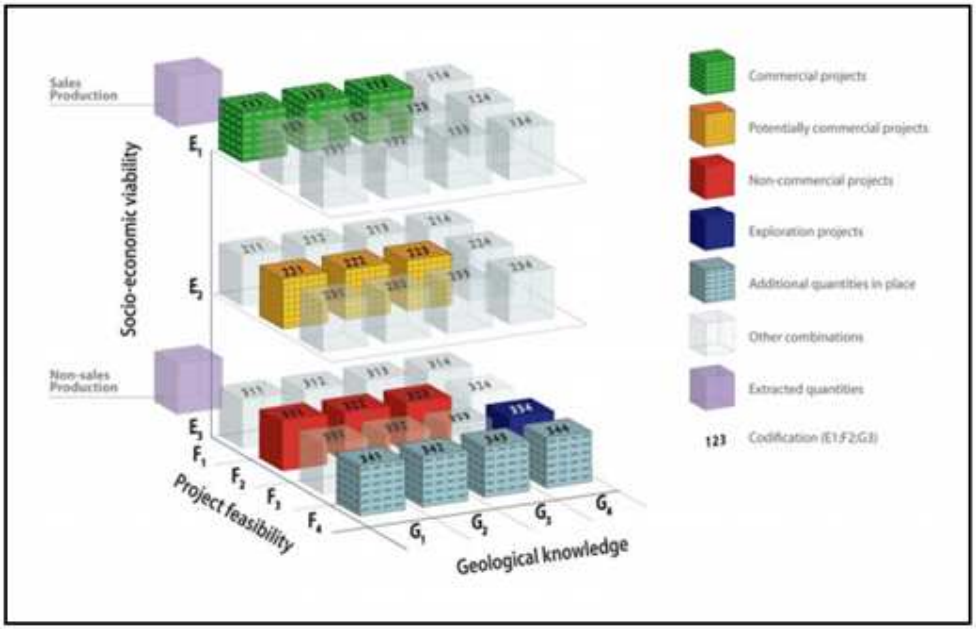
The UNFC-2009 (United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources - 2009) is the third major classification designed during the 1990s. Contrary to CRIRSCO and SPE-PRMS, this classification system is thought as an umbrella, relevant for both fossil energy and minerals. It is based on three dimensions[8]: the economic and social viability of the project (dimension E), the field project status and its feasibility (F) and the geological knowledge about the available quantities (G). Quantifying reserves means attributing a triplet (E,F,G) to these reserves. As an example, a mineral resource described by the triplet (1,1,1) should be understood as a resource for which extraction and sale have been confirmed to be economically viable (first 1), extraction is

[8] Limited explanations exist on the exact reason why a third dimension was introduced into the UNFC classification system. Following UNECE (2009), "the concept of commerciality brings together all relevant aspects of project evaluation, including technical feasibility, economic viability, legal considerations, fiscal terms, environmental regulations, etc. It is achieved at the juxtaposition of the E and the F axes, rather than solely on one or the other. However, in order to ensure that the requirement for commerciality is met for relevant combinations of categories, the F axis was deemed to be the appropriate location to recognize full satisfaction of all commercial criteria including technical considerations, while the E axis was defined to be inclusive of all "market conditions", including prices, costs, legal/fiscal framework, environmental, societal and all other non-technical factors that have a direct impact on economic viability."

technically feasible (second 1) and the quantities associated to this resource can be estimated with a high level of confidence (third 1).

UNFC-2009 categories are precisely defined in an appendix. Figure 4 summarises the main principles of the UNFC-2009 classification system.

Figure 4: UNFC-2009 classification system



d. SEEA-2012 classification system[9]

The SEEA - Central Framework 2012 establishes a framework to develop and integrate environmental accounting of renewable and non-renewable natural resources into the core of official economic statistics. It introduces a new classification for the reporting of stocks of natural resources. This SEEA-2012 classification distinguishes three classes for reporting known deposits.

[9] The SEEA-2012 and SEEA-2003 classification systems should not be confused. Indeed, the SEEA 2003 uses the terminology “proven”, “probable” and “possible reserves” rather than the UNFC-2009 classification system based on codes. Moreover, the terms “proven”, “probable” and “possible reserves” in the SEEA 2003 do not have the same meaning as in the SPE-PRMS classification. The SEEA 2003 defines “proven reserves” as “those where it is technically feasible and economically viable to extract”, “probable reserves” as those “which are known to exist but where some doubt exists over whether they are technically or economically viable” and “possible reserves” as those “where there is considerable doubt over the technical and or financial viability of extraction” (see SEEA 2003 §8.25). Hence, the adjectives “proven”, “probable” and “possible” refer to technical and/or financial uncertainty in the SEEA 2003 whereas they refer to purely geological uncertainty in the SPE-PRMS classification. Technical and/or financial uncertainty is covered by the use of the terms “reserves”, “contingent resources” or “prospective resources” in the SPE-PRMS classification system.

Each class is defined according to combinations of criteria from the UNFC-2009 classification (see SEEA-CF §5.178):

- Class A: Commercially recoverable resources. This class includes deposits for projects that fall in categories E1and F1 and where the level of confidence in the geologic knowledge is high (G1), moderate (G2) or low (G3).

- Class B: Potentially commercially recoverable resources. This class includes deposits for those projects that fall in the category E2 (or eventually E1) and at the same time in F2.1 o F2.2 and where the level of confidence in the geologic knowledge is high (G1), moderate (G2) or low (G3).

- Class C: Non-commercial and other known deposits. These are resources for those projects that fall into category E3 and for which the feasibility is categorized as F2.2, F2.3 or F4 and where the level of confidence in the geologic knowledge is high (G1), moderate (G2) or low (G3).

2. Mapping between existing classifications

The CRIRSCO and SPE-PRMS classifications are built on a similar two-dimensional structure, whereas the UNFC-2009 and SEEA-2012 are three-dimensional. As explained in Henley and Allington (2013), "the CRIRSCO classification is two dimensional, with axes for geological knowledge and for modifying factors; UNFC is three dimensional with axes for geological knowledge, project feasibility, and socio-economic viability. In other words, the "modifying factors" axis of CRIRSCO has been separated into two axes representing technical feasibility and non-technical factors."

Correspondence tables have been built between the CRIRSCO, SPE-PRMS and UNFC-2009 classifications[10]. A correspondence table also exists between the UNFC-2009 and SEEA-2012 classifications (see Appendix). Tables 2 and 3 below make explicit how to move from one classification to another[11].Note that the less economically viable resources, for which extraction has not been evaluated from a technical point of view and for which geological uncertainty is the highest, are excluded from the SEEA-CF reporting.

Even if the SEEA-2012 classification has been thought as a high-level and easy to understand classification, Tables 2 and 3 show that the mapping with the CRIRSCO and SPE-PRMS classifications is not always straightforward. Two issues have to be considered in practice:

- Some resources, for instance "mineral resources" (CRIRSCO) and "contingent resources" (SPE-PRMS), have to be split between class B and class C types of resources in the SEEA-2012

[10] In 2007, a UNECE Task Force was charged to prepare a mapping of the SPE-PRMS, CRIRSCO, Russian Federation and UNFC-2004 classification systems. This Task Force led to the introduction of the UNFC-2009 classification. SPE and CRIRSCO had previously engaged in a similar exercise at the request of the International Accounting Standards Board (IASB) resulting in a detailed mapping between the CRIRSCO and SPE-PRMS classification systems (see UNECE 2009).

[11] The correspondence between the UNFC-2009 and SEEA-2012 classifications presented in those tables are based on UNECE (2009) and SEEA 2012 Table 5.5.1 (see Appendix) but it is more detailed than the latter in order to consider all relevant sub-categories in the CRIRSCO and SPE-PRMS classification systems.

classification system. This is not always possible given the level of aggregation used by countries in their official publications.

- Available data at the national level do not always allow to entirely fill SEEA-2012 classes. For instance, some countries publish natural resource stocks with a lower level of geological uncertainty than the one considered by the SEEA 2012 (G3 category in the UNFC-2009 classification). This, of course, limits the international data comparability.

Table 2: Correspondence between CRIRSCO, UNFC-2009 and SEEA-2012 classifications

Fundamental Characterization	Solid Mineral Classes	Mineral Project Development Stage	UNFC E axis	UNFC F axis	UNFC G axis			
					Proved Measured	Probable Indicated	---------- Inferred	
Discovered and Commercially Recoverable	Mineral Reserves	On Production	1	1.1	1	2		SEEA-2012 Class A
		Project Implementation	1	1.2	1	2		
		Feasibility Study	1	1.3	1	2		
Discovered and Not Commercially Recoverable	Mineral Resources	Pre-Feasibility Study	1	2.1	1	2	3	SEEA-2012 Class B
			2.1	2.1	1	2	3	
		Order of Magnitude Studies	2.1	2.2	1	2	3	
			3.2	2.2	1	2	3	SEEA-2012 Class C
	Discovered Not Economic		2.2	2.3	1	2	3	
	Unrecoverable		3.3	4.1	1	2	3	
Undiscovered	Exploration Results	Conceptual Studies	3.2	3.3	4			
	Unrecoverable		3.3	4.2	4			

Based on UNECE (2009) and SEEA 2012

Raws correspond to items of the CRIRSCO classification and columns to items of the UNFC-2009 classification. SEEA-2012 natural resource classes are indicated with colours.

Table 3: Correspondence between SPE-PRMS, UNFC-2009 and SEEA-2012 classifications

Fundamental Characterization	PRMS Classes	PRMS Sub-Class	UNFC E axis	UNFC F axis	UNFC G axis			
					1P/1C Low Estimate	2P/2C Best Estimate	3P/3C High Estimate	
Discovered and Commercially Recoverable	Reserves	On Production	1.1 or 1.2	1.1	1	1+2	1+2+3	SEEA-2012 Class A
		Approved for Development	1.1 or 1.2	1.2	1	1+2	1+2+3	
		Justified for Development	1.1 or 1.2	1.3	1	1+2	1+2+3	
Discovered and Not Commercially Recoverable	Contingent Resources	Development Pending	1	2.1	1	1+2	1+2+3	SEEA-2012 Class B
			2.1	2.1	1	1+2	1+2+3	
		Development Unclarified or on Hold	2.1	2.2	1	1+2	1+2+3	
			3.2	2.2	1	1+2	1+2+3	SEEA-2012 Class C
		Development not Viable	2.2	2.3	1	1+2	1+2+3	
	Unrecoverable		3.3	4.1	1	1+2	1+2+3	
Undiscovered	Prospective Resources	Prospect	3.2	3.1	4.1	4.1+4.2	4.1+4.2+4.3	
		Lead	3.2	3.2	4.1	4.1+4.2	4.1+4.2+4.3	
		Play	3.2	3.3	4.1	4.1+4.2	4.1+4.2+4.3	
	Unrecoverable		3.3	4.2	4.1	4.1+4.2	4.1+4.2+4.3	

Based on UNECE (2009) and SEEA 2012

Raws correspond to items of the SPE-PRMS classification and columns to items of the UNFC-2009 classification. SEEA-2012 natural resource classes are indicated with colours.

II. Available international and national databases

1. International databases

a. World Bank database (fossil energy and mineral resources)

The World Bank does not collect data on physical stocks of natural resources directly from national sources but from already existing international databases (see World Bank 2014). Data on proved reserves of oil and natural gas for nearly 50 countries and 8 regions/groups are from British Petroleum (BP, Statistical Review of World Energy 2010) from 1980 onwards. Countries with missing reserves in the BP database are replaced with world or regional data. Data on coal reserves for 60 countries are from the U.S. Energy Information Administration (EIA, International Energy Annual). Unlike oil and gas, coal reserves are available for only one year (2005) and this value is used across the entire time period starting from 1970 to 2008. Lastly, data on reserves for 10 minerals (bauxite, copper, lead, nickel, phosphate, tin, zinc, gold, silver and iron ore) are from the U.S. Geological Survey (USGS, Minerals Yearbooks and Mineral Commodity Summaries of various years).

b. British Petroleum (BP) database (oil, natural gas and coal)

The BP database focuses on oil, natural gas and coal. According to publicly available metadata, estimates published in the BP Statistical Review of World Energy are "compiled using a combination of official primary sources and data provided by the OPEC Secretariat, *World Oil and the Oil & Gas Journal* and an independent estimate of Russian and Chinese reserves based on information in the public domain". Moreover, "proved reserves" are defined by BP as "those quantities that geological and engineering information indicates with reasonable certainty [to be recoverable] in the future from known reservoirs under existing economic and operating conditions" (see BP 2014). Note that this definition of "proved reserves" is nearly exactly the same as the one given by CRIRSCO and SPE (2007), thus enabling to translate it into a UNFC-2009 classification code, namely (E1,F1,G1), see Table 4.

c. U.S. Energy Information Administration (EIA) database (oil, natural gas and coal)

The U.S. Energy Information Administration[12] (EIA) also compiles data on "proved reserves" for oil, natural gas and coal[13]. According to publicly available metadata[14], all data for the United States are from the EIA, oil and gas data for other countries are from the *Oil & Gas Journal* and coal data for countries other than the United States are from the World Energy Council. Note that the EIA only certifies reserves data for the United States. As in the BP database, "proved reserves" are defined as

[12] The Energy Information Agency is part of the U.S. Federal Statistical System and the U.S. Department of Energy. It provides data on coal, petroleum, natural gas, electric, renewable and nuclear energy.

[13] The only exception is for coal reserves in the United States for which the EIA reports "measured and indicated reserves". This wording dates back to USGS (1980) but seems to be coherent with the similar wording in the CRIRSCO classification system. Hence, we consider that coal reserves for the United States in the EIA database belong to the (E1,F1,G1-G2) type in the UNFC-2009 classification system.

[14] See http://www.eia.gov/cfapps/ipdbproject/docs/IPMNotes.html#p6

"the estimated quantities which analysis of geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from reservoirs under existing economic and operating conditions"[15]. Hence, we also consider them as (E1,F1,G1) types of reserves in the UNFC-2009 classification system (see Table 4).

d. U.S. Geological Survey (USGS) database (mineral resources)

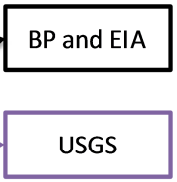
The USGS' database covers a wide range of minerals and countries. It still relies on a classification that inspired but predates the CRIRSCO classification (see USGS 1980). The USGS tries to adjust for specific definitions in use in different countries. Available statistics are generally on the "reserve base", defined as "the in-place demonstrated (measured plus indicated) resource from which reserves are estimated: it may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics", and/or "reserves", defined as "that part of the reserve base which could be economically extracted or produced at the time of determination"[16]. At this stage, we consider that "reserves" in the USGS terminology correspond to the (E1,F1,G1-G2) category in the UNFC-2009 classification system (see Table 4).

[15] Coal data coming from the World Energy Council are data on "proved recoverable reserves", defined as "the tonnage within the proved amount in place that can be recovered (extracted from the earth in raw form) under present and expected local economic conditions with existing available technology".

[16] See http://minerals.usgs.gov/minerals/pubs/mcs/2014/mcsapp2014.pdf, Appendix C.

Table 4: Content of the BP, EIA and USGS databases using CRIRSCO, SPE-PRMS and UNFC-2009 classification systems

Fundamental Characterization	Solid Mineral Classes	*PRMS Classes*	Mineral Project Development Stage	*PRMS Sub-Class*	UNFC E axis	UNFC F axis	UNFC G axis		
							Proved Measured	Probable Indicated	Possible Inferred
							1P/1C Low Estimate		
							2P/2C Best Estimate		
							3P/3C High Estimate		
Discovered and Commercially Recoverable	Mineral Reserves	*Reserves*	On Production	*On Production*	1	1.1	1	2	3
			Project Implementation	*Approved for Development*	1	1.2	1	2	3
			Feasibility Study	*Justified for Development*	1	1.3	1	2	3
Discovered and Not Commercially Recoverable	Mineral Resources	*Contingent Resources*	Pre-Feasibility Study	*Development Pending*	1	2.1	1	2	3
					2.1	2.1	1	2	3
			Order of Magnitude Studies	*Development Unclarified or on Hold*	2.1	2.2	1	2	3
					3.2	2.2	1	2	3
	Discovered Not Economic			*Development not Viable*	2.2	2.3	1	2	3
	Unrecoverable				3.3	4.1	1	2	3
Undiscovered	Exploration Results	*Prospective Resources*	Conceptual Studies	*Prospect*	3.2	3.1	4.1	4.2	4.3
				Lead	3.2	3.2	4.1	4.2	4.3
				Play	3.2	3.3	4.1	4.2	4.3
	Unrecoverable				3.3	4.2	4.1	4.2	4.3



Raws correspond to items of the CRIRSCO and SPE-PRMS classifications and columns to items of the UNFC-2009 classification.

We consider BP's and EIA's definitions of "proved reserves" and the USGS' definition of "reserves".

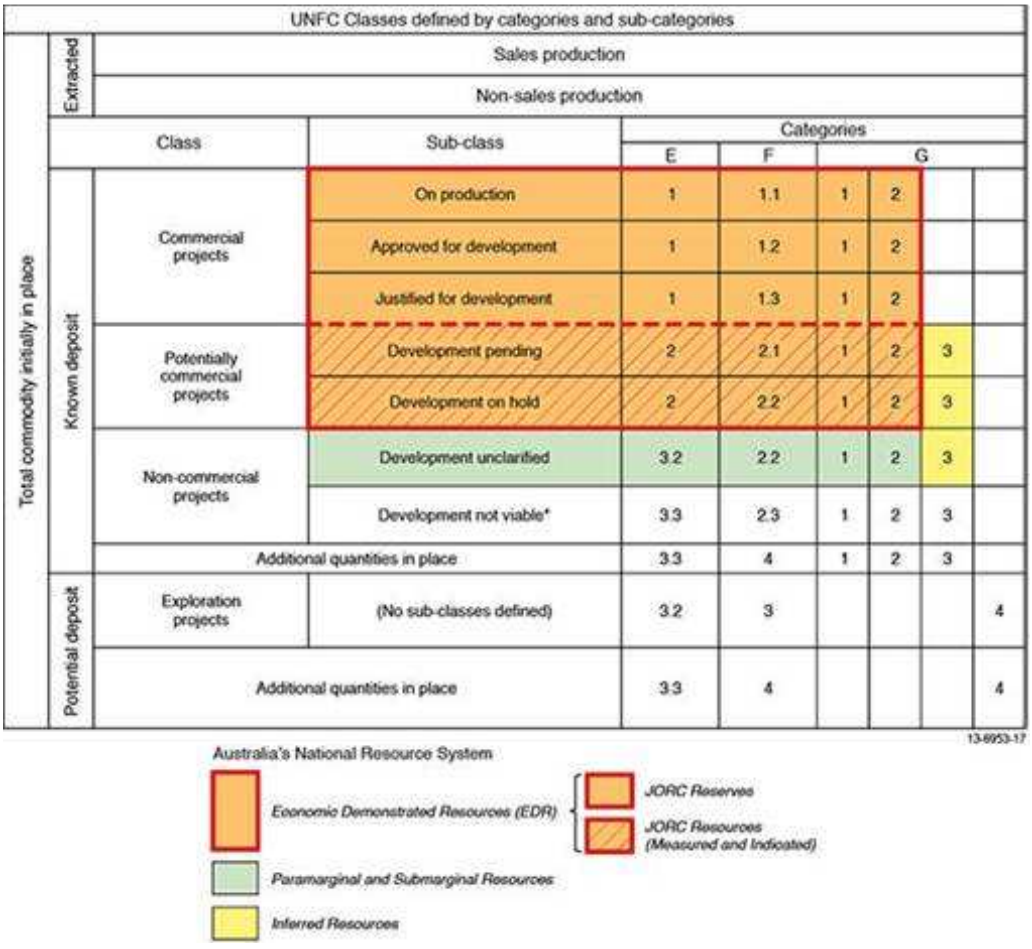
2. National databases

a. Australia (ABS, Geoscience Australia)

Australian data on stocks of natural resources are published by the ABS in Table 62 of the Australian System of National Accounts[17]. The ABS only considers "Economic Demonstrated Resources" (EDRs), defined as "those resources whose geological assurance is demonstrated and for which extraction is profitable over the life of the mine. It approximates both proven and probable reserves"[18].

Geoscience Australia, ABS' data provider for natural resources, gives a clear picture of how EDRs might be defined using the UNFC-2009 classification. EDRs correspond to (E1-E2, F1-F2.2,G1-G2) types of resources with the UNFC classification. They cannot be immediately translated into SEEA-2012 classes A and B (see Tables 5 and 6).

Table 5: Definition of Australia's "Economic Demonstrated Resources" with the UNFC-2009 classification (source: Geoscience Australia)



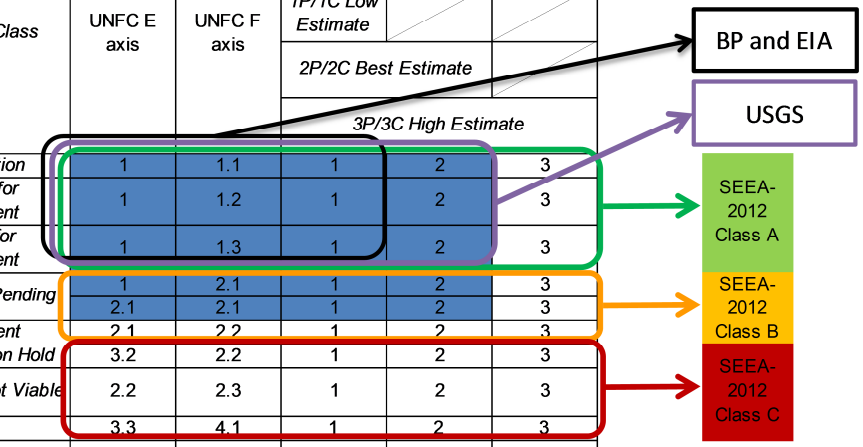
[17] http://www.abs.gov.au/ausstats/ABS@Archive.nsf/log?openagent&5204062_mineral_and_energy_resources.xls&5204.0&Time%20Series%20Spreadsheet&641BE2F6BCA0808ACA257C15001A00C8&0&2012-13&01.11.2013&Latest

[18] http://www.abs.gov.au/ausstats/abs@.nsf/Previousproducts/1350.0Feature%20Article81995?opendocument&tabname=Summary&prodno=1350.0&issue=1995&num=&view=

Table 6: Australia's subsoil assets as measured by the ABS, BP, the EIA, the USGS and how these definitions relate to SEEA-2012 classes

Fundamental Characterization	Solid Mineral Classes	*PRMS Classes*	Mineral Project Development Stage	*PRMS Sub-Class*	UNFC E axis	UNFC F axis	UNFC G axis		
							Proved Measured	Probable Indicated	Possible Inferred
							1P/1C Low Estimate		
							2P/2C Best Estimate		
							3P/3C High Estimate		
Discovered and Commercially Recoverable	Mineral Reserves	*Reserves*	On Production	*On Production*	1	1.1	1	2	3
			Project Implementation	*Approved for Development*	1	1.2	1	2	3
			Feasibility Study	*Justified for Development*	1	1.3	1	2	3
Discovered and Not Commercially Recoverable	Mineral Resources	*Contingent Resources*	Pre-Feasibility Study	*Development Pending*	1	2.1	1	2	3
					2.1	2.1	1	2	3
			Order of Magnitude Studies	*Development Unclarified or on Hold*	2.1	2.2	1	2	3
					3.2	2.2	1	2	3
	Discovered Not Economic			*Development not Viable*	2.2	2.3	1	2	3
	Unrecoverable				3.3	4.1	1	2	3
Undiscovered	Exploration Results	*Prospective Resources*	Conceptual Studies	*Prospect*	3.2	3.1	4.1	4.2	4.3
				Lead	3.2	3.2	4.1	4.2	4.3
				Play	3.2	3.3	4.1	4.2	4.3
	Unrecoverable				3.3	4.2	4.1	4.2	4.3

Australia's Natural Resource System	Reported Categories	E axis	F axis	G axis
Economically Demonstrated Resources (EDRs)	JORC Reserves and JORC Resources (measured and indicated) Development Pending			

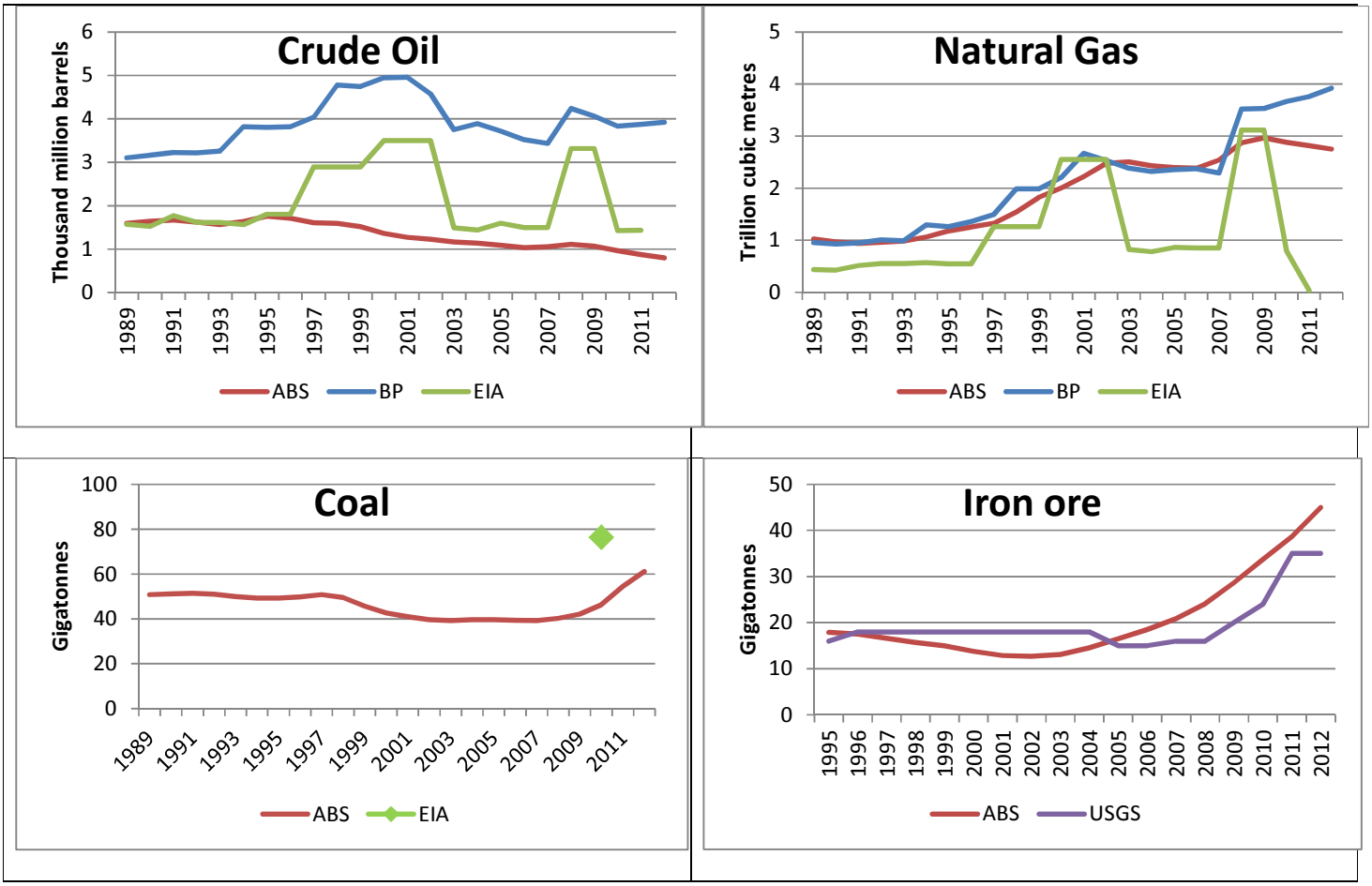


Two conclusions can be drawn from the comparison of Australian crude oil, natural gas, coal and iron ore stocks reported by BP, the EIA, the USGS and the ABS (see Figure 5)[19]:

- Even if BP and the EIA rely on the same definition of reserves, their reported estimates can be extremely different. This is particularly the case for crude oil reserves in Australia.

- Even if the ABS relies on a larger definition of available subsoil assets than BP and the EIA, estimates published by the ABS may be smaller than those published by BP and the EIA. This needs to be further investigated.

Figure 5: Australian crude oil, natural gas, coal and iron ore stocks reported by BP, the EIA, the USGS and the ABS[20]



[19] We focus on Australia's main natural resources in value terms.

[20] All estimates have been converted to end-of-year estimates when needed.

b. Canada (Statistics Canada)

The subsoil asset accounts computed by Statistics Canada only record estimates for "economically recoverable reserves", or simply "economic reserves", i.e. those types of reserves "that can be recovered under current technological and economic conditions". "They are known with sufficient certainty to be considered as economic assets in the SNA sense and, therefore, qualify for inclusion in the National Balance Sheet Accounts"[21].

Statistics Canada's terminology to describe "economically recoverable reserves" is not uniform from one resource to the other[22]. Indeed, the literature dealing with subsoil resources has not yet evolved a single naming convention for reserves. Thus, economic reserves of conventional crude oil and natural gas are termed "established reserves", those for crude bitumen are termed "established reserves under active development", those for coal and uranium are termed "recoverable reserves in active mines"[23] and those for metals and potash are termed "proven and probable reserves". The reason for the adoption of these definitions is twofold: the data obtained from provincial and federal government departments are reported in this manner and the definitions represent broadly similar measures for each of subsoil resource.

- **Crude oil and natural gas**: "Established reserves are those reserves recoverable under current technological and present and anticipated economic conditions, specifically proved by drilling, testing or production, plus that judgement portion of contiguous recoverable reserves that are interpreted to exist from geological, geophysical or similar information, with reasonable certainty." It is assumed that established reserves include "proven reserves" and *some part* of "probable reserves". This assumption is mainly made because of data limitations and the relatively conservative definition of reserves used[24]. It has been suggested that the definition of "proven reserves" is too conservative for macro-economic planning and that "established reserves" reflect what reserves will be available for national production and consumption.

- **Crude bitumen**: For this natural asset, Statistics Canada uses the "remaining established reserves *under active development*" concept from the Alberta Energy Regulator (AER), rather than the broader concept of "established reserves"[25].

[21] See Statistics Canada (2006), p. 6. Note that Statistics Canada plans to replace this manual in 2015 with a new document having much stronger and more explicit links to the SEEA-CF. Efforts will be made to harmonise reserves data and associated classification systems with the UNFC-2009 classification.

[22] *Idem*, pp. 32-34.

[23] In Alberta, coal reserves are called "established reserves in active mines", *i.e.* mines that are either producing or under construction. In all other provinces, these reserves are called "recoverable reserves in active mines".

[24] See Statistics Canada (1992), p. 6.

[25] Although this is the most conservative estimate among those produced by the AER, it is, in fact, the estimate often used by the AER itself when presenting more detailed breakdowns of Alberta's reserves. Also noteworthy is the fact that the reserve estimate used by the Canadian Association of Petroleum Producers (CAPP) in their Statistical Handbook for Canada's Upstream Petroleum Industry is somewhat more conservative than the one used by Statistics Canada, limiting reserves to just those found at currently producing sites or at sites with very significant investment. Adopting the much larger estimate of "established

- **Coal**: "Coal that is anticipated to be minable based on feasibility studies, existing technology and current economic conditions is classified as a recoverable resource […]. Portions of measured and indicated coal resources that are the most likely to be developed commercially are called reserves. Only those reserves that are recoverable in active mines are included […] since only they have a high probability of being extracted in the foreseeable future." [26]

- **Metals**: Statistics Canada's mineral asset accounts are based on the mineral reserves concept. Reserves are estimated at the national level by Canada's Natural Resource agency using information from annual reports of mining corporations, and from mining companies' responses to the annual Survey of Mines and Concentrators. Reserves are defined to include metal in material that companies classify as "proven reserves" or "probable reserves" at producing mines and in deposits that are firmly committed to production[27]. Metals in mineral resources classified as "measured resources," "indicated resources" or "inferred resources" are not included in mineral reserves. Metals contained in deposits that have not advanced beyond the deposit appraisal phase are not included either.
A proven reserve is defined as "the estimated quantity and grade of a mineral body for which information is so well established with respect to size, distribution of values, grade, deposit walls, and thickness, that there is the highest degree of confidence as to the quantity and grade that can be mined at a profit." A probable reserve is defined as "the estimated quantity and grade of a mineralized body for which sufficient information on continuity, extent, grade distribution, operating and capital costs, etc., is available to form the basis of a study indicating an economically viable operation at long-term forecast average metal prices"[28].

Table 7 shows how remaining stocks of Canadian subsoil assets may be defined using the UNFC-2009 classification system. Note that the definition of Canadian "economic reserves" is more restrictive in the F-dimension for crude bitumen and coal than for other subsoil assets. Remind also that for crude oil and natural gas, "established reserves" only include some part of "probable reserves" (see above). The delineation should therefore be somewhere in-between the G1 and G2 categories for these two assets.

Figure 6 shows that Statistics Canada's national estimates of remaining stocks may be very different from what can be found in international databases. This is particularly the case for crude oil and coal. On the contrary, natural gas reported stocks are similar, which may be explained by very close definitions. As was already observed for Australian assets, EIA's and BP's estimates diverge for crude oil even if both databases rely on the same definition of remaining stocks.

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reserves" would mean adding up an enormous quantity of oil sands for which the economic infrastructure required for exploitation does not yet exist.

[26] See Statistics Canada (2006), pp. 32-34.

[27] See http://www.nrcan.gc.ca/mining-materials/exploration/8294?destination=node/4531#t2

[28] See Statistics Canada (2006), pp. 32-34.

Table 7: Canada's subsoil assets as measured by Statistics Canada, BP, the EIA, the USGS and how these definitions relate to SEEA-2012 classes

Fundamental Characterization	Solid Mineral Classes	*PRMS Classes*	Mineral Project Development Stage	*PRMS Sub-Class*	UNFC E axis	UNFC F axis	UNFC G axis		
							Proved Measured	Probable Indicated	Possible Inferred
							1P/1C Low Estimate		
							2P/2C Best Estimate		
							3P/3C High Estimate		
Discovered and Commercially Recoverable	Mineral Reserves	*Reserves*	On Production	*On Production*	1	1.1	1	2	3
			Project Implementation	*Approved for Development*	1	1.2	1	2	3
			Feasibility Study	*Justified for Development*	1	1.3	1	2	3
Discovered and Not Commercially Recoverable	Mineral Resources	*Contingent Resources*	Pre-Feasibility Study	*Development Pending*	1	2.1	1	2	3
			Order of Magnitude Studies	*Development*	2.1	2.1	1	2	3
				Unclarified or on Hold	2.1	2.2	1	2	3
	Discovered Not Economic			*Development not Viable*	3.2	2.2	1	2	3
	Unrecoverable				2.2	2.3	1	2	3
Undiscovered	Exploration Results	*Prospective Resources*	Conceptual Studies	*Prospect*	3.3	4.1	1	2	3
				Lead	3.2	3.1	4.1	4.2	4.3
				Play	3.2	3.2	4.1	4.2	4.3
	Unrecoverable				3.2	3.3	4.1	4.2	4.3
					3.3	4.2	4.1	4.2	4.3

BP and EIA

USGS

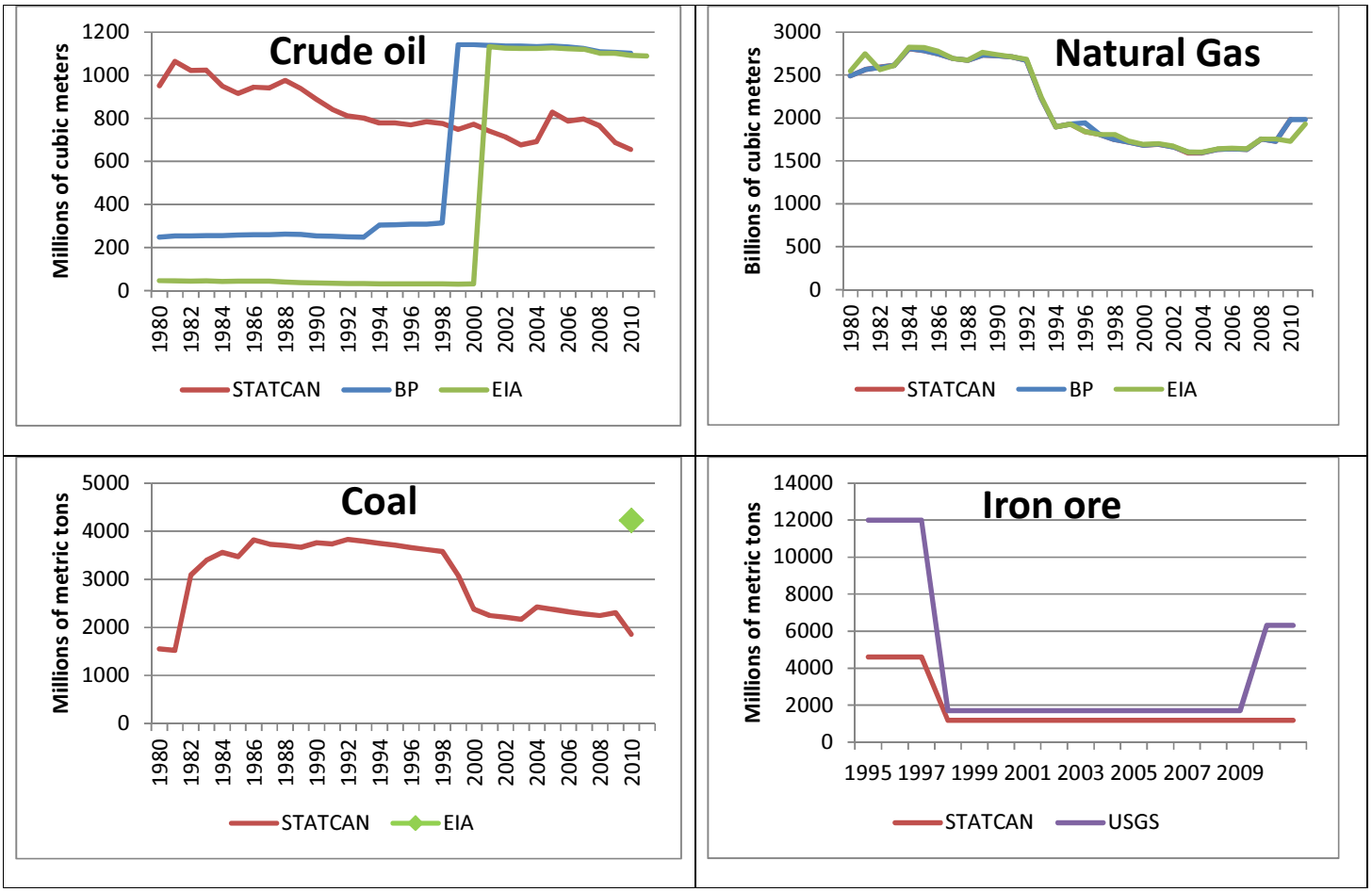
SEEA-2012 Class A

SEEA-2012 Class B

SEEA-2012 Class C

Canada's Natural Resource System	Reported Categories	E axis	F axis	G axis
Economically Recoverable Reserves	Established Reserves (crude oil, natural gas), Proven and Probable Reserves (metals & potash)			
or				
	Recoverable Reserves in active mines (coal), Remaining established reserves under active development (crude bitumen)			

Figure 6: Canadian crude oil, natural gas, coal and iron ore stocks reported by BP, the EIA, the USGS and Statistics Canada[29]



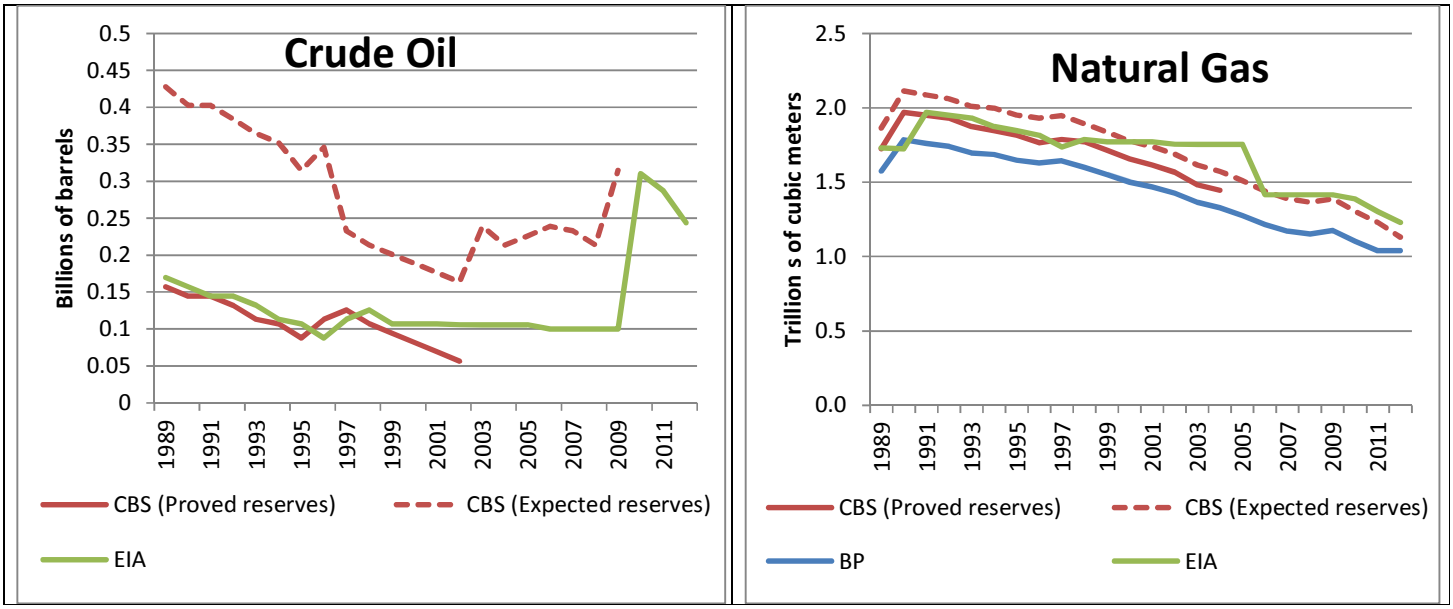
[29] All estimates have been converted to end-of-year estimates when needed.

c. Netherlands (CBS, TNO)

CBS provides data on crude oil and natural gas in the Netherlands[30]. It used to rely on the SEEA-2003 classification until 2011 and moved to the SPE-PRMS classification in 2012. CBS noticed that this classification change did not introduce any time-series break in the total amount of reserves[31] and, therefore, did not backcast the series published prior to 2012 using the new classification system. "Reserves" and "contingent resources" for which "development is pending" are separately reported in the Dutch account, as well as proved and expected reserves. Table 8 shows how these categories relate to SEEA-2012 classes.

Figure 7 compares Dutch national estimates of remaining stocks with those reported by BP and the EIA. In theory, BP's and EIA's time series should match CBS' reported proved reserves. In practice however, the EIA seems to switch from CBS' proved to expected reserves and BP estimates for natural gas are below CBS' proved reserves. Note that BP does not report any estimate for crude oil stocks in the Netherlands.

Figure 7: Dutch crude oil and natural gas stocks reported by BP, the EIA and CBS[32]



[30] See Veldhuizen *et. al.* (2009) and the annual publication "Environmental Accounts in the Netherlands": http://www.cbs.nl/NR/rdonlyres/090445AD-E1CB-4147-A404-0C36F02DF112/0/2013c174pub.pdf

[31] Given the difference between the SEEA-2003 and SPE-PRMS classification systems (see footnote 8), the absence of time-series break was not necessarily expected.

[32] All estimates have been converted to end-of-year estimates when needed. But even after this conversion, stocks reported by the EIA remain shifted by one year compared to those reported by BP and CBS. They were initially shifted by two years. This probably reveals a mistake in the EIA database.

Table 8: Netherlands' subsoil assets as measured by CBS/TNO, BP, the EIA and how these definitions relate to SEEA-2012 classes

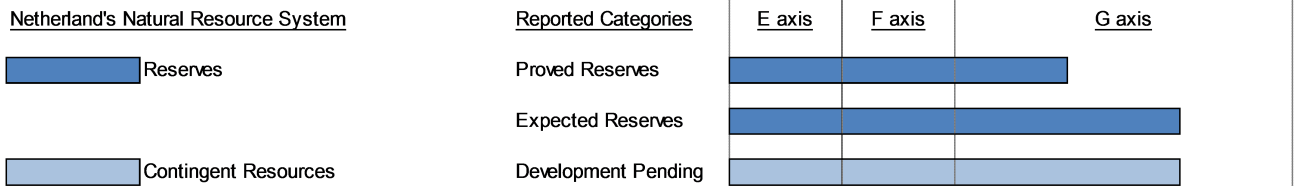
Fundamental Characterization	Solid Mineral Classes	*PRMS Classes*	Mineral Project Development Stage	*PRMS Sub-Class*	UNFC E axis	UNFC F axis	UNFC G axis: Proved Measured	UNFC G axis: Probable Indicated	UNFC G axis: Possible Inferred
							1P/1C Low Estimate		
							2P/2C Best Estimate		
							3P/3C High Estimate		
Discovered and Commercially Recoverable	Mineral Reserves	*Reserves*	On Production	*On Production*	1	1.1	1	2	3
			Project Implementation	*Approved for Development*	1	1.2	1	2	3
			Feasibility Study	*Justified for Development*	1	1.3	1	2	3
Discovered and Not Commercially Recoverable	Mineral Resources	*Contingent Resources*	Pre-Feasibility Study	*Development Pending*	1	2.1	1	2	3
					2.1	2.1	1	2	3
			Order of Magnitude Studies	*Development Unclarified or on Hold*	2.1	2.2	1	2	3
					3.2	2.2	1	2	3
	Discovered Not Economic			*Development not Viable*	2.2	2.3	1	2	3
	Unrecoverable				3.3	4.1	1	2	3
Undiscovered	Exploration Results	*Prospective Resources*	Conceptual Studies	*Prospect*	3.2	3.1	4.1	4.2	4.3
				Lead	3.2	3.2	4.1	4.2	4.3
				Play	3.2	3.3	4.1	4.2	4.3
	Unrecoverable				3.3	4.2	4.1	4.2	4.3

BP and EIA

SEEA-2012 Class A

SEEA-2012 Class B

SEEA-2012 Class C



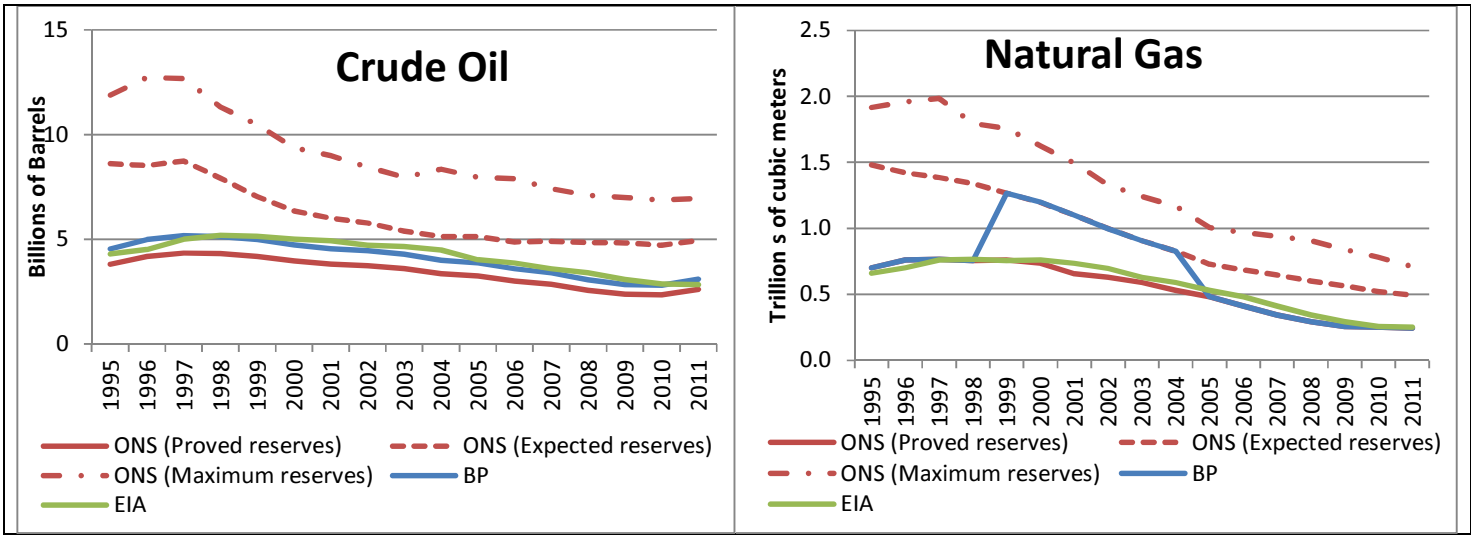
d. United Kingdom (ONS, DECC)

The Department of Energy and Climate Change (DECC) and the Office for National Statistics (ONS) provide data on crude oil and natural gas in the U.K. using the SPE-PRMS classification system, but with a slightly different terminology[33]. The available data are for "discovered reserves" ("proved", "probable" and "possible"), "potentially additional reserves" ("lower", "central" and "upper" estimates) and "undiscovered resources" ("lower", "central" and "upper" estimates).

Communications with the ONS and the DECC established that "potentially additional reserves" ("lower", "central" and "upper" estimates) were equivalent to "contingent resources" (1C, 2C and 3C) in the SPE-PRMS classification system and that "undiscovered resources" ("lower", "central" and "upper" estimates) had the same meaning as "prospective resources" ("low", "best" and "high" estimates). Table 9 shows the available data for crude oil and natural gas in the U.K.. These data allow estimating SEEA-2012 class A resources. However, "potentially additional reserves" would need to be split in order to estimate SEEA-2012 class B and C resources. They cannot be distinguished for the time being.

Figure 8 compares British national estimates of remaining stocks with those reported by BP and the EIA. In theory, BP's and EIA's time series should match the ONS' reported proved reserves. This is practically the case for natural gas estimates reported by the EIA but those reported by BP switch from ONS' proved to expected reserves. For crude oil, BP's and EIA's time series closely converge but they are in-between ONS' proved and expected reserves.

Figure 8: UK crude oil and natural gas stocks reported by BP, the EIA and the ONS[34]



[33] See http://www.ons.gov.uk/ons/rel/environmental/uk-environmental-accounts/2013/rft-estimates-of-remaining-recoverable-oil-and-gas.xls
The Department of Energy and Climate Change (DECC), that provides data on fossil energy to the ONS, still relies on an old terminology dating back to the 1970s. This terminology predates the SPE guidelines but the underlying principles are the same.

[34] All estimates have been converted to end-of-year estimates when needed. But even after this conversion, stocks reported by the EIA remain shifted by one year compared to those reported by BP and the ONS. They were initially shifted by two years. This probably reveals a mistake in the EIA database.

Table 9: UK's subsoil assets as measured by the ONS/DECC, BP, the EIA and how these definitions relate to SEEA-2012 classes

Fundamental Characterization	Solid Mineral Classes	*PRMS Classes*	Mineral Project Development Stage	*PRMS Sub-Class*	UNFC E axis	UNFC F axis	UNFC G axis		
							Proved Measured	Probable Indicated	Possible Inferred
							1P/1C Low Estimate		
							2P/2C Best Estimate		
							3P/3C High Estimate		
Discovered and Commercially Recoverable	Mineral Reserves	*Reserves*	On Production	*On Production*	1	1.1	1	2	3
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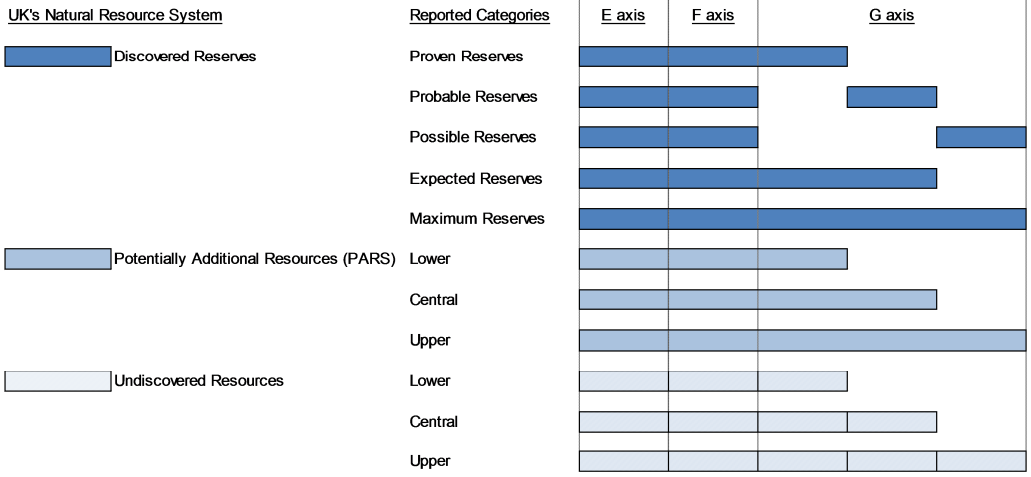
			Feasibility Study	*Justified for Development*	1	1.3	1	2	3
Discovered and Not Commercially Recoverable	Mineral Resources	*Contingent Resources*	Pre-Feasibility Study	*Development Pending*	1	2.1	1	2	3
					2.1	2.1	1	2	3
			Order of Magnitude Studies	*Development Unclarified or on Hold*	2.1	2.2	1	2	3
					3.2	2.2	1	2	3
	Discovered Not Economic			*Development not Viable*	2.2	2.3	1	2	3
	Unrecoverable				3.3	4.1	1	2	3
Undiscovered	Exploration Results	*Prospective Resources*	Conceptual Studies	*Prospect*	3.2	3.1	4.1	4.2	4.3
				Lead	3.2	3.2	4.1	4.2	4.3
				Play	3.2	3.3	4.1	4.2	4.3
	Unrecoverable				3.3	4.2	4.1	4.2	4.3

BP and EIA

SEEA-2012 Class A

SEEA-2012 Class B

SEEA-2012 Class C



III. Conclusion

Two main difficulties can be encountered in practice when trying to compile the natural asset accounts in physical units advocated by the SEEA-CF, following the SEEA-2012 classification. First, data need to be available with a sufficient level of disaggregation in the original classification system. This is not always the case. Second, countries need to consider a wide range of resource types in order to fill the (quite large) resource classes advocated by the SEEA-CF. Some countries currently prefer to focus on the most economically viable deposits and those estimated with the highest geological confidence in their statistical reporting, whereas the SEEA-CF may consider broader definitions. Our advice is therefore that countries engaged or interested in the statistical reporting of physical stocks of natural resources should keep the SEEA-2012 classification in mind.

We also compared national estimates of remaining stocks of selected resources in four countries (Australia, Canada, the Netherlands and the United Kingdom) with those that can be found in international databases (BP, EIA and USGS). Even when definitions are aligned, reported estimates may be extremely different. Based on available estimates for these four countries, our conclusion is therefore that national data sources should be preferred, even if this implies to focus on some resources and the main producing countries in a first stage.

Some prioritisation of natural resources may be needed for countries willing to implement the natural asset accounts advocated by the SEEA-CF. In this case, both the economic and environmental significance of the assets should be considered, not only from the point of view of producing countries but from a global point of view. The report of the European Commission on critical raw materials for the EU (2014) or the OECD report on material resources, productivity and the environment (2014) provide such a prioritisation and may be useful in this respect.

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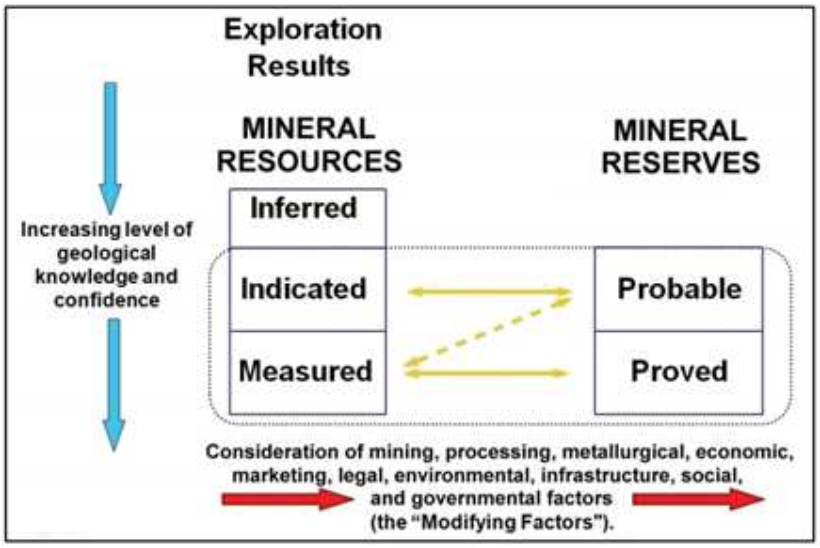
Appendix: Detailed description of available classifications for the volume measurement of stocks of natural resources

1. CRIRSCO classification system



The following definitions come from CRIRSCO (2013).

A **Proved Mineral Reserve** is the economically mineable part of a Measured Mineral Resource. A Proved Mineral Reserve implies a high degree of confidence in the Modifying Factors. A Proved Mineral Reserve represents the highest confidence category of reserve estimate.

A **Probable Mineral Reserve** is the economically mineable part of an Indicated, and in some circumstances, a Measured Mineral Resource. The confidence in the Modifying Factors applying to a Probable Mineral Reserve is lower than that applying to a Proved Mineral Reserve.

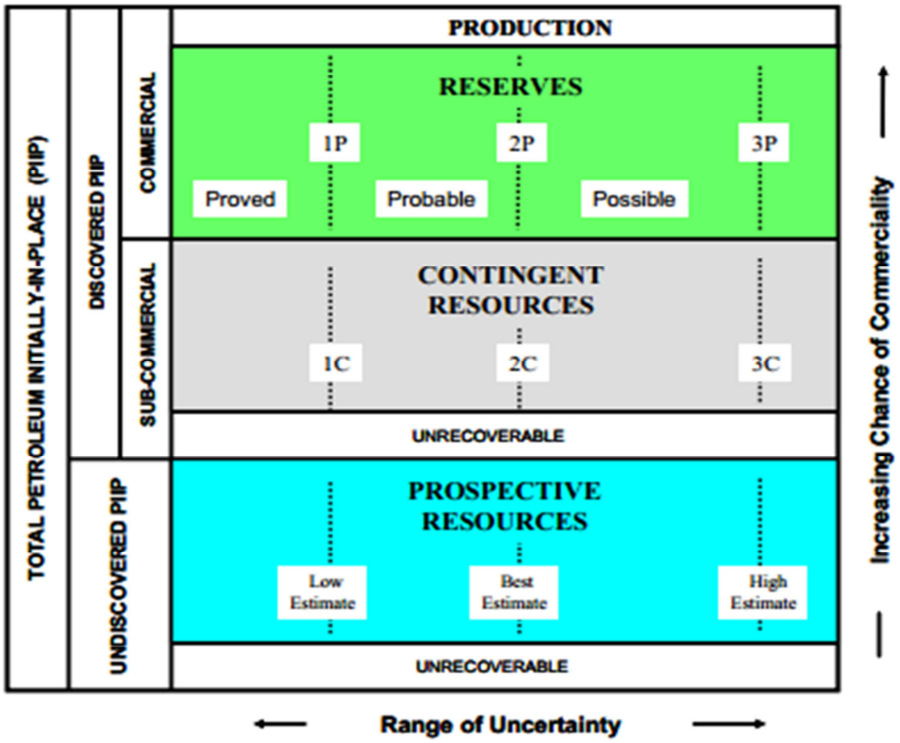
A **Measured Mineral Resource** is that part of a Mineral Resource for which quantity, grade or quality, densities, shape, and physical characteristics are estimated with confidence sufficient to allow the application of Modifying Factors to support detailed mine planning and final evaluation of the economic viability of the deposit. Geological evidence is derived from detailed and reliable exploration, sampling and testing and is sufficient to confirm geological and grade or quality continuity between points of observation. A Measured Mineral Resource has a higher level of confidence than that applying to either an Indicated Mineral Resource or an Inferred Mineral Resource. It may be converted to a Proved Mineral Reserve or to a Probable Mineral Reserve.

An **Indicated Mineral Resource** is that part of a Mineral Resource for which quantity, grade or quality, densities, shape and physical characteristics are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit. Geological evidence is derived from adequately detailed and reliable exploration, sampling and testing and is sufficient to assume geological and grade or quality continuity between points of observation. An Indicated Mineral Resource has a

lower level of confidence than that applying to a Measured Mineral Resource and may only be converted to a Probable Mineral Reserve.

An **Inferred Mineral Resource** is that part of a Mineral Resource for which quantity and grade or quality are estimated on the basis of limited geological evidence and sampling. Geological evidence is sufficient to imply but not verify geological and grade or quality continuity. An Inferred Resource has a lower level of confidence than that applying to an Indicated Mineral Resource and must not be converted to a Mineral Reserve. It is reasonably expected that the majority of Inferred Mineral Resources could be upgraded to Indicated Mineral Resources with continued exploration. An Inferred Mineral Resource has a lower level of confidence than that applying to an Indicated Mineral Resource.

2. SPE-PRMS classification system



The following definitions come from SPE *et al.* (2007).

Proved Reserves are those quantities of petroleum, which by analysis of geoscientific and engineering data, can be estimated with reasonable certainty to be commercially recoverable, from a given date forward, from known reservoirs and under defined economic conditions, operating methods, and government regulations. If deterministic methods are used, the term reasonable certainty is intended to express a high degree of confidence that the quantities will be recovered. If

probabilistic methods are used, there should be at least a 90% probability that the quantities actually recovered will equal or exceed the estimate.

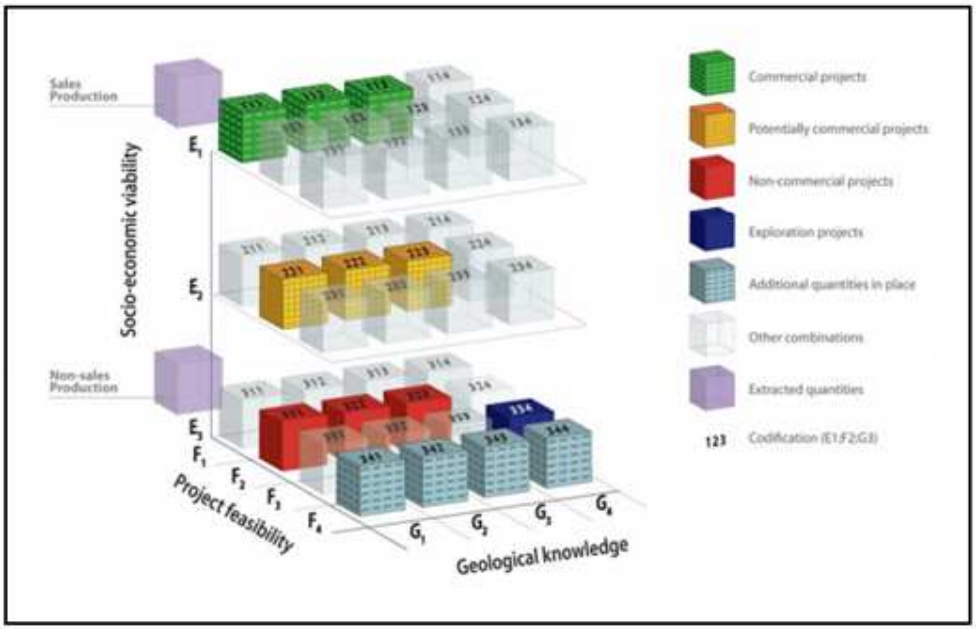
Probable Reserves are those additional Reserves which analysis of geoscientific and engineering data indicate that they are less likely to be recovered than Proved Reserves but more certain to be recovered than Possible Reserves. It is equally likely that actual remaining quantities recovered will be greater than or less than the sum of the estimated Proved plus Probable Reserves (2P). In this context, when probabilistic methods are used, there should be at least a 50% probability that the actual quantities recovered will equal or exceed the 2P estimate.

Possible Reserves are those additional reserves which analysis of geoscientific and engineering data indicate are less likely to be recoverable than Probable Reserves. The total quantities ultimately recovered from the project have a low probability to exceed the sum of Proved plus Probable plus Possible (3P) which is equivalent to the high estimate scenario. When probabilistic methods are used, there should be at least a 10% probability that the actual quantities recovered will equal or exceed the 3P estimate.

Contingent Resources are those quantities of petroleum estimated, as of a given date, which are potentially recoverable from known accumulations by application of development projects, but which are not currently considered to be commercially recoverable due to one or more contingencies. Contingent Resources may include, for example, projects for which there are currently no viable markets, or where commercial recovery is dependent on technology under development, or where evaluation of the accumulation is insufficient to clearly assess commerciality. Contingent Resources are further categorized in accordance with the level of certainty associated with the estimates and may be sub-classified based on project maturity and/or characterized by their economic status.

Prospective Resources are those quantities of petroleum which are estimated, as of a given date, to be potentially recoverable from undiscovered accumulations. Potential accumulations are evaluated according to their chance of discovery and, assuming a discovery, the estimated quantities that would be recoverable under defined development projects. It is recognized that the development programs will be of significantly less detail and depend more heavily on analog developments in the earlier phases of exploration.

3. UNFC-2009 classification system



Here is the precise definition of the UNFC categories[35]:

E1 = Extraction and sale has been confirmed to be economically viable.

E2 = Extraction and sale is expected to become economically viable in the foreseeable future.

E3 = Extraction and sale is not expected to become economically viable in the foreseeable future or evaluation is at too early a stage to determine economic viability.

F1 = Feasibility of extraction by a defined development project or mining operation has been confirmed.

F2 = Feasibility of extraction by a defined development project or mining operation is subject to further evaluation.

F3 = Feasibility of extraction by a defined development project or mining operation cannot be evaluated due to limited technical data.

F4 = No development project or mining operation has been identified.

G1 = Quantities associated with a known deposit that can be estimated with a high level of confidence.

G2 = Quantities associated with a known deposit that can be estimated with a moderate level of confidence.

G3 = Quantities associated with a known deposit that can be estimated with a low level of confidence.

[35] See: http://www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/unfc2009/UNFC2009_ES39_e.pdf

4. SEEA-2012 classification system

We here reproduce SEEA-CF Table 5.5.1 presenting the SEEA-2012 classification system.

Table 5.5.1: Categorisation of mineral and energy resources

	SEEA Classes	Corresponding UNFC-2009 project categories		
		E Economic and social viability	F Field project status and feasibility	G Geological knowledge
Known deposits	Class A: Commercially Recoverable Resources[1]	E1. Extraction and sale has been confirmed to be economically viable	F1. Feasibility of extraction by a defined development project or mining operation has been confirmed	Quantities associated with a known deposit that can be estimated with a high (G1), moderate (G2) or low (G3) level of confidence
	Class B: Potentially Commercially Recoverable Resources[2]	E2. Extraction and sale is expected to become economically viable in the foreseeable future[3]	F2.1 Project activities are ongoing to justify development in the foreseeable future Or F2.2 Project activities are on hold and/or where justification as a commercial development may be subject to significant delay	
	Class C: Non-Commercial and Other Known Deposits[4]	E3. Extraction and sale is not expected to become economically viable in the foreseeable future or evaluation is at too early a stage to determine economic viability	F2.2 Project activities are on hold and/or where justification as a commercial development may be subject to significant delay Or F2.3 There are no current plans to develop or to acquire additional data at the time due to limited potential Or F4. No development project or mining operation has been identified	
Potential deposits (not included in SEEA)	Exploration Projects Additional quantities in place	E3. Extraction and sale is not expected to become economically viable in the foreseeable future or evaluation is at too early a stage to determine economic viability	F3. Feasibility of extraction by a defined development project or mining operation cannot be evaluated due to limited technical data Or F4. No development project or mining operation has been identified	Estimated quantities associated with a potential deposit, based primarily on indirect evidence (G4)

Notes
1. Includes on-production projects, projects approved for development and projects justified for development
2. Includes economic and marginal development projects pending and development projects on hold
3. Potential Commercial Projects may also satisfy the requirements for E1.
4. Includes unclarified development projects, non-viable development projects, and additional quantities in place
Source: UNFC-2009, Figures 2 and 3